RISK ASSESSMENT ASSOCIATED WITH PESTICIDES APPLICATION ON SELECTED AGRICULTURAL FARMLAND IN KANO STATE, NIGERIA.

BY

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ABSTRACT

Background:

Estimates from International Labor Office state that there are more than 1.3 billion agricultural workers worldwide, 60% in emerging countries and more than 47% of the land is used for agriculture and 38% of the population of Kano state is engaged in agriculture. Agricultural work can be very dangerous, resulting in 24.4 fatal injuries for every 100 000 in the developed countries such as USA. However, statistics on farm injury deaths are not available in Kano state and Nigeria at large. In addition, farmers are exposed to intense sun, chemical hazards, and biological hazards, and a variety of repetitive work tasks in stressful working postures. Exposure to pesticides and other agrochemicals can result in acute poisoning, as well as chronic diseases including cancer. This is of particular concern as the volume of pesticides used in Kano State continues to increase.

Objective:

This study examine the risk assessment associated with pesticides application especially on selected agricultural farmland in Kano State, Nigeria.

Methods:

A structure questionnaires was developed focusing on sociodemographic characteristics, knowledge and experience of adverse health effects related to pesticide use, details of work practices and an inventory of pesticides used on the farm. Of the 400 copies of questionnaire administered 392 copies representing 98% of the administered questionnaire was retrieved and found useable.

Results:

89.5% of the farmers make use of pesticide, Of the 351 farmers that made use of pesticides, 31.1% use Apron plus, 12,0% use Atrazine, 33.6% use Cypernethrim while 9.7%, 8.5%, 4.8%, 31.3% and 12.0% of the respondents Thiodan, Fusilade, Primextra and others respectively, 46.2% of the farmers had been using the pesticide for 1-5 years, 48.1% had use it for 10-15, 31.1% of the respondents opined that their main purpose of using pesticide is for weed control, 14.5%, 14.5% and 39.9% of the respondents said that their main purpose of using pesticides was for pest control, rodent control and fungi control respectively, regularity of these symptoms reveals that the majority of the respondents experienced these symptoms on a regular basis (56.1% for headache, 53.8% for stomach cramps, 56.5% for muscles weakness, 56.8% for vomiting, 58.3% for dizziness, 40.7% for shortness of breath, 45.5% for blurred vision and 66.7% for eye irritation, majority of the respondents (76.9%) were aware of the side effect of the use of pesticides with only 23.1% of the respondents not aware of the side effect of pesticide use, it can be deduced that less than half of the farmers who use insecticides are aware of its effect on the environment, less than half of these farmers who make use of pesticides protect themselves by wearing mask, boot or impermeable clothes, 72.6% of the respondents use stock in mixing pesticides, 17.7% made use of their bare hands while 9.7% use other methods, In terms of what they do after applying pesticides 70.4% wash their hands with soap and water, 25.4% claimed that they wash their hands with waters only, 29.1% store pesticide in their rooms, 38.5% stored it outside house while 32.5% of the respondents stored pesticides inside house, 47.0% of the respondents dispose pesticides containers by throwing it in open field, 38.7% throw it in dustbin while 14.2% returns the containers to the seller.

Conclusions:

Training and educational campaigns on pesticides use should be encouraged for this cohorts along with suggestions for alternative methods of pest control.

Key Words:

Pesticides, Agricultural farmers, Personal protective equipment, Personal hygiene, Kuru,

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CERTIFICATION

This is to certify that the project titled **RISK ASSESSMENT ASSOCIATED WITH PESTICIDES APPLICATION ON SELECTED AGRICULTURAL FARMLAND IN KANO STATE, NIGERIA** was conducted by ISAH HUSSAIN MUHAMMAD with matriculation number 17/27/MEHS005 of Environmental Health Unit, School of Allied Health and Environmental Sciences, College of Pure and Applied Sciences, Kwara State University, Malete, Nigeria in partial fulfilment requirements for the award of Master of Science (Msc) Degree in Environmental Health.

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DEDICATION

This dissertation is dedicated to Allah, the all sufficient one, the source of my inspiration, the provider of safe and unpolluted soil for the survival and well-being of man and all other living things.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Agriculture is gradually becoming a substantial part of the economy of Nigeria, and agricultural activities are important for social and economic development. It is therefore inevitable that a large variety of pesticides will be used in agricultural production to reduce the impact of pests on crops (Liu *et al.,* 2012). Moreover, plant protection products, or pesticides, are not only used to protect fruit and vegetables against insects, diseases and weeds, but are also considered to ensure a good harvest and related income. Their widespread use in global food production is further enhanced by the demand for high cosmetic quality (colour, shape, defects) in export markets for fresh fruit and vegetables (Okello and Swinton, 2011). In general, the use of pesticides emphasizes the economic goal of maximum productivity at minimum costs, resulting in an intensification of agricultural production. This intensification is seen as the solution for food security concerns. On the other hand, questions arise when pesticides used for securing food production jeopardize food safety.

Modern agriculture relies heavily on the use of chemicals. It has been estimated that every year 150 million tons of fertilizers and 6 million tons of pesticides are routinely applied to fields and crops with the only objective of increasing agricultural production (Bernhardt *et al.,* 2017). While there is evidence that the use of herbicides can increase yields in many crops (Gianessi, 2013), there is also evidence that most fungicides and insecticides do not help increase such yields (Lechenet *et al.,* 2017). On the other hand, the ecological risks of these chemical inputs to the environment are often ignored by the general public, when not dismissed by those who assert that a growing human population needs to be fed at all costs (Jeschke, 2016), including health, economic and environmental costs (Pop *et al.,* 2013; Wilson and Tisdell, 2001).

Pesticides are considered a vital component in maintaining high agricultural productivity in modern farming. Indiscriminate use and improper handling of pesticides in agriculture have caused serious health problems in many developing countries including Nigeria, which represent 30% of the global pesticide consumer market (Peres *et al.,* 2006). Organophosphate (OP) and Carbamate (CM) insecticides are commonly used for spraying on crops in Nigeria particularly Kano State. Although pesticides have beneficial effects on the crop yield, insufficient protective measures to counter the harmful effects of pesticide is a major health issue in the crop growing areas. Farmers harvesting crop are more prone to adverse health effects of pesticides because frequent spraying is required on the broad and succulent leaves for pest control (McDaniel *et al.,* 2005; Damalas *et al.,* 2006). Acute pesticide poisoning is an illness or a health effect resulting from suspected or confirmed exposure to a pesticide within 48 h (WHO, 2008). Depending on the toxicity of the compound, dosage and exposure time, the symptoms of pesticide exposure vary from headache, vomiting, skin rash, respiratory problems and convulsions (Cornwall *et al.,* 1995). Plasma cholinesterase (PChE) levels are more reliable indicators than the symptoms attributed to exposure, for risk assessment and monitoring of pesticide intoxication in farm workers (Dasgupta *et al.,* 2007).

Pesticides became widely used in many parts of the world during the 20th century. In the 1940s, inorganic pesticides (based on, for example, copper or sulphur) gave way to synthetic pesticides derived from organic chemistry (e.g. organochlorine, organophosphorus and pyrethroid pesticides). Subsequently, numerous kinds of pesticides have been developed and released globally into agricultural fields and thus the environment (Galt, 2008b). At present, pest management is primarily accomplished through the use of pesticides that induce resistance development in pest populations and affect environmental and human health (Matson *et al*., 1997; Konradsen *et al*., 2003). In the European Union (EU), pesticide residues in food and animal feed have a negative public perception due to reported health e.g. Parkinson's disease (Elbaz and Moisan, 2016) and environmental problems (e.g. DDT; Carson, 1962). Closely related to this are concerns about pesticide use in intensive farming systems. Pesticides are viewed as a production system-based risk, and the presence of pesticide residues in fruit and vegetables is one manifestation of this (Tait and Bruce, 2001). However, historical risks related to pesticide use could not be compared with the post-1991 situation. Currently authorized products in the EU are significantly safer from both toxicological and environmental aspects. Today's EU products are evaluated under Council Directives 79/117/EEC and 91/414/EEC and will be re-evaluated under Regulation 1107/2009 (EC 2009) through a science-based risk assessment of their properties and adverse effects for human health and the environment. This safety assessment considers sensitive consumer groups (young, old, pregnant women, immunodeficient people) as well as environmental effects. Products that do not meet the set requirements are removed from the authorized product list for use in the EU or on products consumed in the EU. Currently, world population is growing at an annual rate of 1.2%, i.e. 77 million new mouths to feed annually. Six countries account for half of this growth: India, China, Pakistan, Nigeria, Bangladesh and Indonesia (Carvalho, 2006). In addition, a high percentage of people in many developed countries are obese. This situation stands in sharp contrast to the conditions in many developing countries where currently 925 million people are suffering from undernourishment (Rosenthal and Ort, 2012). The combination of population and economic growth with rising incomes is predicted to double worldwide calorie consumption over the next 25 years. The Food and

Agriculture Organization of the United Nations (FAO, 2016b) expects that, by 2050, an additional 1 billion tons of cereals and 200 million tons of meat will be needed annually to satisfy the growing food demand. Therefore, in developing countries, it is clear that concerns for food safety are far less of an issue compared to food security issues.

1.2 Statement of the Problem

Over 65% of Nigerian population who live in the rural areas are most neglected and deprived of modern healthcare services as well as other modern infrastructural necessities that are essential to the maintenance and promotion of good health (Olujimi, 2006; Ewhrudjakpor, 2008 and Omotosho, 2010). This situation is unfortunate as the majority of the nation's population who produce the nation's food needs including valuable export crops reside in the infrastructural underserved rural areas. Interestingly, over the last 30-40 years there has been growing concern regarding the contamination of the environment by pesticides and public concerns regarding their own exposure to pesticides which began to gain momentum around the early 2000s. But, the use of agrochemicals, though has increased the agricultural productivity, has severely adversely affected soil and aquatic systems with associated flora and fauna and also the health of the farmers and society consuming the chemically grown food. Moreover, the increase of worldwide population and the need to control pests are some of the factors that have led to the application of agrochemicals on agricultural areas to protect and increase crop production. Nevertheless, these substances are of environmental concern since they can reach water reservoirs and act on non-target organisms. Nowadays, the study of pesticide represents an important field of research concerning environmental pollution and many questions remain unresolved on the toxicology and safety of these systems to human and ecosystems health. It is based on the above problem associated with flooding that this research work sought to exploit the risk assessment associated with pesticides application on selected agricultural farmland in Kano State, Nigeria.

1.3 Objectives of the Study

The aim of this research is to examine the risk assessment associated with pesticides application especially on selected agricultural farmland in Kano State, Nigeria.

The specific objectives are to:

i. Determine the commonest used pesticides by farmers in Kano State.
ii. Determine the effects of pesticides, use on farmers' health by monitoring the frequency of clinical symptoms in Kano state.
iii. Determine the health problems associated with exposure to pesticides among farmers in Kano state.
iv. To assess the effects of the pesticide's applications on the environment in the study area.
v. To assess safety practices adopted by the farmers in handling pesticides in the fields by farmers in Kano state.
vi. To assess the farmers' behaviors when using pesticides in Kano state.

1.4 Significance of the Study

Unfortunately, data on risk assessment associated with pesticides application on selected agricultural farmland in Kano State, Nigeria are quite limited. The purpose of this study was to examine the risk assessment associated with pesticides application on selected agricultural farmland in Kano State, Nigeria. An examination of this risk assessment will provide insight into the processes of preventing risk associated with pesticides. This knowledge can assist in the development of intervention programs that could successfully include the farmers and communities as well as identify the community's settings where pesticides associated risk are at a greater risk on agricultural farmlands. This study will bring to the fore the quality of agricultural productivity in the study area: it will also bring to the awareness of the local people the type of safety and application measures that is good for them. Also, it will provide a structural framework for effective and accurate management of agricultural farmland and provide a base line data for researchers involved in ***food resources assessment.***

The health risks associated with pesticide application in agricultural farmland by man and the environment are of concern to environmentalists and government agencies locally and globally and underscores the need for continuous research with a view to ameliorating the problems of food poisoning and environmental pollution by wrongful application of pesticides. It is, therefore, very important for studies to be conducted on the assessment of risk associated with pesticides application on selected agricultural farmland in Kano State, Nigeria. It is expected that the implementation of the new framework may help prevent the registration of dangerous agrochemicals before they are launched to the agricultural market.

1.5 Scope and Limitations of the Study

The study was limited to selected agricultural farmland in Kano State, Nigeria and it is basically concerned with risk assessment associated with pesticides application. Finally, it would focus on seeking and recommending sound mitigate and management policies and practices which when strictly adopted and implemented, would make life better for humans and increase life expectancy.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 General Background Information on Pesticides

This literature review is divided into ten (10) main categories viz:

i. General information on Pesticides
ii. Behavior and fate of pesticides residues in the soil
iii. Impacts of pesticides on Natural Enemies,
iv. Resistance of pests to pesticides
v. Pesticides Misuse
vi. Pesticides Resistance Development
vii. Use of Genetically Modified Crops
viii. Pesticides residue in the Environment
ix. Food Safety and Pesticides in a Global Market
x. Towards Sustainability

Pesticides are known human and environmental toxicants and are widely used throughout the world in order to assure crop protection against pests and guarantee high crop yields (Hashemi *et al.,* 2012; Salameh *et al.,* 2004). Even though several products have been banned due to their acute and chronic effects (Verger and Boobis, 2013), pesticide applicators (PAs) are often not aware that also modern pesticides retain a significant toxicological profile, with a consequent global health burden (Fan *et al.,* 2015; Jeyaratnam 1990). Even though two-thirds of the 350,000 annual pesticide-related deaths occur in developing countries, figures remain of significant relevance also for high income countries (WHO, 2004; Rios-Gonzalez *et al.,* 2013). In Italy, for example, a total of around 2,500 occupational cases of acute pesticide intoxications were identified between 2005 and 2011, representing 5% of all poisonings (Settimi *et al.,* 2010).

Concerns about the massive use of pesticides, in particular insecticides, in agriculture were raised half a century ago by Rachel Carson (Yang *et al.,* 2014), sparking an environmental movement that has lasted to this day. Regulations about the safety of individual pesticides were enacted in the United States and other developed countries in the 1970s, while most developing and underdeveloped countries remained oblivious to their negative effects (Strong *et al.,* 2007; Jeyaratnam, 1990) until their routine misuse impacted on human health (WHO, 2004; Settimi *et al.,* 2010) and brought about other negative environmental consequences (Hashemi and Damalas, 2010; Lekei *et al.,* 2014). Since then, assessment of the risks to humans and the environment has been carried out before a new agrochemical product is launched to the market. However, while impacts on human health are carefully scrutinized, the assessment of impacts on the environment is performed using methodologies that are either inappropriate or lack sound scientific basis. Not surprisingly, the loss of biodiversity in aquatic ecosystems has been correlated with pesticide residues in waters and sediments (Khan and Damalas, 2015; Van Hoi *et al.,* 2009), which change the structure and function of invertebrate communities (Grovermann *et al.,* 2013). At the same time, the entomofauna is collapsing in developed countries (Stadlinger *et al.,* 2012; Sam *et al.,* 2008) while populations of many vertebrate species that depend on them (Chen *et al.,* 1998; Gatto *et al.,* 2016) have been declining as well. The evidence at hand attest to our inability to properly assess the risks that insecticides and other agrochemicals have on the natural environment. Some authors have proposed a post-registration monitoring in an effort "to identify unexpected direct and indirect impacts on organisms by accounting for multiple propagation routes and exposures" (Zyond *et* *al.,* 2010). This approach assumes that pesticides that are already registered may be later found to cause unforeseen effects in the environment, when the damage is already done. It does not prevent the use of a new product and does not guarantee its withdrawal from the market either. We previously evaluated the methods and shortcomings of the current approaches used for assessing the ecological risks of agrochemicals (Yassin *et al.,* 2002) and pointed out their deficiencies, which stem mostly from our poor understanding of toxicological effects at the population and ecosystem levels. In this paper, we suggest a new framework for making the ecological risk assessments (ERA) more realistic, using examples from the past and current failures to illustrate and justify our standpoint.

2.1.1 Toxicity Assessment

The main flaw in the current ecological risk assessments stems from an inadequate understanding of the toxicity of chemicals to populations of organisms. The entire framework is based upon the acute toxicity of a poisonous substance to a small set of non-target species representative of major taxa-the so-called surrogate species in ecotoxicity testing-together with the chronic toxicity to mammals only. This framework is derived from our knowledge of human toxicology, which focuses exclusively on the effects at the individual level and regards effects such as carcinogenicity or mutagenicity very highly, even if they are for the most part irrelevant to animal species in the wild environment; this is because, by their very nature, pesticides are highly poisonous chemicals designed to kill either animals (e.g. insects, worms, snails, rodents) or plants and fungi. They act upon a biochemical or physiological mechanism specific to the target taxa, so the individual organisms usually die before they can develop any long-term effects such as cancer. Teratogenic effects and malformations are very rarely, if at all, caused by pesticides. Other substances, such as dioxins and heavy metals, are typically to be blamed for those aberrations (Dickman and Ryglel, 1996; White and

Seginak, 1994). Obviously, testing for carcinogenic and mutagenic effects is relevant only to human health, not the environment. Currently, ecotoxicity assessments of agrochemicals are based on the median lethal dose (LD50) or concentration (LC50) of a particular chemical to the non-target surrogate species that are presumably present in a given environment. As mentioned above, such endpoints refer to acute lethality, usually within a short time frame: from 24 to 96 hours for most organisms, although 1 or 2 weeks are typical with earthworms. Chronic toxicity is only tested in experimental mammals (e.g. rats, mice or rabbits) because of its relevance to human health. Recent regulations have proposed also chronic toxicity tests with bees (Hesketh *et al.,* 2016; OECD, 2016), but lasting only 10 days while forager bees usually live 30 days and winter bees up to three months.

Knowing the lethal potency of a pesticide is very important, but it is not the only way to assess its impact on populations of organisms. Animals, plants and fungi reproduce, which means they overcome their individual losses, caused by either pesticides or any other factor, by producing new individuals. This is very obvious in the case of insecticide resurgence, whereby an insect pest that has been decimated by an insecticide application reacts by mass-producing more progeny, as the insect pest struggles to cope with a threat to its own survival. A similar outcome is expected in populations of non-target species that may be affected by the toxic effects of the insecticide: it is called recovery, and it allows the populations affected by the toxic chemical to survive in the long-term (Van dan Brink, 1996; Wijngarden *et al.,* 2005). Therefore, no matter how deadly a pesticide may be in the short-term, the survival of a few individuals may be sufficient to restore the impacted populations to their former levels. It also implies that toxicity endpoints that consider only the acute effects of a substance are not suitable to predict its long-term impacts on populations. Our planet, however, is recording an unprecedented loss of populations of species that live in agricultural landscapes and yet are not the target of the pesticides applied in those areas (Chamberlain and Fuller, 2000). While pesticides are not the only factor involved in such declines, as habitat and food losses are also to blame, they are the major contributors to the population collapses (Mineau and Whiteside, 2013). These declines are observed with insect pollinators (Cameron *et al.,* 2011), in particular bees (Cameron *et al.,* 2011; Kosior *et al.,* 2007) and butterflies (Forister *et al.,* 2016; Gilbum *et al.,* 2015), as well as insectivore vertebrates such as frogs (Fellers and Drost, 1993; Lips, 1998), fish (Scholz *et al*), small birds (Fuller *et al.,* 1995; Hart *et al.,* 2006) and bats (Clark, 2001; Stahlschmidt and Bruhl, 2012). Sound ecological theory states that a population of organisms will decline whenever its rate of increase is lower than its rate of mortality (Sibly and Hone, 2002; Walthall and Stark, 1997), while a continuous downward trend will eventually cause its extinction (Tanaka, 1998). The demise of a population, therefore, is more important in ecological terms than the temporary loss of a few individuals that can be offset by recovery. Furthermore, if the declining populations mentioned above are linked to pesticides, a toxicity assessment should be able to explain the physiological mechanisms involved in the long-term declines.

2.1.2 Exposure assessment

Current exposure assessments are performed using a variety of models (Sanchez-Bayo and Tennekes, 2015). The models are necessary for assessing the likely scenarios of exposure to a pesticide during the registration process, since the products are not released into the environment yet. For agrochemicals that are already in use, the data obtained from modeling must be validated with actual measurements done through monitoring under different conditions, locations and crop situations. Bioaccumulation in tissues, degradability in environmental matrices and persistence are the key properties to watch out. Agrochemicals that bioaccumulate should not be considered for registration in the first place, given the problems they cause, as the dark history of organochlorines and chlorfluazuron insecticides has demonstrated. Such chemicals are still present in agricultural soils (Shivaramaiah *et al.,* 2002) and are being transferred to animal tissues (Braune and Malone, 2006; Nag and Raikwar, 2011). The analytical methods available nowadays are sufficiently good to measure any pesticide residues that can be found in the environment. In many surveys, however, the highest residue levels are missed due to using inappropriate sampling procedures. This introduces a bias in the monitoring data gathered, as the worst-case scenarios that may well be the cause of population declines in some species are ignored. Passive samplers deployed in water or air can obtain integrated measurements of residues over a period of time, including peaks and troughs, so are found to produce better data than simple grab samples (Schafer *et al.,* 2011). Whatever the case, the monitoring residue data must be evaluated for the highest peaks as well as the average or the median concentrations of residues in the matrices considered, whether plant products (e.g. pollen, nectar, fruit), soil, water or air. The only requirement for this assessment is to obtain a comprehensive set of values that can be useful for the ERA. In this regard, the only obstacle is the high cost of the analyses, which often impedes or reduces the monitoring efforts necessary for a correct assessment of risks. Cheaper alternatives exist (e.g. ELISA kits), but they are mainly used for screening purposes in routine quality tasks (e.g. to discard negative detections in food or environmental matrices) and are not a substitute for instrumental analyses.

2.1.3 Risk assessment

The existing ERA framework attempts to integrate the toxicity and exposure assessments into a single evaluation that will be used to either register a new product or to assess the ecological impact of the pesticide(s) under consideration in a particular area or region. Many shortcomings are present in the current ERA of pesticides, most of which have been explained in our previous publication (Sanchez-Bayo and Tennekes, 2015), so they won't be dealt with here. Our emphasis now is in applying a rational and logical framework based on the new ecotoxicity data outlined above. The first tier of an ERA aims at screening chemicals that pose an unacceptable risk to the surrogate test species. The standard hazard quotient (HQ) ratio used for this purpose typically evaluates the acute toxicity of the pesticide (e.g. LC50, LD50, NOEL) against the expected environmental concentrations in several media (e.g. air, water, soil), accepting any chemical that produces values below 0.1. There are three reasons for setting this threshold value: i) the acute toxicity data evaluated in the first tier refers to a representative species of a tax on, but we know that differences in sensitivity among species in any one taxon range at least one order of magnitude (Kooijman, 1987) therefore, to account for the sensitivity of other species the HQ threshold should be some 10 times lower; ii) the infamous history of DDT and cyclodiene insecticides revealed that populations of predatory birds affected by eggshell thinning started to decline when these insecticide residues in their bodies were 10 times lower than the median effective doses that produced such an effect (Walker, 2001); iii) a large number of mesocosm studies with insecticides have shown that recovery of aquatic invertebrate populations tends to occur when residue concentrations in water are about 0.1 x EC50 values (Wijngaarden *et al.,* 2005). As a result, values of 1 for HQ ratios that use LC50 or LD50 data are not protective and have to be lowered by a factor of ten. In the current system of pesticide registration, if the resulting HQ exceeds 0.1 for a given surrogate species, the chemical must undergo a second tier evaluation that considers further laboratory toxicity tests (e.g. acute toxicity to more species, microcosms) and trials in semi-field (e.g. mesocosms) or field conditions, under the assumption that such conditions usually reduce the exposure of the organisms and, therefore, the effects may not be as pronounced as predicted by the original HQ values. It should be noted that these evaluations are done using only acute, short-term toxicity data. Whenever the data available are inconclusive to make a decision, a third tier may be considered to evaluate further impacts due to sublethal effects (e.g. endocrine disruption and others). Indirect effects are not considered in any case. In site-specific ERA of pesticides that are currently used in agriculture, the risk assessment may consider species sensitivity distributions (SSD) of acute toxicity values to a range of species in the first tier instead of using HQ values, although more often SSDs are used in the second-tier assessment. In that case, SSD data are used in probabilistic risk assessment (PRA) to determine the proportion of species that would be negatively affected by the highest or normal levels of residues predicted in a given environment (Shi *et al.,* 2014). Up to now risk assessments have been mostly, if not exclusively, based on acute toxicity data, ignoring any other toxicity effects that may be due to chronic exposure but are more relevant to the long-term viability of a species in the natural environment. A new order of priorities is proposed here, which considers mortality under acute or chronic exposure in the first tier, population growth endpoints in the second tier and sublethal effects such as endocrine disruption and other impairments in the third tier (Figure 1). The assessment of acute mortality endpoints can still be done as up to now, but with an additional difference: even if the HQ value is below 0.1, the chemical should not be approved until it is evaluated for its time-cumulative toxicity under sublethal chronic exposures (Figure 1). All agrochemicals should be tested using TTE assays to determine whether or not the chemical has delayed, time-cumulative mortality, whereas chemicals that produce HQ>0.1 should be exempt of further evaluations because they must be rejected. The rationale for acting like this is based on our experience with the novel class of neonicotinoid insecticides, which produce values of HQ below 0.1 for most aquatic and terrestrial species when the acute 24 or 48-h LC50 or LD50 data are used, and yet produce a large proportion of mortality when the same species are exposed to much lower concentrations for a prolonged period of time (Alkassab and Kirchner, 2016). Screening for such chemicals is deemed essential – thus, its inclusion in the first tier. Chemicals that act agonistically upon specific receptors, such as nicotinic receptors or others, tend to produce delayed, time cumulative mortality because the continuous excitation of the receptor often leads to the death of the cell. If the cell cannot be regenerated (i.e. neurons), such an effect is irreversible, hence the resulting pattern of toxicity is not only dependent on dose but also on the time of exposure to sublethal levels (Tennekes and Sanchez-Bayo, 2013). For such chemicals, the risk assessment should aim at determining the time to 50% mortality (T50) in a population under the normal and worst exposure scenarios, as it has been described elsewhere (Sanchez-Bayo and Tennekes, 2015). In our view, chemicals that behave this way should not be approved because the long-term negative impacts they have on the populations of numerous species. Once the first tier is passed, all chemicals should be evaluated for their effects on population growth, which are the effects that really determine whether the species will recover from exposure or not, due to the variety of mechanisms indicated above, under normal and worst-case exposure scenarios. This step is also essential for making a decision about the agrochemical under assessment, so only those compounds that do not affect the fecundity of species and do not produce a negative rate of increase in the populations tested should pass this assessment or else be rejected. Again, the history of DDT and cyclodiene insecticides has shown that while the individual birds of prey that accumulated these chemicals were alive and possibly healthy, their populations were on the road to extinction simply because the hatching of their fragile, thin-shelled eggs failed; consequently, the rates of population growth declined to levels below the natural replacement threshold of the species and were unsustainable in the long-term (Sibly *et al.,* 2000). Indeed, sublethal effects that have a serious impact on the long-term viability of populations are as important or more than lethal effects in the short-term. Lessons from the past such as this should be borne in mind when regulating the use of current systemic insecticides that are implicated on colony collapses of honey bees, and other pollinators, mainly through sublethal effects (Smagghe *et al.,* 2013), and dismiss calls to the contrary (Blacquiere and Van der Steen, 2017). Further tiers of assessment should be kept as they are now, as possible community impacts can only be detected in microcosm or mesocosm studies, while the indirect effects on non-target populations can only be detected after years of using pesticides that are apparently harmless (Poulin *et al.,* 2010). Once again, we should learn from the hard lessons of the past so as not to repeat them (Krebs *et al.,* 1999).

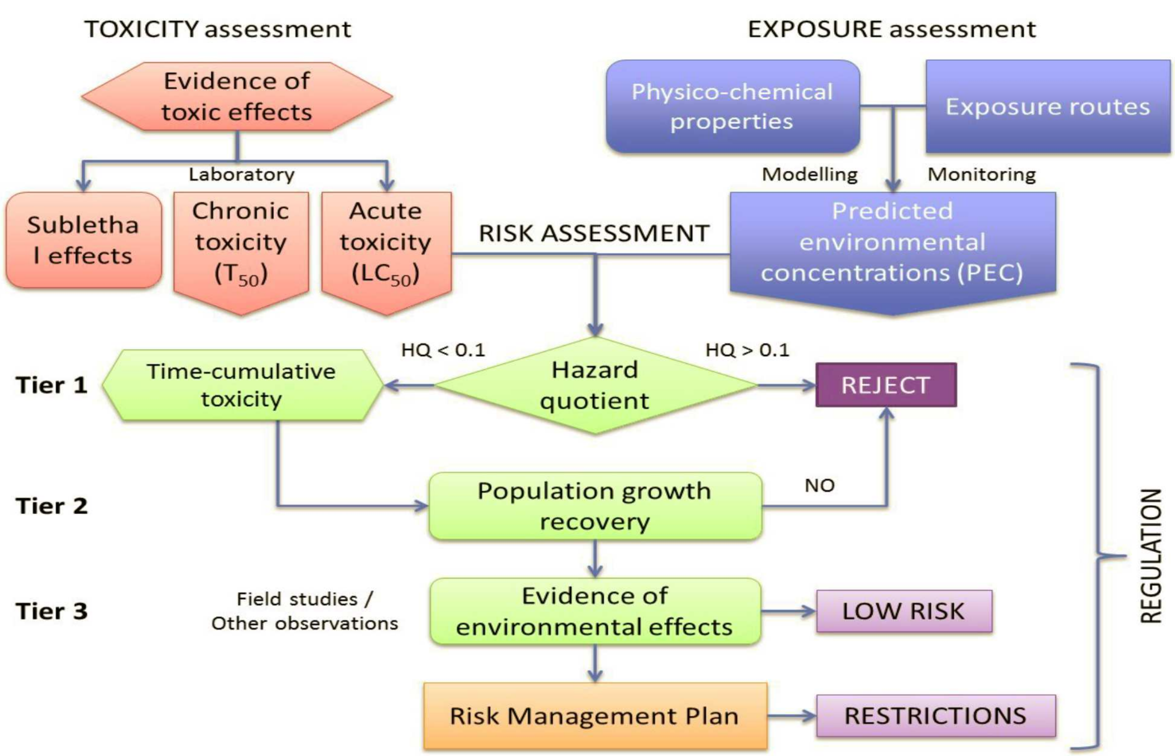

Figure 1. *Proposed framework for ecological risk assessment of agrochemicals.*

2.2 Behavior and fate of pesticide residues in the soil

In addition to accidental or intentional discharges, the presences of pesticides in agricultural soils mainly have two origins: (i) treatments applied to the aerial part of crops to combat pests, when approximately 50% of the product (insecticides and fungicides, and some herbicides) may reach the soil and (ii) the soil itself is directly treated (insecticides, nematicides, disinfectants, and mainly herbicides), which will obviously lead to a higher concentration in the same (Navarro *et al.,* 2007). To understand the behavior of a pesticide, it is essential to have the appropriate analytical tools capable of determining residual concentrations in different media (plant, soil, and water) and the main metabolites that can appear. Analytical procedures typically involve a number of equally relevant steps for sampling, sample preparation, isolation of the target compounds, identification, and quantification mainly by gas (GC-MS) and liquid chromatography (LC-MS) coupled to mass spectrometry and other minority techniques such as capillary electrophoresis (CE), immunochemical methods (ICMs), electrochemical methods (EMs), chemiluminescence (CL) or ion mobility spectrometry (IMS), and data processing (Tadeo *et al.,* 2012; Semen *et al.,* 2016). The fate of pesticides in the soil depends on many processes responsible for their mobility and persistence (Duraes *et al.,* 2018; Borgensen *et al.,* 2015). Persistence may be defined as the tendency of a pesticide to conserve its molecular integrity and chemical, physical, and functional characteristics for a certain time after being released into the soil. The half-life time ($t^{1}⁄_{2}$) is the term commonly used to assess persistence (i.e., the time required for a pesticide to degrade to one-half of its initial amount in the soil). The typical half-life to consider a pesticide as persistent is more than 100 days, while nonpersistent pesticides have less than 30 days. Therefore, moderately persistent pesticides have t½ ranged from 30 to 100 days (Gavrilescu, 2005). From an environmental point of view, persistent pesticides are undesirable because some of them are intrinsically toxic and deleteriously affect human, domesticated animals, agricultural crops, wildlife, fish and other aquatic organisms, or microorganisms. Some recalcitrant (i.e., nonbiodegradable) pesticides are not toxic at the levels found in the soil, but they can reach hazardous levels due to biomagnifications through the natural food chains. For this reason, it is very important to know the process by which a pesticide is degraded in order to determine whether it will accumulate in the soil or pass into groundwater and whether it will persist in either. Once a pesticide is applied to soil, it will most likely follow one of three pathways: (i) adhering to soil particles (mainly organic matter and clays), (ii) degrading by organisms and/or free enzymes, and (iii) moving through the soil with water. From the physical-chemical data of adsorption, mobility, and degradation obtained in the laboratory, it is possible to predict with a high degree of reliability the behavior of pesticides in the soil. For this, different guidelines have been proposed by OECD to study adsorption (OECG, 2000), degradation (OECD, 2002), and leaching (OECD, 2007). Figure 1 shows the schematic behavior of pesticides in the soil. Adsorption that may be chemical (electrostatic interactions) or physical (van der Waals forces) is the result of the electrical attraction between charged particles, pesticide molecules (sorbate), and soil particles (adsorbent). Pesticide molecules that are positively charged are attracted to negatively charged particles on clays and organic matter. Chemical reactions between unaltered pesticides or their metabolites often lead to the formation of strong bonds (chemisorption) resulting in an increase in the persistence of the residues in the soil, while causing it to lose its chemical identity. Degradation generally happens gradually through the formation of one or more metabolites and takes place through photochemical, chemical, and/or microbiological processes. Photodegradation refers to the decomposition induced by radiant energy (ultraviolet/visible light range) on pollutants and is only relevant at the soil surface. The solar light may be absorbed by the pollutant, resulting in the formation of by-products, or does not have a direct effect on the pollutant but acts on other substances (photosensitizers) that will promote the degradation of pesticides (Roof, 1982). Chemical (hydrolysis, oxidation, aromatic hydroxylation, etc.) and biological processes are closely linked, and it is difficult to distinguish between them. For this, the process is commonly called biochemical degradation. The transformations that pesticides may suffer in the soil are many and varied. Besides the characteristics of the pesticide, other factors such as the colloidal composition, texture and moisture content of the soil, the number of microorganisms present (including bacteria and fungi), etc., play a key role. Biodegradation can be defined as a process by which microbial organisms transform or alter, through metabolic or enzymatic action, the structure of pesticides presents in the soil (Das, 2014). The metabolic pathways from natural metabolic cycles have enabled the microorganisms to degrade pesticides in the soil although many of them are recalcitrant pesticides. Whereas biodegradable pesticides are broken down within days or weeks by soil microorganisms, recalcitrant pesticides remain for long periods (years or even decades) in the soil. By a total degradation of a pesticide (mineralization), CO_2, salts, and water are formed, and parts of the chemical are built into new molecular structures in the soil humus or in biomass (bound residues). The terms free and bound residues were coined to indicate that the former can be readily extracted from soil without altering their chemical structures, whereas the latter are resistant to such extraction (Gevao *et al.,* 2000). However, the distinction between these two fractions is not always clear, because while they are in the soil, even the extractable residues are not entirely free from any form of binding because they may be adsorbed to the soil solid phases and, therefore, show reduced bioavailability and degradation. According to Roberts (Roberts, 1984), bound residues are chemical species originating from pesticides, used according to good agricultural practice, that is, unextracted by methods which do not significantly change the chemical nature of these residues. Twelve years later, according to IUPAC, Fuhr *et al.* (Fuhr *et al.,* 1998) proposed a modification to the existing definition of bound residues: Compounds in soils, plant or animals, which persist in the matrix in the form of the parent substance or its metabolite(s) after extraction. Knowledge of the kinetics of biochemical degradation is essential to the evaluation of the persistence of pesticides. Pesticide degradation was described using simple first order (SFO) kinetics for much time, and it is still the most common mathematical description of pesticide degradation in the scientific literature. However, in some cases, this model is not appropriate. The FOCUS (Forum for the Coordination of pesticide fate models and their Use) degradation kinetic expert group, supported by the European Commission, came up with two alternative equations for pesticide degradation in soil. Both are based on first-order kinetics although composed of several processes (Boesten *et al.,* 2005). The alternative equations are the First Order Multi-Compartment (FOMC) equation and the Double First Order in Parallel (DFOP) equation.

$C_t = C_0^{ekt}$ (SFO) (1)

$C_t = C_0 (1 + t/ß)^{\alpha}$ (FOMC) (2)

$C_t = C_1^{e\ k1t} + C_2^{e\ k2t}$ (DFOP) (3)

where C_t = amount of pesticide present at time t, k = rate constant for the degradation process, C_0 = amount of pesticide at time 0 (initial amount), = parameter determined by the variation in k values, = positional parameter, C_1 = amount of pesticide at time 0 in the first compartment, k_1 = rate constant for degradation in the first compartment, C_2 = amount of pesticide at time 0 in the second compartment, and k_2 = rate constant for degradation in the second compartment.

Finally, pesticide transfer refers to the movement of pesticides from their site of application. Five processes that can move pesticides are diffusion, volatilization, leaching, erosion and runoff, assimilation by microorganisms, and absorption by plants. Diffusion can be verified in the gaseous and liquid phases, or in the air of the inter-solid phase. The pesticide is transferred through the soil from one zone where it is more concentrated to another where it is less. The volatilization of pesticides from the soil and their subsequent dispersion in the atmosphere is a common occurrence and is perhaps the most important route by which pesticides dissipate. Once volatilized, a pesticide can move in air currents away from the treated surface, a phenomenon known as vapor drift. The soil can be act as a conveyor of the pesticide when its particle is moved from one place to another through the effects of wind or runoff, leading in certain cases to the contamination of surface waters (rivers, seas, and lakes). Runoff determines the movement of water over a sloping surface that occurs when water is applied faster than it enters the soil. Pesticides carried by surface runoff from agricultural areas are a significant portion of the pesticide pollutant loading rates to surface water bodies. Absorption of pesticides by a target and nontarget organisms (bioaccumulation) is quite variable and it is influenced by species characteristics, environmental conditions, and by the chemical-physical properties of both the pesticide and the soil. Pesticide uptake by plants depends on the environmental conditions and the physical-chemical properties of the soil and pesticides and it is influenced by plant species, growth stage, and intended use. Leaching is the vertical downward displacement of pesticides through the soil profile and the unsaturated zone, and finally to groundwater. Pesticide leaching is highest for weakly sorbing and/or persistent compounds, climates with high precipitation and low temperatures (which leads to high groundwater recharge) and sandy-soils with low organic matter.

2.3 Impacts of Pesticides on Natural Enemies

The concept of Integrated Pest Management (IPM) was initially defined as the combined use of natural enemies and pesticides to manage pests (Stern *et a1.,* 1959). The IPM concept later includes coordinated use of all possible tactics to suppress pest damage (Smith et al., 1976, as cited in Ruberson *et al.,* 1998). Use of selective pesticides or rates, temporal separation of pesticides and natural enemies, and spatial separation of pesticides and natural enemies are three main area of integrating natural enemies with pesticides in pest management programs (Ruberson *et al.,* 1998). Conventional use of insecticides can have deleterious effects on natural enemy populations because beneficial arthropods can have greater susceptibility to low concentrations of insecticides than their prey or host (Ruberson *et al.,* 1998; Torres & Ruberson, 2004). Pesticide compatibility with biological control agents is a major concern to practitioners of IPM, and knowledge about the activity of insecticides toward pests, non-target insects and the environment is a necessity (Stark *et al.,* 2004). Pesticides exert a wide range of lethal (acute and chronic) and sublethal (often chronic) impacts on natural enemies (Rezaei *et al.,* 2007; Ruberson *et al.,* 1998; Stark *et al.,* 2004). Talebi *et al.* (2008) have published a comprehensive reviewed on the22 impacts of pesticides on arthropod biological control agents. Sublethal effects are expressed as some changes in the insect's life history attributes (Ruberson *et al.,* 1998). Many studies have been performed on the evaluation of the toxicity of various pesticides to beneficial organisms (Kavousi & Talebi, 2003; Lucas *et al.,* 2004; Medina *et al.,* 2003; Oomen *et al.,* 1991; Paine *et al.,* 2011; Rezaei *et al.,* 2007; Steiner *et al.,* 2011; Urbaneja *et al.,* 2008; Van de Veire *et al.,* 2002; Van den Bosch *et al.,* 1956; Walker *et al.,* 1998). Some important issues including natural enemy species, life stages/sexes, routes of pesticide entry, life history parameters, plot size for field screenings and pesticide formulations and rates must be considered for designing bioassays evaluating the effects of pesticides on natural enemies (Ruberson *et al.,* 1998). One of the commonly used methods in testing the side effects of pesticides on natural enemies, recommended by the International Organization of Biological Control (IOBC), is a tiered approach whereby initial pesticide screening is done in the laboratory, and, depending on the results obtained, semi-field or field tests may be conducted (Dohmen, 1998; Hassan, 1998). This method has been designed to evaluate the acute residual toxicity as well as sublethal effects of the pesticides on the reproductive performance (Vogt *et al.,* 1992). In this method, dead subjects are recorded (often daily) and the total mortality is calculated. The value of mortality (M) for the treated series is determined as the corrected mortality according to Abbott (1925). The average number of progenies (R) is measured as fecundity affected by exposing to a pesticide. The total effect of a pesticide (E) is calculated by the formula $E = 100\% - (100\% - M) \times R$ proposed by Overmeer & Van Zon (1982). Based on the total effects, a pesticide is classified using IOBC evaluation categories (Sterk *et al.,* 1999). Rezaei *et al.* (2007) investigated the effects of imidacloprid, propargite and pymetrozine in laboratory experiments using IOBC-system on the common green lacewing, *Chrysoperla carnea* (Stephens). All three tested pesticides produced significant adverse effects on preimaginal survival ($p<0.01$). Imidacloprid had no significant effect on fecundity, but propargite and pymetrozin caused significant reductions ($p<0.05$). According to IOBC classification, imidacloprid was found to be harmless (E=27.44%), propargite (E=49.78%) and pymetrozine (E=66.9%) were determined as slightly harmful.

2.4 Resistance of pests to pesticides

Pesticides are used extensively for control of invertebrate pests, plant pathogens, weeds and rodents and other pests in a wide range of crops and for veterinary purpose.

Resistant to pesticides develop in insects, mites, fungi, weeds, bacteria and rodents. Repeated applications and extensive use of the synthetic pesticides has toxicity toward natural enemies and cause resistance development in pest species against major classes of pesticides throughout the world. The repeated and extensive application of pesticides caused majority on susceptible individuals in population and only some resistant individuals survive from pesticide exposure. The offspring genotype of survival individual is homozygous or heterozygous that depends on history of pesticide application and type of pesticides. The offspring inherit the resistant genes and survival ability from the exposure to the pesticides. The surviving individuals multiply in absence of their natural enemies and finally replace the non-resistant population. The development of pesticide resistance is a Darwinian evolutionary process at a rate that rare genes conferring resistance to pesticides are selected by the high selection of pesticides. Resistance to pesticides is defined as "the development of an ability in a population of a pest to tolerate doses of pesticides that would prove lethal to the majority of individuals in a normal population of the same species" (Stenersen, 2004). The first case of resistance occurrence in insect pests was reported in 1908. This document reported the failure in the control of *Quadraspidiotus perniciosus* (Hem. Diaspididae) by sulphur. After this report, Melander (1914) reported resistance of three scale strains in United State to sulphur and sulphur–lime (as inorganic pesticide) (as cited in Stenersen, 2004). The organochlorine and synthetic insecticides were commercialized for chemical control of pests in the 1940's. The first case of DDT resistance in insect was reported in *Musca domestica* few years after introduction. After that, new insecticides such as cyclodienes, pyrethroids, organophosphates (OP), carbamates, formamidines, *Bacillus thuringiensis*, avermectins, spinosyns, insect growth regulators (IGR) and neonicotinoids were introduced for pest control and the cases of resistance to these compounds appeared a few years after their application. Now, more than 504 key pest species were resistant to pesticides and the resistance to pesticides has become a major contemporary problem in pest management programs (IRM) worldwide. Stuart (2003) reported resistance of 520 insects and acari species, 150 plant pathogen species and 273 weed species to pesticides. Pesticides resistance reduces the ability control of pesticides on pests and leads to higher application rates to achieving satisfactory pest control. Pimentel (2003) estimated the major economic and environmental losses due to the application of pesticides on crops and veterinary purpose in the USA and showed the following costs: "public health, $1.1 billion year-1; pesticide resistance in pests, $1.5 billion; crop losses caused by pesticides, $1.1 billion; bird losses due to pesticides, $2.2 billion; and ground water contamination, $2.0 billion" (Pimentel, 2005).

2.5 Pesticide Misuse

2.5.1 Pesticide Mismatch with Targeted Damage-Causing Agents

Proper identification of yield-reducing agents is important whether you are dealing with an insect, weed, plant disease or vertebrate. Misidentification and lack of information about a pest cause people to choose the wrong control method or to apply the control at the wrong time. Plants are also damaged by a lack of nutrients or water and by non-living agents, such as extreme weather, air pollutants, road salt and inadequate or excessive fertilization. Sometimes the damage is mistaken for that caused by living pests or diseases. Applying pesticides in such situations leads to unnecessary contamination with toxic residues. One of the major challenges in crop protection is identifying and controlling plant diseases. Disease symptoms of plants include necrosis, over- or underdeveloped tissues, discoloration and wilt. These symptoms can be caused by several pathogens. It is obvious that, to treat fungi, fungicides have to be applied, bacteria are treated with antibiotics, viruses with viricides and nematodes with nematicides. Knowing that plant pathogens are taxonomically classified into Protozoa (e.g. *Plasmodiophoromycota*), Chromista (e.g. *Oomycota*) or Fungi (e.g. *Chytridiomycota, Zygomycota, Ascomycota, Basidiomycota*), the biodiversity between the different species is much more pronounced compared to the kingdoms of insects or plants. No broad-spectrum fungicides really exist. They are not effective against all plant pathogens at once. If the right pathogen is not correctly identified, the wrong products may be applied. One solution to overcome this problem is to apply mixtures of fungicides. However, applying several pesticides may result in cocktails of pesticide residues in crops, contributing to another food safety issue.

2.5.2 Non-optimal Timing of Pesticide Application

Timing of pesticide application is important. Little is known about pesticide use patterns for different pests, weeds or diseases in each crop. For instance, the life cycle and infection process of fungi necessitate contact fungicides to be applied preventively before disease symptoms occur. Once the plant is externally infected, it is usually too late to heal the crop. Eradication is thus the only solution. Contact products only protect the sprayed parts of the plants so after growth of new plant parts, other pesticide treatments are necessary. This explains the high application rates of fungicides on an almost weekly basis.

2.5.3 Non-optimal Frequency of Application

The frequency of pesticide applications depends on the persistence and corresponding biological action of the pesticides used. Application technology, formulation and climatic conditions such as rainfall and temperature further influence the deposit needed to sustain plant protection.

2.5.3.1 Non-optimal Application Dose

Due to limited knowledge of pest occurrence, pest control and pesticide use, farmers may overuse pesticides to control some pests and underuse pesticides for other pests. Both over- and underuse of pesticides may have side effects. Pesticide overuse is known to induce pest resistance, threaten food safety, damage human health and pollute the environment. It will also kill many beneficial organisms and natural enemies. The negative effects of pesticide underuse have often been ignored in the existing literature. Besides low crop yield caused by the inefficient control of some crop pests, the other negative externalities of pesticide underuse are poorly understood. Since crop pests can cross the physical boundaries of farm fields, pesticide underuse may put pressure on neighbouring farmers to increase their pesticide use to achieve effective control. Moreover, it is also known that even small amounts of pesticides may be sufficient to kill some beneficial organisms and natural enemies. Thus, pesticide underuse may promote the proliferation of crop pests. In addition, insufficient usage of pesticides is associated with the development of pest resistance (Zhang *et al*., 2015a).

2.5.3.2 Non-optimal Pesticide Formulation

A pesticide is rarely used or applied in its pure form. After manufacture, the technical grade compound must be formulated, whether it is a herbicide, insecticide, fungicide or another classification. It is processed into a usable form for direct application or for dilution. Formulating a pesticide improves its properties of storage, handling, application, effectiveness or safety. Tank-mix adjuvants are added to active ingredients of pesticides to make them even more effective for application. Ryckaert *et al*. (2007) showed, for instance, that the use of tank-mix adjuvants better prevented mycotoxin-producing *Fusarium* species and optimized the formulation. For example, when no tank-mix adjuvant was used, the lower part of the ear was reached five times less by the propiconazole spray than the upper part of the ear. When the tank-mix adjuvant was combined with the propiconazole formulation, an increase in residue on both the upper and lower part of the ear was observed.

2.5.3.3 Non-optimal Spatial Application

Residues of crop protection products on foodstuffs in samples taken from field and monitoring samples are shown to exhibit great variability, with coefficients of variation of 80–110% being common. Variability in residues among individual samples is inevitable, partly because it is impossible to achieve uniform deposition of pesticides and partly because variables influencing dissipation processes, such as microclimate and crop growth, are inherently heterogeneous. Application technique, canopy architecture and growth stage have all been shown to affect variability in initial deposit. Significant loss of residues may result from wash-off due to rain, although the exact relationship of residue losses with the amount of rainfall may vary between pesticides (Xu *et al*. 2008).

2.6 Pesticide Resistance Development

Pesticide resistance, the ability of an organism to withstand a poison, is a predictable consequence of repeated pesticide use. It is defined as ‘any heritable decrease in sensitivity to a chemical within a pest population’ (Brent 1986). Resistant organisms are simply following the rules of evolution: the best-adapted individuals survive and pass their resistance traits on to their offspring. In many cases, pesticide resistance has resulted in more frequent spraying, influencing food safety as farmers and residential pest control operators scramble to destroy the resilient organisms, followed by increasing resistance and escalating crop losses or food insecurity.

2.7 Use of Genetically Modified Crops

Agro-chemical companies make large investments in the development of genetically modified (GM) crops. In the context of pesticides, GM crops, like soybeans, corn or potatoes, engineered with Bt-, glyphosate- or pathogen-resistant enzyme systems are on the market. Genetic plant breeding is aimed at reducing pesticide use as well as the improvement of food safety by minimizing pesticide residues (Dias and Ortiz 2013). GM crops have been and continue to be the subject of controversy despite their rapid adoption by farmers when approved (Bonny 2016). Countries vary in their market acceptance of transgenic crops. GM labelling is mandatory in the EU, whereas in the USA, this practice is not imposed. For the last two decades, an important matter of debate has been the impact of GM crops on pesticide use, particularly for herbicide-tolerant crops. Some claim that these crops bring about a decrease in herbicide use, while others claim the opposite. In all cases, it became clear that genetic engineering is not the only solution to solve the issue of crop threats. Weeds, insects and fungi also develop resistance to GM crops, meaning that these crops will never be a standalone solution. Other crop protection methods such as pesticides will remain necessary to secure GM food production. Biotechnology products will only be successful if clear advantages and safety are demonstrated to both growers and consumers.

2.8 Pesticides residue in the environment

Chemical pesticides are used to control target pests. Extensive use of pesticides after World War II has substantially increased the agricultural production. However, non target organisms including human and wildlife are affected. Pesticides are bioactive molecules that interfere with vital biochemical and physiological processes in organisms. Some are lethal to exposed organisms and many can cause disorder at sub lethal level. Extensive research is necessary to clarify the side effects of pesticides on organisms. About 3 billion kg of pesticides is applied each year with a purchase price rose to $47 billion in 2008, worldwide (Pimentel, 2009; Frabotta, 2009). The environmental persistence is different from pesticide to pesticide. Some are persistent and remain in the environment either as a parent compound or transferred products. The fate of pesticides in soil depends on the value of Koc, carbon sorption coefficient. High values of Koc indicate a pesticide that strongly adsorbs to the soil particles and less likely to move with water. Moreover, soil composition, pH, moisture content and microbial activity affect pesticide persistence.

2.8.1 Insecticides

The most toxic and environmentally persistent compounds are found among insecticides; therefore, the emphasis is on groups of insecticides that have been studied in detail.

2.8.1.1 Chlorinated insecticides

The first synthetic insecticide was DDT with a wide spectrum of insecticidal action that was used in agriculture and against insect vectors of deadly diseases. DDT solubility in water is very low, about 0.006 mg/l, which makes it one of the most hydrophobic insecticides. DDT residues either as parent compound or its metabolites DDD and DDE are stable and have high persistence in the environment. It has a great tendency to be stored in fatty tissue of different organisms. After the introduction of DDT, HCH was marketed. HCH has eight isomeric forms of which γ-isomer is called Lindane. Lindane is a volatile insecticide and was used against agricultural and households' pests. Lindane is less persistent than the other organochlorine insecticides especially under moist conditions. The cyclodiens are stable organochlorine soil applied insecticides. These included aldrin, dieldrin, endrin, chlordane, heptachlor and endosulfan. Cyclodiens are environmentally persistent compounds that have raised concern about adverse effects on human health and wildlife. Residues of DDT and its metabolites DDD and DDE, dieldrin and heptachlor epoxide were detected in high percentage of soil and water samples from agricultural areas decades after their use were banned. Extensive studies on organochlorine pesticides has shown the environmental persistence of these Compounds (LeaMond *et al.,* 1992; Reiser & O'Brien, 1999).

2.8.1.2 Organophosphorus Insecticides

Organophosphorus insecticides replaced persistent organochlorine compounds. Utilization of these insecticides increased rapidly and for several decades comprised high proportion of total insecticide use. Organophosphates are unstable compounds, however some of these insecticides are more acutely toxic to invertebrate than chlorinated insecticides. Parathion was the first marketed product that was effective against a wide variety of pests. Some organophosphates caused severe toxicity associated with many deaths especially in developing country, whereas a few compounds such as malathion are relatively safe to mammals and degrade fairly rapidly in the environment. Most organophosphates are harmful to beneficial arthropods, though few compounds such as phosalone and dimethoate are considered as harmless compounds. The occurrence and movement of some organophosphate pesticides are reported in rivers and streams. Several studies conducted to find out the presence of organophosphate residues in California rivers during 1993-1994. Diazinon, methidathion, dimethoate and chlorpyrifos residues were detected in water samples. The detection occurred mostly during rainy season, showing how run off influences the presence of pesticide residues in rivers and streams (Ganapathy *et al.,* 1997).

2.8.1.3 Carbamate Insecticides

Carbamate insecticides are a group of synthetic compounds derived from carbamic acid. The first carbamate carbaryl was an N-methyl carbamate with high insecticidal activity against many insect pests and ectoparasites of animals. Carbamates especially N-mathyl carbamates are extremely toxic to hymenoptera and are lethal to exposed foraging bees. Carbamates biodegradation in environment is relatively rapid. Oxime carbamates are a group of carbamate with systemic action. Aldicarb, an oxime carbamate is the most potent toxic substance (LD50=0.9 mg/kg) ever used in crop protection. Because of high toxicity it is used as granular formulation. Aldicarb sulfoxide is its oxidative metabolite that may undergo further oxidation to the sulfone. Oxidative residues and its parent compound (Tatal aldicarb) are toxic and highly mobile in the environment. Total aldicarb is detected especially in shallow ground water since 1979. Ground water quality monitoring has shown that many samples contain aldicarb residues and some of them exceeded maximum acceptable concentration (Priddle et al. 1989; Marade & Weaver, 1994).

2.8.1.4 Pyrethroids

Pyrethroids are synthesized based on the model of naturally occurring pyrethrins with more stability to light and air. Pyrethroids are used in agriculture, homes, restaurants and hospitals. These compounds are readily metabolized by man, but they are effective against insects. Most pyrethroids are esters however non-ester pyrethroids are discovered with good insecticidal activity and low mammalian toxicity. These readily penetrate insects and paralyze their nervous system (Reigart *et al.,* 1999). Since pyrethroids are highly toxic to insects, both the beneficial and pest insects are affected. Sunlight, microbial activity, heat, and moisture accelerate pyrethroids break down, hence in areas with limited sunlight, pyrethroids persist for a long time. After treatment in the home, cypermethrin persist for about three months (Wright *et al.,* 1993). Pyrethroids are lipophilic compound that strongly absorb to colloids of soil. Dissipation of cypermethrin, fenvalerate, and deltamethrin, were investigated in yellow red soils. The half-life of these compounds was 17, 19, 18 days in unsterilized, compared to 76, 92 and 80 days in sterilized soil (Gu *et al.,* 2008). This experiment shows the effects of biodegradation in pyrethroids life span in soil.

2.8.1.5 Neonicotinoids

Neonicotinoids are similar to nicotine with the same mode of action. These insecticides have been used worldwide. Most neonicotinoids are absorbed and translocated to the tips of the plants. Imidacloprid is the first widely used insecticide of this group with relatively low mammalian toxicity. However, it is harmful to beneficial arthropods including bees (LD50=0.008 µg /bee). Imidacloprid and clothianidin are more toxic to bees as spray than as seed dressing (Tennekes, 2010). Most neonicotinoids are moderately soluble and so they are mobile in the environment. In ground water 18 feet below sandy loam soil concentrations of imidacloprid ranged from < 0.1 ppb to 1 ppb (Bacey, 2000). This observation shows the potential of imidacloprid to leach downward into shallow groundwater. Imidacloprid has a moderate binding affinity to soil colloids. Half-life in soil varies under different conditions. The half-life of imidacloprid in soil was 48-90 days, depending on the ground cover (Scholz & Spiteller, 1992). Laboratory experiments showed that persistence of another neonicotinoid, thiamethoxam is highly depending on moisture and the half-life varied from 45 to 300 days (Gupta *et al.,* 2008). The half-life of neonicotinoids increases with increasing soil colloids. Overall, neonicotinoids have a low potential to persist in soil and accumulate in the environment.

2.8.2 Herbicides

Herbicides are the major class of pesticides to control weeds. Little attention is paid to herbicides as a source of pollutants; mainly because with a few exceptions; most herbicides have not appreciable mammalian toxicity. Among toxic herbicides are paraquat (LD50=125 mg/kg) and dinoseb (LD50=58 mg/kg); however widely used herbicides including 2,4-D and glyphosate are not highly toxic to mammals. On the other hand, groups of herbicides that have potential to persist in soil and enter surface water include triazines, sulfonylureas, phenylureas and uracils. Laboratory experiments have shown that among four triazines; prometryn and terbutylazine half-lives were 263 and 366 days in ground water respectively. The half-lives of simazine and atrazine were shorter than prometryn and terbutylazine (Navarro *et al.,* 2004). Sulfonylureas are high potent herbicides group effective at very low dose (10-15 g/ha), for that reason persistent herbicides from previously sprayed farms may damage the next crop. These herbicides are able to penetrate into deeper layers of the soil profile, where they have a relatively high persistence. A number of sulfonylureas were detected in wetland sediments. Etametsulforun methyl, sulfosulforun and metsulforun-methyl were determined in wetland sediments with mean concentration ranging from 1.2 to 10.0 µg kg-1 (Degenhardt *et al.,* 2010). According to Cessna et al (2006) a half-life of 84 days was observed for metsulforun-mathyl in farm dugouts. Residues of 10 herbicides were detected in prairie farm dugouts. 2,4-D was the most frequent with median concentration 0.05 µg L-1(Cessna & Elliot, 2004). Based on these studies, herbicides have different tendency for binding to soil colloids and so have different movement ability.

2.8.3 Fungicides

Fungicides are substances that destroy or inhibit the growth of fungi. Fungicides are used in agriculture and industry. Early fungicides were organic derivatives of metals such as mercury. Organomercury fungicides were widely used as seed dressing to control diseases of cereals. Although mercury content of these fungicides' formulation were less than 5%, the main concern is the side effects of residues remaining in the environment long enough to enter soil and water. Both inorganic and organic compounds of mercury are toxic, however organic compounds are more lipophilic than inorganic and are liable to adsorption by soil colloids and storage in fat depot. Bioconcentration factor up to 100000 times is reported for the methyl mercury content in fish (USEPA, 1980). Dithiocarbamates (e.g. mancozeb, thiram, zineb and maneb) are the first synthetic organic fungicides. Some fungicides are toxic to aquatic organisms. Maneb is highly toxic to fish and triadimefon is highly toxic to crustaceans. Dithiocarbamate fungicides have low persistence. Among high persistent group of fungicides are triazoles (penconazole, myclobutanil and flusilazole), carboximides (boscalid) and pirimidines (fenarimol) (Wightwick *et al.,* 2010).

2.9 Food Safety and Pesticides in a Global Market

2.9.1 Food Safety Risk Linked to Pesticide Residues on Crops

Different governments worldwide define a maximum residue level (MRL), referring to the permitted residue level on a commodity. This level is based on the highest residue amount that can be found on a crop when the pesticide is used according to standard agricultural practices, also called Good Agricultural Practices or GAP (EFSA 2010). MRLs are not safety barriers, implying that a stricter MRL does not necessarily indicate a safer food product. Hence, when detected residue levels exceed the crop's MRL, the human health safety risk has to be assessed case by case. Safety limits consider the Acceptable Daily Intake (ADI) for long-term exposure and the Acute Reference Dose (ARfD) for short-term exposure. Furthermore, if a pesticide's MRL is not considerably lower than the public health safety limit (ADI), the pesticide is banned during the authorization process. In developed countries, pesticide residues in fruits and vegetables are a major concern to consumers due to their possible negative health effects. Although such residues have also been found in processed products, several studies have found that food processing reduces pesticide residues (Keikothlaile *et al*. 2010). Awareness of pesticide residues in agricultural produce is also increasing in developing countries. Monitoring of pesticide residues in food may be confusing to consumers because the majority of samples contain no detectable levels of pesticide residues. Therefore, and counterintuitively, the recitation of findings from regulatory monitoring programmes is of little value in terms of assessing the potential health risks posed by the consumption of the tested foods. This is primarily due to the fact that the allowable residue levels are not indicators of safety but rather reflect enforcement tools to assess whether Good Agricultural Practices have been followed (Winter, 1992). As such, excessive residue levels often indicate breaches of Good Agricultural Practices but only on very rare circumstances represent cases of health concern (Winter and Jara 2015). According to the Codex Alimentarius, a risk is defined by a function of the probability of an adverse health effect and the severity of that effect, consequential to hazards in food. The potential health risks posed by pesticide residues in foods can best be assessed by developing estimates of dietary exposure to pesticides and comparing exposure estimates to toxicological indicators of health concern such as the ARfD or ADI. An accurate estimation of dietary pesticide exposure requires data on specific levels of pesticide residues detected (not just whether the residues were legal or excessive) as well as estimations of consumption amounts of all foods for which residues are detected. Several findings indicate that both the probability (due to wrong use, inappropriate equipment) and severity (e.g. banned, adulterated pesticides) of pesticide hazards for consumers seem higher in developing countries than, for example, in EU member states. However, an accurate assessment of pesticide food safety in developing countries is difficult because these calculations require data on pesticide residues in the food products combined with knowledge of food consumption. These data are available in only a few developing countries (FAO/WHO 2016).

Dietary risk assessment has traditionally been done for an individual compound in a single crop. However, in real life, humans are usually exposed to multiple compounds in their diet. This combined exposure can have toxicological effects that can be independent, dose additive or interactive (i.e. synergistic or antagonistic). Until cumulative risk assessment tools become available, it will remain difficult to determine whether continuously lowering residue levels towards zero makes sense from the public health, agricultural and economical points of view. In developed countries, risk assessments are frequently performed to investigate where measures should be taken to lower health risk. An example is the Belgian risk assessment study (Claeys *et al*., 2011) which used official monitoring data on pesticide residues and food consumption data. This study suggests that pesticide residues on fruit and vegetables do not pose major public health risks. However, it was pointed out that although exposure of the adult population to pesticide residues appeared to be under control, a high consumption of fruit and vegetables by young children may be exceeding the ADI levels. This indicates that risks of pesticide use and the acceptable residue level depends on the context. Furthermore, to further reduce coincidental risks, the safety of pesticides is currently being assessed separately in Europe for several pesticides – food commodity combinations.

2.9.2 International *versus* Local Production

2.9.2.1 Pesticide Use in EU *versus* Developing World

In the EU, plant protection products cannot be placed on the market or used without prior authorization. A two-tier system is in place, in which the European Commission evaluates active substances used in plant protection products and Member States evaluate and authorize the products at the national level (active ingredient plus additives and/or adjuvants). The authorization of products occurs according to Regulation (EC) 1107/2009 (EC 2009) after a peer review by the risk assessment body of the European Food Safety Authority (EFSA). Each new regulation implies the removal of a (large) number of active substances from the market due to decreasing risk tolerance. The use of pesticides in the EU is further restricted because of environmental reasons. Pesticide contamination in surface water and ground water is addressed by several directives, such as the Pesticides Framework Directive (Directive 2009/128/EC) and the Water Framework Directive (WFD) (2000/60/EC). Other EU measures are established to strictly control pesticides in the environment. The Thematic Strategy on the Sustainable Use of Pesticides (COM/2006/0372 final) includes a number of measures to encourage the sustainable use of pesticides that were later transformed into Directive 2009/128/EC, establishing a framework for community action to achieve the sustainable use of pesticides, and Regulation (EC) 1107/2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC (EC 2016b).

Harmonization in the framework of EU Directive 91/414 has led to a reduction in the number of pesticides authorized for use in Europe. As a consequence of the high costs of authorization, pesticide producers do not tend to invest in the authorization of pesticides for small crops because of insufficient return. Consequently, the number of authorized pesticides for small crops is limited, which may lead to illegal use of pesticides and a higher exposure risk, comparable to what is observed in developing countries. It may also cause insufficient protection and accordingly possible growth of spoilage causing or mycotoxin-producing fungi or pests. Apart from the use of illegal pesticides, the EU market today faces a number of new threats, such as generics, rising internet sales and pirate companies copying the packaging of big international brands so that the distinction between the original and the replacement is difficult to make without the right analytical equipment (B. Schiffers, personal communication, 2012). Questions arise about the purity of generic active substances and the additives and adjuvants used to improve efficiency. The use of these sometimes unauthorized unknown molecules is motivated by the fact that they may not be fully included in the scope of monitoring programmes, and that no analytical detection methods exist yet. In some developing countries such as Cameroon (Amouh 2011), there is a market for the recycling of old pesticides from obsolete stocks. Obsolescence arises because a product has been deregistered locally or banned internationally. More commonly, a stock of pesticides becomes obsolete because of long-term storage (in third countries) during which the product and/or packaging degrades (FAO, 1995). Reuse must be strictly controlled. If not, a food safety issue occurs. This may also affect food security because the dated material is no longer effective for pest control. To overcome food safety issues in developing countries characterized by smallholder farms, access to biodegradable, low-cost and low-risk pesticides should be improved. This is important since it is expected that these countries may suffer first from climate change. The risk today is that some countries may even reintroduce or increase the use of banned or restricted pesticides (Delcour *et al*. 2015).

2.9.2.2 Harmonization of the Maximum Residue Limit (MRL)

In the EU, the EFSA and the European Commission are responsible for setting the MRLs. However, MRLs are part of the legal requirements in most countries. If national or regional limits are not available, the MRLs of internationally recognized bodies such as the WHO Codex Alimentarius Commission (2016) can be used as guidance. Furthermore, MRL harmonization, having the same settings across countries, is an emerging trend which is highly supported by international organizations such as the FAO, WHO, Codex Committee on Pesticide Residues (CCPR) and Organization for Economic Co-operation and Development (OECD). For example, in the EU, MRL harmonization started in 2008 under Regulation (EC) 396/2005 (OECD, 2010). In some developing regions, efforts to harmonize MRLs were initiated by the Global MRL Harmonization Initiative (an Africa Project supported by the US Department of Agriculture, the Foreign Service, IR-4 Project and US Environmental Protection Agency). This project showed that most African countries have adopted the Codex Alimentarius MRLs, while only South Africa established MRLs of its own (Keikotlhaile, 2011). Although in some developing countries, pesticide legislation enhancing food safety is in place, it is often not efficiently implemented which affects, for example, pesticide monitoring (Ecobichon, 2001). Amouh (2011) indicated a shortage of trained personnel to enforce legislation and to monitor the use of pesticides and residue levels in food and the environment. This shortage is caused by a lack of knowledge and the cost of laboratory equipment. However, other developing countries, often with a high level of agricultural export, succeed in organizing pesticide monitoring, because their international trade forces them to achieve a higher level of food safety assurance.

2.9.2.3 Guidelines for Trade

Historically, most fruit and vegetables were produced for local consumption. However, trade has rapidly grown since the 1980s, allowing the virtual elimination of seasonality and geographical distances between production and consumption (Huang, 2004). The EU is both the leading importer and exporter in the global trade of fruit and vegetables (Huang, 2004). In 2011, the EU imported 11.6 million tons of fruit and 1.8 million tons of vegetables. Export accounted for 3.6 million tons of fruit and 1.6 million tons of vegetables. The trade in these products also implies the trade of pesticide residue risks. Many African countries have ratified international legal instruments related to the management of chemicals (the FAO Code of Conduct, the Rotterdam Convention on Prior Informed Consent (PIC), the Stockholm Convention on Persistent Organic Pollutants (POPs), the Strategic Approach to International Chemical Management (SAICM), the Basel Convention, the Bamako Convention, and the Common Regulations of the Comité Permanent Inter-états de Lutte contre la Sécheresse dans le Sahel – Permanent Inter states Committee for Drought Control in the Sahel – CILSS). One of these agreements, the POP Convention adopted in May 2001, calls for an outright banning and destruction of some of the world's most dangerous chemicals. Moreover, the FAO worked out a code for the distribution and use of pesticides, which describes the responsibilities and standards of conduct for all public and private entities engaged in, or affecting, the distribution and use of pesticides, particularly where there is little or no adequate national law to regulate pesticides. These specifications also provide quality standards for buying and selling pesticides, guidelines for the official approval of pesticides, and support to manufacturers dealing with national and other specifications. The code covers guidelines for vendors to protect themselves against inferior products and describes the link between biological efficacy and specification requirements (FAO 1995). In the global context of trade of foods and frequent human travel, the food safety impact is not restricted to the local situation. In Europe, the safety of locally grown foods and products imported from developing countries seems to be guaranteed at a high level. However, in developing countries, the local population and tourists or people travelling for business consume foods from local markets and restaurants, and thus may be at a much higher risk of exposure to pesticide residues through food consumption.

2.9.2.4 Implementation of Guidelines

A study in Tanzania on fruit and vegetables (Ngowi and Partanen, 2002) and a study in Nigeria (Ivbijaro, 1990) on cocoa and other related crops (Asogwa and Dongo, 2009) show that the absence of strong enforcement policies with regard to pesticide use represents a human health problem for farmers (via direct exposure to the pesticides during application) and likely consumers (indirectly through the intake of contaminated food). A case in point is the agricultural use of organochlorine insecticides which have been banned or severely restricted in many developed nations and some developing countries due to their adverse effects on human health and the environment. Regrettably, due to a combination of factors including inadequate regulation and management, trade, weak import controls, illegal use and lack of logistics to monitor these pesticides, the ban or restrictions on these pesticides may be ineffective, as there is evidence for their continued application to crops, vegetables and fruits (Okoffo *et al*., 2016). Also, the pattern of herbicide usage in developing countries has changed. In many areas, a change from multiple soil cultivation for weed control to reduced tillage to prevent soil erosion has led to greater dependence on herbicides such as glyphosate. Associated factors include the wide availability of cheap herbicides and an increase in the cost of hand weeding resulting from socioeconomic changes (Okoffo *et al*. 2016). The continuous use and even greater dependence on these sometimes problematic pesticides is a result of their low cost, their versatility against various pests, weeds and diseases and their availability (Okoffo *et al*. 2016). Although the implementation of international and national agreements needs to be substantially improved, they can be seen as a first step towards sustainable production and towards controlling the risk associated with the use of pesticides. This can be illustrated by the case of Senegal, which was the first developing country to notify the population of highly hazardous pesticides under the Prior Informed Consent (PIC) Convention, and to alert decision makers in other countries to the risk posed by these particular products (Williamson, 2003). Aiming for safe exposure, the FAO also worked out a code on the distribution and use of pesticides. This code describes responsibilities and standards of conduct for all public and private entities engaged in or affecting the distribution and use of pesticides, particularly where there is little or no adequate national law to regulate pesticides. The specifications also provide quality standards for buying and selling pesticides. They provide guidelines for the official approval and acceptance of pesticides and support manufacturers on how to deal with national and other specifications. Finally, the code includes guidelines on ways in which purchasers can protect themselves against inferior products and describes the link between biological efficacy and specification requirements (FAO, 1995).

2.9.2.5 Border Control

In recent years, pesticide residues in food expressed as MRLs have become a focus for food safety and trade. Quarantine regulations sometimes require pesticide treatment of food shipments to prevent establishment of exotic pests. Nonetheless, local consumers and international trading partners increasingly demand food that is free from unsafe pesticide residues. Therefore, many countries have initiated programmes to monitor pesticide residues in food (Zhang *et al*. 2015b). In Europe, the Rapid Alert

System for Food and Feed (RASFF) was created to allow food and feed control authorities to exchange information about measures taken in response to serious risks detected in food or feed products. This exchange of information helps Member States to act more rapidly and in a co-ordinated manner in response to a health threat caused by food or feed. Border rejections are one type of RASFF notification concerning food and feed consignments that have been tested and rejected at the external borders of the EU (and the European Economic Area) when a health risk has been found. Galt (2009) raised the question as to what extent residue testing methods used on imported produce correspond to the pesticides used on crops. He reported that the US Food and Drug Administration (FDA)'s residue testing failed to identify residues of the majority of pesticides used on crops imported into the USA and suggested that FDA residue testing on imported produce is inadequate in its coverage. A similar situation occurs in the EU, where the total number of pesticides identified in analytical laboratories significantly differs between countries and even between laboratories. Moreover, the number of identified pesticides increases annually: the average number of pesticides labelled in 2006, 2007 and 2008 increased from 209 to 218 and up to 235, respectively (EFSA 2010). Food considered as (pesticide) safe or of low risk in one country or by one laboratory or in one year may be considered not safe in another place or a couple of years later. Border rejections are directly related to the safety of food and feed products, but, at the same time, they indirectly affect food security. Food produced for export in developing countries replaces the local food production which is needed to contribute to local food security. It is obvious that, when exported food is rejected at the border, the financial return for this replacement to produce local food is totally lost. One of the solutions is perhaps monitoring food and feed products before shipment. However, when this control shows that products do not comply with EU guidelines, moral and ethical questions arise when these products are then sent to a less stringent, often local, market. In Europe, it seems that harmonization across the borders of EU countries has not been fully realized. In fact, there exists a (regionally) different authorization/registration procedure among European Member States. In certain countries, some product formulations of active ingredients (marketed plant protection products) are not allowed, although the active ingredient is authorized at the EU level. This raises the issue of the implementation of harmonization and risk management among EU Member States; what is considered to be acceptable or safe in one EU country seems not to be so in another. For example, crops containing a given pesticide can be exported to every European country due to freedom of trade. A country can accept crops containing Residues of that pesticide, while its own farmers are not allowed to use it to cultivate that same crop, which seems to create a paradox.

2.9.2.6 Secondary Standards

Export crops are considered to be pesticide intensive, while local and national crops are regarded as environmentally benign. This discrepancy has fuelled debates concerning developing countries' dependence on agricultural export and the impact on development, equity and the environment (Galt, 2008a). However, in a globalizing economy, the organization of the food chain and its requirements is not only influenced by countries' legislation but also by voluntary private, also called secondary, standards, defining a food safety approach to pesticide residues. The standards are based on established regulatory levels but go beyond the legal requirements, for example, they may be a percentage of the MRL or the ARfD. The secondary standards are set or benchmarked (e.g. by GLOBALG.A.P. certification, available for three scopes of production: Crops, Livestock, Aquaculture or the Global Food Safety Initiative as collective recognized food safety schemes, supported predominantly by European and

USA retailers or international food companies) or set as private standards on an individual basis per retailer or manufacturer. Although these standards are not legally binding, farmers are virtually obliged to comply with what has become an unofficial licence for national and international trade. The stringent demands of course have an impact on market access for farmers worldwide (Henson *et al*. 2011; Jaffee 2012).

2.10 Towards Sustainability

2.10.1 Judicious Use of Pesticides

Here, sustainability is referred to in the context of lowering pesticide risks to avoid human and environmental exposure. A study by Mokhele (2011) showed that farm workers in Lesotho were exposed to a greater health risk when there was lack of training on the use of pesticides. Pesticide companies, large corporate international food companies and universities organize such trainings on pesticide use. A system of 'stewardship', where teachers train farmers, is used to reduce the hazard of operator exposure. Education on the correct products to be applied against a certain pest, disease or weed is an ongoing activity. Many students move to developed countries to get a higher education, which they can implement back home. Since 2015, farmers in the EU need to be licensed to spray pesticides, by proving that they have relevant education or sufficient experience. In order to keep this certificate, they have to attend several training courses. These can be provided by the government or information services and cover personal protection, spraying techniques and equipment and integrated pest management. Failure to adhere to trade standards can result in loss of revenue for farmers supported by the food industry (Okello and Swinton, 2010). This is illustrated by Kenya's green bean farmers, who implemented pesticide standards from developed countries because of retailer requirements to show evidence of compliance with UK pesticide legislation (Okello and Swinton, 2010). The same study noted that Kenya had become one of the leading producers of green beans since the 1990s, and an important supplier for developed countries. The study by Mokhele (2011) also demonstrated the benefits of reduced pesticide use by comparing the occurrence of illnesses and acute symptoms of pesticide exposure in monitored *versus* unmonitored farmers. This benefit was attributed to farmers' education on the use and handling of pesticides and the implementation of protective measures. Although the Kenya story seems positive, the question arises whether the impact of globalization in trade has really spread across the entire country or whether it is restricted to the regions where green beans are being produced for export. Unlike the Kenya bean farmers' situation, banana production in Cameroon shows no real benefit from globalization (Amouh, 2011). Nevertheless, another study illustrated the impact of globalization on the banana trade by the multinational Chiquita which introduced sustainability principles more than 20 years ago. According to the Rainforest Alliance (RA), a non-profit organization dedicated to protecting tropical forests, this banana company made significant strides. In the early 1990s, the two organizations started talking about reducing pesticide use, recycling, eliminating deforestation and respecting workers' rights. In 1994, the RA began to certify Chiquita's plantations when they met its social and environmental standards. By 2005, Chiquita was selling bananas in Europe with the rainforest-safe label, i.e. the 'green frog'. Now, all Chiquita farms and most of its independent suppliers are certified by the RA group. One negative point of Chiquita's tactics was that they made consumers believe that they were producing 'green' (ecological) bananas, which is not the case. Similarly, in the EU, the use of certain pesticides from natural origins such as copper, sulphur or the synergist piperonylbutoxide (sometimes in very high amounts) in organic farming is questioned because it might negatively influence food safety. Using these active substances is even more toxic compared to synthetic ones. Organic farming is in fact not equal to 'zero risk' farming but is a more philosophical way of farming of which people believe that it results in healthier/safer or more sustainable products. Hoefkens *et al*., (2009) showed no real differences in food safety and food quality between organic and conventional produce. However, if products of organic farming are indeed proved to be healthier, the question remains whether it is ethical that people have to pay more for these 'low-risk' products (i.e. poor people would have to consume high-risk food). Besides organic farming, products obtained directly from the farm are currently gaining popularity. It should be noted that although all farmers must comply with legal requirements and are open to inspection by the authorities, farmers delivering crops directly to the market are exempt from additional controls and demands from private standards occurring in business-to-business sales in the conventional (long) supply chain. It remains to be seen whether less controlled fresh produce implies less safe produce. Since this seems to be the case in developing countries, it is likely that EU farm products (home sales) are also not necessarily healthier than products in the retail market.

2.10.2 Low-residue Farming

In contrast to natural contaminants produced by micro-organisms or fungi, pesticide residues in food can be controlled by human actions. Highly toxic crop protection chemicals can, for instance, be replaced by agro-ecological, less dangerous or more human and environmentally friendly alternatives. Winter (2012) analysed pesticide residue data and confirmed that, while pesticide residues are frequently detected in a variety of food products, typical dietary exposure to pesticides continues to be at levels far lower than levels considered to be of health concern. Consumer fears about pesticide residues provide the potential for consumers to reduce their consumption of fruits, vegetables and grains, negating the positive health benefits attributed to consumption of large amounts of such foods. Consumers of conventionally produced food are typically exposed to a very low level of pesticide residues. Findings also indicate that further reducing one's exposure to pesticide residues through purchase of organic foods may not provide any appreciable health benefit. Furthermore, organic foods have been shown to contain pesticide residues as well, although at lower frequency than their conventional counterparts (Winter 2012). Agricultural farming today can be roughly divided into two main groups: conventional farming, which is now changed to integrated farming in Europe (IPM), and organic farming. Both apply pesticides or plant protection products to maximize crop quality and ensure crop yields. Both methods have drawbacks. Organic agriculture, applying biopesticides, is more labour intensive and water consuming and has lower crop yields and also contains residues, while it is believed that synthetic crop protection products pose potentially higher risks for consumers and the environment. An upcoming farming system in Belgium is low-residue farming. As biopesticides and chemically synthesized pesticides may have a human and environmental impact, low-residue cropping seeks to find a compromise between these two worlds. In low residue cropping, the fate of crop protection products in plants is modelled over time. Dissipation of pesticides in plants depends on plant growth and external factors like sun photodegradation, evaporation, metabolism and/or chemical breakdown. Farmers are allowed to use biological or chemical crop protection products to protect their crops from pests or diseases and are also guaranteed that the crop will have no detectable residue of said products at harvest. This alleviates concern for consumers' health, without compromising crop yield.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter, the research method used in conducting this study is presented under design of the study, area of the study, population of the study, sample and sampling technique, source of data collection, method of data collection, validation of the instrument and method of data analysis.

3.1 Research Design

The descriptive survey research design was adopted for the study. The descriptive survey design according to Osuala (2005) is a kind of research design in which the researcher collects data from a cross section of the study population in respect of the variables. This design was considered appropriate for the study since it solicits information from a target group. The design involves collection and analyzing data gathered. Kerlinger in Akpomi, Yusuf and Yusuf (2009) described descriptive survey design as a type of design to be employed when a study involves the use of questionnaire to seek the opinion of the respondents. Kerlinger added that the descriptive survey type of design is the most convenient way to obtain real facts and figures in which the results of the analyses will be used for decision making or generalization. This research design is considered suitable for this study considering the fact that this study's primary objective centers on risk assessment associated with pesticides application on selected agricultural farmland in Kano State. The choice of descriptive survey design is premised on its value and facility in addressing the research problem raised in the study.

3.2 The Study Area

3.2.1 Location

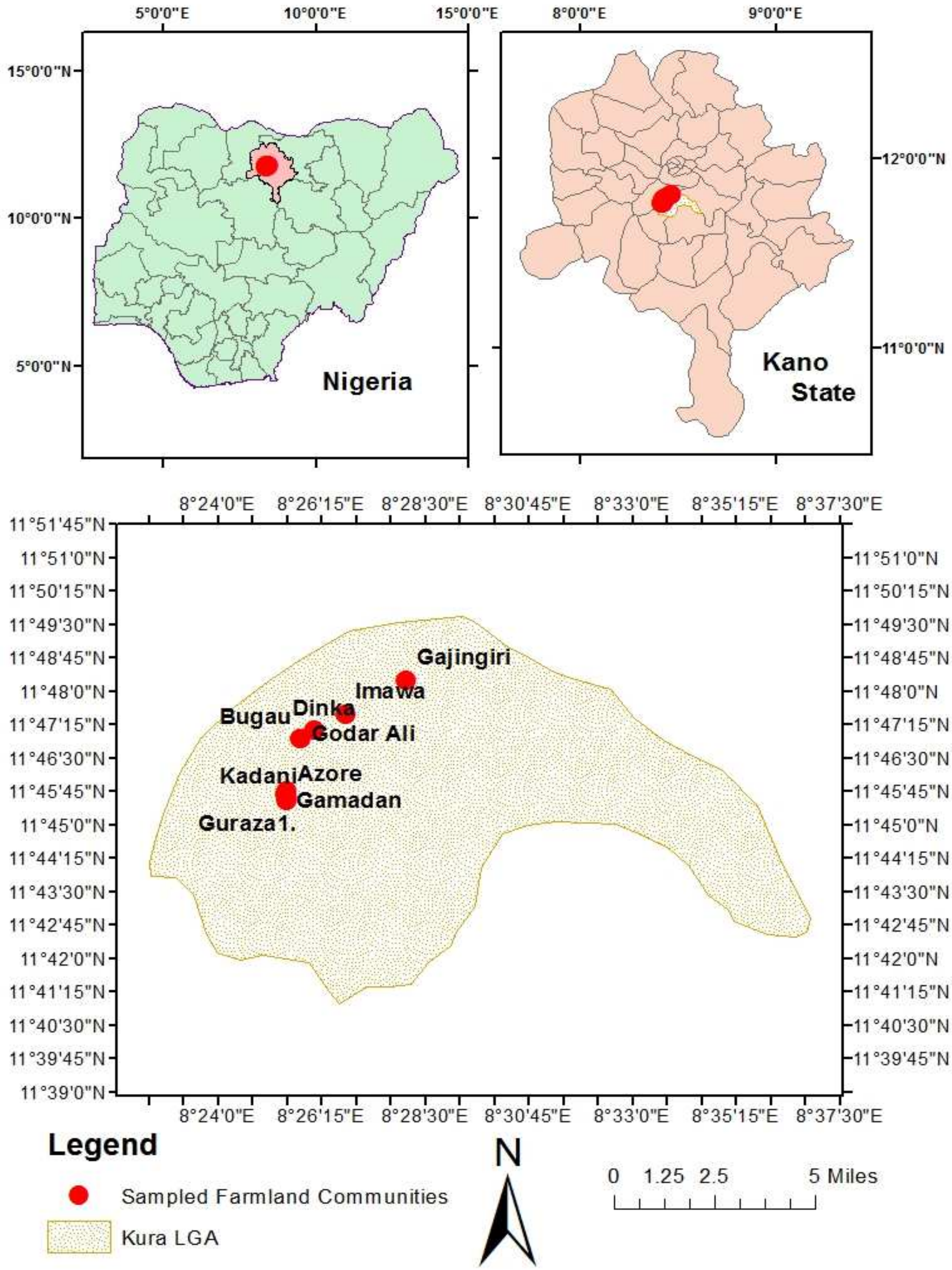

Figure 3.1: Map of Kano State showing the Study Area

Kano State is a state located in North-Western Nigeria. Created on May 27, 1967 from part of the Northern Region, Kano state borders Katsina State to the north-west, Jigawa State to the north-east, and Bauchi and Kaduna states to the South. The capital of Kano State is Kano. Kano derived its name from the ancestor of the Abagayawa -the earliest settler, who migrated from Gaya in search of ironstone and chemicals. Kano State was first created under this name on May 27, 1967, when Nigeria assumed the twelve states structure. Being the most populous state, on August 27. 1991 Jigawa State was carved out from it and it now composed only of Kano Emirate. Kano State of the Federal Republic of Nigeria lies between latitude 130N in the North and 110N in the South and longitude 80W in the West and 100E in the East. Kano State is made up of the following forty-four local government areas: Ajingi, Albasu, Bagwai, Bebeji, Bichi, Bunkure, Dala, Dambatta, Dawakin Kudu, Dawakin Tofa, Doguwa, Gabasawa, Garko, Garun Mallam, Gaya, Gezawa, Gwale, Gwarzo, Kabo, Karaye, Kibiya, Kiru, Kumbotso, Kura, Kunchi, Madobi, Makoda, Minjibir, Kano Municipal, Nassarawa, Rimin Gado, Rogo, Shanono, Sumaila, Takai, Tarauni, Tsanyawa, Tudun Wada, Tofa, Warawa and Wudil. The total land area of Kano State is 20,760sq kilometers with a population of 9,383,682 (2006 provisional result).

Some Local Government areas of Jigawa State were part of Kano Emirate before the creation of that state. The people of Kano State who have no other hometown call themselves Kanawa. Kano City has been the capital of Kano State since the earliest recorded time. It is located on latitude 12.000N and longitude 8.300E within the semi-arid Sudan savannah zone of West Africa about 840 kilometers from the edge of the Sahara Desert. Kano has a mean height of about 472.45m above sea level. Kano City has expanded over the years and has become the third largest conurbation in Nigeria; it had a population of 1,412,255 when the last population census was conducted in 1991.

It is made up of six local government areas: Municipal, Gwale, Dala, Tarauni, Nassarawa and Fagge. Kano's most enduring legacy Gidan Rumfa (Emir's Palace) the seat of Kano's prestigious Sarauta institution (Kingship) built over five hundred years ago is located in the Municipal Local Government Area. The Kano State Government House is located in Tarauni Local Government Area.

Kano State is the second largest industrial center in Nigeria and the largest in Northern Nigeria with textile, tanning, footwear, cosmetics, plastics, enamelware, pharmaceuticals, ceramics, furniture and other industries. Others include agricultural implements, soft drinks, food and beverages, dairy products, vegetable oil, animal feeds etc. The Hausa Kingdom of Kano was based on an ancient settlement of Dalla Hill. While small chiefdoms were previously present in the area, according to the Kano Chronicle, Bagauda, a grandson of the mythical hero Bayajidda,. became the first king of Kano in 999, reigning until 1063. The Kano Chronicle stated that the Kingdom of Kano was founded as one of the Seven True Hausa States or Hausa Bakwai by Baguada in 999. Bagauda was a grandson of Abuyazidu (Bayajda), who was acknowledged by legend to be the origin of the Hausa people. During the rule of King Gajemasu from 1095 to 1134, the kingdom's capital was transferred from Sheme towards the current location. In 1340s, Islam was introduced to Kano by Malinke scholars, who originated from Mali Empire. Yaji, who ruled from 1349 to 1385, may have been the first Muslim king of Hausa. The religion Islam got the blame for Kano's loss against Zaria around 1400 and it was relinquished by King Kanajeji.

According to the 2016 PON census (unofficial) figures from Nigeria Kano State had a population totaling 9, 383, 682. Officially, Kano State is the most populous state in the country. The state is mostly populated by Hausa people. The official language of Kano State is Hausa language, but Fulani languages are commonly spoken. The temperature of Kano usually ranges between a maximum of 33^0C and a minimum of 15.8^0C although sometimes during the harmattan it falls down to as low as 10^0C. Kano has two seasonal periods, which consist of four to five months of wet season and a long dry season lasting from October to April. The movement of the South West maritime air masses originating from the Atlantic Ocean, influences the wet season which starts from May and ends in September. The commencement and length of wet season varies between northern and southern parts of Kano State. The length of the season in Riruwai, which is southern part of Kano State, is six months from early May to late September. While in northern parts it is from June to early September.

The average rainfall is between 63.3mm + 48.2mm in May and 133.4mm + 59mm in August the wettest month. The movement of the tropical maritime air masses from the Southwest to the North determines the weather of Kano State during the wet season. This air mass carries a lot of moisture from over the Atlantic Ocean. This moisture condenses when it is forced to rise by convection or over a barrier of highlands or an air mass; it then falls back as rain. The period of the heights occurs when the sun passes over West Africa between March and June. The dry season starts in October and lasts till about April of the following year. Temperatures are low during this period because the sun is in the Southern Hemisphere and because of movement of the desiccating continental air mass, which originates from the Sahara area and blows from the Northeast carrying along with it the harmattan dust. This is also the harvesting season.

The vegetation of Kano State is the semi-arid savannah. The Sudan Savannah is sandwiched by the Sahel Savannah in the north and the Guinea Savannah in the south. The savannah has been described as the zone that provides opportunity for optimal human attainment. This is because it is rich in faunal and floral resources, it is suitable for both cereal agriculture and livestock rearing, and the environment is relatively easy for movement of natural resources.

The canopies of the trees are very wide and most of them are less than 20m tall. The following are the common trees of Kano State: Acacia albida (Hausa: gawo), Acacia nilotica (Hausa: gabaruwa), baobab Adanosia digitata (Hausa: kuka), Anogeissus leiocarpus (Hausa: marke), neem Azadirachta indica (Hausa: dogon yaro), desert date Balanties aegyptica (Hausa aduwa), ebony Diospyros mespiliformis (Hausa: kanya), mahogany Khaya senegalensis (Hausa: madachi), locust bean Parkia clappertoniana (Hausa: dorawa), Piliostigma thonningii (Hausa: kargo), Sclerocarya birrea (Hausa: danya), Vitex doniana (Hausa: dinya), Ziziphus spina-christi (Hausa: kurna) (Nichol 1988). These trees are very resistant to drought. It has been suggested that these products have been available as part of the vegetable resources in the West African savannah for two to three thousand years. Domesticated crops include sorghum, millet and African rice, several indigenous yams, two African groundnuts, cowpeas and black beniseed. The natural vegetation of Kano State has been modified as result of several centuries of human activities such as bush clearing and burning for cultivation and hunting as well as animal grazing.

3.3 Population and Sample Size

The population for this study comprised farmers in Kura Local Government Area of Kano State, North West, Nigeria. Based on available statistics based on 2006 Population Census showed that Kura Local Government Area has a total population of 143,094 people with 80% of them been farmers (Ayodele, 2016). Hence, the population of the farmers was estimated to be 114475. The population of the study was projected to 2018 using population growth rate of 2.47 percent as provided by the Nigeria population commission (NPC, 2006). The projected population was obtained as follows:

$$P_t = P_0\left(1+r\right)^t$$

P_t = Projected population, P_o = population as at 2006, =114475, r = population growth rate (%) = 2.47% = 0.027, and t = number of years = 12.

$$P_t = P_0\left(1+r\right)^t = 114475\left(1+\frac{2.47}{100}\right)^{12} = 114475\left(1+0.0247\right)^{12}$$

$$= 114475\left(1+0.0247\right)^{12} = 114475\left(1.0247\right)^{12} = 114475\left(1.3402\right) = 153417$$

Hence, the projected population of 153417 farmers in Kuru Local Government Area of Kano State was estimated.

3.4 Sample Size

A sample size of 399 farmers in Kuru Local Government was estimated using Taro Yamane (1967). The sample size was estimated as follows:

$$N = \frac{N}{1+N\left(e\right)^2}$$

n = Sample size to be determined, e = Level of significance and N = Population size.

$$N = \frac{N}{1+N\left(e\right)^2}, \quad N = 153417, \quad e = 0.05$$

$$N = \frac{153417}{1+153417\ (0.05)^2}$$

$$N = \frac{153417}{1+153417\ (0.0025)} = \frac{153417}{1+383.5425} = \frac{153417}{384.5425} = 398.9$$

$$n = 399$$

3.5 Sampling Techniques

The study adopted a multi-stage random sampling techniques in the selection of the sample. At the first stage of the sampling, the simple random sampling was used to sample of 10 villages out of the total of 26 villages in Kura Local Government Area. Randomisation was done through balooting. The selected villages are Sarkin Kura, Gamadan, Azore, Kadani, Guraza, Imawa and Godar Ali. At the stage of sampling, the simple random sampling was used to select sample of farmers from each of the selected 10 villages. To give each of the selected villages each number of farmers, the sample size was divided equally across the 10 selected villages and a sample of 40 farmers were selected from each of the village.

3.6 Instruments for Data Collection

Researcher-developed instruments entitled "Risk Assessment Associated with Pesticides Application Questionnaire" was used in data collection. The instrument comprised 25 items which focused on the different areas of research which include sex, marital status, age, educational qualification, farming experience, farm size and land ownership status, use of pesticides, common used pesticides, effect of pesticides, health problem associated with the exposure to pesticide use and the effect of the pesticide's application on the environment. The study also assesses safety practices adopted by the farmers in handling pesticides and the behaviours when using pesticides.

3.7. Validity of Instrument

The instrument was presented to experts for face-validation. Copies of the instrument were presented to three experts, two from Environmental Health Science, Kwara State University and one expert in research and Statistics (Statistician). These experts were required to examine the validity of the instrument in terms of language, clarity and content in line with the purpose of the study, research questions and the hypotheses it will measure.

3.8. Method of Data Collection

To facilitate data collection, the researchers seek the services of four research assistants. The two research assistants helped in the administration of the data. The research assistants were properly briefed on how to administer the instrument. The instrument was administered within two weeks. Each of the research assistant covered two communities while the researcher also covered two communities. Out of the 400 copies of the questionnaire administered 392 copies representing 98% of the administered questionnaire was retrieved and found useable.

3.9. Methods of Data Analysis

Data obtained were analysed using frequencies, simple percentages, Chi- Square test and logistic regression. Frequency and simple percentages were used to analyse the demographics of the respondents and to answer the research questions. Also, result of the analysis of some vital results were also presented using pictorial representation like bar chart, cluster bar charts and other forms of pictorial representation. To enhance data analysis and computation of results, the Statistical Package for Social Sciences (SPSS version 20.0) was used.

CHAPTER FOUR

RESULTS AND DISCUSSION OF THE FINDINGS

4.1 Results

In this chapter, results of data obtained from the study were analyzed. To answer the research questions frequency and simple percentages were used while hypotheses were tested using Chi-Square test and logistic regression analysis at 0.05 level of significance. The findings were carefully discussed in relation to the existing literature in this chapter.

Table 4.1: Demographics of the Respondents

Demographic variables	No. Of Respondents	Percentage (%)
Sex		
Male	214	54.6
Female	178	45.4
Marital status		
Married	238	60.7
Single	133	33.9
Divorced	21	5.4
Age (years)		
16-25 years	69	17.6
26-35 years	82	20.9
36-45 years	103	26.3
46-55 years	78	19.9
Above 55 years	60	15.3
Education		
No formal education	79	20.2
Primary	124	31.6
Secondary (SSCE or Equivalent)	142	36.2
OND/NCE	25	6.4
B.Sc/HND	18	4.6
Post graduate degrees	4	1.0
Farming Experience		
1-10 years	181	46.2
11-20 years	187	47.7
Above 20 years	24	6.1
Farm size		
0.5-2	170	43.4
2.5-4	151	38.5
Above 4 hectares	71	18.1

Land ownership		
Inheritance	205	52.3
Lease	187	47.7

Source: Field Survey (2019)

Table 4.1 presents the demographics of the respondents. Result of the distribution of the respondents based on sex reveals that 54.6% of the farmers were male and 45.4% were female. Result also shows that 60.7% were married, 33.9% were single and 5.4% were divorced. The distributions of the respondents based on age were as follows: 17.6% were between ages 16-25 years, 20.9% were between 26-35 years, 26.3% were between 36-45 years, 19.9% were between 46- 55 years while the remaining 15.3% of the respondents were above 55 years. In terms of their educational qualification, 20.2% of the farmers had no formal education, 31.6% had primary education, 36.2% of the farmers had secondary education, 6.4% were OND/NCE holders, 4.6% were B.Sc/HND holders while 1.0% had postgraduate degrees. Result also shows that 46.2% of the respondents had 1-10 years of farming experience, 47.7% had 11-20 years of farming experience and 6.1% of the farmers had above 20 years of farming experience. The distribution of the farmers based on farm size reveals that 43.4% of the respondents had 0.5-2.0 hectares of land, 38.5% had 2.5-4.0 hectares of land and only 18.1% of the farmers had above 4 hectares of land. In terms of land ownership status, 52.3% of the farmers acquired their land through inheritance while 47.7% of the farmers acquired their lands through leasing.

4.2 Answering of Objective Questions

Objective 1: Determine the commonest used pesticides by farmers in Kuru Local Government Area of Kano State.

Table 4.2: Use of pesticides, type of pesticide use, years of usage of pesticides and source of information about pesticide use and main purpose of using pesticides by farmers in the study area

Questions	No. of Respondents	Percentage (%)
Do you use pesticides		
Yes	351	89.5
No	41	10.5
If yes, what type of pesticide do you use?		
Apron plus	110	31.3
Atrazine	42	12.0
Cypernethrim	118	33.6
Sevin	34	9.7
Thiodan	30	8.5
Fusilade	17	4.8
Primextra	110	31.3
Others	42	12.0
Years of pesticides use		
1-5 years	162	46.2
10-15 years	169	48.1
16-20 years	8	2.3
Above 20 years	12	3.4
How do you know about pesticides usage		
Retailers	158	45.0
Co- farmers	129	36.8
Consultancies	64	18.2
What is your main purpose of using pesticides		
Weed control	109	31.1
Pest control	51	14.5
Rodent control	51	14.5
Fungi control	140	39.9

Source: Field Survey (2019)

Table 4.2 presents the use of pesticides among farmers in Kura Local Government Area of Kano state. Result reveals that 89.5% of the farmers make use of pesticide while only 10.5% of the respondents do not use pesticides. Of the 351 farmers that made use of pesticides, 31.1% use Apron plus, 12,0% use Atrazine, 33.6% use Cypernethrim while 9.7%, 8.5%, 4.8%, 31.3% and 12.0% of the respondents Thiodan, Fusilade, Primextra and others respectively. Result also shows that 46.2% of the farmers had been using the pesticide for 1-5 years, 48.1% had use it for 10-15, 2.3% had use it for 16-20 years and 3.4% of the respondents had use pesticide for more than 20 years. One hundred and fifty-eight respondents (45.0%) knew about the use of pesticide through retailers, 36.8% heard about it from co-farmers and 18.2% of the respondents heard about pesticide use through consultancies. One hundred and nine respondents representing 31.1% of the respondents opined that their main purpose of using pesticide is for weed control, 14.5%, 14.5% and 39.9% of the respondents said that their main purpose of using pesticides was for pest control, rodent control and fungi control respectively. The commonest pesticides used by farmers in Kuru Local Government are presented using bar chart shown below.

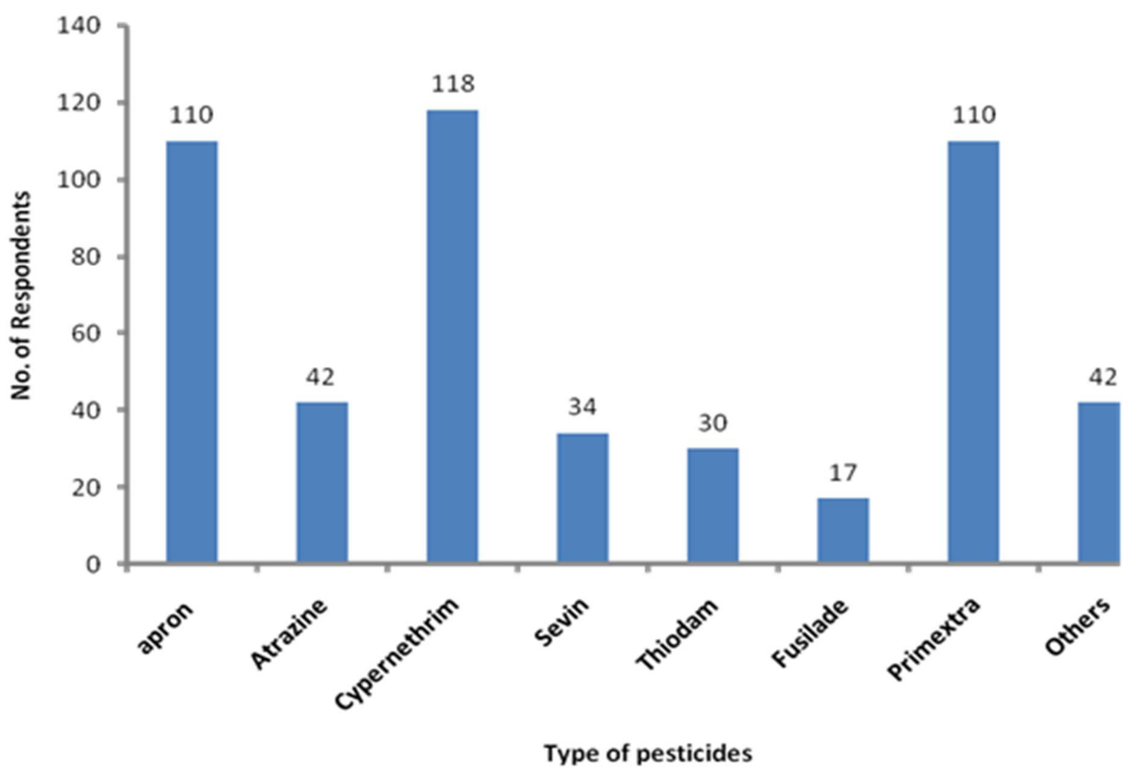

Fig 1: Chart showing the different types of pesticides used by farmers in Kuru LGA of Kano State.

Objective 2: Determine the effects of pesticides, use on farmers' health by monitoring the frequency of clinical symptoms in Kano state.

Table 4.3: Symptoms of its frequency among farmers who made use of pesticides and experience some of its symptoms

	Frequency of the Symptoms			
Health related symptoms	Regularly, n (%)	Occasionally, n (%)	Rarely, n (%)	Total
Headache	23(56.1)	13(31.7)	5(12.2)	41 (41.4)
Stomach cramps	21(53.8)	14(35.9)	4(10.3)	39(39.4)
Muscles weakness	26(56.5)	15(32.6)	5(10.9)	46(46.5)
Vomiting	21(56.8)	12(32.4)	4(10.8)	37(37.4)
Dizziness	21(58.3)	13(36.1)	2(5.6)	36(36.4)
Shortness of breath	11(40.7)	11(40.7)	5(18.5)	27(27.3)
Blurred vision	5(45.5)	2(18.2)	4(36.4)	11(11.1)
Eye irritation	36(66.7)	13(24.1)	5(9.3)	54(54.5)

Values in the brackets are percentages

Table 4.3 shows that 41.4% of the respondents who complained of pesticides related problems had headache, 39.4% had stomach cramps, 46.5% complained of muscle weakness, 37.4% complained of vomiting, 36.4% complained of dizziness, 27.3% complained of shortness of breath, 11.1% complained of blurred vision while 54.5% complained of eye irritation. Result of the analysis of the regularity of these symptoms reveals that the majority of the respondents experienced these symptoms on a regular basis (56.1% for headache, 53.8% for stomach cramps, 56.5% for muscles weakness, 56.8% for vomiting, 58.3% for dizziness, 40.7% for shortness of breath, 45.5% for blurred vision and 66.7% for eye irritation.

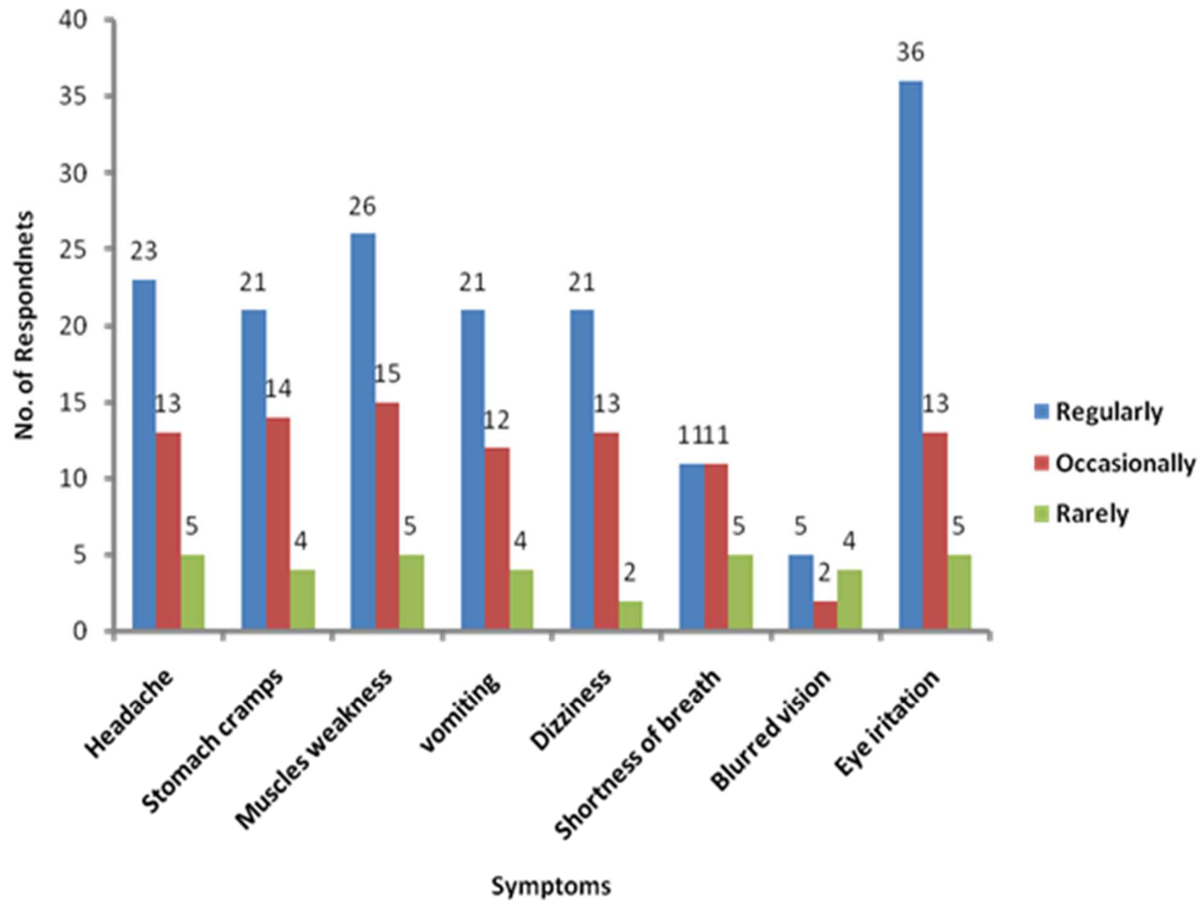

Fig 2: Cluster bar chart showing the distribution of the symptoms of pesticide use and frequency of clinical symptoms in Kano state.

Objective 3: Determine the health problems associated with exposure to pesticides among farmers in Kano state.

Table 4.4: Health problems associated with exposure to pesticides among farmers in Kano State.

Questions	No. of Respondents	Percentage (%)
Are you aware of the side effect of the use of pesticides		
Yes	270	76.9
No	81	23.1
Have you ever had any pesticide related health symptoms		
Yes	99	28.2
No	252	71.8
If yes, which of the following health related symptoms have you experienced		
Headache	41	41.4
Stomach cramps	39	39.4
Muscles weakness	46	46.5
Vomiting	37	37.4
Dizziness	36	36.4
Shortness of breadth	27	27.3
Blurred vision	11	11.1
Eye irritation	54	54.5
How often do you experience theses symptoms?		
Regularly	54	54.5
Occasionally	27	27.3
Rarely	18	18.2

Table 4.4 shows that the majority of the respondents (76.9%) were aware of the side effect of the use of pesticides with only 23.1% of the respondents not aware of the side effect of pesticide use. Out of the 351 farmers who have used pesticides, 28.2% complained of pesticide related symptoms with 41.4% complained of headache, 39.4% complained of stomach cramps, 46.5% complained of muscle weakness, 37.4% complained of vomiting, 36.4% complained of dizziness, 27.3% complained of shortness of breath, 11.1% complained of blurred vision while 54.5% complained of eye irritation. When they were asked about the regularity of these symptoms 54.5% said they experienced these symptoms regularly while 27.3% and 18.2% of the respondents experienced these symptoms occasionally and rarely.

Objective 4: To assess the effects of the pesticide's applications on the environment in the study area

Table 4.5: Effects of the pesticide's applications on the environment in the study area

Effects of the pesticide's applications on the environment in the study area	**No. of Respondents**	**Percentage (%)**
Do think the use of pesticides could affect the environment in the following ways		
Destruction of soil by reducing its quality	126	32.1
Harm to beneficial insects	134	34.2
Decrease in biodiversity	140	35.7
Pollute rivers and streams	160	40.8
Harm non-target organism	154	39.3

Multiple responses applied.

Results presented in Table 4.5 shows that some of the effects of the pesticide's applications on the environment that respondents were aware of include destruction of soil by reducing its quality (32.1%), harm to beneficial insects (34.2%), decrease in biodiversity (35.7%), pollute rivers and streams (40.8%) and harm non- target organism (39.3%). From these results, it can be deduced that less than half of the farmers who use insecticides are aware of its effect on the environment. This is because less than half of these users of pesticides were able to identify the effect on its application on the environment.

Objective 5: To assess safety practices adopted by the farmers in handling pesticides in the fields by farmers in Kano State

Table 4.6: Safety practices adopted by the farmers in handling pesticides in the fields by farmers in Kano State.

Safety practices adopted by the farmers in handling pesticides	**No. of Respondents**	**Percentage (%)**
Do you protect yourself while using pesticides		
Yes	178	50.7
No	173	49.3
If yes, which of the following protective do you put on		
Wear gloves	89	50.0
Wear mask	77	43.3
Wore boot	62	34.8
Wore impermeable clothes	87	48.9

Results summarized in Table 4.6 shows that 50.7% of the respondents said that they protect themselves anytime they want to use pesticides while 49.3% do not protect themselves when using pesticides. When they were asked the safety strategy they adopt, 50.0% were gloves, 43.3% wear mask, 34.8% wear boot and 48.9% said they do wear impermeable clothes. Result shows that less than half of these farmers who make use of pesticides protect themselves by wearing mask, boot or impermeable clothes.

Objective 6: To assess the farmers behaviours when using pesticides in Kano State

Table 4.7: Farmers behaviours when using pesticides in Kano State

Farmers behaviours when using pesticides	No. of Respondents	Percentage (%)
How do you mix pesticides		
Use stick	255	72.6
Bare hand	62	17.7
Others	34	9.7
What do you do after applying pesticides		
Wash hands with soap and water	247	70.4
Wash hands with water only	89	25.4
Won't wash	15	4.3
Where do you store pesticides		
Store room	102	29.1
Outside house	135	38.5
Inside house	114	32.5
How do you dispose pesticides containers		
Throw in open field	165	47.0
Throw in dustbin	136	38.7
Return to seller	50	14.2

Result in Table 4.7 reveals that 72.6% of the respondents use stock in mixing pesticides, 17.7% made use of their bare hands while 9.7% use other methods. In terms of what they do after applying pesticides 70.4% wash their hands with soap and water, 25.4% claimed that they wash their hands with waters only. Also, 29.1% store pesticide in their rooms, 38.5% stored it outside house while 32.5% of the respondents stored pesticides inside house (32.5%).

Result also reveals that 47.0% of the respondents dispose pesticides containers by throwing it in open field, 38.7% throw it in dustbin while 14.2% returns the containers to the seller.

4.3 Discussion of Findings

Interpretation of the Findings

A review of the samples in question

Before the results of the statistical analyses are observed, the samples in question needs to be reviewed so as to ascertain from what specific population the results were generated.

The socio-demographic characteristic, including sex, marital status, age, farm size, land ownership, educational levels and farming experience of the farmers regarding pesticide handling is shown in Table 1 above. There was a significant difference observed in the distribution of gender participants in their classification. The number of male respondents was 54.6% greater than the number of female respondents. This view is also supported by Abubakar *et al.* (2015) who found that majority, 93% of the farmers are male, while 7% are female and Govinda *et al* (2018) who reported that about 90% of the farmers interviewed were males. But is contrary to the study conducted by Prince *et al.* (2016) who found that male (21.7%) and female (78.3%) and Pornpimo *et al.,* (2018) who state that most Thai agricultural workers in their study were women (60%) and that the characteristics of the agricultural workers in this study varied by farm type This study were different from the report of World Bank with similar number of female and male agricultural workers in Southeast Asia in 2007 (World Bank, 2007). It was postulate that it found a higher percentage of women agricultural workers due to more recent economic drivers that push more men to move to urban areas where they are hired in manufacturing or other cash economy jobs; however, it could also be that more women than men were willing to be subjects in their study. However, as demographic shift occurred and become more industrialized, young people discover that the hard work and high cost of farming produces an uncertain income due to the dependence on weather patterns and crop prices. Interestingly, there has been a transition in the population engaged in agriculture in Kano State. Increasingly young people are leaving the rural areas and migrating to the cities to get industrial or service sector jobs. They return to help with the agricultural work on the family farm when needed. The 36-45year age groups were the largest groups in the study. However, these findings are consistent with the study done by Govinda *et al.* (2018) who found that 47% were 30 to 49years old and the remaining 23% were above 50 years old. This was as a result of the stratified sampling procedure. This was done in order to minimise the effect that small cell sizes have on skewing the frequency distributions. Similarly, this view is contrary to the study conducted by Prince *et al.* (2016) who found that the 46-55 years (34.8%) were the largest groups in the study who engage in farming activities. The largest levels of education were SSCE or its equivalent (36.2%) as against a minority of post graduate (1.0%) who had advanced level of education. Farmers education level ranged from no formal education to a doctorate with most (36.2%) farmers having completed SSEC or its equivalent. This shows that the literacy level of participating farmers was fairly high with the majority having completed at least a secondary (36.2%) education. Meanwhile, these finding is consistent with Govinda *et al.* (2018) who found that about 30% of the farmers were illiterate and the rest had different levels of education such as primary (23%), lower secondary (20%), secondary (19%) and college (8.7%). Studies have shown that educated farmers are in a better position to receive and understand information about the health effects of pesticides, compared with those with little education (Gomes *et al.,* 1999). However, this view is contrary to the study conducted by Prince *et al.* (2016) who found that the 48.9% of the farmer had no formal education.

A significantly higher proportion of participants are married (60.7%) compared to participants who are single (33.9%). This view is supported by Prince *et al.,* (2016), who found that 23 (25.0%) were single while 64 (69.6%) were married and 5 (5.4%) were divorced. Meaning that respondent with marital status of married are more involved than respondents from other categories, thus, the sample was a representative sample of the community composition. On farmer's experience, it shows that (46.2%) had between 1 and 10 years' experience while (47.7%) had between 11 and 20 years' experience and (6.1%) had more than 20 years' experience. This view is contrary to the study conducted by Prince *et al.* (2016) who found that 67 (72.8%) had between 1 and 10 years' experience while 25 (27.2%) had between 11 and 20 years' experience.

Commonest used pesticides by farmers in Kano State.

Farmers in Kano practice both subsistence and commercial farming, which use large amounts of pesticides. It was notice that the most commonly used pesticide Cypernethrim 118 (33.6%) was applied often in Kano, followed by Apron 110 (31.3%) and Primextra 110 (31.3%), Atrazine 42 (12.0), Sevin 34 (9.7%), Thiodam 30 (8.5%), Fusilade 17 (4.8%) and Other 42 (12.0%). Surprisingly, it was further notice that in some parts of Kano, people consumed pesticide-treated seedlings fully knowing that these seedlings could affect their health. This view is contrary to the study conducted by Abubakar *et al.* (2015), who found that the pesticides commonly used by the farmers were identified as Apron plus (93.8%) followed by Sevin used by 80.5% of the farmers. Other pesticides were Cypermethrin (73.4%), Atrozine (19.5%), Fusillade (59.4%), Primextra (51.6%) and Thiodan (19.5%). This is an indication that pesticides play an important role in the control of pests and increasing crop yields (Banzo *et al.,* 2010).

Effects of pesticides, use on farmers' health by monitoring the frequency of clinical symptoms in Kano state.

Participants in the study knew about the dangers of pesticide use and the potential adverse environmental and health impacts. The farmers related the potential symptoms from pesticides exposure that corresponded to the toxicological effects associated with acute poisoning. This might be because most of them were literate and because many of them had experienced some of the symptoms mentioned. Result of the analysis of the regularity of these symptoms reveals that the majority of the respondents experienced these symptoms on a regular basis (56.1% for headache, 53.8% for stomach cramps, 56.5% for muscles weakness, 56.8% for vomiting, 58.3% for dizziness, 40.7% for shortness of breath, 45.5% for blurred vision and 66.7% for eye irritation. This finding are not consistent with the study done by Govinda *et al* (2018) which shows that almost all farmers perceived acute health symptoms after pesticide application. The most frequently self reported toxicity symptoms related to pesticides were headache (73.8%), skin irritation (62.3%), eye irritation (32.8%), weakness (22.4%) and muscle pain (19.1%). His findings are consistent with past studies done in Nepal (Atreya, 2008a) and Vietnam (Dasguptal *et al.,* 2007).

Conversely, this finding are not also consistent with the study of Maria *et al.,* (2006) which shows that the most frequent symptoms reported was cephalea (77 individuals or 51.7% of 149 intoxicated individuals) followed by dizziness (48 individuals) and vomiting (42 individuals). Less than half of the agricultural workers who reported cephalea (29 individuals) identified this symptom as characteristics of pesticides intoxication (self-reported intoxication). On the other hand, all individuals who reported diarrhea and more than 50% of the individuals who reported vomiting, dizziness and stomach discomfort considered themselves intoxicated. Other symptoms reported by the agricultural workers in their study were loss of appetite, fatigue, blurred vision, burning face, fever, body itching, spots on the body and ringing in the ears.

Furthermore, less than half of the 149 individuals who reported symptoms after using pesticides considered themselves intoxicated by these products. Yassin *et al.* (2002) found a higher incidence of self reported intoxication among younger workers and suggested that this population might express themselves better during the interviews. Some studies found that an applicator that experienced symptoms or illness that led to a visit to a health care provider was more likely to remember the event than other who did not seek care (Keim and Alavanja, 2001; Lichtenberg and Zimmerman, 1999). Symptoms reported by the individual in this study such as cephalea (headache), dizziness, abdominal pain and vomiting are typical of exposure to pesticides, including the organophosphorus and Carbamate insecticides (Smit *et al.,* 2003; Kamel *et al.,* 2005). Similarly, this finding are not also consistent with the study which shows 96% of the respondents knew skin irritation as poisoning symptoms of pesticides use (Lekei *et al.,* 2014) which is not consistent with the study which shows 66% of the respondents had awareness regarding skin irritation. The findings of the study showed that 98% and 96% of the respondents knew dizziness and headache as poisoning symptoms of pesticides use in nervous system. The findings of (Lekei *et al.,* 2014) show that the study are not consistent with the study which shows 49% had awareness regarding dizziness and 66% about headache. 84% of respondents were aware nausea as poisoning symptoms of pesticides use in gastro-intestinal system (Lekei *et al.,* 2014) which is not consistent with the study which shows 34% had awareness regarding nausea.

The fore going re-affirmed that exposure to pesticides is one of the most important occupational risks among farmers in developing countries and is of great interest in order to identify the hazards of pesticide use and the establishment of safe methods of pesticide handling. Notwithstanding, the findings that most farmers in the study area lack formal education and without any form of training, and therefore need to be educated and trained on the hazard associated with pesticide usage cannot be overemphasized. This is in tandem with Prince *et al.* (2016) who found that majority of the farmers were illiterate and a small group are educated/ literate. He also found that 48.9% of the farmers were not at all trained and do not know the proper use of agrochemicals, they simply use by learning from their elders, which may not always be correct. Furthermore, Regulatory System of Controlling Pesticide use proffered is eminent. According to the study, residual pesticide is probably a problem that worries consumers the most when they buy agricultural products and public concern about pesticides in the environment and their impacts on human health is rising.

Health problems associated with exposure to pesticides among farmers in Kano state.

The toxicity of a particular pesticides is not a direct measure of its human health hazards. It is an important clue to a potential hazard. However, until the mode of action of action of pesticides is better understand, estimates of toxicity to man must await experience based upon human exposure, either accidental or planned. The general toxicity by the common exposure routes viz: respiratory, oral and dermal (injection is seldom a route of human exposure to pesticides) is the most important guide to potential human hazards and thus to the type of protection that is needed. Acute effects are easily detected in man by observation of accidental exposures when they occur. Chronic effects may not be found either in animals or in man because the dosage was too low or the exposure too short, or for any one of a number of other reasons. Thus, it is never possible to prove that there is no chronic toxicity from a given material. Understanding of the health hazards involved with specific pesticides is simplified if they are grouped according to chemical structure.

Majority of the respondents (76.9%) were aware of the side effect of the use of pesticides with only 23.1% of the respondents not aware of the side effect of pesticide use. However, this is contrary to the work of Prince *et al.,* (2016) who found that majority, 53(57.6%) indicated that the use of pesticide was always good while 34(37.0%) indicated that it was sometimes harmful and 5 (5.4%) said they don't know. Meanwhile, in the same study, it was found that majority 46 (50.0%) indicated that the use of pesticides damages human health, 23(25.0%) indicated that it damages water bodies while 13(14.1%) indicated that it damages animal health and 10(10.9%) indicated that it damages wildlife. The overall prevalence of self-reported health problems among these Kano (Karu) agricultural farmers, out of the 351 farmers was found to have used pesticide: 28.2% complained of pesticide related symptoms with 41.4% complained of headache, 39.4% complained of stomach cramps, 46.5% complained of muscle weakness, 37.4% complained of vomiting, 36.4% complained of dizziness, 27.3% complained of shortness of breath, 11.1% complained of blurred vision while 54.5% complained of eye irritation. This was contrary to the study conducted by Pornpimo *et al.,* (2018) who found that asthma 3%; allergy 4%; diabetes 7%; high blood pressure 24%; heart disease 3%; cancer 1%; thalassemia 0.5%; hypercholesterolemia 7%; thyroid disease 3%; and arthritis 5%. Symptom reports by farmers in the past 3 months after they used pesticides included dizziness 26%, nausea/vomiting 13.4%, blurry vision 23%, cramps 17%, and sweating 34%. Several symptoms were significantly different by farm type; dizziness, nausea/vomiting, and sweating were reported most frequently by rice farmers and least frequently by flower farmers.

Effects of the pesticide's applications on the environment in the study area.

Modern civilization and especially urbanization is built upon introduction of new forms and extensive use of many chemicals. All these substances serve an intended purpose for varying periods. When their usefulness is expended they create a disposal problem. The disposal of pesticides is important because their usefulness is based on biological activity. Problems of contamination of the environment with special ecologic implications may be involved. Fear that pesticides may create serious disruptions in the ecosystem has led to much discussion of the possible consequences and need for control. The most extensive recent investigations of the current situation was that conducted by the subcommittee on Reorganization and international organization of the senate committee on Government operations beginning in 1964 (United State Congress, 1964). This committee, under the chairmanship of senator Ribicoff (United State Congress, 1966) reported a consensus "that mankind must continue to fight insects and other pests in the most efficient manner possible". The present use of chemical pesticides constitutes a hazards to human health or to the productivity of our environment.

Some of the effects of the pesticide's applications on the environment and respondent's awareness include destruction of soil by reducing its quality (32.1%), harm to beneficial insects (34.2%), decrease in biodiversity (35.7%), pollute rivers and streams (40.8%) and harm non-target organism (39.3%). From these results, it can be deduced that less than half of the farmers who use insecticides are aware of its effect on the environment. This is because less than half of these users of pesticides were able to identify the effect on its application on the environment. This is not in tandem with Abubakar *et al.,* (2015) who found that farmers' perception of pesticides effects on the environment include, soil destruction (54.7%), harming beneficial insects (28.1%), decrease biodiversity (61.7%) and contribute to air pollution (48.1%). About 70% of the farmers were of the opinion that pesticides pollute streams and rivers while majority

(80.5%) perceived that harmful side effects of pesticides on non-target animals, birds and earthworms. The study revealed that vegetable cultivating farmers in the study area were aware of various issues related to misuse of pesticides.

Safety practices adopted by the farmers in handling pesticides in the fields by farmers in Kano state.

Available studies suggest that farmers may actually ignore appropriate preventive measure notwithstanding an appropriate awareness of related risks, not only in emerging countries, because of factors other than knowledge of pesticide health effects (Ricco *et al.,* 2018). For example, unavailability and/or inappropriate handling of PPE may be easily recognized and fined by work inspectors, and therefore the use of some PPE may be perceived by the worker more as a regulatory requirement rather than as a safety measure, ultimately operating the equipment without any understanding of its rationale (Ricco *et al.,* 2018). Again, as climate scenarios project an increase in global mean temperature and in the frequency and intensity of heat waves over most areas around the world in the near future (Ricco *et al.,* 2018), rigorous usage of PPE becomes ever more difficult, especially in an increasingly older group of workers. Finally, we cannot rule out that the use of PPE may have been perceived by participants as the “socially appropriated” behaviour (i.e. social desirability bias), with our results ultimately overstating their actual use (Ricco *et al.,* 2018). The prevalence of symptoms potentially related to pesticide intoxication may be interpreted as an outcome of knowledge, attitudes and practices of farmers regarding pesticide handling and personal protective measures, including both the use of PPE and personal hygiene practices (Ricco *et al.,* 2018). Results shows that 50.7% of the respondents said that they protect themselves anytime they want to use pesticides while 49.3% do not protect themselves when using pesticides. When they were asked the safety strategy they adopt, 50.0% were gloves, 43.3% wear mask, 34.8% wear boot and 48.9% said they do wear impermeable clothes. Result shows that less than half of these farmers who make use of pesticides protect themselves by wearing mask, boot or impermeable clothes. This was contrary to the study conducted by Ricco *et al.,* (2018) who found that Focusing on the use of personal protective equipment (PPE) during the disposal of pesticides, the majority of participants regularly wore specific gloves (92.7%), a face mask (91.2%), long sleeve clothes (84.3%), and a hat or a hood (80.8%). Similarly, a high share of respondents mentioned not drinking and/or eating (96.9%), not smoking (92.3%), and not chewing gum (96.2%). After pesticide handling, the majority of respondents reported to regularly wash the hands (94.6%), taking a shower or a water bath (86.2%), managing the face mask or the filters (88.5%), changing (84.2%) or cleaning/washing the clothes (80.8%), and replacing/cleaning the gloves (76.5%). Eventually, 76.5% of PAs reported that they did not consume food and/or drink water after the pesticide dispersal, whereas 18.5% referred to regularly smoke and 10.8% chewed gum. This is of particular interest not only for occupational health and safety, but also in broader terms, as storing pesticides at home or in inappropriate working environment can easily contaminate drinking water and food, ultimately threatening the health of other non-professionally exposed family members, whereas the disposal of the empty containers in the field or by throwing them near or into local waste containers has been reported as a major public health problem in a number of studies (Ricco *et al.,* 2018). Unsurprisingly, not only storing pesticides at home was associated with a lower KS, but also an appropriate storage and disposal were consistently associated with better scores. Analysis of personal practices identified a more ambiguous pattern. On the one hand, available evidence suggests a general acknowledgement that the use of appropriate PPE (i.e. long-sleeved shirts, impermeable working clothes, work boots, gloves and a hat/hood) at spraying significantly decreases the probability of poisoning in pesticide handlers (Ricco *et al.,* 2018). On the other hand, personal hygiene measures such as washing hands, changing clothes, showering, and washing work clothes from household laundry immediately after work have been also described as efficient in order to avoid poisoning after pesticide application (Ricco *et al.,* 2018), but are more inconsistently applied, and frequently neglected (Ricco *et al.,* 2018). In facts, several studies have found detectable levels of pesticide residues on farm workers' work boots, clothes etc., suggesting a significant household contamination from inappropriate practices of personal hygiene measures (Ricco *et al.,* 2018).

Farmers behaviours when using pesticides in Kano state.

One of the most common cause of death from pesticides is carelessness in application. Spray applicators frequently ignore recommended procedure and cover themselves with the pesticides they are using. Most of the exposure is dermal. Pray droplets are too large to be easily inhaled. Protective clothing is uncomfortable to wear, especially in warm weather, when most applications take place. Usually, frequent bathing and fresh clothes would be adequate to prevent fatal exposure since dermal absorption is not apt to be extremely fast. Moreover, prompt medical treatment also would usually be successful, but there are still cases of exposed workman who take atropine by mouth when they feel nauseated. Because this relieve the symptoms they return to work instead of seeking medical attention. Result reveals that 72.6% of the respondents use stock in mixing pesticides, 17.7% made use of their bare hands while 9.7% use other methods. In terms of what they do after applying pesticides 70.4% wash their hands with soap and water, 25.4% claimed that they wash their hands with waters only. Also, 29.1% store pesticide in their rooms, this is in tandem with Abubakar *et al.,* (2015) who found that storage of pesticides in family bedroom is another misuse indicated by 26.6% of the farmers while the majority (96.1%) regarded improper disposal of pesticides containers as a misuse. 38.5% stored it outside house while 32.5% of the respondents stored pesticides inside house (32.5%). Result also reveals that 47.0% of the respondents dispose pesticides containers by throwing it in open field, 38.7% throw it in dustbin while 14.2% returns the containers to the seller. This was contrary to the study conducted by Ricco *et al.,* (2018) who found that The majority of participants (90.8%) claimed that there was a special site for pesticide storage, either nearby home or in the farm, and only 26 individuals (10.0%) reported storing these products inside their house. The empty pesticide containers were returned to the specific disposal program by 93.5% of respondents, whereas 13 (5.0%) washed and reused the containers. Similarly, majority of participants disposed leftover pesticides through specific programs (81.9%), 18.8% stored them for reuse and 9.2% simply poured them on the fields. No one reported to have buried or burned the containers or leftover pesticides, but 1 participant (0.4%) declared that he preferred to not share information about the management of containers. However, this high level of knowledge about pesticides hazards which the end users of pesticides have is important for the prevention of acute poisoning (Zyoud *et al.,* 2010).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Given the prospects of Kano State food situation in the coming century and the central goal of contributing to food security policy, intensive cropping system with increasing use of modern input will likely continue to be the dominant farming practice in Kano. An increasing use of chemical pesticides is also expected to be continued if no practical alternative pest management technologies, regulations, and policies are developed to effectively reduce the overuse of pesticides in crop production. However, chemical pesticide is a double-edged sword. In this study, we show that both visible acute and invisible chronic health impairments and health costs were closely linked with the extent of their exposure to pesticides.

This study has important policy implications. First, increasing farmers' awareness of the hazardous effects of pesticides to human health and improving farmers' knowledge of pest management and pesticide safety issues are critical. The Nigerian government should exert concrete efforts in convincing farmers to reduce pesticide use. These may include a better dissemination of pest management related information, and better education, training, and extension services for farmers. Second, identifying alternatives to chemical pesticide as a way of reducing the high risk of farmer's health is also of critical importance in Nigeria. As a substitute for pesticides, host-plant resistant and genetically modified varieties could lead to substantial reduction in pesticide use without reducing crop yield (Widawsky *et al.,* 1998; Huang *et al.,* 2002). Finally, while the concept of integrated pest management (IPM) has gained strong support, extending IPM technology is facing a greater challenge because of the millions of small householders in Nigeria. Hence, the government should exert efforts to speed up the development of local pesticide spraying services in the short run, and promote large-scale farming in the long run.

5.2 Conclusion

It can be said that pesticides are not significantly different in principles from other chemical substances that are an integral part of modern civilisation. Their ultimate disposal may produce particular problems if they persist in the environment. In conclusion, this study adds to the evidence that pesticides along with other nonchemical options represent an effective and efficient means to control pests in food production, be it conventional or organic in terms of approaches. Advances in agricultural practices have, in fact, kept the total use of pesticides relatively unchanged since the mid-1980s. There is little doubt that this area of intense public concern and scrutiny is considered seriously by farmers and an understanding of the facts around pesticide usage and regulation will help the farmers make wise choices related to their agricultural practices. After all, understanding and communicating the interconnected balance among

i. optimizing agricultural pesticide practices for more effective and efficient food production,
ii. benefits of these practices to nutrient and food availability around the globe, and
iii. potential risks posed by pesticide usage require solid, evidence-based knowledge of all these topics.

Respondents have awareness that use of pesticides causes adverse effects on human health. They are aware that skin irritation, dermatitis, dizziness, headache, nausea, vomiting, dyspnoea, throat itching, eye irritation and burning, and tachycardia are poisoning symptoms of pesticide use. They are aware that use of pesticides may cause cancer, infertility, miscarriage, birth defects and foetal death as long term effects.

All of them are aware that immediate actions after pesticides contact with body. There is therefore need for continued research on the nature of the degradation of the chemicals in various elements of the environment. It will also require adequate attention of the hazards to man and other elements of the environment during the degradation process.

5.3 Recommendations

- It is suggested that education on modern trends of health and environmentally friendly pesticide application methods including the wearing of protective clothing among others should be emphasized for the farmers by extension agents with the view to reducing the extent of exposure and pesticide cocktails which will ultimately reduce health risk among farmers in the study area.
- The use of personal protective equipment (PPEs) will also reduce the health risk associated with the pesticide application among farmers in the study area.
- Identify the circumstances under which chemical pesticides may be required in future pest management.
- Determine what types of chemical products are the most appropriate tools for ecologically based pest management.
- Explore the most promising opportunities to increase benefits and reduce health and environmental risks of pesticide use.
- Recommend an appropriate role for the public sector in research, product development, product testing and registration, implementation of pesticide use strategies, and public education about pesticides.

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APPENDIXES 1

RISK ASSESSMENT ASSOCIATED WITH PESTICIDES APPLICATION ON SELECTED AGRICULTURAL FARMLAND QUESTIONNAIRE

1. Sex (a) Male ☐ (b) Female ☐

2. Marital status (a) Single ☐ (b) Married ☐ (c) Divorced ☐

3. Age (years) (a) 1☐ (b) 26-3 5 (c)☐45 (d) 46- ☐ 55

(e) Above 55 ☐

4. Educational qualification

(a) No formal Education ☐

(b) Primary education ☐

(c) SSCE/GCE ☐

(d) OND/Diploma ☐

(e) HND/B.Sc ☐

(f) Postgraduate degrees ☐

5. Farming Experience

(a) 1-10 years ☐

(b) 11-20 years ☐

(c) Above 20 years ☐

6. Farm size (hectares) (a) 0.5-2 ☐ (b) 2.5-4 ☐ (c) above 4 hectares ☐

7. Land ownership status (a) Inheritance ☐ (b) Leasehold ☐

SECTION B

8. Do you use pesticides (a) Yes ☐ (b) No ☐

9. What type of pesticide do you use?

(a) Apron plus ☐

(b) Atrazine ☐

(c) Cypernethrim ☐

(d) Sevin ☐

(e) Thiodan ☐

(f) Fusilade ☐

(g) Primextra ☐

(h) Others ☐

10. Years of pesticide use

(a) 1-5 years ☐

(b) 10-15years ☐

(c) 16- 20 years ☐

(d) Above 20 years ☐

11. How do you know about pesticides (a) Retailer ☐ (b) co-farmers ☐ (c) consultancies

12. What is your main purpose of using pesticides?

(a) Weed control ☐

(b) Pest control ☐

(c) Rodent control ☐

(d) Fungi control ☐

13. Are you aware of the risk associated with the use of pesticides (a) Yes ☐ (b) No ☐

14. Pesticides usage (a) sprayer ☐ (b) non- sprayer ☐

15. Are you aware of the side effect of the use of pesticides (a) Yes ☐ (b) No ☐

16. Do think the use of pesticides could affect the environment in the following ways (Tick as many that apply)

Yes

No ☐

(a) Destruction of soil by reducing its quality ☐

(b) It is harmful to beneficial insects ☐ ☐

(c) Decrease biodiversity ☐ ☐

(d) Pollute rivers and stream ☐ ☐

(e) Harmful effect on non- target organism ☐ ☐

17. Have you ever had any pesticide related health symptoms (a) Yes ☐ (b) No ☐

18. If yes, which of the following health related symptoms have you experienced?

Yes

No

(a) Headcahe ☐ ☐

(b) Stomach cramps ☐ ☐

(c) Muscle weakness ☐ ☐

(d) Vomiting ☐ ☐

(e) Dizziness ☐ ☐

(f) Shortness of breath ☐ ☐

(g) Blurred vision ☐ ☐

(h) Eye irritation ☐ ☐

19. How often do you experience theses symptoms?

(a) Regularly ☐

(b) Occasionally ☐

(c) Rarely ☐

20. How do you mix pesticides (a) use stick ☐ (b) Bare hands ☐ (c) Others ☐

21. Do you protect yourself while using pesticides (a) yes ☐ (b) No ☐

22. If yes, which of the following protective do you put on?

Yes

No

(a) Wear gloves ☐ ☐

(b) Wear mask ☐ ☐

(c) Wore boot ☐ ☐

(d) Wore impermeable clothes ☐ ☐

23. What do you do after applying pesticides (a) wash hand using soap ☐ (b) wash hand with water only ☐ (c) won't wash ☐

24 Where do you store pesticides (a) store room (b) outside house inside house

25. How do you dispose pesticides containers (a) throw in open field (b) Throw in dustbin (c) return to seller