NEGATIVE EXTERNALITIES OF PESTICIDE USE IN THE VEGETABLE SUB-SECTOR IN KENYA

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Dedication

To my beloved wife, Jacinta and my children Grace and Justin

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Macharia Ibrahim

Hanover, 06.05.2010

Zusammenfassung

Negative Externalitäten, verursacht durch den Einsatz von Pestiziden, sorgen weltweit für Besorgnis. In Kenia, haben wissenschaftliche Studien die Existenz dieser Externalitäten nachgewiesen. Allerdings sind Ausmaß und Wert weitgehend unbekannt. Viele dieser Auswirkungen sind ein direktes Resultat von unsachgemäßer Handhabung der Pestizide, da oftmals die tatsächlich ausgeführte Anwendung von der empfohlenen abweicht. Bisher sind die angewendeten Pestizidpraktiken, das Ausmaß der Abweichung dieser Praktiken zwischen Empfehlung und Umsetzung und die zugrunde liegenden Faktoren im Gemüsesektor noch nicht ausreichend erforscht. Zudem wurde das spezifische Wissen der Bauern und ihre Wahrnehmung von Risiken gegenüber Pestiziden noch nicht bewertet. Diese Informationen sind notwendig, um effektive Politikmaßnahmen, die auf die Minimierung der negativen Externalitäten abzielen, zu entwerfen und zu entwickeln. Ziel dieser Doktorarbeit ist es, diese Forschungslücken zu schließen. Die spezifischen Ziele der Arbeit sind: i) die Identifizierung des Pestizideinsatzes und die Handhabungspraktiken von Kleinbauern und die Bewertung der Determinanten, ii) die Bestimmung der durch den Einsatz von Pestiziden entstandenen Gesundheitskosten für die Farmer und iii) die Quantifizierung und Bewertung von negativen Externalitäten durch den Einsatz von Pestiziden in der Gemüseproduktion in Kenia. Die Studie hat einen Bezugsrahmen zur Bewertung von Externalitäten, die durch die Verwendung von Pestiziden verursacht wurden, entwickelt, welcher an die Bedingungen in Entwicklungsländern angepasst ist. Die Daten wurden mit Hilfe von Haushaltsbefragungen, Pestizidrückstandsanalysen am Gemüse und Experteninterviews erhoben. Außerdem wurde die Datenbasis durch Informationen von Bestands- und Sekundärdaten, die von Forschungs- und Regierungsorganisationen erhoben wurden, ergänzt.

Ergebnisse zeigen, dass die Anzahl der Pestizidprodukte in der Gemüseproduktion mit 19 neuen Produkten in 2008 im Vergleich zu 2005 angestiegen sind. Manche wurden von der Weltgesundheitsorganisation als sehr toxisch eingestuft. Zudem wurde ein signifikanter Anstieg der Anwendungsrate und der Frequenz der Anwendung festgestellt. Besonders stark war die Zunahme bei Kartoffeln und Tomaten. Mit Hilfe des EIQ Models und des „EIQ field use rating systems“ wurde der Einfluss verschiedener Pestizide auf die Umwelt verglichen. Die Mehrheit der Farmer (85%) habenPestizide unsachgemäß angewendet indem sie Pestizide unsicher gelagert haben (23%), die Überreste in Pestizidbehältern und -vorrichtungen nicht sicher entsorgt haben (40%), nicht die minimal vorgeschriebene

Schutzkleidung getragen (68%), oder eine Überdosis an Pestiziden verwendet haben (27%). Dennoch waren sich die meisten Farmer des Risikos der Pestizidverwendung bewusst. 81% gaben an, dass Pestizide schädlich sind für Mensch, Tier, nützliche Arthropoden, und das Wasser verschmutzt. Das Regressionsmodell hat gezeigt, dass die Wahrscheinlichkeit von unsachgemäßer Handhabung von Pestiziden geringer ist, wenn die Farmer Aufzeichnungen machen und wenn sie aus dem Meru Central Distrikt kommen. Dagegen wird die Wahrscheinlichkeit einer unsachgemäßen Verwendung von Pestiziden erhöht, wenn Ratschläge zur Handhabung hauptsächlich von Händlern angenommen werden, die insgesamt verwendeten Pestizide und die der Klasse WHO II steigen, und wenn die Farmer aus dem Kirinyaga und Makueni Distrikten kommen. Weder Risikoempfinden gegenüber der Verwendung von Pestiziden, noch negative Erfahrung mit Pestiziden haben einen direkten Einfluss auf die Handhabung von Schädlingsbekämpfungsmitteln.

Das Auftreten von akuten Krankheitsfällen in kleinbäuerlichen Haushalten, ausgelöst durch den Einsatz von Pestiziden, stieg über 70%, von 20% in 2005 auf 34% in 2008. Die Abschätzung von neuen Krankheitsfällen auf 55% deutet darauf hin, dass sich dieses Problem weiterhin fortsetzen wird. Im Durchschnitt betrugen die jährlich durch Pestizide verursachten Gesundheitskosten 3.54 US$ pro Farmer. Ein positiver Zusammenhang zwischen Gesundheitskosten und akuten Krankheitssymptomen konnte festgestellt werden. Akute Krankheitssymptome konnten positiv mit der Handhabung verschiedener Pestizide assoziiert werden. Das Bildungsniveau, die Aufzeichnung von Produktionsaktivitäten und die Benutzung einer Schutzausrüstung reduzieren beträchtlich das Auftreten von Krankheitssymptomen.

Die indirekten Kosten des Pestizideinsatzes auf einer Fläche von 221.318 ha mit intensivem Gemüseanbau wurden auf 12.83 Millionen US$ pro Jahr geschätzt. Dieser Betrag ist höher als der Marktwert der im Gemüseanbau eingesetzten Schädlingsbekämpfungsmittel. Der höchste Anteil dieser Kosten fällt dabei auf die potentiellen Verluste in der Gemüseproduktion, gefolgt von denen in der Viehhaltung, Gesundheitskosten, Kosten zur Beseitigung leerer Pestizidbehälter und zur Schadensvorbeugung. Weitere Nebenwirkungen wurden ebenfalls in dieser Studie aufgezeigt. Mehr als 58% der Kleinbauern beobachteten, dass nützliche Gliederfüßer und Vögel innerhalb von 24 Stunden nach dem Einsatz der Pestizide starben. Zudem sagten 80% aus, dass sie eine kumulative Abnahme in der Population beobachten konnte, welches sie auf das eingesetzte Bekämpfungsmittel zurückführten. Aufgrund fehlender Daten konnte dieser Rückgang allerdings nicht genau bestimmt werden.

Obwohl diese Studie nicht die Analyse von politischen Instrumenten beinhaltete, die zur Reduktion oder Vermeidung von negativen Externaltitäten beigetragen hätten, so können dennoch einige allgemeine Empfehlungen abgeleitet werden. Zum einen wird, angesichts der festgestellen Mängel im Umgang mit Pestiziden, vorgeschlagen, effektivere und zielorientierte Trainingsprogramme für Kleinbauern einzurichten. Aus der ökonometrischen Analyse läßt sich ableiten, dass die Aufzeichnung von Produktionsaktivitäten durch den Kleinbauern ein wirksames Instrument zur Förderung des Bewußtseins für den Umgang mit Pestiziden darstellt. Zum zweiten, sollten mehr Informationen über negative Langzeitfolgen verbreitet werden. Drittens, könnten die berechneten externen Kosten, an eine breitere Zuhörerschaft übermittelt, einen guten Ausgangspunkt für einen politischen Dialog bilden. Viertens, als eine konkrete Maßnahme könnte die Einrichtung eines Pfandsystems für Pestizidbehälter empfohlen werden. Weiterhin wäre es notwendig die Überwachung von Nebenwirkungen, ausgelöst durch den Einsatz von Pestiziden, zu verbessern, welches die intensivere Kontrolle von Pestizidrückständen beinhaltet. Zudem sollten Mechanismen, die die formale Dokumentation von Krankheitsfällen bei Mensch und Tier ermöglichen, verbessert werden. Hierzu könnte die Befürwortung einer kostenlosen medizinischen Betreuung im Kranheitsfalle in human- als auch veterinärmedizinischen Zentren beitragen. Schließlich könnte eine Steuer auf die schädligsten Pestizide zur Entwicklung und Adoption von alternativen Schädlingsbekämpfungsmethoden beitragen.

Die hier aufgelisteten Empfehlungen sind vorläufiger Natur. Die Ableitung von spezifischeren und zielorientierteren Empfehlungen bedarf weiterer Forschungsanstrengungen. Dennoch sollte diese Studie die Tür für weitere Vorhaben den Einsatz von Schädlingsbekämpfungsmittel und die damit verbundenen externen Effekte in verschiedenen landwirtschaftlichen Systemen Afrikas zu erforschen, geöffnet haben. Der Forschungsbedarf besteht, da Kleinbauern weiterhin Pestizide verwenden und deren Risiken ausgesetzt sind, und somit das Krankheitsrisiko steigt, welches die Verwundbarkeit in Armut zu fallen, erhöht.

Schlagwörter: Kenia, Pestizide Externalitäten, Gemüseproduktion

Abstract

Pesticide negative externalities have become a major concern globally. In Kenya, primary research findings have indicated existence of these externalities. However, the magnitude and value remain largely unknown. Many of these impacts are a direct result of inappropriate pesticide handling practices, often due to deviation from recommended use and handling procedures. However, pesticide-handling practices, the extent of deviation of those practices from recommendations and the underlying determinants are not well understood in the vegetable sub-sector. In addition, farmers' knowledge and perception of pesticides risks have not been assessed. In order to develop and design effective policies that can minimize pesticide externalities, such information is needed. This dissertation aimed at filling these research gaps. The following objectives were defined: i) identify pesticide use and handling practices by small-scale farmers, and evaluate their determinants, ii) determine the health costs from pesticide use incurred by farmers and iii) quantify and value the magnitude of pesticide negative externalities in vegetable production in Kenya. The study developed a framework for evaluating the externalities of pesticide use adjusted to the conditions of a developing country. Data were collected by means of farm household surveys, vegetable pesticide residue analysis, and expert interviews. The data were also supplemented with information from inventory and secondary data collected from research organizations and government institutions.

Results showed that in vegetable production the number of pesticide products had increased, with about 19 new products applied in 2008 as compared to 2005. Some classified as very toxic by Worlds Health Organization. There was also a significant increase in the application rate and frequency of application, being most intensive in potatoes and tomatoes. With the application of the EIQ model and the EIQ-field use rating system, comparison of environmental impacts between different pesticides was realized. Majority of the farmers (85%) had inappropriately handled pesticides, mainly through, unsafe storage (23%), unsafe disposal of leftover in either sprays solutions, or rinsate and empty pesticide containers (40%), failure to wear the required minimum protective gear (68%), or over-dosed pesticides (27%). However, majority of those farmers were aware of the risks of pesticide use, with over 81% expressing the view that pesticides have harmful effects on human health, livestock, beneficial arthropods, and on water. The regression model showed that the probability of inappropriate handling of pesticides is lower with record keeping and being located in the district of Meru Central. Similarly, pesticide

traders as the main sources of advice on pesticide use, the number of pesticides handled, handling pesticides in WHO II and being located in the districts of Kirinyaga and Makueni significantly increases the probability of handling pesticides inappropriately. Neither pesticide risks perceptions nor did experiences of a negative pesticide impacts had a direct influence on pesticide handling practices.

The incidences of pesticide related acute illness among the farmers increased by over 70% from 20% of the cases in 2005 to 34% of the cases in 2008. New incidences were calculated at 55%, indicating persistence of the problem to many farmers. On average pesticide related health costs were calculated at about US$ 3.54/farmer/year. A positive relationship between the health costs and the pesticide related acute symptoms was established. Acute symptoms were positively associated with handling of different pesticide products. Level of education, record keeping of production activities and use of personal protective equipments considerably reduces the number of pesticide-related acute symptoms.

For the 221,318 ha of intensive vegetable production, the indirect costs of pesticide use were estimated at US$ 12.83 million/year. This amount is higher than the market value of pesticides used in vegetables. The highest share of these costs were attributed to potential vegetable losses, followed by livestock losses, human health costs, disposal of empty pesticide containers and damage prevention costs. There were other side effects of pesticides identified in this study. Over 58% of the farmers had also observed mortality of beneficial arthropods and birds 24 hours after spraying pesticides. In addition, about 80% had witnessed a cumulative decline of the same species populations in their sprayed fields, of which they attributed to the pesticides sprayed. However, these could not be valued due to lack of data.

Although this study did not include the analysis of policy instruments to reduce or avert pesticide externalities some general recommendations can nevertheless be derived. Firstly, given the widespread inappropriate pesticide-handling practices identified it is suggested that policymakers to design more effective and more participatory and targeted extension programmes. Based on the results of the econometric analysis, the promotion of record keeping of farming activities by farmers would be an effective tool to raise farmers' awareness. Secondly, more information on the broader long-term negative effects of pesticides should be disseminated. Thirdly, the external costs of pesticides calculated can provide a good basis for entering into a policy dialogue by making these results known to a broader audience. Fourthly, concrete measure could be the establishment of a deposit-refund collection system for pesticide containers. Furthermore, it is necessary to improve the monitoring system on pesticide side effects, including more intensive residue testing. Mechanism to facilitate formal documentation of pesticide related cases of poisoning of both human and livestock should be improved. This could be stimulated for example by advocating free medical assistances for pesticide poisoning in medical and veterinarian centers. Finally, a tax imposed on those pesticides, which cause most damage, could be one way to stimulate the development and adoption of safer alternatives.

The recommendations made here are preliminary and more research is needed to come up with more specified and targeted policy recommendations. However, it is believed that this study has opened the door for more studies on pesticide externalities in the different agricultural systems of Africa. Such work is needed as pesticide exposure can increase the risk of other diseases, which can make farmers more vulnerable to poverty.

Key words: Kenya, pesticide externalities, vegetable production

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List of Abbreviations

a.i.	Active Ingredient
AAK	Agrochemical Association of Kenya
ADE	Acceptable Daily Exposure
ADI	Acceptable Daily Intake
CE	Choice Experiments
CV	Contingent Valuation
DDT	Dichlorodiphenyltrichloroethane, Organochlorine insecticides
e.g.	For Instance (*exampli gratia*)
e.t.c.	And others (*et cetera*)
EIQ	Environmental Impact Quotient
et al.	And others (*et alii*)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
FPEAK	Fresh Produce Exporters Association of Kenya
GLOBALGAP	EU Retailers Produce Working Group for Good Agricultural Practices
HCDA	Horticultural Crop Development Authority
ICIPE	African Insect Science for Food and Health
IPM	Integrated Pest Management
IUCN	International Union for the Conservation of Nature
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
Kg	Kilogram
KSh	Kenya shillings
LC	Lethal Concentration
LD	Lethal Dose

m	Meter
MoA	Ministry of Agriculture
MRLs	Maximum Residue Levels
NEMA	National Environment Management Authority
NGO	Non-Governmental Organization
PCPB	Pest Control Products Board
POPs	Persistent Organic Pollutants
PPE	Personal Protective Equipment
UK	United Kingdom
UNEP	United Nations Environment Programme
US$	United States of America Dollar
USA	United States of America
WHO	World Health Organization
WTA	Willingness to Accept compensation
WTP	Willingness to Pay

1 Introduction

1.1 Background and research problem

Increased agricultural productivity through the green revolution during the past years has generated tremendous benefits both for farmers and for society as a whole. However, the dramatically increased use of chemical pesticides as the main pest control strategy caused negative externalities[1] in terms of impairments of human health, production losses (livestock and crops) degradation of the environment, loss of bio-diversity, destruction of natural enemies, development of pesticide resistance in pests, honeybee losses, bird and other wildlife losses (Zilberman and Katti, 1997; Pretty *et al.,* 2000; Pimentel, 2005).

Rachel Carson's book Silent Spring (Carson, 1962) played a pivotal role in drawing public attention to the negative externalities caused by pesticide use mainly in US agriculture and her concerns have been increasingly shared globally. This concern is evident from increasingly more stringent standards on pesticide use, *e.g.* European Retailers Produce Working Group for Good Agricultural Practices (GLOBALGAP) which at present, have over 250 control points, of which over half define criteria for the correct use of chemicals during crop production (GLOBALGAP, 2004) and the promotion of Integrated Pest Management (IPM)[2]. In addition, pesticides pollution has now become a global problem, as toxic compounds from pesticides accumulate in oceanic food chains, and even in the tissues of land mammals in 'pristine' polar regions (Blais *et al.,* 1998).

Since pesticide externalities, affect goods and services 'outside' the market, they are difficult to value. Thus, the market price of pesticides is generally below their economic price[3]. Therefore, some of the costs of pesticides are borne by consumers and the society in general.

If externalities are not included in the price, net benefits of pesticide use tend to be overestimated and in the absence of intervention, pesticide use will generally be excessive from society's point of view, even though the level of usage of each individual farmer would seem to be perfectly logical from their own perspective.

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[1] Exists when the activity of one entity (individual/firm) directly affects the welfare of another in a way that is external to the market mechanism (not transmitted by prices).

[2] IPM is a systematic strategy for managing pests, which considers prevention, avoidance, monitoring, and suppression. Where chemical pesticides are necessary, a preference is given to materials and methods that maximize public safety and reduce environmental risk.

[3] Ideally, a tax should be used to pay for the hidden costs of pesticide use.

Pesticide externalities have five features commonly found across all the agricultural related externalities: i) their costs are often neglected, ii) they occur with a time lag, iii) they often damage groups whose interests are not well represented in political or decision-making processes, iv) the identity of the source of the externality is not always known, and v) they result in sub-optimal economic and policy solutions (Pretty *et al.,* 2000).

The few studies conducted at the international level have shown considerable external costs associated with the use of pesticides (Steiner *et al.,* 1995; Waibel *et al.,* 1999; Pretty *et al.,* 2000; Azeem *et al.,* 2003; Tegtmeyer and Duffy, 2004; Pimentel, 2005). Most of these studies have been done in either developed or in Asian and Latin American Countries with intensive pesticide use. There is very little information however on the situation in Africa, where most studies have been limited to human health only (Ajayi, 2000; Maumbe and Swinton, 2003; Ngowi *et al.,* 2007). The only three known studies that attempted to assess the costs beyond human health in Africa are the study by Ajayi *et al.* (2002) on cotton sub-sector in Mali, Houndekon et al. (2006) for locust control in Sahel-Niger and Leach *et al.* (2008) for locust control in Senegal. However, in all the cases the studies concentrated on just few externality categories[4].

In Kenya, some research findings have indicated existence of some pesticides related negative externalities, *e.g.* Mugambi *et al.* (1989) found pesticide residues in eggs of free range chicken; Waikwa (1998), confirmed fish killed by leaching pesticides in ponds in Nyeri districts; IUCN (2005), indicated that pesticides were threatening Lake Naivasha local hippopotamus populations. Kinyamu *et al.* (1998) found higher residues levels of Organochlorine pesticides in milk of breast feeding mothers. Few have also confirmed the link between pesticide use and farmers' health (Ohayo-Mitoko *et al.,* 2000; Okello, 2005; Asfaw, 2008). The recent findings of the presence of export vegetables with high maximum residue levels (PAN-UK, 2006), is a classic example pointing out the seriousness of the problem in this sector. However, the magnitude and value of these externalities remain largely unknown.

Many of these impacts are a direct result of inappropriate pesticide handling practices, often due to deviation from recommended use and handling procedures. However, pesticide-handling practices, the extent of deviation of those practices from

[4] Livestock and livestock product losses, pesticide-related destruction of natural enemies, development of pesticides resistance in pests, honeybee losses, crop and crop product losses, bird, fish, and other wildlife losses; and governmental expenditures to reduce the environmental and social costs.

recommendations and the underlying determinants are not well understood in the sub-sector. In addition, farmers' knowledge and perception of pesticides risks have not been well documented.

In order to develop and design effective policies that can minimize pesticides related negative externalities, such information is needed. This thesis aims to fill these research gaps through a detailed analysis of the pesticide use practices, and an assessment of the nature and magnitude of pesticides externalities. Though the study was carried out only in the vegetable sub-sector, the results can as well serve as a benchmark guide for policy makers in the development of strategies that can help to minimize negative externalities of pesticide use in the entire agriculture sector.

1.2 Objective and research question of the study

The motivation of this study is threefold. First, it is the policy relevance of this research, *i.e.* the heavy and inappropriate use of pesticides in vegetable production and their human health implications. Second, the still existing lack of knowledge by farmers regarding the safe handling of pesticides and third, the general lack of information about the existence and extent of pesticide externalities by the general public in Kenya.

The objectives were thus to:

i) identify pesticide use and handling practices by small scale farmers and evaluate their determinants,

ii) determine incidences of acute pesticide poisoning symptoms and associated health costs over time, and

iii) quantify and value the magnitude of negative externalities of pesticide use in the sub-sector.

The study took up the challenge which most of researchers undertaking studies on externalities studies, are facing, *i.e.* to develop an appropriate framework for evaluating the externalities of pesticide use.

In order to achieve its objectives the following specific research questions were formulated:

1. What is the extent of pesticide use in the vegetable production with respect to the range of products, patterns of application and what is known about their risk?

2. What are the current pesticide handling practices and what determines them?

3. What factors are associated with incidences of pesticide related acute symptoms and health costs over time?

4. What are the major types, the magnitude, and the value of pesticide negative externalities?

These questions are addressed in a series of separate chapters as outlined in the thesis structure.

1.3 Thesis structure

In chapter two, some background information of the importance and trends of the vegetable production in Kenya is presented. The chapter also gives insight of the pesticide market taking into account the registration, regulation, and imports.

Chapter three gives an overview of the study methodology and procedures of data collection. Here special attention is paid to the details of data collection methods and the type of data collected. The latter also includes the description of the procedure of an expert workshop, which generated additional data and at the same time was used to control the primary data collected in farm household surveys for plausibility.

In chapter four the first research questions is addressed. The chapter provides a detailed analysis of pesticide use in terms of types of products used, patterns of application and the associated risks in vegetable production in Kenya. Potential substitution of highly hazardous products by less toxic ones is also established. The analysis is based on the farm household survey data collected in 2005 and 2008.

Chapter five is devoted to answering the second research question. It first provides a detailed analysis of the current pesticide handling practices, considering details about pesticide storage, methods of application, dosage, disposal of the pesticide left over and empty containers, and use of personal protective equipment. Next, the relationship between farmers' awareness, knowledge and perceptions about pesticide risks and the actual pesticide use practices is also established and the factors associated with those practices are identified. The analysis is based on farm household surveys data collected in 2008.

Chapter six reports empirical analysis of the factors associated with pesticide related health costs, acute symptoms, and health impairments controlling for unobserved heterogeneity, addressing research questions three. Here a balanced panel data of two farm household surveys conducted in 2005 and in 2008 is used.

Results regarding the externalities of pesticide use in the sub-sector answering question 4 are presented in Chapter seven. A framework used to quantify and value pesticide externalities is presented. This is followed by a discussion of the specific externality category and its estimated costs.

Finally, Chapter eight gives a summary of the major findings, draws conclusions, and makes recommendations based on policy implications.

2 Kenyan Vegetable Sub-sector and Pesticide Imports

2.1 Overview of vegetable sub-sector

Agriculture remains the engine of Kenya's economic growth, accounting for about 27% of real GDP, 60% of the country's total export earnings, and 45% of government revenue, with about 75% of Kenyans employed in the agricultural sector (Kenivest, 2009). Vegetable production is one of the key sub-sectors of the agricultural sector in the Kenyan economy. Vegetables have received a great deal of attention from local and international researchers, governments, and donors over the past decade, due to the rapid and sustained growth of its exports. As indicated in Figure 2.1 there has been an almost three-fold increase in vegetable production and a corresponding increase in the productivity. However, productivity increase was uneven, *i.e.* only marginally from 1997 to 2003, and followed by a drastic increase of almost 100% from 2004 to 2007. One major factor that caused this increase was the high commodity prices that prevailed during those years resulting from an increase in economic activity in the country that boosted demand and consumption resulting in low post harvest losses at farm level. The absence of adverse weather conditions and use of high yielding varieties were also seen as contributing factors (MoA, 2005).

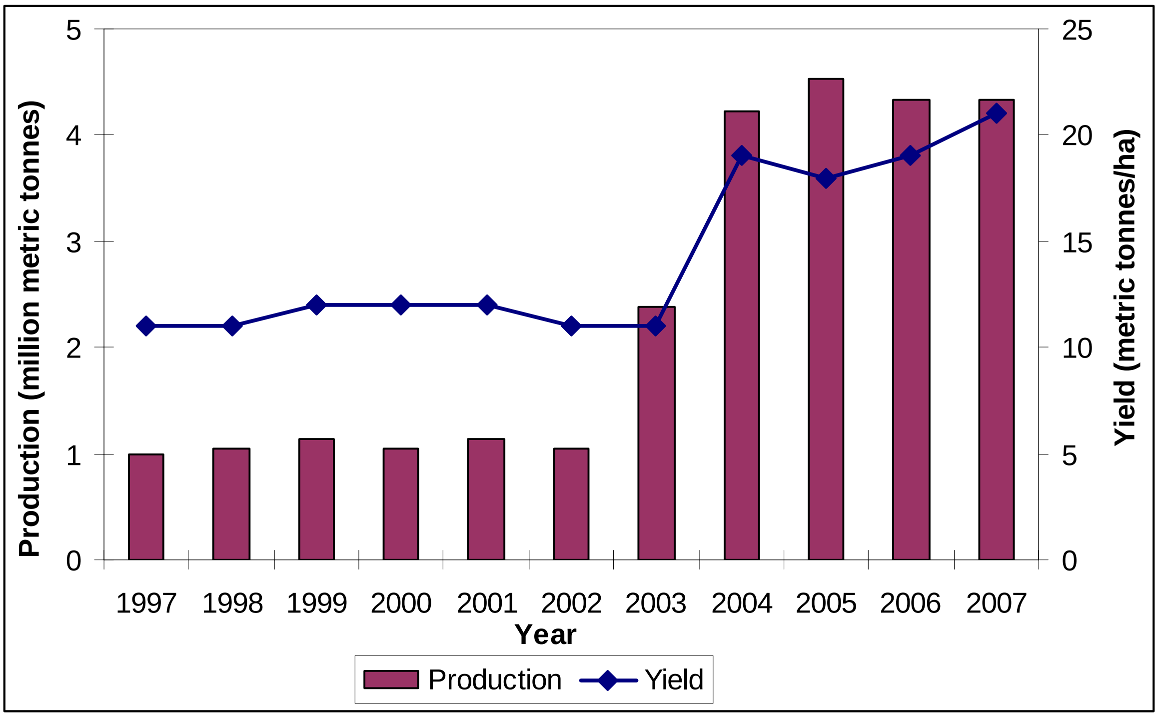

Figure 2.1: Trends in vegetable production in Kenya, 1997-2007
Source: HCDA, 2008 and MoA, 1997-2007

Besides its high growth rate in production, the vegetable production has also expanded in terms of export volumes over the last decade, surpassing coffee – the historically Kenya's most foreign exchange earning export crop – as the nation's second major source of foreign exchange in the agricultural sector after tea (Government of Kenya, 2006). A total of 85,000 tonnes was exported in 2007, a growth of nearly 40% compared to 2006 (Figure 2.2). The reason for this increase is processed beans (canned and frozen) exports, which had more than tripled to 3,870 metric tonnes exported in 2006). Secondly from fresh vegetables with 72,000 metric tonnes (25% increase compared with 2006), green beans 38,000 metric tonnes (25% increase), followed by mixed vegetables (16,000 metric tonnes, 33% increase), (HCDA, 2007).

This significant growth has undoubtedly contributed to increased rural incomes and reduced rural poverty through both direct production effects and linkage effects, as horticultural incomes from export are spent in rural areas. Studies have even shown that a single export crop (French bean) provides half a million people with their main source of income (Swanberg, 1995). A recent study of the relevance of export vegetable production for poverty alleviation in Kenya also showed a significant positive impact of the industry on producers and the workforce employed in the sector (McCulloch and Ota, 2002). In addition, export vegetable production in Kenya is concentrated in areas severely affected by poverty and hence makes a significant contribution to poverty reduction in rural areas. A 2001 study estimates that there were more than 6,000 smallholder out-growers[5] producing vegetables for exports, (IFAD, 2004), while HCDA estimated that 40% of exported fruit and 70% of exported vegetables are produced by smallholders (Harris *et al.,* 2001). A recent review and update, estimates the current number at about 12,000 smallholders producing for the vegetable export market in nine districts of Kenya (Mithöfer *et al.,* 2008).

Europe is the main market for Kenyan fresh horticultural produce with the main importing countries being United Kingdom, Germany, France, Switzerland, Belgium, Holland, and Italy. Other importing countries include Saudi Arabia and South Africa. The domestic market, although very important, receives less attention in discussions and literature as

[5] System whereby a vegetable exporting company purchases the harvests of individual farmers, and the terms of the purchase are arranged through agreements. However, the agreements between exporters and farmers are often unwritten and are subject to frequent disputes. If the market price falls, the exporter may fail to pick up the produce and try to source elsewhere. If the market price rises, farmers may sell elsewhere and default on the agreement (Jaffee, 1995).

compared to export horticulture. However, the vegetable production sold and then consumed domestically over the past five years has been at least four-to-five times as large as the value exported in fresh and processed form (52% compared to 12%). If produce consumed on the farm is included, the domestic share rises to seven-to-eight times that of the export market. The total value added in domestic vegetable markets is nearly three times that in vegetable export markets. Furthermore, domestic markets nonetheless remain the primary outlet for vegetable production and generate much more value added than do export markets (Tschirley *et al.,* 2004). The brokers networks, that distorts the market to benefit from rock bottom farm gate prices and the demand for certification under GLOBALGAP standards for all the export vegetables have been a challenge for many vegetable producers.

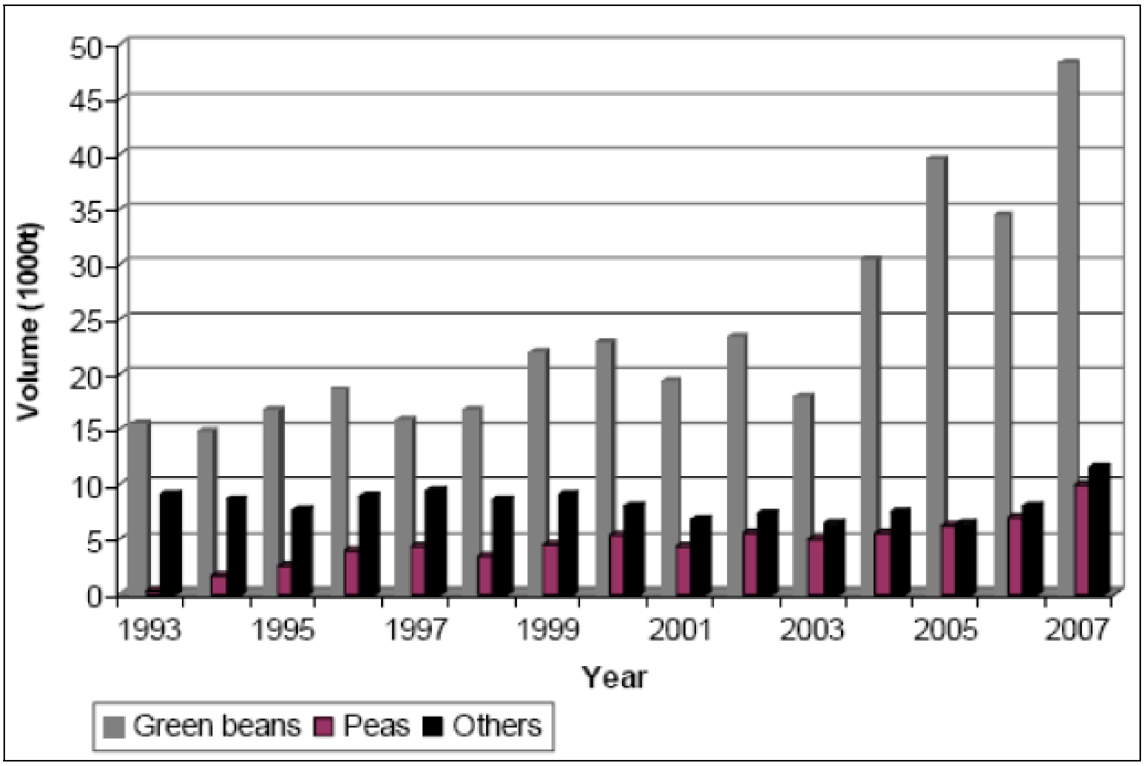

Figure 2.2: Trends in vegetable exports from Kenya, 1993-2007
Source: HCDA, 2008

There are a number of institutions, both government, semi-government and private members associations, which directly or indirectly participate, toward improving the vegetable sub-sector. Each one of them offers supportive and useful facilitating roles. Table 2.1 is a list of the institution with major functions. The importance attached to the vegetable sector by government is reflected in the fact that the Ministry of Agriculture (MoA) has a full-fledged horticultural division in all the vegetable production area that provides extension services to producers. Further, Kenya Agricultural Research Institute (KARI) has, as part of its research stations, a National Horticultural Research Institute charged with research and development of vegetable crops.

The Fresh Produce Exporter Association of Kenya (FPEAK) is a non-governmental organization formed in 1975. Its activities include market research, representing exporter interests to the government, liaison with research and regulatory organizations, support for smallholder out grower schemes, and the drafting and implementation of the Code of Practice for horticultural producers. FPEAK, in collaboration with HCDA and others have drafted a 70-page Code of Practice for vegetable growers and exporters (IFAD, 2004).

Table 2.1: Role of major institutions and trade associations

Name	Type [a)]	Major role
Ministry of Agriculture (MoA)	G	➢ Supply information management to Agricultural sector ➢ Facilitation of appropriate agricultural extension services ➢ Research liasion ➢ Promotion of private sector development
Kenya Agricultural Research Institute (KARI)	G	➢ Horticultural Research
Horticultural Crops Development Authority (HCDA)	SG	➢ Licensing horticultural exporters ➢ Advising growers on the use of certified planting materials and post handling techniques ➢ Training farmers on the proper use of farm inputs, pesticides and Maximum Residue Levels (MRLs) ➢ Organizing groups of small-scale growers for production and marketing purposes ➢ Registering fruit tree nurseries ➢ Provision of cold stores and pre-cooling facilities at major collection centres and their management ➢ Provision of a specialized market oriented service ➢ HCDA in collaboration with other governmental Institutions
Fresh Produce Exporters Association of Kenya (FPEAK)	PMA	➢ Provision of market information ➢ Promotion of members exports, through overseas exhibitions etc ➢ Training members on production ➢ Outgrower scheme ➢ Code of Practice

Table 2.1: Continued

Name	Type [a)]	Major role
National Irrigation Board (NIB)	G	➢ It is involved in the production of irrigated horticultural crops ➢ It liaises with the stakeholders in the provision of irrigation infrastructure for horticultural development
Agricultural Finance Corporation (AFC)	G	➢ Field Inspection of land offered as collateral ➢ Charging of land at the Land Control Board ➢ Train of loan beneficiaries in farm management skills ➢ Recovery of loans
Kenya Export Promotion Council (KEPC)	SG	➢ Spearhead horticultural promotion activities

[a)] G=Government, SG=Semi-government, PMA=Private Members Association
Source: Institutions reports

2.2 Overview of Pesticide Import and Registration

In the 1950s, only five pesticide products were available in the Kenyan market. These were DDT, 2-4-D, TEPP, Tixol (Arsenicoldip) and Copper formulation (Bordeaux). However, in the decades between 1970 and 1990, many pesticides entered the market and to date more than 370 formulations can be found with 110 products registered in 2006 (PCPB, 2006). Pesticide imports have been rising although uneven (Figure 2.3). In 2005, it was estimated that 7,047 metric tonnes of pesticides with a value of US$ 54 million were imported into the country (PCPB, 2006).

The major active substances involved were Glyphosate 1,3-Dichloropropene, Amitraz, Mancozeb, Imiprothrin, D-allethrin, Chlorothalonil, Copper hydroxide, Cuprous Oxide, Dimethoate, Metolachlor+Atrazine, Sulphur, Diazinon, Methyl Bromide, Deltamethrin, 2, 4-D Amine and Cobox in order of decreasing volume[6]. Much of the imported pesticides are normally consumed locally, with only 3% being exported to neighboring countries. A high share is claimed to be used in horticulture sector, where heavy use of pesticides has been reported (Ohayo-Mitoko *et al.,* 1999).

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[6] Many of these pesticide groups belong to pesticides that are more hazardous.

The pronounced decline in imported volumes in 2001 (Figure 2.3) could be attributed to poor economic position of the farmers that reduced demand, coupled with the ban and restriction on the use of Organochlorine pesticides. However, the continued increase of fungicides from 1,657 metric tonnes in 2003, about 2,031 tonnes in 2004, to 2,361 metric tonnes in 2005 could be attributed to the revival of coffee farming, where especially copper-based fungicides were on high demand (PCPB, 2006).

In general, insecticides imports have also been growing. However, it is important to note that Kenya is the leading producer of a natural pesticide (pyrethrin), which is a broad-spectrum insecticide from the dried flowers of pyrethrum *(Chrysanthemum cineraria folium*). The crop has been grown in Kenya for export purposes for the last 70 years. Up to 8,000 metric tonnes of dried flowers are produced annually. Ninety-five percent of all the crude pyrethrin is exported to developed countries in the West, *i.e.* 60% to USA and 35% to Europe. Only 5% is used in Africa, Egypt and South Africa take 2% each and only 1% remains in Kenya (PCPB, 2006). It is a pity that Kenya exports nearly all its natural insecticides, only to import synthetic ones. Pyrethrin-based insecticides can replace most of the imported synthetics. This would reduce the health and environmental risks that the synthetic pose. However, the main problem is that the Kenyan pyrethrins earn a premium price in the more environmentally conscious developed countries so that Kenyans are left with the option of importing the cheaper synthetics or pyrethrin analogs. This scenario raises questions on the willingness and ability of Kenyan to pay for better environmental health. Kenya also have opportunities for the manufacture of fungicides using some imported ingredients and mixing with locally available filler materials such as soapstone, limestone, clay *e.t.c.* The processing of neem tree extract as a source of a pesticide raw material has also been explored by ICIPE and it has been found that the extract has pesticidal properties. These are very promising area that should be exploited.

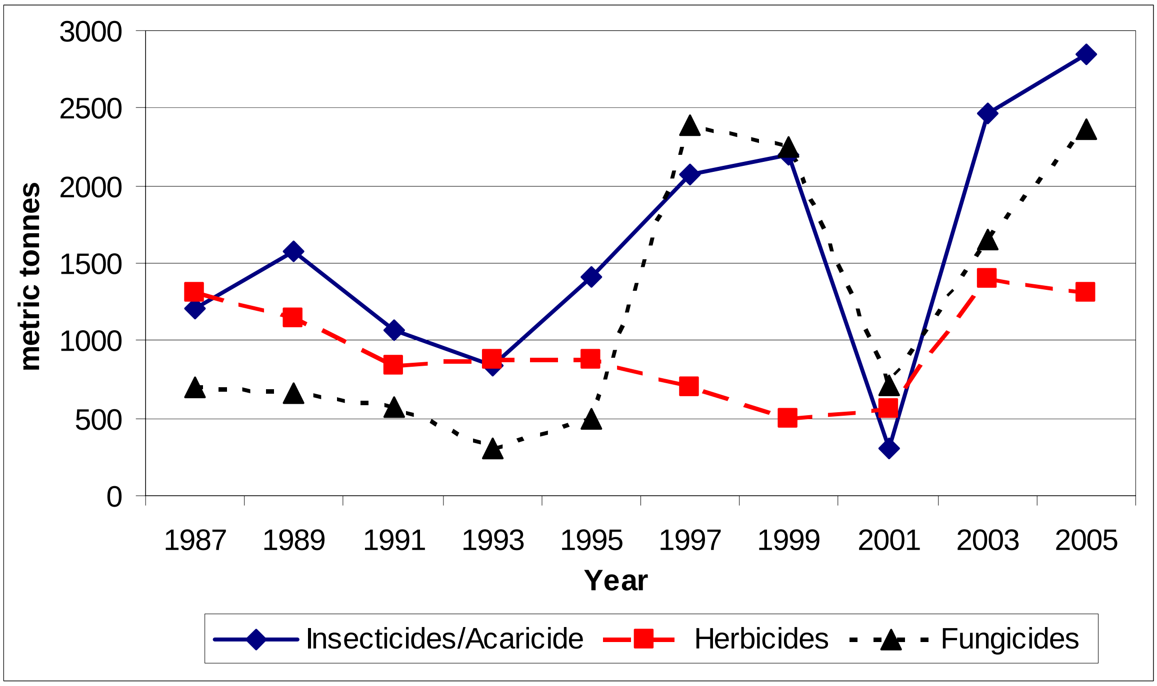


Figure 2.3: Trends in pesticide imports, 1987–2005
Source: PCPB, 1988-2006

The registration of pesticides in Kenya is governed by the Pest Control Products Act, Cap 346 of the Laws of Kenya, and is executed by the Pest Control Products Board (PCPB). PCPB is a statutory organization of the Kenyan Government established under an Act of parliament in 1982 to regulate the importation, exportation, manufacture, distribution, and use of pest control products. It registers all agricultural chemicals imported or distributed in Kenya following local testing by an appointed research agency. The Board is also empowered to revoke registration (deregister) of pest control products with reasons. It also inspects and licenses all premises involved in the production, distribution, and sale of the pesticide chemicals (PCPB, 2005).

No agricultural chemicals can be imported into Kenya without prior PCPB authorization in legal forms. Unfortunately violations do occur, with fake and counterfeit products and smuggling of pesticides from neighboring countries. For example during the 2005 financial year, 4.9 metric tonnes of illegal pesticides were seized from the countryside by inspectors and a total of eleven cases involving alteration of dates of expiry of pesticide labels (expired products to appear as if they were still useful), and counterfeit (actual active ingredient was different from the registered specifications), were investigated. However, only one case made it through the court process and the accused person was convicted and fined Ksh. 6000 (US$ 81) on each of the three counts or imprisonment for 18 months. The products that were affected included cymoxanil (Milraz 76 WP), lambda cyhalothrin (Karate 12.5EC), mancozeb (Dithane M45), copper oxychloride (Cupprocaffaro), and carbofuran (Furadan) (PCPB, 2005) which are the main pesticides used in vegetable production. In 1999, counterfeit agrochemicals made up 15% of the Kenyan market causing estimated 40–60% yield losses due to ineffective action (AGROW, 1999).

Many reports also indicate inappropriate use of pesticides (Ohayo-Mitoko *et al.,* 1999; Ohayo-Mitoko *et al.,* 2000; Macharia *et al.,* 2005; Okello, 2005; Asfaw, 2008). These inappropriate uses of pesticides in vegetable crops increase the danger of human poisoning and damage to the environment. Some research findings have indicated existence of some pesticides related negative externalities, *e.g.* IUCN (2005), indicated that pesticides are threatening Lake Naivasha local hippopotamus populations. Kinyamu *et al.* (1998) found higher residues levels of Organochlorine pesticides in Milk of breast feeding mothers. Few have also supported the link between pesticide use and farmers' health (Ohayo-Mitoko *et al.,* 2000; Okello, 2005).

While carrying out its regulatory function PCPB may also ban or restrict pest control products. However, banning or restriction of chemicals normally follows the recommendations of the Multilateral Environmental Agreements (MEAs), which the Kenyan Government has ratified and is therefore in force. Examples of MEAs that the Board has domesticated are the Basel Convention on Trans-boundary movement of certain hazardous chemicals, the Rotterdam Convention on Prior Informed Consent (PIC) and the Stockholm Convention on Persistent Organic Pollutants (POPs). Lists of products that are already banned in Kenya are indicated in appendix A and the restricted[7] products, in appendix B. However, the restricted products are readily available at retail agriculture stores in Kenya and controlling for their use is practically impossible. Recently in 2009, Furadan 5g (Carbofuran) which had been registered for use in coffee, bananas, maize, groundnuts, potatoes, rice, sugarcane, pyrethrum, tobacco and vegetable was being considered for banning by PCPB after highly publicized intentional poisonings of lions in Kenya's national parks and killing of birds from ingesting the pesticide off crops (News, 2009).

[7] Can only be sold to licensed distributors or licensed pest control operators.

Apart from the PCPB, other bodies involved in pesticide regulation include the Agrochemicals Association of Kenya (AAK), National Environment Management Authority (NEMA), Kenya Plant Health Inspectorate Service (KEPHIS), and the Kenya Environment Secretariat. The AAK incorporates most of the pesticide manufacturers and distributors of agrochemicals throughout Kenya. The main objectives being to safe guide the industry by promotion of public education concerning the safe use of pesticides and providing an agency for liaison with government and others, on all matters involving safety codes and promotion of the Food and Agriculture Organization (FAO) Code of Conduct on distribution and sale of pesticides. Members have to sign a "Code of Conduct" based on the United Nations FAO Code. This document requires rigid controls in manufacture, packaging, labeling, and distribution. It also mandates an ethics code. AAK work closely with PCPB and the Department of Crop Protection of the Ministry of Agriculture (MoA) in advancing training to all stakeholders in the Agriculture industry. NEMA coordinates all issues related to environmental problems.

Kenya Plant Health Inspectorate Service is a state corporation in the agricultural sector whose mission is to provide dependable, effective, and competitive regulatory services for ensuring quality agricultural inputs and produce, thereby promoting sustainable agricultural and economic growth. It has an Analytical Chemistry Laboratory (ACL) that is accredited to ISO/IEC 17025 by South African National Accreditation System (SANAS). It tests pesticides to verify conformity with labels and carry out private pesticide analysis in food commodities. It is approved for grading, Maximum Residue Level (MRLs) testing and inspection of fruits and vegetables by the European Commission (Commission Regulation, 2006).

The Kenya Environment Secretariat coordinates all matters regarding pesticide use and links between Kenya and other international organizations like FAO, United Nations Environment Programme (UNEP) and World Health Organization (WHO) through which, important information and policies are discussed.

Many companies import and sell pesticides in Kenya. Apart from many traders involved, a large number of trade names exist for a common active ingredient, *e.g.* dimethoate is being sold under some 20 different trade names (PCPB, 2007). There are two main types of pesticide channels serving the small-scale farmer in Kenya. The first is the commodity-based interlinked input-credit-output marketing system and the other is the un-integrated system of independent importers, wholesalers, and retailers operating on a cash basis. Under commodity-based interlinked arrangements, the marketing firms offer pesticides on credit to farmers with the condition that they have the exclusive right to sell the output on behalf of the farmers. In this way, the firms are able to recover their costs from the sales before releasing the balance to growers. The main two interlinked models in Kenya involve coffee cooperatives that supply inputs to its members across the country and some vegetable exporters.

2.3 Summary

This chapter has shown the importance of the vegetable sub-sector as a key component of the agricultural sector in the Kenyan economy, providing foreign exchange earnings, farm income opportunities and a sizable employment. The brief review also indicates that vegetable production and pesticide consumption have increased over time.

It was shown that there are a great number of institutions, both government, semi-government (parastatals) and private members associations, which directly or indirectly participate in vegetable production. Each one of them offers supportive and useful facilitating role. The governmental institutions, *e.g.* Kenya Agricultural Research Institute, conduct research and extension programmes geared toward increasing vegetable productivity, while the private members associations like Horticultural Fresh Produce Exporters Association of Kenya are involved with provision of market information and promotion of members' exports, through overseas exhibitions.

Registration of pesticides is governed by the Pest Control Products Act, Cap 346 of the Laws of Kenya, and is executed by the Pest Control Products Board (PCPB). It registers all agricultural chemicals imported or distributed in Kenya following local testing by an appointed research agency. Apart from the PCPB, other bodies involved in pesticide regulation include the Agrochemicals Association of Kenya, National Environment Management Authority, Kenya Plant Health Inspectorate Service, and the Kenya Environment Secretariat. However, in spite of many governmental agents involved in pesticides regulation and use, evidence from many reports indicates illegal and inappropriate use of pesticides, suggesting a dysfunctional regulatory framework. This increases the danger of human poisoning and damage to the environment. The evidence presented in this chapter also supports the findings of earlier research in Kenya (Waikwa, 1998; Ohayo-Mitoko *et al.,* 2000; Okello, 2005), which have indicated the existence of pesticides related negative externalities. However, these studies did neither quantified nor value pesticide externalities. The next chapter describes the theoretical framework and data collection methods, which were developed for quantifying and valuing negative externalities of pesticides in Kenyan vegetable production.

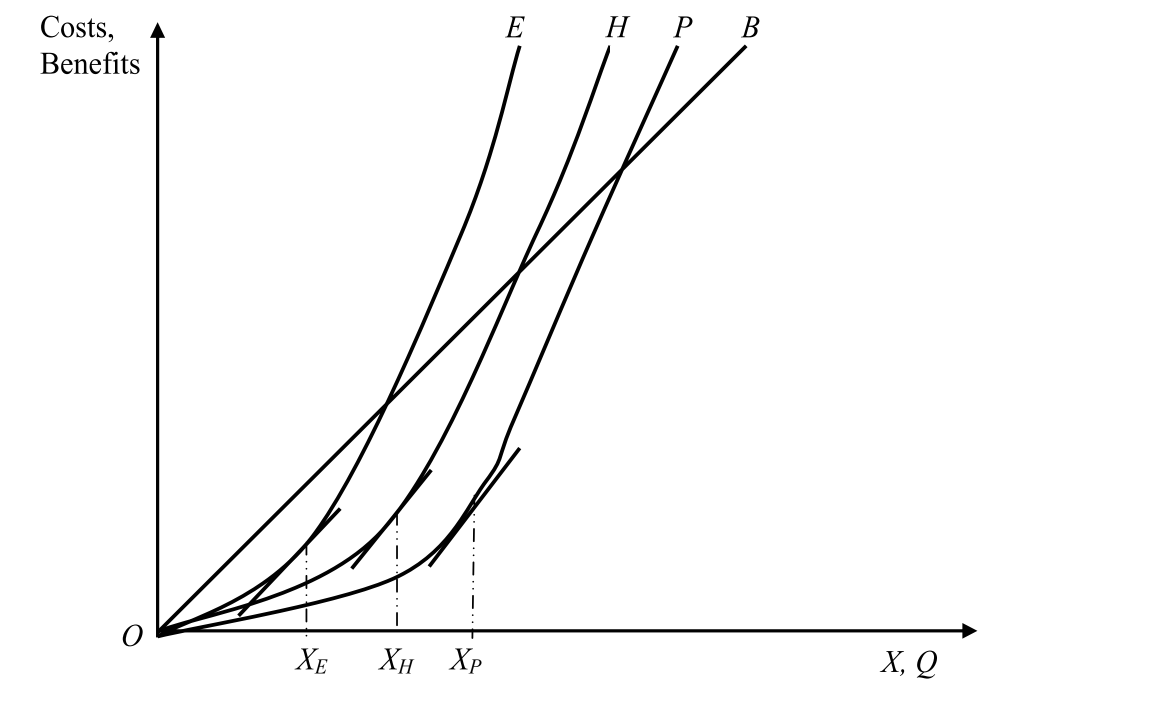
3 Conceptual Framework and Data Collection Methods

3.1 Conceptual Framework

A general framework for evaluating the impacts of pesticide use in agriculture is offered by Antle and Capalbo (1995). Pesticide costs can be grouped into three categories: i) direct costs paid by farmers in terms of pesticide purchases, costs of personal protective equipment (PPE) and labour for application, ii) indirect costs borne by farmers on own health costs, and livestock losses, iii) indirect costs borne by society (consumers, tax-payers, governments, health service providers), normally referred to as externalities as they are borne by entire society other than the users. Examples include harm caused by pesticide residues in food and water, secondary pest outbreak due to pesticide-related destruction of natural enemies, development of pesticide resistance in pests, and honeybee losses. Others include crop and crop product losses resulting from reduction of pollinating insects, losses caused by pesticide on bird, fish, wildlife and biodiversity, and governmental expenditures to reduce the environmental and social costs.

In economic analyses of pesticides, it is assumed that farmers use pesticides to protect their crop in order to ensure financial profit. It is also assumed that farmers will not consider the potential negative effects posed by pesticides to human health and environment unless an incentive structure is in place that encourages them to do so. Therefore, the optimum level of pesticide use can be defined in different ways. Figure 3.1 illustrates that the social optimum of pesticide use is higher than the private level. Benefits are defined as crop loss prevented, while costs can be defined in several ways following the concept of Antle and Cabalbo (1995). Considering only the perceived cost, *i.e.* the direct cost of pesticide use leads to farmer's optimum level of pesticides use denoted as $X_{P.}$

Given that use of pesticides can result in both acute and chronic illnesses of the pesticide user the cost curve shifts from OP to OH, and consequently the optimal level of use of pesticides is reduced to $X_{H.}$ Further, if other costs incurred by society are added, the cost curve shifts to OE. Hence, the social optimum level of pesticides use is denoted with $X_{E.}$



X_P = Optimum level of Pesticides (perceived direct cost)
X_H = Optimum level of Pesticides (when health effect is included)
X_E = Optimum level of Pesticides (when health and environmental effects are included)
Q = Potential yield loss prevented by pesticides
X = Pesticides
B = Benefit from pesticides
P = Perceived cost (direct cost of the pesticides application)
H = Direct cost plus human health cost (both acute and chronic)
E = Social cost curve (direct cost plus human health cost plus environmental costs)

Figure 3.1: Impact of human health and environmental costs on optimum use of pesticides
Source: After Waibel, 1994

The theory as outlined above therefore, demonstrates that pesticide externalities constitute one type of market failure, leading to a divergence between the private and the social optimum in their level of use. This study intends to estimate the costs resulting in OE and pesticide-monitoring spending that can be reduced when pesticides are used at X_E.

3.2 Externality Valuation and Methodological Issues

Two basic difficulties in valuing pesticide externalities can be identified. First, is how to establish the scientific causality between pesticide use and their actual effects on human and the environment, including the degree of uncertainty to assess the extent of damage.

A major difficulty is that pesticides are often used as mixtures or in combination with other potentially harmful substances. In addition, their effects may be only observable on the long term. The following examples from the literature illustrate the difficulties that exist in establishing causality.

Krishnamachari *et al.* (1978) and Mohan (1987) thought that the musculo-skeletal condition in humans was caused by the accumulation of pesticide residues in the food chain through the consumption of crabs and fishes from pesticide-sprayed rice paddy fields. However, studies by Agarwal *et al.* (1997) found that the disease was the result of a high rate of inbreeding among affected communities. The decline in vulture population in India was first thought to be pesticide induced (Anon, 1999b; Nair, 1999; Prakash, 1999) until it was found to be the result of an unexpected interaction between a veterinary medicine (Diclofenac) and vulnerable avian kidneys (Green *et al.,* 2004; Oaks *et al.,* 2004). The bovine spongiform encephalopathy (BSE) crisis in the UK was also wrongly attributed to Organophosphates use (Purdey, 1996; Gordon *et al.,* 1998).

The second difficulty stems more from methodological issues in that market-based approaches can only be used in cases where the impacts are associated with a marketable output. This limits their application to the valuation of other potential pesticide related health effects and of wider ecosystem effects.

To date several attempts have been made to describe and quantify external costs of pesticides (Table 3.1). These studies vary by type of market they rely on, and the attribution in the ecosystem. These studies can be grouped here into three broad categories, i) those that follow an 'accounting approach' based on actual market prices with scientific evidence of the externalities, ii) those which utilize the 'economic approach' based on hypothetical and surrogate markets in the absence of market prices, and iii) those that combine both approaches.

The studies that utilize the accounting approach follow three steps, *i.e.* identification, quantification, and monetarisation. Identification involves collection of all available scientific evidences from different sources to establish the attribution. Quantification involves establishment of the quantities of the physical impacts, while monetarisation involves putting a value to the quantities estimated and then summing up the totals.

Studies based on the 'economic approach' treat pesticide externalities as non-market goods because they cannot be bought neither exchanged in a market situation, and thus use hypothetical or surrogate market prices. Non-market valuations can be direct or indirect (Zilberman and Marra, 1993; Hanley *et al.,* 1997).

Direct methods also referred to as stated preference methods include: the contingent valuation (CV) and the choice experiment (CE). Contingent Valuation tries to judge individuals' value for non-marketed goods by asking respondents directly, their 'willingness to pay' (WTP) for improvements in non-market goods and services or their 'willingness to accept' (WTA) for the loss of well being associated with a change. For example, respondents can be asked about their WTP for pesticides that are less toxic to their health or they can be asked about their compensation (WTA) for deterioration of health due to toxic pesticides.

The CE is a technique that allows respondents to trade off between the attributes and indicate their most preferred alternative in each choice set. Two assumptions in using these methods must be fulfilled. First, respondents must have knowledge about the issue being valued; secondly, they must have well defined preferences for market goods on the one hand and non-market goods being valued on the other hand. The results are analyzed by estimating random utility functions using the indicators relating to externality effects and the economic costs as attributes in choice sets.

Indirect methods, also called revealed preference methods, observe behavior in related markets and use the data as proxies (surrogate market). They include the following techniques as described by Farber *et al.* (2002).

i) hedonic price: - the price of a service is identified by considering how it affects the price of an associated good. The price of a related market good is a function of its attributes, *e.g.* the value of clean air can be assessed indirectly through the value of residential areas where the value of clean air is a component of the price of houses. The other common example is in wage studies, where the wage that an employee earns is expected to reflect, in part, the risk levels that she/he faces hence wages for spraying pesticides are always higher than for other farm activities.

ii) travel cost: - the travel cost method draws upon the price of visiting outdoor recreation sites as a proxy for environmental amenities, *e.g.* to value the benefits associated with a park one could examine the average number of per capita visits.

iii) avoidance cost: - purchase of goods in economic markets that can be used to mitigate adverse health and environmental effect *e.g.* purchasing bottled water free from contaminants, farmers use of personal protective equipments.

iv) dose response: - observe or introduce a change and measure cost/benefit of attributable technical consequences. One technique is the Factor Income approach where the value of a service is identified through its effect on incomes, *e.g*. the incomes of anglers increase with improvements in water quality.

Studies that tried to combine the two approaches include the study by Waibel *et al.* (1999) and Pretty *et al.* (2000). In the two cases, results of different case studies in accounting approach were combined with economic studies. For example in Germany, losses in production sectors were calculated using market prices, while for the irreversible loss of wildlife species contingent valuation approaches were considered. Pretty *et al.* (2000) estimated the cost of monitoring and remediation of damaged habitats, bee colony losses, treatment of pesticide-contaminated drinking water, and the treatment of acute pesticide poisonings, unlike Pimentel (2005) study that relied on the assumptions associated with the subjective value of a single bird or fish or of a human life.

Table 3.1: Summary of valuation studies of pesticide externalities

Approach	Country	Description	Authors
Accounting	Mali	Estimated the external costs in cotton growing area by considering official data and extrapolation. Annual external costs of pesticide use were estimated for human health (US$ 1 million) and pesticide resistance (US$ 9 million) with a total of US$ 10 million.	Ajayi *et al.* (2002)
	Niger (Sahel region)	Health costs, defined as medical expenses plus the value of time lost, were found to increase by US$ 0.46/farmer for each year of pesticide use. Livestock losses due to intoxication were valued at US$ 0.33/treated hectare. Costs of destroying obsolete pesticides estimated at US$ 0.06/ha treated.	Houndekon *et al.* (2006)
	Thailand	Estimated the external costs of pesticides to be almost equal to their market value or US$ 228.9 million/annum.	Jungbluth (1996)
	USA	Costs were based on readily available data on a number of cases of human health, costs of hospitalization, biodiversity impacts, veterinarian costs, additional pesticide costs from pesticide resistance and loss of natural enemies, compensation costs, and costs because of loss of honey production. Total costs were estimated at US$ 9,645 million.	Pimentel (2005)
Economic- (direct methods- CV)	USA	Investigated consumer WTP for fresh pesticide free produce. The results indicated that consumers were willing to pay up to a 10% premium for pesticide residue free produce.	Misra *et al.* (1991)
	Nicaragua	Farmers' valuation of health effects of chemical pesticides was measured as their WTP for low-toxicity pesticides. Results indicated that farmers were willing to spend additionally 28% of pesticide expenditure for avoiding health risks.	Garming and Waibel (2009)
Economic- (indirect methods- avoidance cost)	USA	Study examining public expenditure on apples over a six-year period running up to the controversy over the use of the growth regulator Alar. Percentage changes expenditure were estimated for Alar and Alar-free apples. Study found that consumers were WTP up to 31% extra to avoid Alar in fresh apples.	Van Ravensway and Hoehn (1991)
Economic- (indirect methods- response dose model	Canada	Found the monetary health savings for farmer applicators and their families when growing genetically modified New Leaf Pro genetically modified potatoes to be ranging from US$ 4.7 to 45.	White *et al.* (2004)

Table 3.1: Continued

Approach	Country	Description	Authors
Accounting plus economic	Germany	Estimated external costs at DM252 million/ year. Figures included the costs of monitoring drinking water, the processing of water to remove unwanted chemicals, poison damage to honey bees, and working days lost as a result of pesticide-related ill-health. WTP for species conservation were considered for loss of wildlife estimations.	Waibel and Fleischer (1999)
	UK	The study only estimates externalities giving financial costs, *i.e.* treatment, prevention, and administration costs and costs of restoring species and habitats as a proxy of the costs of wildlife and habitat losses. Costs from pesticides removal in drinking water were estimated at £120 million/year. Costs for pesticide monitoring in food at £5.4 m and at £4.75 m at surface and groundwater.	Pretty *et al.* (2000)

Source: Own presentation

These efforts illustrate the difficulties of developing a uniform, comprehensive, and clear measurement framework for pesticide externalities valuation.

3.3 Methodological framework for data collection

The method applied in this study is a modification of the accounting approach. In contrast to the earlier studies, the framework started with the identification and classification of the relevant externality categories that were expected in the Kenyan vegetable sub-sector and assigned possible valuation methods. The impact categories were then classified according to those that could be valued and those that could only be quantified or identified (Table 3.2). However, the indirect costs to the farmers arising directly from their production activities are often not considered as externalities (Ajuzie and Altobello, 1997). For simplicity reasons, as well as following other scholarly work they are here grouped as externalities. In addition, Kenyan government also subsidizes cost of human and livestock treatments through the cost sharing programmes and thus shouldered by entire society (Collins *et al.,* 1996).

The study mainly followed three steps: i) identification of the externalities relevant in the vegetable sub-sector through literature review, group discussions and expert consultations,

ii) quantification and valuation by analysis of the existing information or inventory taking, farmers interviews, pesticide residues analysis and expert interviews, and iii) validation of the estimates through expert workshops.

Table 3.2: Pesticide externalities and possible methods for valuation in this study

Externality type		Possible assessment	Method [a]
Cost values	Human health	Cost of Illness Approach [b]	Farmer interviews
	Residues in vegetables	Value of produce that has to be withdrawn from the market due to exceeding maximum residue levels Avoidance costs: extra costs incur to obtain pesticides free vegetables	Residue analysis, expert interviews
	Livestock poisoning	Value of loss: treatment cost, value of lost livestock, loss of products	Farmer interviews
	Residues in water	Mitigation costs (costs for cleaning-up the drinking water) Cost of alternative sources	Residue analysis Contingent valuation
	Pesticide resistance	Additional cost of pest control	Farmer and expert interview
	Loss of bees	Loss of honey and productivity loss from reduced pollination	Farmer and expert interview
	Loss of beneficial organisms	Production value (lost production due to increased pest outbreaks and costs of additional pest control)	Farmer and expert interview
	Damage prevention costs	Fraction of budgets from research institution and government geared toward pesticide risk reduction	Expert interviews
Quantification	Fishery losses	Farmers and experts subjective estimates	Farmer and expert interview
	Birds and soil biota losses	Farmers and experts subjective estimates	Farmer and expert interview
Identification	Biodiversity loss	Farmers and expert experiences	Farmer and expert interview

[a] In all cases, inventory taking was the first step of data collection

[b] Costs incurred through doctor consultations, hospitalizations, opportunity costs of traditional medicine, medications, transport to and from clinics, dietary expenses resulting from illness like drinking milk, and workdays lost

Source: Own presentation

3.3.1 Inventory taking

Review of official and research documents were the main source of secondary data during the inventory taking. These were collected from official documents from the various ministries, non-governmental organizations, veterinaries, hospitals, the Central Bureau of Statistics (CBS), and other relevant sources. Research articles from various organizations including NGOs that had been involved in pesticide studies were also reviewed. From government ministries, secondary data were collected at provincial, district and divisional level in major vegetable production districts.

Environmental Impact Quotient (EIQ) values for pesticides active ingredient were obtained from internet sites such as Integrated Pest Management Programme (Cornell University Extension Toxicology Network, 2009), or calculated based on the chemical's toxicological and physical properties using the procedure outlined by Kovach *et al.* (1992).

3.3.2 Farm household surveys

Interviews were conducted in seven major vegetable producing districts of Central and Eastern provinces of Kenya, namely: Kiambu, Kirinyaga, Muranga, Nyandarua, Nyeri North, Makueni and Meru Central (Figure 3.2) in 2005 and 2008. These districts contribute approximately 72% of the national vegetable production (MoA, 2005). Meru Central district is located at higher altitude (above 2300m) primarily producing French beans, while Nyeri North, Kirinyaga, and Muranga are situated in middle altitude (1850-2100m), with Kiambu and Nyandarua being located in higher altitude (above 2300m). The entire districts produce wide range of beans, peas, kales, tomatoes, cabbages, and onions. Nyandarua is well known for the production of cabbage and potatoes. Makueni district is located at lower altitude (600-1100m) mainly known for the production of Asian vegetables (Table 3.3).

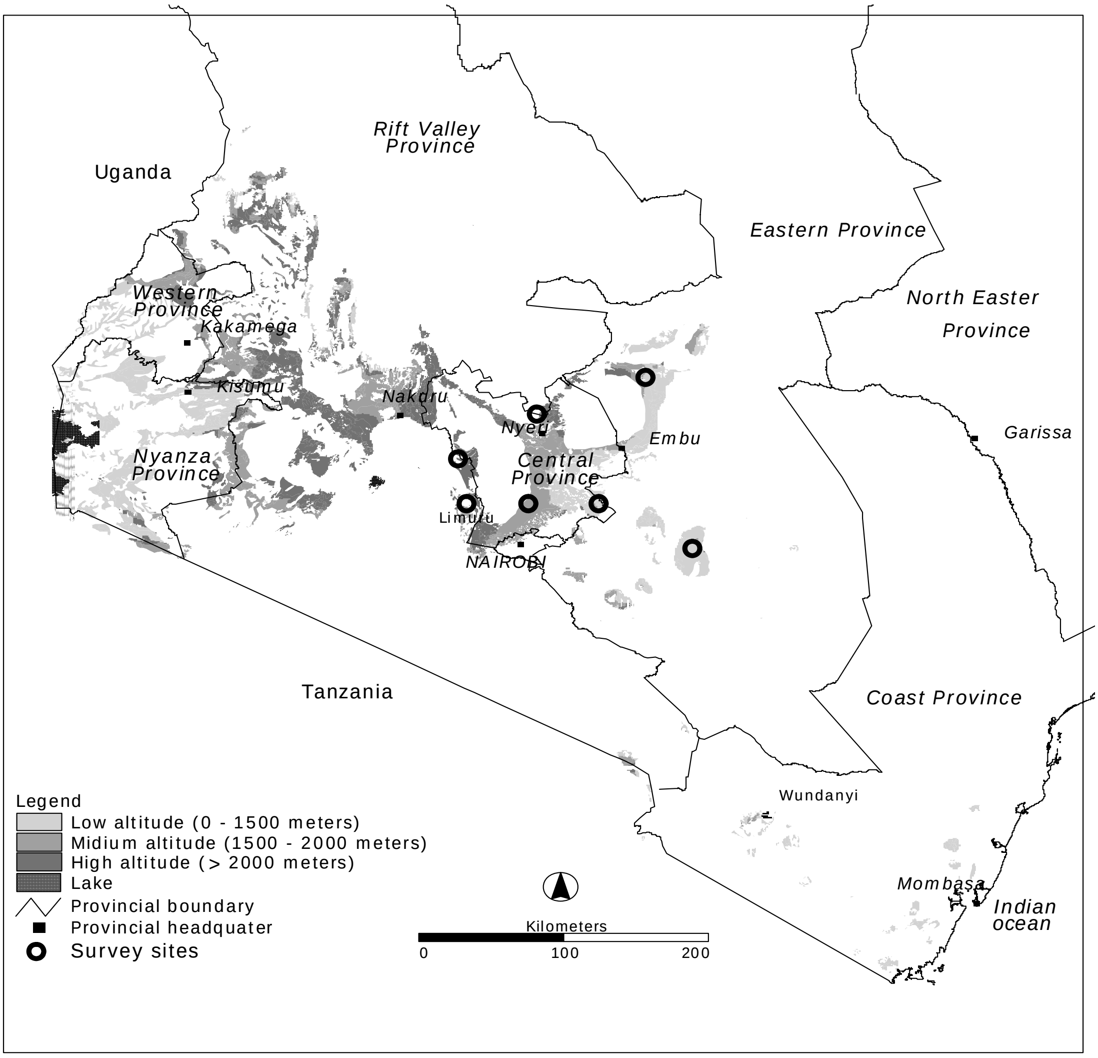


Figure 3.2: Study sites
Source: Own presentation based on GIS mapping of potential vegetable production areas

The 2005 survey comprised of 839 interviews from the Diamondback moth biological control impact assessment survey (DBMI[1]-295 farmers) and the Global Good Agricultural Practices assessment survey (GLOBALGAP[2]-544 farmers). In both surveys, a multi-stage sampling procedure was used to select districts, sub-locations, and farmers respectively. First, districts were purposely sampled according to intensity of vegetable production and agro-ecological zones. Lists of farmers that were compiled by extension workers at sub-location level, served as sampling frame from which, 839 farmers were randomly sampled

[1] Diamondback moth, Plutella xylostella (Linnaeus) biological control programme based on importation and release of exotic parasitoids Diadegma semiclausum (Helle´n) (Hymenoptera: Ichneumonidae) Initiated by the International Centre of Insect Physiology and Ecology (Löhr *et al.,* 2007; Macharia *et al.,* 2005).
[2] GLOBALGAP (formerly known as EUREPGAP) study with main goal of evaluating the impact of compliance of vegetable farmers with EU private standards.

by probability proportional to size procedure. This ensured that sub-locations with a higher population size had a proportionately higher sample size allocation.

Sampled farmers were then monitored in one cropping season and were trained in record keeping of their production activities by enumerators[3]. The enumerators under direct supervision of the researcher visited the farmers to check the records and transferred the information to the survey questionnaire. Due to budget constraints, the 2008 survey was a recall survey of a random sub-sample of 425 farmers among the 839 farmers again sampled by probability proportional to size procedure. Table 3.3 displays the distribution of farmers in the sampled districts.

Table 3.3: Regional distribution of survey respondents

Province	District	Main vegetable crops		Estimate 2005 [a)]	2005 survey	2008 survey
		Domestic	Export			
Central	Kiambu	Cabbages, kales, spinach		97	48	27
	Kirinyaga	Tomatoes, peas,	French beans	3073	155	74
	Muranga	Kales, tomatoes	French beans	472	51	24
	Nyandarua	Cabbages, potatoes		1408	119	52
	Nyeri North	Peas, cabbage, onions, carrots	French beans	2073	277	116
Eastern	Makueni	Cabbages, kales	Asian vegetables [b)]	650	49	22
	Meru Central	Peas, tomatoes, cabbage, onions	French beans	1480	140	110

[a)] Estimated number of farmers in 2005 by MoA extension officers from compiled list
[b)] Brinjals, karella, dudhi, okra, turia, valore and aubergine
Source: Own presentation

The semi-structured questionnaires used in both survey years covered a wide range of topics, such as cropping systems, demographics, common farming practices, pesticide use

[3]Enumerators were trained for 4 days. One day was used for pre-testing the questionnaire. The pre-testing aimed at improving the skills of the enumerators and also testing the applicability of the questionnaire to the study area. During the first pre-testing, random selected enumerators did the interview, while the others listened and observed. A discussion of the experience under the guidance of the researcher was then conducted in a plenary every enumerator contributing to what he/she observed as an improvement or a mistake. The enumerators were then divided into groups of two and interviewed the respondents in turns.

and handling practices, type and quantities of pesticides sprayed and pesticide-related health problems (frequency, related costs of treatment, lost days due to the illness). Only those that began during the spraying operation or within 24 hours after spraying were considered. However, more extensive and detailed data on pesticide use, handling, disposal of pesticide wastes, farmer perception, and experience of pesticide side effects (health effects and poisoning of livestock, natural enemies, bees, soil biota, and birds) were collected in the 2008 survey. For the full version of the questionnaires, see appendix C.

Interviews were conducted in either the farmers' fields or homes at the convenience of the farmer. During interviews, a friendly environment was maintained to extract correct and reliable information.

To test farmers' recognition of the natural enemies and soil biota known to them, a self-made arthropods zoo (clear plastic jar containing the most common life natural enemies, *i.e.* ladybird beetles, praying mantis, spiders, dragonflies, fire ants, and soil biota, *i.e.* earthworms, millipedes, and crickets) was shown to them. For the identification of the farmland birds, farmers were offered a list of the most common species by the local language and were asked to name species they knew to be visiting their vegetable fields. In both cases, they were also encouraged to add to the list. To get accurate information on pesticide products used respondents were asked to show the samples of pesticide containers or labels they had used. Recommended dosages for pesticide application were also cross-checked from those in the pesticide labels, and afterwards cross-referenced with those conventionally put in company catalogue.

Detailed observations were recorded of farmers' storage of pesticides and spraying practices as a check on the reliability of the questionnaire interviews. Because most farms were irregularly shaped and vegetable plots were fragmented, tape measure or normal footsteps were used to get an accurate size. In addition, to further confirm and ascertain farmers' pesticide containers disposal methods, a walk through the farm was conducted and the number of empty pesticide containers lying in the vegetable field, near the vegetable field, in ponds or nearby streams were assessed and counted.

Ten pictograms used on pesticide labels in Kenya for instructions on appropriate pesticide use were also shown to farmers in order to assess farmers' understanding of them and their link with actual pesticide handling practices. Interviewers were instructed to record all responses in the exact words of the farmer, which were later compared with the correct instruction and scored 1 if it was right or 0 when it was wrong.

3.3.3 Vegetable sampling survey

Vegetable samples from plots that were ready to be marketed (just before their sale) were randomly sampled from half of the surveyed farmers (208) for pesticide residue analysis. The samples were drawn from the upper, middle, and lower part of the harvested produce (mostly from crates for tomatoes, French beans, as well as peas, and bags for cabbage, kales and spinach). The samples were then stored in sterile polythene bags, appropriately labeled, and placed into large cool boxes packed with freezer ice, and transported to the Kenya Plant Health Inspectorate Service (KEPHIS) laboratory for analysis.

The analysis was performed through the ethyl-acetate method. Extraction was done by ethyl acetate followed by partitioning steps with cyclohexane (Fernandez-Alba *et al.,* 1994; Specht *et al.,* 1995). Residue levels were determined by Gas Chromatography (GC) with Electron-Capture Detection (ECD), Nitrogen-Phosphorus (NPD) and UltraViolet (UV) light (Colume *et al.,* 1999; Podhorniak *et al.,* 2001). Residue identities were confirmed by GC coupled with mass spectrometry in the selected ion-monitoring mode. Pesticides were identified according to their retention times, the target and qualifier ions, and the qualifier-to-target abundances ratios (Ueno *et al.,* 2003). The target and qualifier abundances were determined by injection of individual pesticide standards under the same chromatographic conditions using full scan.

3.3.4 Workshop and Expert Consultation

A stakeholder workshop was organized at the end of data collection. The main objectives were to validate, extrapolate and substantiate available empirical findings of some of the pesticide externalities from farmers' estimates, identify the main drivers perceived to encourage the use of pesticides and examine the factors that can reduce pesticide externalities. Workshop participants were identified during the initial secondary data collection. The workshop was organized in alternating plenary and working group sessions lasting for two days.

A questionnaire survey in which each participating expert was asked about own observations and opinions on different pesticide externality categories and their severity was included in between by a modified Delphi approach, *i.e.* results from the first round were presented, and the participants were allowed to revise their responses in the second round (Landeta, 2006; Bonnemaizon *et al.,* 2007). The workshop was hosted at ICIPE and 25 experts attended (Macharia and Mithöfer, 2008). Follow up interviews for the expert survey were also conducted to those invitees who had not been able to attend the workshop.

3.4 Summary

Data collection for externalities assessment is a challenging endeavor. Two basic difficulties in valuing pesticide externalities include: i) the level of scientific uncertainty surrounding the mechanisms of damage and its extent, and ii) the valuation of pesticide effect on non-market goods and services.

To date several attempts have been made to describe and quantify pesticide related external costs. These techniques vary by type of market they rely on, and attribution of the complex interaction within the ecosystem. These studies can be grouped here into three broad categories: i) those that follow an 'accounting approach' based on actual market prices with scientific evidence of the externalities, ii) those which utilize the 'economic approach' based on hypothetical and surrogate markets in the absence of market prices, and iii) those that combine both approaches.

In order to obtain more comprehensive externalities valuation in the vegetable sub-sector in Kenya, a modification of the accounting approach was employed. The framework started with the identification and classification of the relevant externality categories that were expected in the Kenyan vegetable sub-sector and assigned possible valuation methods. The impact categories were then classified according to those that could be valued and those that could only be quantified or identified.

The study followed three steps: i) identification of the externalities relevant in the vegetable sub-sector through literature review, group discussions and expert discussions, ii) quantification and valuation via analysis of the existing information from secondary data/inventory taking, formal farm household surveys, lab analysis of pesticide residues and expert interviews, and iii) validation of the estimates through expert workshops.

In the next chapter, a descriptive analysis of pesticide use in the vegetables production by small-scale farmers is presented.

4 Pesticide Use by Small-scale Farmers in Vegetable Production in Kenya[1]

4.1 Introduction

In Kenya, the use of pesticides has been promoted to expand agricultural production and increase productivity. However, little is, known about the products used in the vegetable production and their associated risks. In addition, no information exists on the changes in intensity and frequency of pesticide use and application patterns. The objectives of this chapter are to establish pesticide use patterns in the vegetable production as well as to assess the associated risks of the products used. Such information can guide farmer on the choice of products that are less harmful.

As a proxy for assessing risks, the Environmental Impact Quotient (EIQ) model is applied. Other environmental impact assessment models that can be applied include: Pesticide environmental impact indicator (Ipest) (Van der Werf and Zimmer, 1998), Environmental Yardstick (EYP) (Reus and Leendertse, 2000), Environmental performance indicator of pesticides (p-EMA) (Lewis *et al.,* 2003), Environmental Potential Risk Indicator for Pesticides (EPRIP) (Trevisan *et al.,* 2000), System for Predicting the Environmental Impact of Pesticides (SyPEP) (Beernaerts and Pussemier, 1997), and Pesticide environmental Risk Indicator (PERI) (Nilsson, 1999). The information included in these indicator models varies widely and depends on the developers.

Environmental Impact Quotient system model was chosen for this study because of its structural simplicity, general applicability, ease of use and being the choice model by many scholars (Fernandez-Cornejo, 1998; Edwards-Jones and Howells, 2001; Ziegler *et al.,* 2002; Bues *et al.,* 2003; Lan *et al.,* 2003; Brimner *et al.,* 2005).

[1] Adapted version, published as: Macharia, I., Mithöfer, D. and Waibel, H. (2009). Potential environmental impacts of pesticide use in the vegetable sub-sector in Kenya. *African Journal of Horticultural Sciences*, 2: 138-151.

4.2 Methods

4.2.1 Data and EIQ Model

The chapter primarily uses the farm level data collected in 2005 and 2008 surveys. The yearly horticultural reports from the Ministry of Agriculture (MoA) were consulted for vegetable area and production statistics. Annual reports from the PCPB provided the pesticide import volumes. Recommended dosages for pesticide application were obtained from pesticide labels and cross-referenced with those conventionally put in company catalogue.

Environmental Impact Quotient values for pesticide active ingredients were obtained from internet sites such as Integrated Pest Management Programme (Cornell University Extension Toxicology Network, 2009), or calculated based on the chemical's toxicological and physical properties using the procedure outlined by Kovach et al. (1992).

The EIQ system model was developed by Kovach et al. (1992) to support environmentally sound pesticide choices in assessing compatibility of pesticides with integrated pest management (IPM) practices. To estimate the hazard to farm workers, consumers and ecological factors, the EIQ utilizes toxicological data. The toxicological data are normalized to a three-point scale of 1, 3 or 5 in accordance with their hazard (1 being the lowest hazard, 5 the highest). The potential risks for each pesticide is based on measures of toxicity such as the LD50 (dose at which 50% of the treatment group dies within the specified period) or LC50 (concentration at which 50% of the treatment group dies within the specified period), and potential exposure such as the half-life, runoff or leaching potential. The farm worker category includes potential effects to applicators and field-workers. The consumer category includes the potential effects of residues on the consumer and ground water contamination. Ground water effects are included in the consumer component because it is more of a human health issue (drinking contaminated water) than a wildlife issue. The ecological category includes the potential effects on aquatic organisms, bees, birds, and beneficial arthropods. The formula for determining the EIQ value of an individual pesticide is given by Kovach *et al.* (1992).

$$\text{EIQpesticide} = (\text{EIQfarmworker} + \text{EIQconsumer} + \text{EIQenvironmental})/3 \quad (4.1)$$

Where: $\text{EIQfarmworker} = C(DT*5)+(DT*P)$

$\text{EIQconsumer} = (C*(S+P)/2)*SY)+(L)$

$\text{EIQenvironmental} = (F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)$

The symbols are described in Table 4.1.

Table 4.1: Rating system for the variables in EIQ model

Variables	Symbol	Rating scores		
		1	3	5
Chronic toxicity	C	Little or none	Probable	Evidence
Acute dermal toxicity (LD50-rabbits/rats mg/kg)	DT	>2000	200–2000	0–200
Bird toxicity (8 day LC50)	D	>1000 ppm	100–1000 ppm	1–100 ppm
Lethality to honey bees (at field doses)	Z	Relatively non toxic	Moderately toxic	Highly toxic
Beneficial arthropod toxicity	B	Low	Moderate	Severe
Fish toxicity (96 hr LC50)	F	>10 ppm	1–10 ppm	<1 ppm
Soil residue half-life	S	<30 days	30–100 days	>100 days
Plant surface residue half-life	P	1–2 weeks	2–4 weeks	> 4 weeks
Mode of action (systemicity)	SY	Non -systemic	Systemic	
Leaching potential	L	Small	Medium	Large
Surface loss potential	R	Small	Medium	Large

Source: Adapted after Kovach *et al.* (1992) and Levitan, (1997)

The EIQ system relies on published toxicology and environmental 'fate data' from several sources such as EXTOXNET (Hotchkiss *et al.,* 1989), SELCTV database (Theiling and Croft, 1988) for impacts on beneficial insects, and GLEAMS for estimating ground water mobility of individual pesticides (Leonard *et al.,* 1987).

Once an EIQ value has been established for the active ingredient of a pesticide, the EIQ score can be turned into a field use rating in order to compare the risks involved by different pesticides and the least toxic pesticide can be selected among several pesticides depending on the environmental impact. An EIQ field use rating is calculated as the EIQ value for individual pesticides, multiplied by the percentage active ingredient multiplied by the total amount of pesticides used (kg/ha) (equation 4.2).

$$\text{Field use rating} = \text{EIQ}^* \ \% \ \text{active ingredient}^* \ \text{application rate (kg/ha)} \quad (4.2)$$

4.3 Results and Discussion

4.3.1 Vegetable grown

Potatoes followed by kales and cabbages occupied the highest plot size as compared with other vegetables (Table 4.2). Cabbage and kale production almost exclusively targets the local market and the export share is less than 1%. French beans are the major export vegetables and accounted for 61% and 44% of the volume of vegetables exported in 2005 and 2007 respectively (HCDA, 2005; 2008). Vegetable plot sizes varied between 0.004 ha to 2.32 ha with an overall average of 0.14 ha/farmer in 2005 and 0.17 ha/farmer in 2008. The farms varied in size from 0.02-11.23 ha and comprised five general cropping systems, *i.e.* cereals, legumes, fruit crops, fodder crops for dairy, and intensive vegetable plots. Nonetheless, the mean share of vegetable production areas to the average landholding constituted 12-16%, considering the five main cropping systems.

Based on the plot sizes, number of farmers growing each of vegetable and the reported hectares by MoA, the total number of vegetable farmers was estimated[2] at 183,021 in 2008.

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[2] The total area for each vegetable was first divide by two, assuming two-crop season in a year and then divided by the plot size to arrive at the estimated number of farmers for each vegetable. Summation of the estimated number of farmers was divided by 2.3 representing the number of crops a farmer can have (993 number of crop/425).

Table 4.2: Major vegetables grown in 2005 and in 2008

Type	n		Plot size (ha/farmer) a)		t-stat b)	Total area (ha) c)		Production (mil met tons) c)	
	2005	2008	2005	2008		2005	2008	2005	2007
Asian d)	21	49	0.16 (0.01)	0.19 (0.03)	1.22	2,348	2,156	0.035	0.026
Cabbages	295	224	0.21 (0.02)	0.19 (0.01)	-0.60	20,529	25,290	0.529	0.609
Carrots	22	81	0.12 (0.01)	0.16 (0.02)	0.97	2,737	4,925	0.038	0.063
F. beans	226	177	0.10 (0.01)	0.15 (0.01)	3.97 ***	7,004	6,713	0.063	0.063
Kales	52	155	0.07 (0.01)	0.11 (0.01)	2.83 ***	26,818	29,630	0.315	0.423
Onions	7	27	0.07 (0.02)	0.18 (0.03)	1.43 **	6,395	8,860	0.069	0.119
Peas	68	97	0.09 (0.01)	0.13 (0.01)	3.57 ***	5,313	12,012	0.023	0.059
Potatoes e)		31		0.27 (0.04)		120,842	104,266	2.640	1.968
Spinach	4	40	0.09 (0.03)	0.12 (0.02)	0.49	2,172	3,905	0.029	0.047
Tomatoes	30	58	0.12 (0.02)	0.13 (0.03)	0.48	20,743	20,000	0.337	0.567
Others f)	17	54	0.11 (0.04)	0.15 (0.02)	1.65 **	30,759	3,561	0.455	0.394
Total	993	993	0.14 (0.01)	0.17 (0.02)	2.38 ***	245,660	221,318	4.533	4.338

Source: a) Own survey, figure in parenthesis are standard errors
b) Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability
c) HCDA, 2008 and MoA, 2005 and 2008
d) Brinjals, karella, dudhi, okra, turia, valore
e) Irish potatoes are mainly grown in Nyandarua district but was not captured in 2005 survey
f) Capsicums, baby corn, broccoli, courgettes, cauliflower, lettuce

In general, the distance of the vegetable plots to the streams and rivers for many of the farms ranged from as close as 0.2 meter to about 500 meters. In some areas like in Meru and Kirinyaga districts where the farmers practice furrows irrigation, the water passes through one farm to the next before it drains into a stream or a river. Thus, surface water bodies in the study areas were at risk from pesticide runoff. Fish, frogs, and other aquatic species that are abound in these surface waters including the animals that drink this water are exposed to pesticide surface runoff. Though the damage to fish production is unknown, many farmers in Nyeri North district experienced the impact (Waikwa, 1998). Some of the farmers, particularly in Nyeri North, had ponds and wells, about 6 meters deep, as their main source of irrigation water, which they also sometimes use as drinking water and watering their farm animals.

4.3.2 General pesticide use

A total of 62 pesticides products, comprising of 36 active ingredients formulated singly or in mixture, were used to control various vegetable pests in 2005. The number increased slightly to 66 products in 2008 with 44 active ingredients in the formulations. However, close analysis showed that 19 new products were applied in 2008, implying that 15 products of those used in 2005 were dropped. This high number of products use could be due to many new products coming up in the market and farmers assuming that the solution to pest problems is using different types of pesticides (Dinham, 2003). On the other hand, the vigorous promotion and advertisement over the radio by agro-vets, pesticide dealers, and company representatives who even perform demonstration at farm level to boost their sales cannot be ignored as this had been found to influence farmer choices of pesticides (Epstein and Bassein, 2003).

Table 4.3 shows the main 20 pesticides farmers used with the application rates and EIQs in 2005 and 2008. The insecticides as compared to fungicides are more in both cases, suggesting insect pests as the major problem in vegetable production. Incidentally, Kenya is the leading producer of a natural pesticide, pyrethrin which is a broad-spectrum insecticide made from the dried flowers of pyrethrum (*Chrysanthemum cinerariaefolium*). However, 95% of all the crude pyrethrin is exported to the more environmentally conscious developed countries, where it earns a premium price so Kenyans are left to import the cheaper toxic synthetics analogues. Pyrethrin-based insecticides can replace most of the imported synthetics and can reduce the health risk that the synthetics pose. The low use of herbicides by farmer can be explained by availability of labor for weeding from family members. This is contrary to the situation in Ghana where herbicides are the predominant pesticide types in use in vegetable production (Ntow *et al.,* 2006).

The commonly used products in both years included: dimethoate (Dimeton 40EC), lambda cyhalothrin (Karate 2.5WG), cymoxanil (Milraz 76WP), cypermethrin (Bestox 20EC), cyfluthrin (Bulldock 25EC), mancozeb (Dithane M45), and deltamethrin (Decis 25EC).

Frequency of pesticides application ranged from once to as many as 28 times in one cropping season. However, it depended on the product, type of crop and target pest. The highest frequency of application recorded in 2008 involved Thiovit 80WP, Milraz 76WP and Dimeton 40EC applied on tomatoes and cabbage.

Application rates ranged between 0.01 to 10.71 kg/ha/season, with an average of 1.23 kg/ha/season in 2005 and 2.01 kg/ha/season in 2008. However, although the rate was statistically higher in 2008, it is still very low as compared to other developing countries in Latin America (7.17 kg/ha) and Asia (3.12 kg/ha) (Repetto and Baliga, 1996).

Pesticide use intensity was found highest in potatoes (3.6 kg/ha/season) and lowest in Asian vegetables (0.2 kg/ha/season). However, the calculated amount of pesticides per season was poorly correlated with the vegetable plot size (0.16), suggesting that application amount was not simply based on bigger plot size but depended more on the vegetable type.

Application of mixtures of fungicides and insecticides, and use of old stock of pesticides carried forward from the previous seasons was also common to most of the farmers. These are not recommended practices as the antagonistic and synergistic activities of products in mixtures are largely un-documented. Smit *et al.* (2002) found that there was an interaction between fungicides, insecticides, and water mineral content that affected the efficacy of the pesticide against fungal pathogens and insect mortality. Mixtures of insecticides result in the simultaneous development of resistance (Metacalf, 1980). All farmers used lever-operated knapsack sprayers, which are relatively cheap and easy to operate and maintain.

The total amount of pesticide used was estimated[3] at 570 metric tonnes for 2008. Dithane M45 was the most extensively used fungicide with 99 tonnes applied, followed by Dimeton 40EC (61 tonnes). Only 5 tonnes of the commercial bio insecticides (*bt* based)

[3] The percentage of the farmers reporting use of each of the pesticide for each of the vegetable grown were multiplied with the total area under that vegetable as stated in the annual reports to arrive at the area treated with each of the pesticide. Summation of all areas for each vegetable treated resulted in the total area treated with that product. The rate of the formulated product/hectare/season was multiplied with the area treated to arrive at the approximate amount of pesticides used.

was used. About 41% of the volumes used belonged to the group of Carbamates, 19% to Pyrethroids, 16% to Organophosphates, 13% to Acetamides, and 5% to Inorganics. Others included Azoles, Avermectins, Bipyridylium, Microbial, Pyrimidines, Strobilurins, Triazinones, Triazoles, Tributyltins, but were less than 2% each.

According to World Health Organization risk classification (WHO, 2006), 7% of the commonly used pesticides are extremely hazardous (WHO Ia and WHO Ib *e.g* Methomyl (Lannate 90SP, Agrinate 90SP, Methomex 90) and Dichlorvos (Phosvit)), and 36% moderately hazardous (WHO II *e.g.* dimethoate, cyhalothrin, cypermethrin). Similarly, 61% of the quantities are indicated by Pesticides Action Network North America (PANNA, 2009) to be bad actor chemicals (*i.e.* chemicals that are highly acutely toxic, cholinesterase inhibitor, known/probable carcinogen, known groundwater pollutant, or known reproductive or developmental toxicant), 64% to be ground water contaminant, and 47% are said to be very harmful to beneficial arthropods.

Two farmers were found using dichlorodiphenyltrichloroethane (DDT) and paraquat on cabbage and capsicum, even after DDT was officially banned in 1986 in Kenya, an indication of a dysfunctional regulatory framework. Studies conducted by Wandiga *et al.* (2002), Lalah *et al.* (2003) and Barasa *et al.* (2007) also supported the probability of illegal use of DDT in agriculture in Kenya.

The pattern of pesticide use differed significantly among the vegetables and between the surveyed years. The insecticides and fungicides applied in French beans were much higher as compared to kales in 2005. However, the application rates for specific pesticides were significantly higher for kales than other crops *e.g.* Bulldock 25EC and Dithane M45. Differences were even most apparent when individual insecticides were consolidated into chemical families. Only one herbicide (Gramoxane) was being applied on peas, while the three acaricides (Dynamec, Omite and Vapcothion) were utilized on specific vegetables. Omite was purposely used on tomatoes probably to control the notorious red spider mite *Tetranychus evansi*, which is the major constraint in tomato production in Kenya, and Vapcothion to control the same mite on peas. Dynamec was applied on all crops (Figure 4.1 and Figure 4.2). Similarly, the same pattern was eminent in 2008 with new products (Figure 4.3 and Figure 4.4).

Table 4.3: EIQ values for the 20 commonly used pesticides, with application rate and field use rating (n=839, 2005 and 425, 2008)

Active ingredient	Trade name	Family name	WH-O [a)]	EIQ [b)]				% farmer		Rate (kg/ha) [c)]		t-stat [d)]	Field use
				F	C	E	A	2005	2008	2005	2008		
Insecticides													
azadirachtin	Achook	Tetranortriterpe-noid	NL	6	6	25	12	6		1.58 (0.21)			12
B. thuringiensis	Dipel	Microbial	U	7	3	30	13	5		0.89 (0.31)			3
B.thuringiensis	Thuricide HP	Microbial	U	7	3	30	13	2	5	1.45 (0.00)	1.74 (0.44)	0.34	4
Bifenthrin	Brigade 25EC	Pyrethroid	II	14	8	112	44		5		2.84 (0.8)		11
Chlorpyriphos	Dursban 4EC	Organophosphate	II	18	4	109	44	1		0.67 (0.13)			3
Cyfluthrin	Bulldock 25EC	Pyrethroid	II	7	4	108	39	10	20	2.24 (0.52)	1.70 (0.22)	-0.9	5
Cyhalothrin	Karate 2.5WG	Pyrethroid	II	21	3	108	44	27	27	1.44 (0.26)	2.47 (0.26)	2.4**	16
Cypermethrin	Bestox 100EC	Pyrethroid	II	21	22	62	36		22		1.51 (0.20)		11
Cypermethrin	Cyclone 505EC	Pyrethroid	II	21	22	62	36	6	11	0.69 (0.08)	1.56 (0.20)	4.3**	91
Cypermethrin	Tata Alfa 10EC	Pyrethroid	II	21	22	62	36	4	5	0.39 (0.09)	0.99 (0.26)	2.7**	1
Deltamethrin	Atom 2.5EC	Pyrethroid	II	18	2	65	28	1		1.10 (0.33)			
Deltamethrin	Decis 25EC	Pyrethroid	II	18	2	65	26	12	14	0.44 (0.05)	0.69 (0.10)	2.3**	3
Deltamethrin	Farm-X	Pyrethroid	II	18	2	65	26	13		0.36 (0.04)			13
Diazinon	Alfatox	Organophosphate	II	7	2	122	44		11		1.31 (0.29)		44
Dimethoate	Danadim 40EC	Organophosphate	II	31	12	101	34	3		1.15 (0.12)			14
Dimethoate	Dimeton 40EC	Organophosphate	II	31	12	101	34	37	48	1.79 (0.24)	1.93 (0.11)	0.5	14
Fenpyroximate	Ogor 40EC	Pyrazole	NL						11		1.71 (0.26)		
Methomyl	Lannate 90SP	Carbamate	IB	6	11	49	22	3		0.52 (0.06)			40
Profenophos	Polytrin 440EC	Organophosphate	II	8	3	168	60	1		1.62 (0.62)			264

Table 4.3: Continued

Active ingredient	Trade name	Family name	WH-O [a)]	EIQ [b)]				% farmer		Rate (kg/ha) [c)]		t-stat [d)]	Field use
				F	C	E	A	2005	2008	2005	2008		
Fungicides													
Azoxystrobin	Ortiva SC	Strobilurin	U	8	3	67	27	3	7	0.93 (0.13)	0.53 (0.08)	2.7*	27
Copper sulfate	Copper	Inorganic	II	24	13	148	62	3		0.54 (0.14)			124
Cuprous oxide	Copper Nordox	Inorganic	II	12	5	83	33	3		1.45 (1.01)			66
Cymoxanil	Milraz 76WP	Acetamide	III	6	6	14	9		22		2.71 (0.25)		14
Famoxadone	Equation pro	Oxazolidinedione	U	9	3	20	11	2		1.37 (0.31)			4
Mancozeb	Dithane M45	Carbamate	U	20	5	49	26	14	18	2.51 (0.34)	3.56 (0.36)	1.8	18
Mancozeb	Oshothane 80WP	Carbamate	U	20	5	49	26		5		3.05 (0.68)		21
Metalaxyl	Ridomil MZ68	Carbamate	III	8	12	38	19		8		2.16 (0.44)		26
Sulphur	Thiovit 80WP	Inorganic	U	10	6	121	46		9		2.51 (0.53)		110
Sulphur	Wetsulf WP	Inorganic	U	10	6	121	46		5		3.18 (0.76)		92
Tebuconazole	Folicur 250EW	Triazole	III	20	31	70	40		10		1.18 (0.23)		100
Herbicides													
Metribuzin	Sencor 70WP	Triazinone	II	8	8	69	28		5		1.36 (0.35)		10
Mean				18	10	77	35			1.23 (0.07)	2.01 (0.06)	8.1***	39
Median				18	6	70	36			0.59	1.19		21
Mode				20	5	49	44			0.40	1.19		11

a) Ia = extremely hazardous; Ib = highly hazardous; II = moderately hazardous; III = slightly hazardous; U = unlikely to present acute hazard in normal use; O = obsolete as pesticide; NL = not classified

b) F = farm worker component; C = consumer component; E = ecological component; A = average

c) Figures in brackets are standard errors

d) Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Own survey

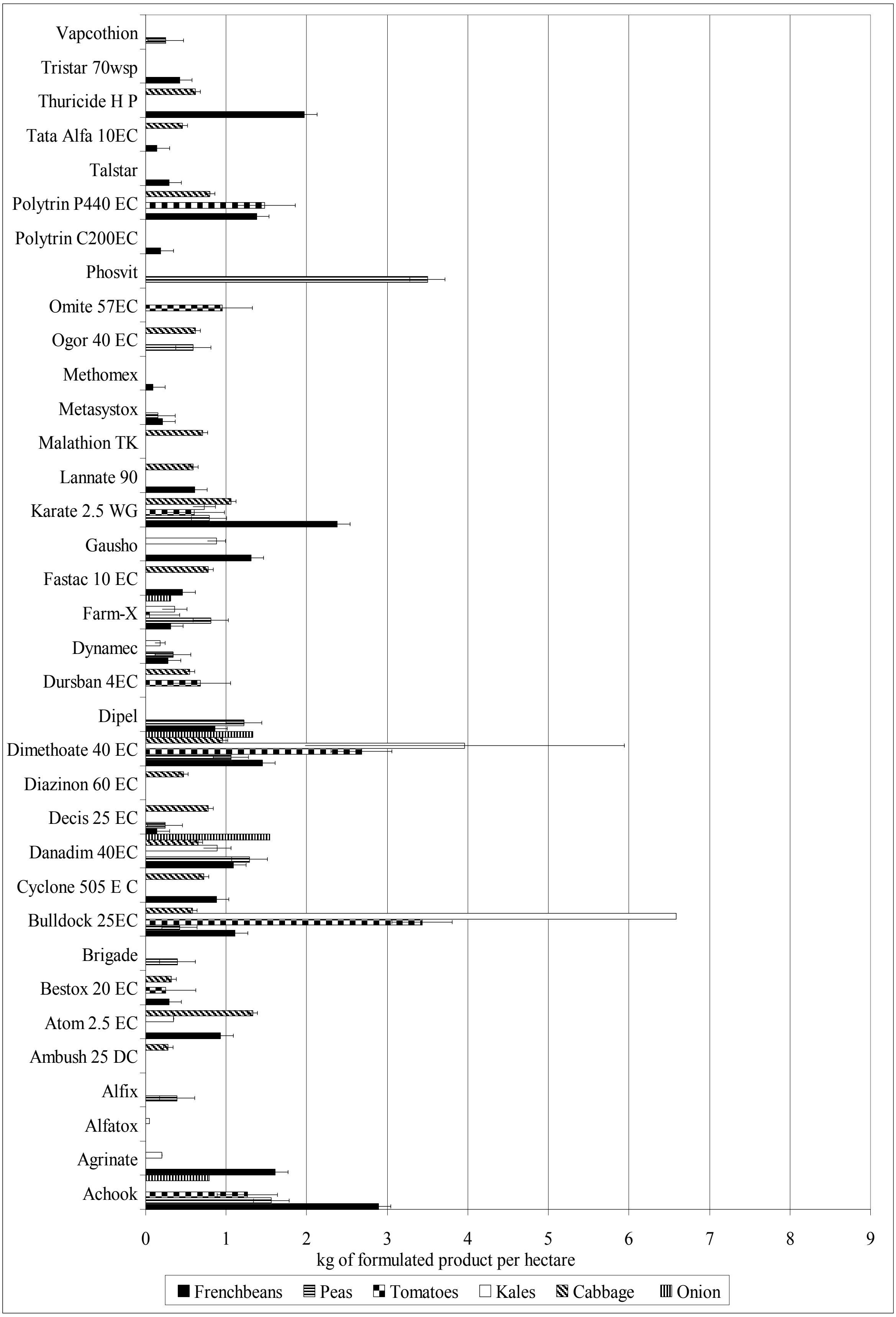

Figure 4.1: Insecticides and acaricides (Dynamec, Omite and Vapcothion) used in the major vegetables grown in 2005 (n=839)
Source: Own survey

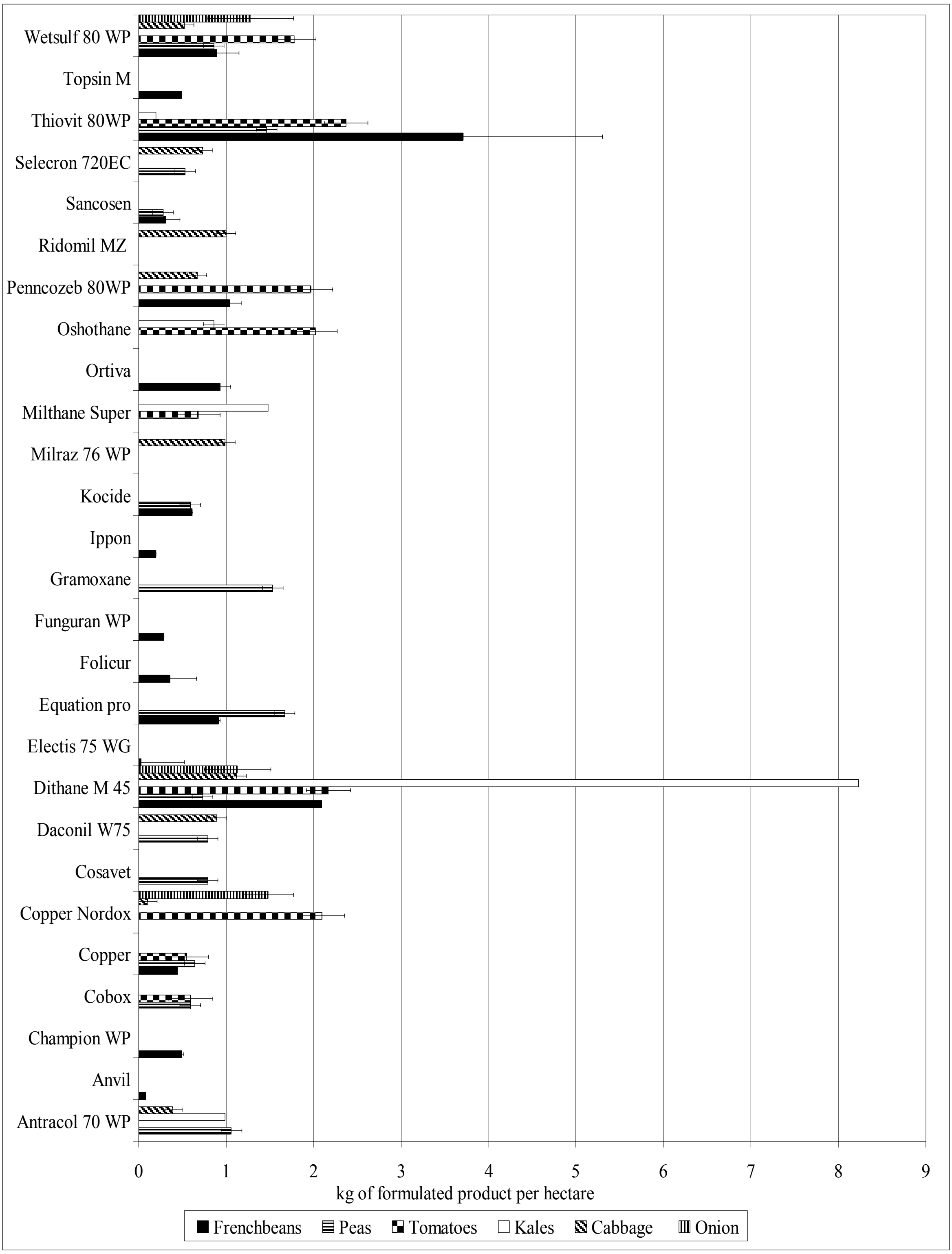

Figure 4.2: Fungicides and herbicide (Gramoxane) used in the major vegetables grown in 2005 (n=839)

Source: Own survey

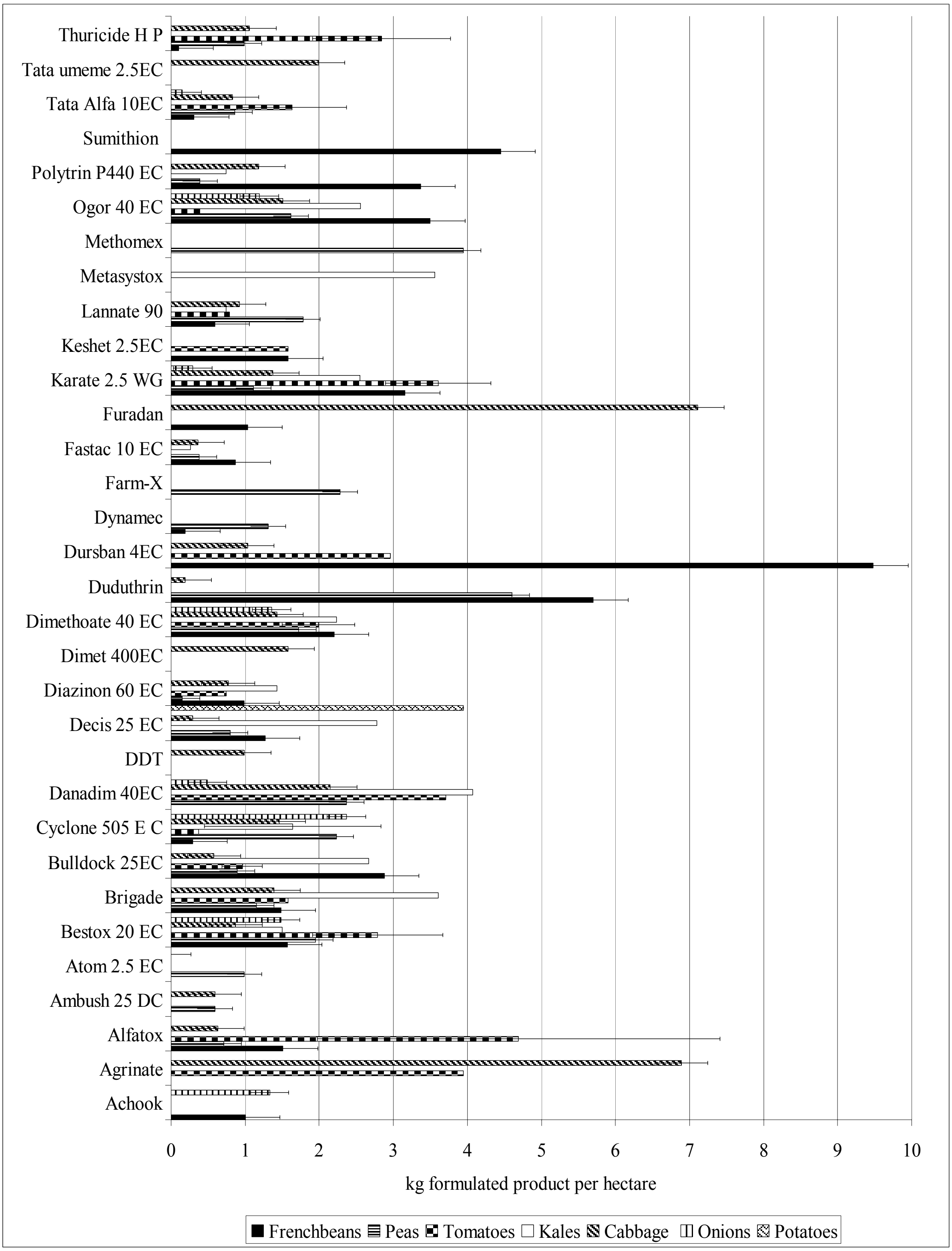

Figure 4.3: Insecticides and acaricide (Dynamec) used in the major vegetables grown in 2008 (n=425)
Source: Own survey

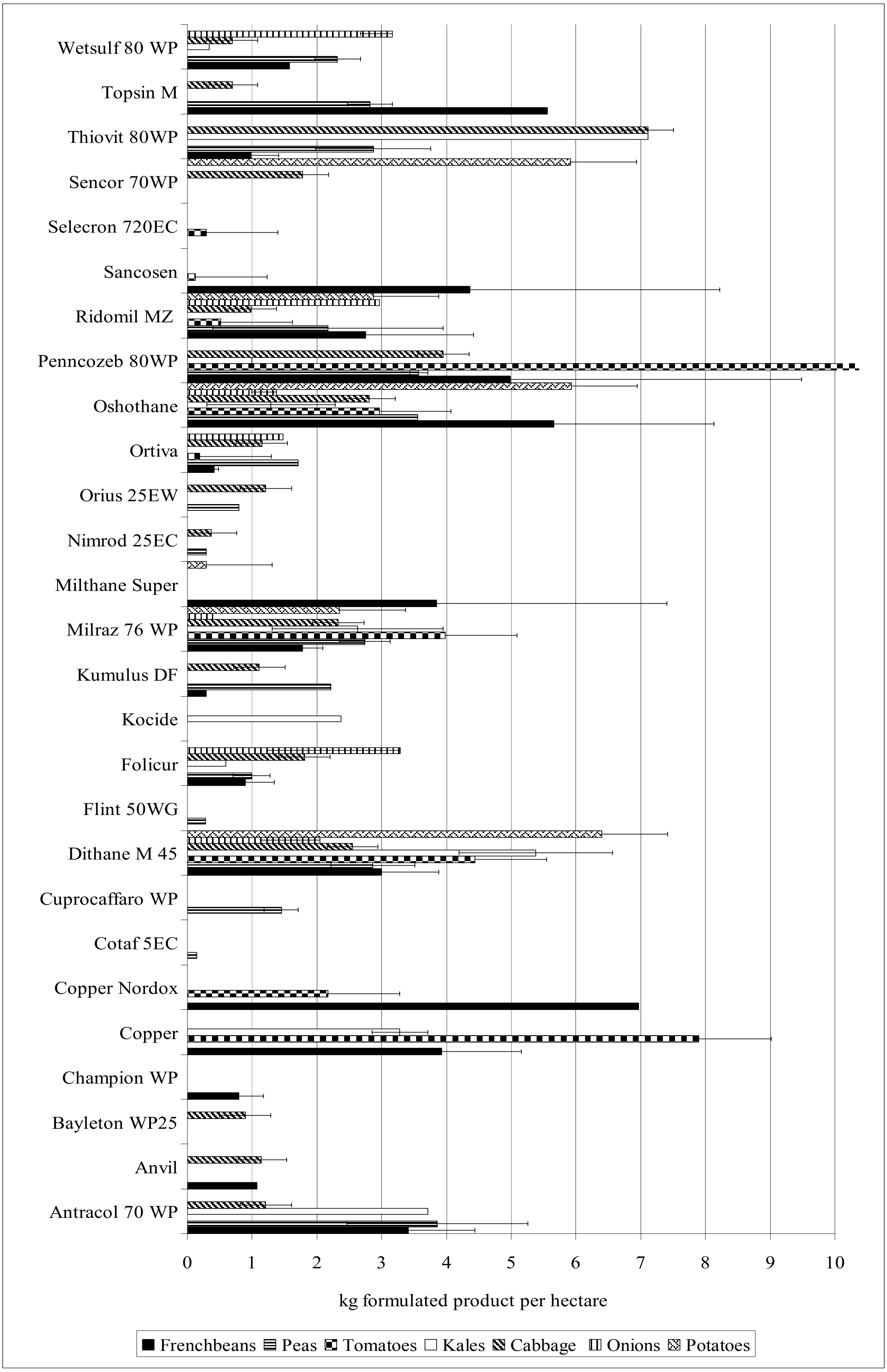

Figure 4.4: Fungicides and herbicides (Gramoxane, Sencor, Farmuron) used in the major vegetables grown in 2008 (n=425)
Source: Own survey

When farmers were asked their trend of pesticide use in the last 5 years, majority (57%) were of the opinion that they were increasing their use of pesticides, while 18% felt it was constant and 24% had the opinion that it was decreasing. Table 4.4 shows the first three major reasons given by farmers for their trends in pesticide use.

Table 4.4: Trend in pesticide use reported by respondents in the survey area, 2008

Trend	Main three reasons given by the respondents for their opinions (in descending order of frequency)
Increasing trend (57%)	i) increase of insect pest populations and diseases ii) ineffective/weak pesticides iii) increase in farm acreage due to market demand
Constant (18%)	i) same application due to the same acreage ii) pesticides expensive iii) pesticides effective as before
Decreasing trend (24%)	i) pesticides expensive ii) reduced farm area iii) practice other pest management practices

Source: Own survey

4.3.3 EIQ and Field use rating

The calculated EIQ values for the commonly used pesticides groups are also listed in Table 4.3. The value ranges from 11 to 74, with an average of 35 for all products used in both 2005 and 2008. The Mean EIQ indicates that the farm worker component is about 2 times greater than the consumer component, and environmental factors are rated 4 times greater than the farm worker component and 8 times higher than the consumer component, suggesting a higher probability of impact on the environment component. For a complete list of pesticides applied by the farmers with their associated risk factors, see appendix D.

According to the Mazlan and Mumford (2005) EIQ classification rule (low (0 – 20), medium (21 – 40) and high (≥41), many pesticide are in the medium class, (Figure 4.5). Comparison between 2005 and 2008 shows the pesticides in medium and high class increased while those in low class reduced. This indicates that farmers are still relying on broad-spectrum synthetic pesticides with relatively high EIQ values to control pests.

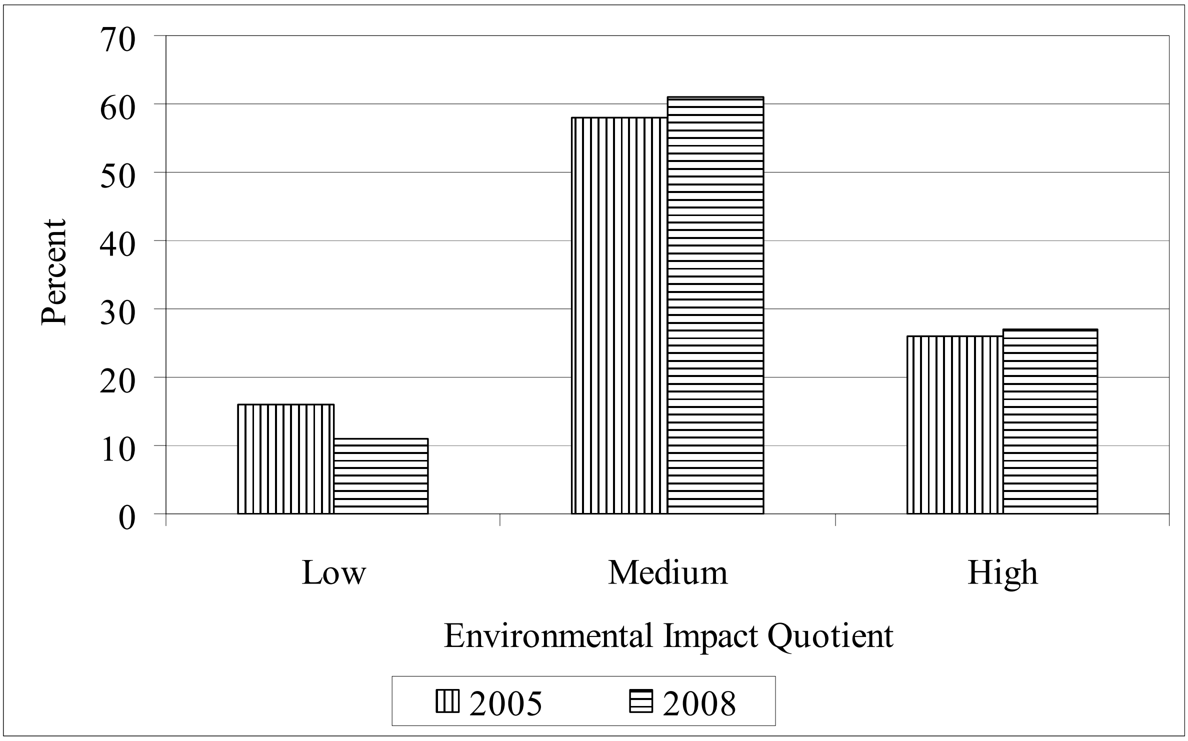

Figure 4.5: Comparison of environmental impact quotient (EIQ) values for pesticides used by farmers in 2005 and in 2008

The field use EIQ rating ranged from 0.2 to 424.8, being lowest for Keshet 2.5EC (deltamethrin) and highest for Selecron 720EC (profenofos). The number for Selecron was higher primarily due to the high percentage active ingredient formulation. Comparing 2008 to 2005, it was apparent that the field use rating decreased by 21%.

According to the EIQ field use rating, comparison of pesticides can be done and the pesticides with the least detrimental effects can be chosen. For example, both Methomex 90 and Karate 2.5WG are used for the management of aphids and thrips on beans. However, the impact of Methomex (field rate = 9) is quite low as compared to Karate (field rate = 16). This fact can guide farmers to choose less harmful pesticides that reduce the environmental impact. Though ecotoxicologists have questioned the predictive value of such tests, noting that interactive effects of pesticides at the ecosystem levels can be different from inferred from single-species effects, and that the higher-level impacts can be of greater long-term environmental significance (Cairns, 1991; Karr, 1992), no standardized datasets exist for pesticide impacts at these higher levels of ecological organization.

4.4 Summary

The results of this study showed that, pesticide products used in vegetable production had increased, with about 19 new products applied in 2008 as compared to 2005. There was also a significant increase in the application rate, though much lower as compared to Asian countries. Comparison of pesticide use in different vegetables singled out potatoes as the most pesticide-intensive crop, followed closely by tomatoes. However, intensity was least in Asian vegetables.

Approximately 570 tonnes of pesticides was estimated applied in 2008, with 61% of the volumes indicated to be bad actor chemicals, 64% to be ground water contaminants, and 47% to be very harmful to beneficial insects by Pesticides Action Network North America (PANNA, 2009).

According to World Health Organization risk classification (WHO, 2006), 7% of the pesticides commonly used are extremely hazardous (WHO Ia and WHO Ib) and 36% moderately hazardous (WHO II).

Mean EIQ-value for all the pesticides was calculated at 18, 10 and 77 for farm workers, consumers and the environment respectively with an overall average at 35. These results indicate that the sub-sector potentially has negative external effects, especially in the environmental dimension. Though there are no safe synthetic pesticides, the EIQ field use rating clearly demonstrated that some pesticides that pose fairly low threat can be chosen. Thus, a combination of pesticide regulatory policies to control the use of the high toxic pesticides and raising farmers’ awareness of the pesticides that pose little threat would help safeguard the environment and human health.

5 Determinants of Pesticide Handling Practices by Vegetable Farmers in Kenya[1]

5.1 Introduction

In Kenya, some research findings have indicated existence of pesticide related negative effects, *e.g.* pesticides threatening Lake Naivasha local hippopotamus populations (IUCN, 2005) and farmers' health impairment (Ohayo-Mitoko *et al.,* 2000; Okello, 2005; Asfaw, 2008). Many of these impacts are a direct result of the inappropriate handling of pesticides, often due to deviation from recommended application and handling procedures.

Unsafe handling of pesticides usually due to negligence, lack of information or lack of training can pose a serious health risk for farmers who are the major pesticide users and are regularly exposed to pesticides (Reeves and Schafer, 2003). Several dimensions of unsafe practices in the handling of pesticides include farmers may apply higher or lower than recommended dosages, store pesticides unsafely, dispose of pesticides left over and containers unsafely, or fail to wear the required personal protective equipments. Extremely unsafe practices include mixing pesticides with bare hands, splashing pesticides onto crops using brushes or twigs and tongue testing to assess concentration strength of the chemical (Dinham, 2003). This consequently increases the chances of pesticide side effects on the farmer and the environment as a whole.

Safe handling of pesticides is considered a pivotal aspect in the reduction of health and environmental hazards of pesticides (Keifer, 2000). A study conducted by Mancini *et al.* (2005) demonstrated that handling pesticides unsafely during spraying enhanced health risks of farmers. Currently, relatively little is known about pesticide handling practices in African countries especially Kenya. A better understanding of how vegetable farmers are handling pesticides and the factors that influence those practices is a precondition for the design and implementation of any policy intervention. The main objective of this study was to identify the determinants for pesticide handling practices and develop recommendations that can reduce the health and environmental hazards associated with those practices.

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[1] Modified version, submitted as: Macharia, I., Mithoefer, D. and Waibel, H. (2010). Determinants of Pesticides Handling Practices by Vegetable farmer in Kenya. *Agriculture systems.*

5.1.1 Conceptual framework

The conceptual framework for the analysis of factors associated with farmers' pesticide risk perception and the determinants of their pesticide handling practices is presented in Figure 5.1. This framework is a combination of two existing analytical tools: the farm structure theory developed for agricultural studies (Tucker and Napier, 2001) and the psychometric paradigm framework used in risk perception research (Slovic, 2000). These tools incorporated farm-specific factors such as farm size and crops; individual features such as age, gender, knowledge, training and psychometric factors such as risk perception, and who are trusted sources for providing pesticide risk information. Within the psychometric paradigm, people make quantitative judgments about the current and desired 'riskiness' of diverse hazards and the desired level of regulation of each. It is thus, hypothesized that farmer risk perception, is influenced by socio-economic and demographic factors, and in turn drives farmers' decisions on how to handle pesticides among the other factors.

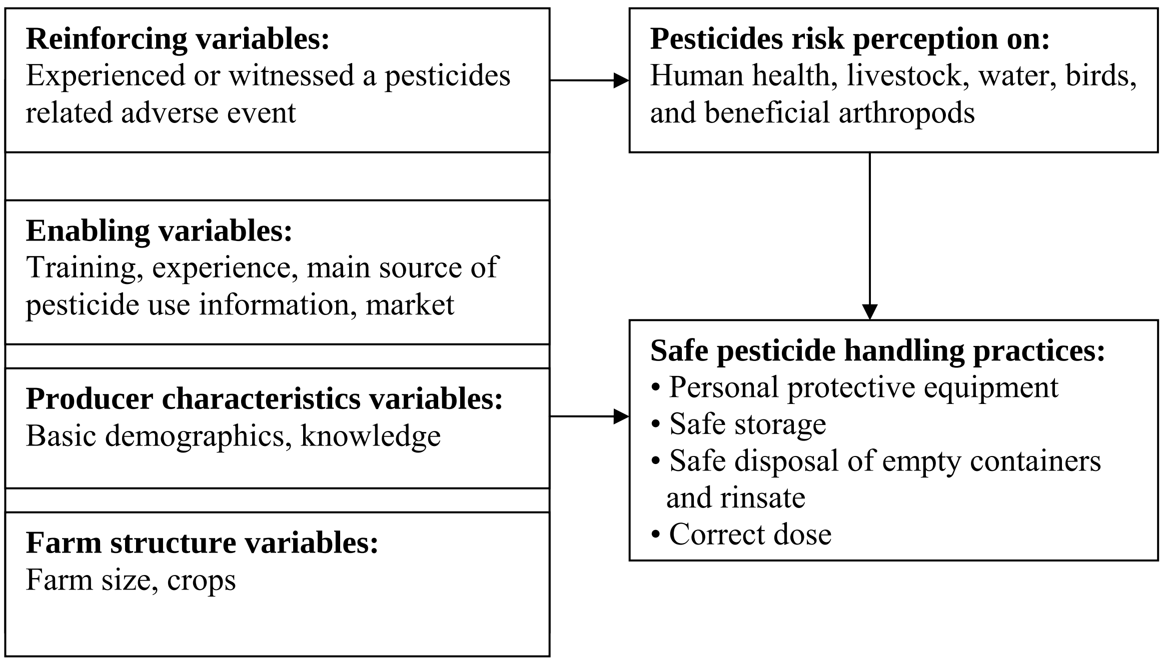

Figure 5.1: Factors associated with risk perception and pesticide handling practices
Source: Own illustration

5.1.2 Data and Model

The data used in this analysis are from a cross section farm survey collected in 2008 based on a random sample of 425 farmers. To model determinants of the degree of pesticide risk perceptions and pesticide handling practices, a count data model is used (Poisson regression). The Poisson regression model is commonly applied in the analysis of count data (Wooldridge, 2006). The count of risk perceptions or the counts of handling practices y_i were assumed Poisson distributed and can be expressed as:

$$prob\,(Y_i = \lambda_i) = \left\lfloor e^{-\lambda i} \lambda_i^{yi} \right\rfloor / \, y_i! \qquad (5.1)$$

Where y_i = 0, 1, 2...

The expected parameter λ_i is assumed both the mean and the variance of the count data (y_i). This property is called equidispersion. The distribution is extended to obtain a regression model by allowing each observation y_i to have a different value of λ. The popular formulation is an exponential relationship between the expectation rate and a set of regressors, expressed as:

$$E[y_i \mid x_i] = \mathrm{var}[y_i \mid x_i] = \lambda_i = \exp(\beta' x_i + \mu_i) \qquad (5.2)$$

Where x_i is the vector of regressors, β is the vector of estimated parameters, which captures the effect of the regressors on the dependent variables (*i.e.* pesticide risk perceptions and pesticide handling practices), and μ is the error term.

Maximum likelihood estimation procedure for the estimation of the parameters β and μ in Stata Version 10 was used. For the empirical model, the risk perception equation was specified as equation 5.3 below and handling practices as the fourth equation (5.4).

To simplify counts of farmer risk perception, responses with: 1) Beneficial 2) Somewhat beneficial 3) No effect, were grouped together and coded as 0 and were referred to as pesticides are 'harmless' whereas responses with, 4) Somewhat harmful 5) Harmful were grouped and coded as 1 and referred as 'harmful'. Theoretically, farmers' pesticide risk perception can be shaped by a variety of factors including the potential health implications, formal education, and experience (Warburton *et al.,* 1995). The perception equation considered these factors alongside with the gender, GLOBALGAP certification, farmer being the primary pesticides applicator, record keeping of pesticide use activities, main source of pesticide use information, target markets, toxicity levels of pesticide handled, and location. Variable definitions and summary statistics are shown in Table 5.1.

PERCEPTION= f (IMPACT, EDUCATION, EXPERIENCE, EXPERIENCESQ[2]*, GENDER, GLOBALGAP, APPLICATOR, RECORD, EXTENS, FARMER, RADIO, TRADER, EXPORT, LOCAL, NPEST, PWHOIab, PWHOII, PWHOIII, PWHOU, District Dummies)* (5.3)

The pesticide handling practices was constructed as a count of the responses for over-dose, unsafe storage of pesticides, unsafe disposal of pesticides rinsate and containers, and failure to wear the minimum protective equipments (long-sleeved shirt, long trousers or overalls, gloves, and gumboot). Each was coded as 1 and referred to as inappropriate handling practices and 0 otherwise. The equation was then, specified as a function of farmers pesticide risk perception, impact, level of education, experience in agricultural production, gender, GLOBALGAP certification, farmer being the primary pesticides applicator, record keeping of pesticide use activities, farm size, main source of pesticide use information, target markets, toxicity levels of pesticide handled, and location.

[2] According to human capital theory, there is a concave relationship between experience and returns to experience (Mincer, 1974). Applied in our case it means that the more experienced the farmers are, they may be expected to perceive pesticide to be risky and handle them safely. However, this expectation may decline after a certain point due to depreciation effects of human capital.

HANDLING= f (PERCEPTION, IMPACT, EDUCATION, EXPERIENCE, EXPERIENCESQ, GENDER, GLOBALGAP, APPLICATOR, RECORD, FARMSIZE, EXTENS, FARMER, RADIO, TRADER, EXPORT, LOCAL, NPEST, PWHOIab, PWHOII, PWHOIII, PWHOU, District Dummies) (5.4)

All variables were cross-checked for problem of multicollinearity, through the simple correlation matrix between all the variables and the highest correlation coefficient was 0.38, thus, correlation between explaining variables could not affect the estimation of coefficients. Likewise, for endogeneity none of the independent variables was suspected to be explained within the equation in which it appeared. To check the robustness of the model a negative binomial regression model was fitted, which is preferred when there is overdispersion (Long and Freese, 2003). The likelihood ratio test and the statistical evidence did not indicate overdispersion[3]. In addition, to check the robustness of all the models, other restricted models were estimated in which subsequently insignificant variables were dropped (see results section). The statistical quality of the models, the direction of the signs did not change and the coefficients deviated only marginally.

[3] Overdispersion normally occurs when the mean < variance.

Table 5.1: Definition and summary statistics of variables used in empirical estimations

Variables	Definition	Mean [a)]
Dependent variables		
PERCEPTION	Farmer perceive pesticides to be harmful to human health, livestock, water and fish, beneficial arthropods and birds (count)	4.00 (0.06)
HANDLING	Farmer overdose pesticides, unsafely stored pesticides, unsafely disposed of pesticides containers and failed to wear the minimum protective equipments (count)	1.57 (0.05)
Reinforcing variables		
IMPACT	Farmer experienced/witnessed a pesticide associated human health impairment, livestock poisoning, mortality of beneficial arthropods and birds (count)	2.15 (0.83)
Farmer characteristics variables		
EDUCATION	Level of education: 0=None; 1=Pre-primary school; 2=Primary school; 3=Secondary school; 4=College	2.53 (0.04)
GENDER	1, if farmer is a male; 0, otherwise	0.70 (0.02)
Enabling variables		
EXPERIENCE	Farming experience in agriculture production (years)	20.85 (0.58)
EXPERIENCE-SQ	Farming experience in agriculture production (years squared)	579.30 (30.87)
GLOBALGAP	1, if farmer has ever been GLOBALGAP certified (proxy for pesticide use training); 0, otherwise	0.21 (0.02)
APPLICATOR	1, if the farmer is the primary pesticides applicator; 0, otherwise	0.86 (0.02)
EXTENS	1, if extension officers are the main source of advice on pesticide use; 0, otherwise	0.23 (0.02)
FELLOW	1, if other farmers are the main source of advice on the pesticide use; 0, otherwise	0.05 (0.01)
LABEL	1, if label is the main source of information on the pesticide use; 0, otherwise (base in estimation)	0.20 (0.02)
RADIO	1, if radio is the main source of information on the pesticide use; 0, otherwise	0.29 (0.02)
TRADER	1, if pesticide traders including agro-vets are the main source of advice on the pesticide use; 0, otherwise	0.23 (0.02)
BOTH	1, if farmer producing for domestic as well as export market; 0, otherwise (base in estimation)	0.46 (0.02)
EXPORT	1, if farmer produce exclusively for the export market; 0, otherwise	0.04 (0.01)
LOCAL	1, if farmer produce exclusively for the local market; 0, otherwise	0.50 (0.02)

Table 5.1: Continued

Variables	Definition	Mean [a)]
Farm management and other variables		
RECORD	1, if the farmer keep records of the pesticide use activities; 0, otherwise	0.31 (0.02)
FARMSIZE	Total farm size (hectares)	1.01 (0.05)
NPEST	Number of pesticide products farmer handled (count)	4.06 (0.02)
PWHOIab	Amount of pesticides applied and classified as WHO Ia or Ib (extremely or highly hazardous) (g)	32.96 (11.17)
PWHOII	Amount of pesticides applied and classified as WHO II (moderately hazardous) (g)	654.20 (60.98)
PWHOIII	Amount of pesticides applied and classified as WHO III (slightly hazardous) (g)	177.96 (24.22)
PWHOU	Amount of pesticides applied and classified as WHO U (unlikely to present any acute hazard use) (g)	301.44 (37.91)
KIAMBU	1, if the farmer is located in Kiambu; 0, otherwise	0.06 (0.01)
KIRINYAGA	1, if the farmer is located in Kirinyaga; 0, otherwise	0.18 (0.02)
MAKUENI	1, if the farmer is located in Makueni; 0, otherwise	0.05 (0.01)
MERU CENTRAL	1, if the farmer is located in Meru Central; 0, otherwise	0.26 (0.02)
MURANGA	1, if the farmer is located in Muranga; 0, otherwise (base in estimation)	0.06 (0.01)
NYANDARUA	1, if the farmer is located in Nyandarua; 0, otherwise	0.12 (0.02)
NYERI NORTH	1, if the farmer is located in Nyeri North; 0, otherwise	0.27 (0.02)

[a)] Figures in parenthesis are standard errors
Source: Own survey

5.2 Results and Discussions

5.2.1 Descriptive statistics

5.2.1.1 Farmer characteristics

The average age was calculated to be 46 years with nearly 23% of the farmers being under the age of 35, and 29% older than 50 years. Most farmers were literate and only 2% of the farmers had not attended any formal school. Almost half (47%) of the farmers had received formal primary education, whereas about 40% had received secondary education and about 11% had earned at least a diploma. The female farmers were approximately 30% and the average years of experience in agricultural activities by all the farmers were 21 years. The farmers' most important source of information for pesticide use for agricultural production were the radio (29%), the Agricultural Extension Officers (23%), the pesticide label (20%), agro-vets (18%), pesticide dealers or company representatives who come to the farm (5%), and fellow farmers (5%).

5.2.1.2 Knowledge and handling practices

Table 5.2 summarizes the farmers' knowledge of the safety measures pictograms normally found on pesticide labels on the Kenyan market and how they responded to them (practiced). Though the majority (63%) of farmers stated that they read and understand pesticide labels, a sizeable percentage (65%) did not know the correct meaning of all the main and simple pictograms used in pesticide labeling with only 4 farmers adhering to all. Prior knowledge on need to wear an apron and pesticides are harmful to water bodies was statistically associated with the farmer practices.

A sizeable proportion of the farmers (23%) stored the pesticides in places such as in the kitchen, bedrooms or in the farm store together with farm produce and other equipments without any safety precaution. Approximately 32% reported wearing the required minimum protective gear. By impromptu observation a clear under-use of protective equipments, particular use of gloves was revealed, with only 1 out of 7 randomly selected farmers seen in gloves during spraying, strengthening the validity of farmers' responses. Low use of protective equipments has also been reported among farmers in other countries like in Ethiopia, Brazil and the United States (Carpenter *et al.,* 2002; Mekonnen and Agonafir, 2002; Delgado and Paumgartten, 2004). In most cases, use of protective equipments was very low despite the availability of protective equipments and farmer awareness of the potential impact of pesticides on their health.

The farmers disposed empty pesticide containers within the farm by burying or throwing into the latrine (56%), disposal pit (28%), dumping by the field (13%) or washed and reused (2%). By cross checking, an average of 2 pesticide containers were observed lying either in or near the vegetable field, water ponds, and near homestead of 33%, 2% and 13% of the sample farmers respectively. Hurtig *et al.* (2003), Ntow *et al.* (2006), and Recena *et al.* (2006) reported similar, unsafe disposal methods of empty pesticide containers. The majority of the farmers also indicated that they continuously sprayed the leftover pesticide solutions on the same crop the same day (60%), 12% emptied the leftover spray solutions nearby wells or ponds. Equipments used to apply the pesticides were washed with a water hose near the homestead (44%) or in the field using water from ponds, streams or from the wells with 17% releasing the rinsates into pond or stream.

The majority of the farmers (91%) stated that they followed the label instructions when determining the application rates. However, the comparison between the farmers' application rates to the existing recommended rates (*i.e.* the application rates indicated on pesticide labels, which were also cross-referenced with those conventionally put in company catalogues), showed that only 3 farmers actually sprayed the recommended rates[4] for all the pesticide sprayed. Even allowing an error of 25% for the total number of pesticides sprayed did not change the number of farmers. Approximately 27% of the farmers had over-dosed pesticides with an average over-use rate of 0.42 kg/application. However, only 10% over-dosed pesticides on the export crops as compared to 17% on the domestic crops. Over-dose results in financial losses because of waste of pesticides and decreased yields due to phytotoxicity (Asogwa and Dongo, 2009). However, the biggest risk of over-dose is the increased likelihood for the development of resistance against pesticides, which can have devastating large-scale effects on crop production. It also increases the chances of pest resurgence due to destruction of natural control organisms (Meijden, 1998).

[4] The amount the farmer exceeded from recommended dose indicated on the label of the pesticide container for each of the individual pesticides was first calculated. If the farmer used more than the recommended dose, over-dose was coded as 1 and if it was less than the recommended dose under-dose likewise coded 1. This calculation was performed for all the pesticide products used in each application, then summed across each farmer.

Table 5.2: Pictograms presented to farmers and level of understanding, *i.e.* knowledge and their practices (%)

Pictogram	Meaning	Know	Practice		
			Yes	No	$\chi^{2\ a)}$
	Keep locked away and out of reach of children	Yes	47	13	0.35
		No	29	10	
	Wear boots	Yes	80	12	1.39
		No	8	0	
	Wear overall	Yes	59	24	2.94*
		No	10	6	
	Wear gloves	Yes	32	61	0.52
		No	2	5	
	Dangerous/harmful to livestock and poultry [b)]	Yes	3	51	0.23
		No	1	43	
	Dangerous/harmful to fish and water bodies [c)]	Yes	33	18	3.87**
		No	28	22	
	Wash after use	Yes	80	0	0.51
		No	20	0	

[a)] Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability
[b)] Practice: do not feed livestock with freshly sprayed vegetable residue
[c)] Practice: do not dispose of leftover spray solutions, rinsates or empty pesticide containers into pond, rivers or dams
Source: Own survey

Many farmers recognized the major natural enemies found in the vegetable crops with over 90% identifying 3 out of the 4 insects that they were asked to identify (ladybird beetles 90%, spiders 99%, fire ants 99%). However, only 66% clearly identified dragonflies, and they were uncertain of their role.

5.2.1.3 Experience and perception of pesticide negative impacts

Over 35% of the farmers reported at least one of a variety of acute illness symptoms of pesticide poisoning within 24 hours after spraying pesticides, with half indicating that they witnessed a fellow farmer intoxicated by pesticides (Table 5.3). The most common symptoms reported were sneezing, headache, stomach pains, dizziness, burning skin/rash, eye irritation, shortage of breath, vomiting, blurred vision, and coughing in the order of most frequently reported. These symptoms are associated with pesticide acute poisoning (Extension Toxicology Network, 2004). In addition, a sizable number had also observed/witnessed livestock poisoning, mortality of beneficial arthropods and birds during or 24 hours after spraying pesticides, all attributed to the pesticide sprayed. Majority farmers (81%) also regarded pesticides as harmful for their health and environment.

Table 5.3: Farmers experience and perception of harmful effects of pesticides (%), 2008

Category	Impact		Perception		
	Experienced	Witnessed from neighbours	Harm -less	Harmful	Don't know
Human health	35	50	5	93	2
Livestock	12	30	8	85	7
Beneficial arthropods	54	57	25	70	4
Water, frogs and fish [a)]	-	-	10	80	10
Birds	6	9	14	74	12
Average	27	37	12	81	7

[a)] It was difficult for farmers to associated pesticide use with fish mortality or notice contamination of water by pesticides apart from the smell, which is subjective

Source: Own survey

5.2.2 Models estimation results

The results of the two models are presented in Table 5.4. Starting with the risk perception model (Column 2, unrestricted), the results indicate that the probability of risk perception significantly increases with, male farmers, GLOBALGAP certification, fellow farmers as the main sources of advice on pesticide use, production of vegetable geared exclusively for domestic market as well as the number of pesticides handled. Farmers as the primary pesticides applicator, growing vegetables targeting export markets, handling pesticide in WHO U, and being located in the districts of Kirinyaga and Kiambu reduces the probability of pesticide risks perception.

Neither experience/witness of a pesticide related negative impact[5] nor education had any significant effect on risk perceptions. The restricted model re-estimated by dropping insignificant variables, shows that the estimates of the coefficients and their directions are robust.

The second equation for the pesticide handling model in Table 5.4 (Column 3, unrestricted), clearly shows that the probability of inappropriate handling of pesticides is lower if farmers keep record and if they are located in the district of Meru Central. For the "record keeping" variable, the explanation could be that farmers who keep records are more aware and more judicious in their pesticide use. With records, a farmer can have a better pesticide use planning, can also see how well she/he is managing production operations, and can identify the strengths and weaknesses in those activities. The district of Meru appears to be less prone to unsafe handling of pesticides perhaps as a consequence of record keeping.

The positive significant coefficient on pesticide traders as the main sources of advice on pesticide use, numbers of pesticides handled, and handling of pesticides in WHO II, suggests a probability of inappropriate handling of pesticides association. In the Philippines, increased pesticide misuse was found to be strongly associated with visits by chemical company representatives or by agricultural technicians (Tjornhom *et al.,* 1997). Furthermore, pesticides dealers particularly the companies have an incentive to push pesticides use by advertising and promotion and this creates a bias in favour of their use (Tisdell *et al.,* 1984). The analysis further indicates that farmer located in the districts of Kirinyaga and Makueni have a higher chance of inappropriate handling of pesticides.

Contrary to theoretical expectations, pesticide risk perceptions, and previous experience/witness of a negative pesticide impact has no significant influence on pesticide handling practices[6]. Kishi *et al.* (1995) reported that farmers take pesticides poisoning symptoms as normal effects so they get used to them. Similarly, the study in Côte d'Ivoire by Ajayi (2000) also showed that pesticide applicators tended to accept a certain level of illness as an expected and normal part of farming. This could be the reason why farmers did not handle pesticide safely even after experiencing a negative impact. In addition, most

[5] In an alternative model specification, with set of dummies for impacts on health, livestock, beneficial arthropods, and birds yielded no statistical significance.

[6] Even after controlling for specific impact and risk perceptions, i.e. on health, livestock, beneficial arthropods, and birds no statistical significance was found.

farmers do not keep records of their pesticides related losses, as they do not appreciate its importance. Furthermore, the lack of diagnosis attributed to pesticide exposure, make farmers also to ignore the dangers of pesticide use as the long-term effect is not easy to prove (Pimentel and Greiner, 1997).

Similar findings on lack of association between handling practices and risk perceptions were reported in studies that showed that knowledge of the pesticide negative effects was not directly reflected on the use of protective equipments (Martinez *et al.,* 2004) or did not influence farmers crop production practices (Ecobichon, 2001). Damalas (2006) noted that although farmers' knowledge of possible hazards by pesticide use was high, the reported safety measures were poor. Tucker and Napier (2001) also found that although some Midwestern US farmers were aware of potential negative effects of pesticides use, they still relied heavily on chemical control.

Though the coefficients on farmer as the primary applicator, farm size, and GLOBALGAP certification are insignificant, they have the expected negative sign. Further analysis on GLOBALGAP certification showed that many of the farmers (69%)[7] who were certified before the survey did not maintain their certification. Probability of these farmers not following the recommended practices as required might offer a partial explanation of this apparently perverse result. When the model was re-estimated (restricted) by dropping insignificant variables, the estimates of the coefficients were robust.

[7] It has been argued that smallholder vegetable farmers can achieve GLOBALGAP certification, but continuous maintenance is a problem due to the high costs of compliance.

Table 5.4: Estimation results of farmer risk perception and pesticide handling models

Variables	Risk perception		Pesticide handling	
	Coefficient [a]		Coefficient [a]	
	Unrestricted	Restricted	Unrestricted	Restricted
IMPACT	0.01 (0.01)		0.03 (0.02)	
PERCEPTION			0.01 (0.03)	
EDUCATION	0.00 (0.02)		-0.05 (0.04)	
EXPERIENCE	0.01 (0.00)		0.01 (0.01)	
EXPERIENCE-SQ	-0.00 (0.00)		-0.00 (0.00)	
GENDER	0.06 (0.03)*	0.06 (0.03)*	0.05 (0.07)	
GLOBALGAP	0.13 (0.04)***	0.13 (0.04)***	-0.04 (0.09)	
APPLICATOR	-0.09 (0.04)**	-0.09 (0.04)***	-0.04 (0.08)	
RECORD	0.02 (0.03)		-0.17 (0.07)**	-0.18 (0.07)**
FARMSIZE			-0.00 (0.03)	
EXTENS	0.06 (0.04)		0.03 (0.11)	
FELLOW	0.14 (0.06)**	0.13 (0.05)***	0.07 (0.14)	
RADIO	0.04 (0.04)		0.05 (0.09)	
TRADER	-0.06 (0.05)		0.15 (0.09)*	0.09 (0.06)*
LOCAL	0.08 (0.03)**	0.08 (0.03)***	-0.01 (0.07)	
EXPORT	-0.21 (0.09)**	-0.26 (0.08)***	-0.11 (0.15)	
NPEST	0.02 (0.01)***	0.02 (0.01)***	0.02 (0.01)*	0.02 (0.01)*
PWHOIab	0.00 (0.00)		0.00 (0.00)	
PWHOII	-0.00 (0.00)		0.00 (0.00)*** [c]	0.00 (0.00)***
PWHOIII	0.00 (0.00)		-0.00 (0.00)	
PWHOU	-0.00 (0.00)** [b]	-0.00 (0.00)**	-0.00 (0.00)	
KIAMBU	-0.41 (0.11)***	-0.36 (0.08)***	-0.32 (0.22)	
KIRINYAGA	-0.21 (0.09)**	-0.19 (0.04)**	0.40 (0.13)***	0.34 (0.06)***
MAKUENI	0.05 (0.09)		0.32 (0.16)**	0.22 (0.11)**
MERU CENTRAL	-0.09 (0.09)		-0.29 (0.15)***	-0.34 (0.09)***
NYANDARUA	0.01 (0.09)		0.10 (0.15)	
NYERI NORTH	-0.02 (0.08)		-0.00 (0.14)	
Constant	1.23 (0.11)***	1.31 (0.05)***	0.22 (0.23)	0.36 (0.06)***
Observations	411	416	411	415
Log likelihood	-729.92	-743.51	-567.46	-577.99
Wald χ^2	142.34***	110.37***	108.12***	80.55***

[a] Figures in parenthesis are robust standard errors, statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

[b] z- value =-1.89 and [c] z- value =2.61

Source: Own survey

To provide more detailed information about changes in pesticide risk perception and handling practices as a consequence of changes in the explanatory variables, marginal effects[8] for each unrestricted model in Table 5.4 was calculated. From Table 5.5, column 2, gender, GLOBALGAP certification, and production of vegetable for local markets are associated with over 22% increases in the probability of pesticide risk perception. If the farmer is the primary applicator of pesticides, this reduces the probability of risk perception by 35% despite the fact that the sprayers of pesticide may be at a greater risk of pesticide negative effect. Farmers who grow vegetable exclusively for export markets and being located in the district of Kiambu or Kirinyaga also leads to over 76% decrease in probability of risk perception.

For the pesticide handling specification (column 3), record keeping is associated with a 24% lower chance of inappropriate handling of pesticides, as opposed to advice on use of pesticides from pesticide traders which increase the probability with same magnitude. Dummy variables for geographical location indicate that being located in Kirinyaga or Makueni is associated with a 56–69% probability of inappropriate handling of pesticides, while being in Meru Central decrease the probability by over 40%. Once again, this may stem perhaps on differences in record keeping and infrastructural setting.

[8] Marginal effects (evaluated at the mean) are calculated using a continuous approximation for continuous variables and changes from 0 to 1 for discrete variables.

Table 5.5: Marginal effects for farmer risk perception and pesticide handling model

Variables	Risk perception		Pesticide handling	
	Coefficient [a)]	z-value	Coefficient [a)]	z-value
IMPACT	0.05 (0.03)	1.40	0.05 (0.03)	1.56
PERCEPTION			0.01 (0.04)	0.29
EDUCATION	0.00 (0.06)	0.06	-0.08 (0.06)	-1.37
EXPERIENCE	0.02 (0.02)	1.09	0.02 (0.01)	1.32
EXPERIENCESQ	-0.00 (0.00)	-0.39	-0.00 (0.00)	-1.21
GENDER	0.22 (0.12)*	1.72	0.08 (0.09)	0.77
GLOBALGAP	0.55 (0.18)***	3.03	-0.07 (0.12)	-0.51
APPLICATOR	-0.35 (0.15)**	-2.28	-0.07 (0.12)	-0.58
RECORD	0.06 (0.12)	0.53	-0.24 (0.10)**	-2.36
FARMSIZE			-0.04 (0.17)	-0.24
EXTENS	0.23 (0.18)	1.33	0.05 (0.17)	0.28
FELLOW	0.60 (0.28)**	2.12	0.11 (0.21)	0.50
RADIO	0.16 (0.17)	0.89	0.07 (0.14)	0.56
TRADER	-0.24 (0.19)	-1.20	0.24 (0.14)*	1.63
LOCAL	0.31 (0.13)**	2.26	-0.01 (0.10)	-0.14
EXPORT	-0.77 (0.29)**	-2.67	-0.16 (0.20)	-0.78
NPEST	0.06 (0.02)***	2.78	0.04 (0.02)*	1.70
PWHOIab	0.00 (0.00)	1.32	0.00 (0.00)	0.71
PWHOII	-0.00 (0.00)	-0.39	0.00 (0.00)***	2.63
PWHOIII	0.00 (0.00)	0.80	-0.00 (0.00)	-1.12
PWHOU	-0.00 (0.00)**	-1.89	-0.00 (0.00)	-0.18
KIAMBU	-1.36 (0.30)***	-4.52	-0.41 (0.25)	-1.63
KIRINYAGA	-0.76 (0.31)**	-2.45	0.69 (0.25)***	2.72
MAKUENI	0.22 (0.37)	0.57	0.56 (0.32)*	1.72
MERU CENTRAL	-0.33 (0.33)	-0.99	-0.41 (0.19)**	-2.11
NYANDARUA	0.02 (0.34)	0.07	0.16 (0.25)	0.64
NYERI NORTH	-0.06 (0.31)	-0.19	-0.00 (0.00)	-0.00

[a)] Figures in brackets are robust standard errors, statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Own survey

5.3 Summary

Pesticide handling practices have a strong bearing on the exposure of toxic effects to target and non-target organism. Empirical evidence of factors that influence farmer's pesticide handling practices in developing countries is non-existence. This chapter is an attempt to fill this research gap.

In the survey, approximately 85% of the farmers had inappropriately handled pesticides, mainly through, inappropriate storage (23%), unsafe disposal of leftover either sprays solutions, rinsates and empty pesticide containers (40%), failure to wear the required minimum protective gear (68%), or over-dosed pesticides (27%). However, majority of those farmers were aware of the risks of pesticide use, with over 81% expressing the view that pesticides have harmful effects on human health, livestock, beneficial arthropods, and water. Furthermore, over half of the farmer had, either experienced health problems linked to pesticides or witnessed/knew of other farmers who had been victims of pesticide poisoning.

Using a Poisson count model the variables found to be significantly associated with the probability of farmers' pesticide risk perception were, gender, GLOBALGAP certification, main pesticides applicator, main sources of advice on pesticide use, target market, number and amount of pesticides handled as well as geographical location.

The analyses further indicated that record keeping of vegetable production activities could significantly reduce the inappropriate pesticides handling practices, while handling pesticides in WHO II and receiving advice on pesticides use from pesticide traders could significantly increase inappropriate pesticides handling practices. This emphasizes the need for more participatory and targeted outreach programmes, which deal specifically on promotion of record keeping and reduction on use of pesticides, particularly in WHO II.

It is remarkable that farmers' pesticide risk perceptions and previous experience/witness of a negative pesticide impact has no direct influence on farmers' pesticide handling practices. Hence, the learning effect of experience is very little. Thus, there is a need to bring to the attention of farmers the broader long-term chronic effects of pesticides on human and ecosystems as a whole.

The results further suggest widespread inappropriate handling of pesticides in Kirinyaga and Makueni districts. The district of Meru appears to be less prone to these practices, perhaps due to record keeping. Further research on specific location differences may provide more useful insights.

6 Health Effects of Pesticide Use among Vegetable Farmers in Kenya

6.1 Introduction

The exposure to pesticides results in both short-term (acute) and long-term (chronic) illnesses. Acute illnesses include: i) skin irritation (*e.g.* rash, itching, burning), ii) eye irritation (conjunctivitis, impaired vision, redness), iii) stomach irritation (nausea, vomiting, diarrhea, abdominal pain), and iv) respiratory irritation (chest pain, cough, running nose, difficulties in breathing). Chronic illnesses include: i) cancer, ii) neurological problems (seizures, confusion), iii) asthma iv) stillbirths and abortion (Antle and Pingali, 1994; Maumbe and Swinton, 2003; Dick *et al.,* 2007; Hancock *et al.,* 2008). How seriously these illnesses are manifested depends on the toxicity of pesticide and duration of exposure.

Pesticide exposure can be significantly averted by appropriate pesticides handling practices such as safe storage in a properly secured pesticide storage area, safe disposal in a pesticide disposal pit and the use of full protective equipments during pesticide mixing and application. However, most of the vegetable growers as described in chapter five do not often handle pesticides safely.

The World Health Organization (WHO) and the United Nations Environment Program (UNEP) estimates pesticide-poisoning rates of 2-3 per minute, with approximately 20,000 workers dying from exposure every year (Dasgupta and Meisner, 2005). The largest number of poisonings and deaths are said to occur in developing countries (Wilson, 2005). It has been argued that pesticide related health issues constitute a serious threat to development and can easily reverse or undermine the gains made in agricultural growth (Binswanger and Townsend, 2000). Poor access to health services and medical profession that lacks the ability to recognize pesticide-related morbidity raises further concerns in developing countries (Pesticide Trust, 1993). Although pesticide-related poisoning is still not as high or more pronounced in Africa as in Asia, it is a growing problem, as the increasing intensification of agricultural production with more widespread use of pesticides will possibly result in an increase in pesticide poisoning (London *et al.,* 2005).

In Kenya, by some empirical studies the link between pesticide use and farmers' health has been documented (Ohayo-Mitoko *et al.,* 2000; Okello, 2005; Asfaw, 2008). However, these studies were based on snap short cross sectional surveys and a clear trend of poisoning is not well understood. In addition, the only two studies that looked at the determinants of pesticide-related acute poisoning symptoms among farmers are the studies by Okello (2005) and Asfaw (2008). However, the problem is that pesticide-poisoning effects on human heath are not random but rather depend on other unobserved characteristics such as genetic characteristic. Such effects cannot be captured with cross sectional data as utilized in the earlier studies. Thus the true underlying causal relations may be very different either larger or smaller than those noted in those research.

The objective of this chapter is to examine the incidences and the determinants of acute pesticide poisoning among vegetable farmers in Kenya controlling for unobserved heterogeneity.

6.2 Methods

6.2.1 Data and Model

The study used the data set from both the 2005 and 2008 survey as described in chapter three. It was decided to exclude from the sample the entire sampled farmers that did not have a balanced data set[1] for both the 2005 and 2008 survey. The sample size, after dropping these observations (farmers), reduces to a balanced panel of 363 farmers. However, comparing the responses from unmatched farmers on several characteristics showed that the two groups were not statistically different.

Panel data models offer some distinct advantages over cross sectional data analyses. Greene (2008) concluded that the main advantage of panel data is that one can formally model the heterogeneity across groups that are typically present in panel data. Baltagi (2005) confirms this in his statement that the first benefit of panel data is ‘controlling for individual heterogeneity’. Additional benefits of using panel data include that panel data models are able to capture both cross-section and time-series variation in the dependent variable, and to measure not only the effects that observable variables have on the

[1] Missing observations occurred due to outliers and erroneous values of some variables. Dropping observations with any missing data point results in consistent estimators (Wooldridge, 2007).

dependent variable, but also the effects of relevant unobservable or non-measurable influences (Baltagi, 2005).

A general panel regression model is presented as:

$$\begin{aligned} y_{it} &= \alpha_0 + \beta X_{it} + \gamma Z_i + V_{it} \\ V_{it} &= \varepsilon_i + \mu_{it} \end{aligned} \qquad (6.1)$$

Where y_{it} is the response of the dependent variable (in our case this is the cost of illness and count of acute symptoms) for the *i*th farmer in the sample at the *t*th year. α_0 is an intercept that may be different for each point in time, and β and γ are vectors of coefficients. X_{it} is the set of K-vector of time-variant covariates, *e.g.* amount of pesticides handled for the *i*th farmer at the *t*th year, and Z_i is a vector of time invariant variables, *e.g.* gender and location. V_{it} is the error term, which is decomposed into ε_i, and $\mu_{it.}$ ε_i is regarded as the combined effect on *y* of all unobserved variables that are constant over time (time-constant unobserved heterogeneity such as cognitive ability, motivation *e.t.c.*) and μ_{it} representing the idiosyncratic error term (what is unaccounted for in the model) and varies over individual farmers and over time.

The two main methods of dealing with ε_i are to make the random effects (RE) or fixed effects (FE) assumption. Random effects, assumes that the ε_i are random variables (ε_i is i.i.d. $(0, \sigma_\varepsilon^2)$ and that $Cov\ (x_{it,}\ \varepsilon_i) = 0$, while with fixed effects, ε_i are assumed to be potentially correlated with X_{it}. In fixed effect regressions we cannot estimate the effects of time constant covariates as these are normally cancelled out by the within transformation. Thus, classic fixed effects approaches do not produce any estimates of the effects of variables that do not change over time. Moreover, in some cases fixed effects estimates may have substantially larger standard errors than random-effects estimates, leading to higher *p*-values and wider confidence intervals. In addition, fixed effects estimates use only within-individual differences, essentially discarding any information about differences between individuals unlike random effects that uses information both within and between individuals. Thus, if predictor variables vary greatly across individuals but have little variation over time for each individual, then fixed effects estimates will be rather imprecise (Wooldridge, 2002; Baltagi, 2005).

Thus in principle, random effects is more attractive because observed characteristics that remain constant for each individual are retained in the regression model. In fixed effects estimations, they have to be dropped. In addition, with random effects estimation we do not lose *n* degrees of freedom, as is the case with fixed effects. However, if either of the preconditions for using random effects is violated, one should use fixed effects instead. One precondition is that the observations can be described as being drawn randomly from a given population. The standard procedure in determining the appropriate regression to use is implemented by performing both random and fixed effect regressions and testing through the Durbin–Wu–Hausman test. The test just as in its other applications, determines whether the estimates of the coefficients, taken as a group, are significantly different in the two regressions. If the test indicates significant differences in the coefficients, one should use the fixed effects and vice versa. When neither the cross-sectional unit nor times have significant effects, all of the data can be pooled and one can have the constant coefficients model (Wooldridge, 2002).

The analysis in this chapter was implemented in two steps. First, the cost of illness model was estimated to evaluate the determinants of health costs among the vegetable farmers. The cost of illness was computed as the sum of farmer-reported medical treatment costs in terms of doctor consultations, medications, opportunity costs of traditional medicines, transport to and from health facility, dietary expenses resulting from illness like drinking milk, and the opportunity cost of workdays lost to illness. A daily farm wage rate was used to calculate the opportunity cost of days.

In the second step, the principal factors associated with the acute pesticide poisoning symptoms were examined seeking those that are relevant at policy recommendation.

6.2.1.1 Cost-of-Illness Model

In previous studies, the health costs of pesticides were modeled using a Logarithmic regression model (Maumbe and Swinton, 2003; Asfaw, 2008). In this study the estimations of the determinants of health costs was modeled using a censored[2] random effects Tobit model (Xttobit), since zero costs from respondents who had suffered pesticide related

[2] Only farmers that reported health impairment were considered.

illnesses but incurred no costs were considered. Using a Logarithmic model would have required adding a small unity value as log of zero is undefined. Estimation of dependent variables result into biased estimators in linear models (Tobin, 1958). The structural equation in the Tobit model is represented as:

$$y^*_{it} = x_{it}\beta + \varepsilon_i + u_{it} \tag{6.2}$$

Where, X_{it} is the vector containing the observations on the exogenous variables, ε_i represent individual effects and it is assumed ε_i i.i.d. $N(0, \sigma_\varepsilon^2)$ and μ_{it} i.i.d. $N(0, \sigma_\mu^2)$ independent of ε *'s* ($i=1,..n;\ t=1,..T$). y^* is a latent variable that is observed for values greater than T and censored otherwise. The observed y is defined by the following measurement equation:

$$y_{it} = \begin{cases} y^* & if \quad y^* > T \\ T_y & if \quad y^* \le T \end{cases} \tag{6.3}$$

In the typical Tobit model, we assume that T= 0, *i.e.* the data are censored at 0.

For the empirical model, the explanatory factors for the model explaining health costs incorporate four broad classes of variables namely those related to health (number of acute symptoms and symptoms severity), farmer characteristics variables (age, education, gender), farm management variables (farm size[3], GLOBALGAP certification, and record keeping), and location control (district dummies) (see equation 6.4). Variable definitions and descriptive statistics are presented in Table 6.1.

It is hypothesized that the number of acute symptoms, symptom severity, age, and farm size are positively associated with the health costs, while a negative association is expected for level of education, GLOBALGAP certification, and record keeping. The direction of the effect of gender on health costs is not clear a priori.

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[3] Proxy for wealth.

It is anticipated that young farmers may have a higher tendency to protect against pesticides exposure and consequently reduce the pesticide-related acute symptoms and associated health costs. Increased education is also expected to reduce health costs because farmers are more likely to read pesticide labels and follow the recommendation, again reducing the exposure and the acute symptoms. Likewise, GLOBALGAP certification, and record keeping can result in a more judicious use of pesticide use and higher tendency to protect against pesticide intoxication resulting in reduced acute symptoms.

HealthCost= f (TACUTE, SEVERE, AGE, AGESQ, EDUCATION, GENDER, FARMSIZE, GLOBALGAP, RECORD, District Dummies, YEAR2008 Dummy (6.4)

6.2.1.2 Acute symptoms Model

The determinants of the number of acute symptoms were modeled as random effects. A Negative Binomial Regression model (Xtnbreg) was chosen to account for overdispersion, since the equidispersion assumption that has to be met with the Poisson model was violated, *i.e.* the variance was larger than the mean and just over two third of the counts were zero. When there is overdispersion, the Poisson regression is not appropriate because the standard errors estimated are biased downward and the p-values are small and spurious (Long, 1997).

A Negative Binomial Regression model is a count data model and a good facet of the model is that the Poisson model is nested within it (Long, 1997). However, the assumption of the standard Poisson model that the variance of the dependent variable is equal to the mean is not binding for the negative binomial model (Cameron and Trivedi, 1998). Negative Binomial Regression model deal with the problem of overdispersion by assuming that y_{it} has a negative binomial distribution, which can be regarded as a generalization of the Poisson distribution with an additional parameter allowing the variance to exceed the mean. The negative binomial function can be presented as equation (6.5):

$$f(y_{it} \mid \mu_{it}, \varepsilon_i) = \frac{\Gamma(\mu_{it} + y_{it})}{\Gamma(\mu_{it})\Gamma(y_{it} + 1)} \left(\frac{\varepsilon_i}{1 + \varepsilon_i} \right)^{y_{it}} \left(\frac{1}{1 + \varepsilon_i} \right)^{\mu_{it}} \tag{6.5}$$

Where Γ is the gamma function, parameter ε_i is assumed constant over time for each individual parameter while u_{it} is assumed both the mean and the variance and depends on covariates by the function below:

$$\ln \mu_{it} = \beta X_{it} \tag{6.6}$$

Where the mean and variance of y_{it} are given by:

$$E(y_{it}) = \varepsilon_i \mu_{it}, \quad \text{var}(y_{it} = (1 + \varepsilon_i)\varepsilon_i \mu_{it} \tag{6.7}$$

Under this model, the ratio of the variance to the mean is $1+\varepsilon_i$ that can vary across individuals but is constant over time. The basic idea for this model is that the predictor information is related to the rate of the response to increase or decrease in counts.

For the empirical model, the acute symptoms model aggregates skin irritation, diarrhea, sneezing, headache, dizziness, vomiting, stomach poisoning, blurred vision, eye irritation, and backache episodes incurred by the farmer during and/or soon after spraying pesticide as the dependent variable. For the explanatory variables, the medical literature indicates that the type and severity of pesticide poisoning depends on the toxicity of the pesticides, amount of pesticides involved in the exposure and route of exposure (Extension Toxicology Network, 2004). The specification accounted for these factors. In addition, in order to understand farm management variables that can affect pesticide poisoning, GLOBALGAP certification and record keeping were included. Furthermore, following Antle and Pingali (1994), Wilson and Tisdell (2001) and Asfaw (2008), other control variables under farmer characteristics, *i.e.* age, gender, education and geographical location were also included (equation 6.8).

A priori, it is anticipated that WHO class Ia, Ib and II pesticides are positively correlated with incidences of acute poisoning whereas negative correlation can be expected with category III and U pesticides[4]. Age could increase acute symptoms, as older farmers may be less concerned about health effects of pesticides. As already mentioned in cost of illness

[4] Pesticides in WHO Iab and WHO II are very toxic, while class III and U are relatively low in toxicity.

model it is expected that pesticide-related acute symptoms decrease with the increase in level of education, GLOBALGAP certification, record keeping of production activities and appropriate use of personal protective equipments.

TACUTE= f (AGE, AGESQ, EDUCATION, GENDER, GLOBALGAP, RECORD, NPEST, PWHOIab, PWHOII, PWHOIII, PWHOU, COAT, GLOVE, GUMBOOT, MASK, District Dummies, YEAR2008 Dummy) (6.8)

The models were estimated using the random effect estimator as the Hausman test showed the fixed effects were not correlated with the regressors. All variables were cross-checked for the problem of multicollinearity, through the simple correlation matrix and variance inflation factor (VIF). The highest correlation coefficient was 0.32 and VIF were by far less than three, indicating that correlation between explaining variables could not affect the estimation of coefficients. Likewise, for endogeneity none of the independent variables was suspected to be explained within the equation in which it appeared. Misspecifications of the models were also checked using a regression specification error test (Ramsey, 1969). In respect to the robustness of the Negative Binomial Regression model, a Poisson model was first fitted and the likelihood ratio test together with the statistical evidence of overdispersion indicated that the Negative Binomial Regression model was preferred to the Poisson model. In addition, to check the robustness of all the models other restricted models were estimated in which, subsequently insignificant variables were dropped. The statistical quality of the models, and the direction of the signs did not change, and the coefficients deviated only marginally.

6.3 Results and Discussions

6.3.1 Descriptive statistics of variables used in empirical estimations

Table 6.1 summarizes the main descriptive statistics comparing 2005 and 2008 with t and z tests for the main variables investigated. The results showed that the incidences of pesticide-related acute illness had increased by over 70%. By cross check, although not shown in the tables the analysis revealed that only 45% of the farmers consequently reported the effect once more in 2008 showing a high rate of new episodes cases. However, the number of symptoms per farmer dropped by almost half in 2008. In terms of frequency of symptom occurrence, headache and sneezing were reported as the main symptoms in both surveys. Dizziness, which is one of the major neurological effects of pesticide exposure, was also found to have doubled in 2008. These symptoms have been associated with pesticides acute poisoning (Extension Toxicology Network, 2004). They are also consistent with other studies of pesticides exposure on farmers' health elsewhere (Kishi *et al.,* 1995; Alavanja *et al.,* 2001; Martin *et al.,* 2002; Atreya, 2005).

For minor poisoning, many farmers used home remedies such as milk, lemon juices, honey, and herbs. The medicines from the local pharmacy shops which were sometimes painkillers were bought in cases where the symptoms of illness were mild and farmers visited the health clinic if the symptoms either persisted or became serious, *i.e.* the victim was unable to talk, walk, see, or vomited continuously. This evidence seems to suggest that many farmers treat acute pesticide effects as minor problems that do not warrant medical attention. Although only about a quarter of the cases a physician was consulted this cost component accounts for the largest share of the total.

The health cost almost doubled in 2008 as compared to 2005. On average, health cost was estimated at US$ 6.55/farmer/season for 28% of the farmers who reported pesticide-related illnesses. These costs equal 47% of mean household chemical expenditures in 2008. Considering all the farmers this translates to a mean of US$ 1.77/farmer/season and assuming two crop seasons per year the costs amount to US$ 3.54/farmer/year. However, the true health costs are likely to be much higher because the costs arising from chronic diseases resulting from long-term pesticides exposure were not considered, as this would have required more detailed medical assessments. Moreover, only costs directly involving family members were reported, costs occurring to hired farm laborers were not included.

Furthermore, other 'costs' to restore health status completely and non-monetary costs like suffering and income lost by family members assisting in seeking treatment were not captured (Rola and Pingali, 1993; Freeman, 1993). In addition, preventive costs associated with precautions taken to reduce exposure such as wearing protective equipments were not considered because they were mainly improvised from old clothing or pieces of cloth wrapped around the nose and mouth to reduce inhalation exposure. The cloths were also used for other purposes like spraying on coffee, other farm work and it was difficult to desegregate specifically for spraying pesticides on vegetable crops. However, the combined mean of personal protective equipments used increased by 43%, with the largest increment noted for gumboots. Over 20% of farmers also paid wage premiums of up to 32% above the normal wage to hired labour for spraying pesticides, which were normally paid in cash.

Comparison with other studies conducted in developing countries like Indonesia, Philippines and Vietnam shows that 58%-99% of the farmers exposed to pesticides had at least one health effect symptom (Pingali *et al.,* 1994). In Tanzania, farmer spending on health due to pesticide exposure ranges between US$ 0.018 and 116 in a year (Ngowi *et al.,* 2007). In West Africa, the economic value of pesticide-related health costs equals to US$ 3.92/household/season in the case of cotton–rice systems (Ajayi *et al.,* 2002). Zimbabwe Cotton growers incur a mean of US$ 4.73 in Sanyati and US$ 8.31 in Chipinge on pesticide-related direct and indirect acute health effects (Maumbe and Swinton, 2003). In Sri Lanka, costs to farmers from pesticide exposure equal 10 weeks' income (Wilson, 1998), while in India the average annual welfare loss to an applicator from pesticide exposure amounts to US$ 36 (Devi, 2007). The immediate costs of a typical intoxication (medical attention, medicines, days of recuperation, *e.t.c.*) equaled the value of 11 days of lost wages in Ecuador (Yanggen *et al.,* 2003).

Pesticide application rate/hectare/season also increased by 47%. Comparison between the years for the specific farmers who participated in the DBM survey showed that many farmers had reduced the pesticide application rate by 8%, while the GLOBALGAP surveyed farmers had increased by 40%. Similar findings in support of the reduction of pesticide use were reported by Jankowski (2007) and Löhr *et al.* (2007) where farmers in the study areas with DBM bio-control (*Diadegma semiclausum)* reduced pesticide applications with others even stopping spraying altogether.

The increase in application rate by GLOBALGAP farmers can partially be explained by the low number of farmers who were certified at the time of survey and the failure of the farmer certified in 2005, to maintain their certification status, *i.e.* certified farmers dropped from 18% to 7%, with only 31% of the farmers maintaining their certification for 2008.

Table 6.1: Descriptive statistics of variables used in empirical estimations (N = 726)

Variables	Definition	Unit	Mean [a)]		t or z stat [b)]
			2005	2008	
Dependent variables					
TACUTE [c)]	Number of symptoms	count	1.89 (0.13)	1.09 (0.03)	-7.07***
TACUTE	Number of symptoms	count	0.38 (0.48)	0.37 (0.03)	-0.15
HealthCost [c)]	Cost of illness	US$	4.15 (1.70)	7.98 (1.57)	1.57
HealthCost	Cost of illness	US$	0.84 (0.35)	2.72 (0.58)	2.80**
Farmer characteristics variables					
AGE	Age of the farmer	years	43.19 (0.66)	46.18 (0.67)	6.30***
AGESQ	Age of the farmer (years squared)	years	2024.43 (62.80)	2292.64 (66.85)	65.21***
EDUCATION	0=None; 1=Pre-primary; 2=Primary; 3=Secondary; 4=College	ordinal	2.45 (0.05)	2.51 (0.04)	1.09
GENDER	Male	1/0	0.70 (0.02)	0.70 (0.02)	0.00
EXPERIENCE	Farming experience	years	18.42 (0.74)	20.56 (0.07)	2.38**
Health-related and pesticide exposure variables					
HEALTH	Farmer reported a symptom	1/0	0.20 (0.02)	0.34 (0.02)	4.26***
SEVERE	1=mild, 2=severe, 3=very severe	ordinal	1.11 (0.08)	1.59 (0.36)	1.22
PWHOIab	WHO Ia and Ib (extremely hazardous)	g	8.79 (2.32)	33.55 (12.79)	1.92**
PWHOII	WHO category II (moderately hazardous)	g	129.87 (10.15)	432.63 (25.20)	10.97***
PWHOIII	WHO category III (slightly hazardous)	g	18.95 (3.39)	166.12 (19.23)	7.45***
PWHOU	WHO category U (no hazard)	g	79.87 (7.47)	167.79 (16.86)	4.87***
PESTHA	Total amount applied	g/ha/ season	1,473.00 (201.82)	2,124.87 (118.28)	2.97***
NPEST	Pesticide products	count	2.89 (0.09)	3.32 (0.08)	3.37***
COAT	Wear coat/apron	1/0	0.49 (0.03)	0.71 (0.02)	6.06***
GLOVE	Wear gloves	1/0	0.26 (0.02)	0.35 (0.02)	2.49**
GUMBOOT	Wear boots	1/0	0.26 (0.02)	0.89 (0.02)	17.35***
MASK	Wear facemask	1/0	0.24 (0.02)	0.40 (0.02)	4.36***

Table 6.1: Continued

Variables	Definition	Unit	Mean a)		t or z stat b)
			2005	2008	
TPPE	Protective equipments	count	2.81 (0.07)	4.00 (0.11)	10.85***
Farm management variables					
FARMSIZE	Total farm size	ha	1.46 (0.08)	1.06 (0.05)	-4.46***
GLOBAL-GAP	GLOBALGAP certified	1/0	0.07 (0.01)	0.19 (0.02)	0.15
RECORD	Keeps records	1/0	0.71 (0.02)	0.32 (0.01)	-10.47***

All monetary variables *e.g.* health costs were adjusted (normalized) to US$ of 2008 to take account of inflation. US$ = 72 KSh (2005) and 75 KSh (2008)

[a)] Figures in parenthesis are standard errors

[b)] Statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability. Categorical variables were analyzed using z-test

[c)] With only farmer who reported the health impairment

Source: Own survey

6.3.2 Model estimations

6.3.2.1 Cost-of-Illness Estimation

The estimation results of the Tobit models with the health costs as dependent variable are reported in Table 6.2. Result shows that health costs are positively associated with number of symptoms and symptoms severity, which implies that an increase in any of these variables spontaneously influences positively the health costs, holding other factors constant.

The finding that the GLOBALGAP certification tends to decrease the health costs could indicate that the certified farmers use adequate safety precautions, or use low toxic pesticides, which generally reduce the health impairments and thus decrease costs. It could also be that these farmers are able to use the minimum treatment possibilities.

Among the farmers' characteristics variables, *i.e.* age, education and gender none had any discernable effect on health costs. In addition, farm size, though considered as an indicator of wealth, does not have a direct effect on health costs, though it has the correct sign. Perhaps it could be due to the facts that farms do not present 'liquid cash' that can be accessed immediately in time of need. In addition, no direct association was found between record keeping and the health costs.

District controls are insignificant, so location does not directly affect the health costs. When the model was re-estimated (restricted) by dropping insignificant variables, the estimates of the coefficients were robust.

Table 6.2: Tobit model for Cost of illness estimations

Model	Unrestricted		Restricted	
Variables	(coefficient) [a)]	z- value	(coefficient) [a)]	z- value
TACUTE	7.45(4.08)**	1.83	6.20 (2.00)***	3.10
SEVERE	9.01 (2.52)***	3.58	11.07 (2.17)***	5.12
AGE	-0.48 (1.09)	-0.44		
AGESQ	0.01 (0.01)	0.61		
EDUCATION	1.46 (2.36)	0.62		
GENDER	-2.84 (4.33)	-0.66		
FARMSIZE	3.25 (2.88)	1.13		
GLOBALGAP	-21.75 (3.40)*	-1.62	-18.71 (7.47)**	-2.50
RECORD	-1.08 (4.89)	-0.22		
KIAMBU	2.50 (10.31)	0.24		
MAKUENI	-15.08 (17.25)	-0.87		
MERU CENTRAL	1.65 (8.71)	0.19		
MURANGA	-5.48 (11.75)	-0.47		
NYANDARUA	-5.61 (8.81)	-0.64		
NYERI NORTH	6.62 (8.47)	0.78		
YEAR2008	7.93 (9.15)	0.87		
Constant	-23.23 (29.41)	-0.79	-19.54 (4.45)***	-4.39
Log Likelihood	-464.10		-549.55	
Wald χ^2/ LR χ^2	40.18***		43.22***	

[a)] Figures in parenthesis are robust standard errors, statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Own survey

6.3.2.2 Acute Symptoms Estimation

Given the critical contribution of pesticide-related acute symptoms to the health costs as indicated in Table 6.2, the principal determinants of these symptoms are reported in Table 6.3.

The model shows that pesticide-related acute symptoms increase significantly with the number of pesticide products handled. This is not surprising, given that different pesticide products require different application rates and have different levels of toxicity. In addition, handling different pesticide products can increase incidences of symptoms since an interaction between pesticides can lead to unknown toxic chemical reactions (Yánez *et al.,* 2002). Likewise, although, the coefficients for pesticides in WHO Iab and II are insignificant, they are positively correlated with acute symptoms whereas negative correlation is observed with WHO III and WHO U pesticides. Pesticides in WHO Iab and WHO II are very harmful, while WHO III and WHO U are less harmful[5]. The significant negative sign of the variable "record keeping" suggests that the probability of pesticide-related illnesses is less for farmers who keep records. This result is in line with the earlier chapter, which showed that record keeping actually reduces the inappropriate pesticides handling practices (Chapter 5, pp. 62).

The level of education reduces the probability of reported symptoms, which implies that farmers with higher education level are more knowledgeable and therefore have a better understanding of the dangers posed by pesticides. In previous studies however, the contrary effect was found because respondents with higher knowledge were more likely to report more health symptoms (Maumbe and Swinton, 2003).

The use of personal protective equipments particularly the use of a coat/apron and facemask significantly reduce the number of symptoms. Exposure to pesticides is often attributed to a failure to use protective equipments (Rola and Pingali, 1993; Cole *et al,* 1998). The positive sign of the use of boots although insignificant seems perverse and alarming at first glance. However, as the researcher had observed in the field, the improper use, *i.e.* putting the trouser inside the boots may offer a partial explanation of this

[5] WHO category Ia or Ib (extremely or highly hazardous), WHO category II (moderately hazardous), WHO category III (slightly hazardous), WHO category U (unlikely to present any acute hazard in normal use).

apparently perverse result. This finding is analogous to that found by Ohayo-Mitoko (1999), where use of gumboots was associated with high acetyl cholinesterase[6] inhibition.

Location control for agro-ecology and differences in institutional settings shows that, farmers in the districts of Kiambu, Meru Central, Makueni, Nyandarua and Nyeri North experience significantly high cases of pesticide ascribed health symptoms as compared to the Kirinyaga (base). Perhaps this is due to the use of protective equipment by farmers located in Kirinyaga.

Contrary to the expectations, the analysis does not support the hypothesis of a significant influence of GLOBALGAP certification on the outcome of health, but the variable has the correct signs. Once again, the low number of farmers who were certified and the failure of the certified farmers to maintain their certification may be the cause of the insignificance. The hypothesis that gender and age have a stronger relation to the acute symptoms is also not supported by the results.

The likelihood ratio test used to assess the statistical quality of the model showed that the model was statistically valid[7]. The reduced model with only the variables that had a significant effect on the dependent variable shows that the statistical quality of the model does not differ much and the direction of the coefficient are identical, suggesting the robustness of the model (Table 6.3).

[6] An enzyme that breaks down acetylcholine (ACh) into choline and acetic acid. It is released onto the sarcolemma of muscle fibres and destroys ACh after the ACh has combined with receptors on the muscle fibre. Thus, it prevents continued muscle contraction in the absence of additional nervous stimulation.

[7] Dispersion parameter alpha was greater than zero.

Table 6.3: Binomial Regression Model for the acute symptoms estimations

Model	Unrestricted		Restricted	
Variables	(coefficient) [a)]	z- value	(coefficient) [a)]	z- value
AGE	0.04 (0.04)	1.13		
AGESQ	-0.00 (0.00)	-1.21		
EDUCATION	-0.16 (0.07)**	-2.13	-0.14 (0.07)*	-1.94
GENDER	-0.10 (0.16)	-0.67		
GLOBALGAP	-0.33 (0.29)	-1.11		
RECORD	-0.44 (0.17)***	-2.57	-0.55 (0.15)***	-3.77
NPEST	0.09 (0.05)**	1.88	0.10 (0.05)**	2.39
PWHOIab	0.00 (0.00)	1.28		
PWHOII	0.00 (0.00)	0.68		
PWHOIII	-0.00 (0.00)	-0.28		
PWHOU	-0.00 (0.00)	-0.13		
COAT	-0.29 (0.16)*	-1.82	-0.29 (0.15)**	-2.03
GLOVE	-0.26 (0.21)	-1.23		
GUMBOOT	0.32 (0.23)	1.36		
MASK	-0.35 (0.20)*	-1.74	-0.39 (0.17)**	-2.30
KIAMBU	1.69 (0.36)***	4.67	1.63 (0.32)***	5.20
MAKUENI	1.74 (0.49)***	3.55	1.50 (0.46)***	3.35
MERU CENTRAL	1.18 (0.31)***	3.82	0.95 (0.25)***	3.77
MURANGA	0.64 (0.46)	1.40		
NYANDARUA	0.90 (0.34)***	2.66	0.80 (0.28)***	2.81
NYERI NORTH	0.93 (0.30)***	3.07	0.79 (0.24)***	3.26
YEAR2008	-0.05 (0.21)	-0.23		
Constant	-1.22 (1.06)	-1.15	-0.01 (0.48)	-0.02
Log Likelihood	-518.85		-535.52	
Wald χ^2	73.74***		60.96***	

[a)] Figures in parenthesis are robust standard errors, statistical significant at the 0.01 (***), 0.05 (**), 0.1 (*) level of probability

Source: Own survey

6.4 Summary

The findings in this chapter indicate that the incidence of pesticide-related acute illness had increased with over 55% new episodes in 2008 as compared to 2005. Many farmers used home remedies to cure the symptoms and they only visited the health clinic if the symptoms either persisted or became serious. This evidence seems to suggest that many farmers treat pesticide-related acute illness as a minor problem that does not warrant medical attention.

The results further show that farmer lose on average about US$ 3.54/farmer/year on pesticide-related indirect health costs. These costs equal 47% of mean household pesticide expenditures. However, the true health costs are likely to be much higher because chronic illnesses resulting from long-term pesticide exposure, costs to restore the health status completely, and non-monetary costs like suffering and income lost by family members assisting in seeking treatment were not captured (Rola and Pingali, 1993; Freeman, 1993).

Estimation results show that health costs are significantly explained by variation in pesticide-related acute symptoms and severity of the symptoms. These symptoms are increased significantly by handling different pesticide products. Level of education, record keeping of production activities and use of protective equipments in particular apron/coat and facemask considerably reduces the number of pesticide-related acute symptoms.

These findings hint at some important points for policies aiming at reducing pesticide poisoning among vegetable farmers in Kenya. First, the role of education in the reduction of pesticide-related acute symptoms, indicate the need for farmer education in exposure averting strategies. Likewise, encouraging farmers to use protective equipments especially coat/apron and facemask, and to keep record of their production activities seems to stimulate them to adopt safer practices which consequently would reduce the associated health costs. Future studies should cover the costs related to pesticide-induced chronic illnesses and hired workers. It would be of value also to investigate whether pesticide exposure increases the risk of other conditions such as other diseases and making farmers more vulnerable to poverty.

7 Indirect Costs of Pesticide Use in the Vegetable Production in Kenya[1]

7.1 Introduction

Research and documentation of negative externalities of pesticides in developing countries is sparse despite extensive documentation of unsafe use and handling of pesticides (Yassin *et al.,* 2002; Salameh *et al.,* 2004). The few studies conducted in developed as well as Asian and Latin American countries have shown substantial external costs associated with the use of pesticides (Waibel *et al.,* 1999; Pretty *et al.,* 2001; Azeem *et al.,* 2003; Tegtmeyer and Duffy, 2004; Pimentel, 2005).

The studies which have been conducted in Africa were mostly concentrated on pesticide related human health effects (Ajayi, 2000; Ohayo-Mitoko, 2000; Maumbe and Swinton, 2003; Okello, 2005; Ngowi *et al.,* 2007; Asfaw, 2008). Few studies in Africa included other effects on livestock, pesticide-related destruction of natural enemies, development of pesticide resistance, crop losses, and governmental expenditures to reduce the environmental and social costs such as Ajayi *et al.* (2002) on cotton in Mali, Houndekon *et al.* (2006) for locust in Sahel in Niger and Leach *et al.* (2008) for locust in Senegal. Further studies in Kenya documented pesticide residues in eggs of free-range chicken (Mugambi *et al.,* 1989), fish killed by leaching pesticides in ponds in Nyeri districts (Waikwa, 1998), and Organochlorine pesticides residues found in breast feeding mothers (Kinyamu, *et al.,* 1998). So far, however, no study exists in Kenya that has established the costs associated with these negative effects. Hence, the objective of this chapter is to account for external and indirect costs related to pesticide use in the vegetable production in Kenya. The results may serve as a basis for the development of future policies aiming to reduce pesticide externalities and promote sustainable crop protection measures in agriculture.

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[1] Modified version, coming soon as: Macharia, I., Mithoefer, D. and Waibel, H. (2010). Indirect and External Costs of Pesticide Use in the Vegetable production in Kenya. In the Vegetable Production and Marketing in Africa: Socio-Economic Research (Edited by D. Mithöfer and H.Waibel). CAB International, London.

7.2 Methods

7.2.1 Analytical Framework and Data

As described in chapter three, externalities categories were divided into three sub categories, namely (1) those that could be valued, (2) those that could only be quantified and (3) those that could only be identified (Table 3.2). For those effects where valuation has been undertaken, the basis always was the market price (Table 7.1). In most cases, the estimation tended towards a conservative approach, *i.e.* where more than two estimates were found an average was used. Whereas no valuation was possible, for effects such as effect on natural enemies, birds, pest resistance and resurgence, a thorough description of the identified effects is given.

Table 7.1: Evaluation of external costs

Externality type	Description of cost assessment
Human health impairments	Doctor consultations, opportunity costs of traditional medicines, medications, transport to and from clinics, dietary expenses resulting from illness like drinking milk, and workdays lost
Livestock poisoning	Treatment costs, market value of lost livestock, production loss
Residue in vegetables	Quantities of vegetables that have to be withdrawn from the market due to exceeding MRLs multiplied by farm gate price
Collection and disposal of empty pesticide containers	Number of empty pesticide containers unsafely disposed of, multiplied by price of collecting them (assumed deposit price)
Damage prevention costs (Government regulation and research institutions)	Fraction of budgets that can be minimized if social costs are reduced from research institutes geared toward pesticide risk reduction

Source: Own presentation

The chapter make use of the results of pesticide human health effects presented in chapter six, data from 425 farmer interviews from the survey of 2008, pesticide residues analysis and expert interviews.

7.3 Results and Discussion

7.3.1 Indirect and external costs estimates

7.3.1.1 Human health impairments

Referring to chapter six, the pesticide related health costs was calculated at an average of US$ 6.55/farmer/season for the 28% of the farmers who reported the problem. Considering the total sample this translates to a mean of US$ 1.77/farmer/season, assuming two crop seasons per year the costs amount to US$ 3.54/farmer/year. A more detailed analysis of health costs in the vegetable production is required. However, health costs are likely to be much higher because chronic diseases resulting from long-term pesticide exposure, non-monetary costs like suffering and income lost by family members assisting in seeking treatment were not included.

7.3.1.2 Pesticide residues in vegetables

Out of the 208 samples screened for pesticide residues, no sample was found contaminated with Organochlorines, Organophosphates, or Pyrethroids above the limit of determination (LOD). However, nearly all samples (92%) had a value higher than the LOD for Dithiocarbamates of which 9% exceeded the set Maximum residue levels (MRLs)[2] levels (Table 7.2). These samples pose health hazards to the consumers. The MRLs expressed as carbon disulfide (CS_2) arises from different Dithiocarbamates, which includes maneb, mancozeb, metiram, propineb, thiram, and ziram.

The mean for the domestic crops (0.22±0.02 mg CS_2/kg) was statistically different from the mean of the export crops (0.14±0.01 mgCS_2/kg) (t test= 3.47, $p < 0.01$), suggesting two different standards of pesticide handling patterns, depending on the target market. The vegetables with the highest number of samples deviating from set Dithiocarbamates MRLs were spinach (94%) and kales (5%). However, spinach MRLs is set at the lower limit of

[2] MRLs represent the maximum concentration of that residue (expressed in mg/kg) that is legally permitted in a crop. They are often referred to as the legal trading limit. They are derived from an assessment of the residues found when the crop is treated according to Good Agricultural Practices (GAP). They are not permanent, they can be raised or lowered to take account of new information and data. They are normally fixed at the lower limit of analytical determination where there are no authorized uses.

analytical determination since no better information exists. Spinach as well as kales are produced for the domestic market only. None of the export crop exceeded the set MRLs.

Across all active ingredients, tomatoes had the highest average residue quantities (0.26 mg CS_2/kg), more than two fold higher than the lowest (baby corn). Vegetables with the lowest average levels were baby corn, French beans, courgette, pea, cabbage, and kales in the order of increasing levels

Table 7.2: Dithiocarbamates residue data (mgCS_2/kg) in various vegetables analyzed

Vegetable	N	Mean	Standard Error	Median	Range	MRL[a)]	% samples above MRL
Kales	44	0.25	0.05	0.15	<LOD-1.62	0.5	5
Tomatoes	17	0.26	0.11	0.12	0.02-2.59	3	0
Cabbages	76	0.20	0.01	0.18	<LOD- 0.71	3	0
Frenchbeans	27	0.12	0.01	0.11	0.09- 0.26	1	0
Peas	25	0.16	0.01	0.16	0.10-0.27	1	0
Spinach	17	0.20	0.07	0.13	0.01-1.18	0.05 [b)]	94
Courgette [c)]	1	0.12	0.00	0.12	0.12	2	X
Baby corn [c)]	1	0.11	0.00	0.11	0.11	0.05 [b)]	X
Total	208	0.20 [d)]	0.00	0.15	2.59		9 [c)]

[a)] EU (2008) also cross-referenced with the Codex Alimentarius (2009)
[b)] Indicated as the lower limit of analytical determination (pesticides not authorized for use)
[c)] During the sampling only few farmers were found harvesting, thus the low samples
[d)] Weighted average, X= not considered due to the low number of samples
Source: Own survey

Direct toxic effects of pesticides on animals and humans are easily recognized, but the effects that result from long-term exposure to low doses of a regular intake of pesticide residues in vegetables or food or results from multiple pesticide residue combinations are hard to detect and quantify. Assuming that the fraction of each of the vegetable crops with residues above the set MRLs represent that vegetable crop's yield produced in 2008 exceeding MRLs results in the total volume which under the conditions of an effectively enforced pesticide regulation should be taken out of the market. Therefore, the costs of pesticide externalities from residues were calculated by multiplying the production volume above MRL with the farm gate prices derived from the farmer survey gives the loss of vegetables due to pesticide residues. Thus, the cost of external effects due to pesticide residues amounted to US$ 9.64 million (Table 7.3). These costs are borne by the vegetable consumer who suffers from pesticides related ailments. This is a conservative estimate, as the study did not capture all the different types of vegetables grown and consumed.

Table 7.3: Pesticide use externality for vegetable production in the sub-sector, 2008

Vegetable	Production (million metric tonnes) [a]	% of samples above MRL	Volumes above MRL [b] (metric tonnes)	Price (US$/kg)	Loss (million US$)
Kales	0.423	5	19,261	0.13	2.50
Spinach	0.048	94	44,615	0.16	7.14
Total	0.471	49 [c]	63,876	0.15 [c]	9.64

[a] MoA, 2007 and HCDA, 2008
[b] Quantities needed to be discarded, as they are not fit for human consumption
[c] Mean
US$= 75 KSh (2008)
Source: Own survey

7.3.1.3 Livestock poisoning

Livestock such as goats, cattle, chicken, and pigs were commonly found in the study areas. Nearly all the farmers (97%) kept livestock between 2003 and 2007. Livestock is an important asset that provides regular income and can be sold in times of hardship providing a safety net. For most farmers cattle are the most important type of livestock. Next to milk and manure, they provide draft power especially in Kirinyaga and Meru districts. According to the responses of 13% of the farmers who reported having experienced livestock poisoning due to pesticide used in vegetable production, approximately 166 cattle, 2 oxen, and 2 sheep died because of pesticide poisoning between 2003 and 2007. However, though it is difficult for direct attribution without clinical analysis. Many farmers in the study site knew the main symptoms of pesticide poisoning in animals, which included difficulty in breathing, excessive foamy salivation, vomiting, bloat, abdominal cramps and fall off after feeding or passing through the sprayed fields.

Applying the direct market approach, consisting of treatment costs and value of lost livestock, the average livestock loss was estimated at US$ 118.39/farmer/year for the 13% farmers affected and at a mean of US$ 13.45/farmer/year considering all farmers of the survey who kept livestock between 2003 and 2007 (Table 7.4).

Veterinarians in the study sites also confirmed treating livestock poisoning and advising farmers not to take the milk from the sick animals. Unfortunately, they neither keep the records of the animals they treat nor update names of the farmers. According to averaged estimates from veterinarians, about 28 cases of poisoned livestock are treated per year in some Divisions[3], out of which 5 animals (18%) die. Poisonings of chicken and cats were also indicated to be common, though via secondary poisoning, when they eat dead or crippled insects and rats because of pesticide sprayed.

Table 7.4: Livestock poisoning due to pesticide used in vegetable production [a)]

Average livestock poisoned (number/farmer/year)	2
Consulted a veterinarian (% farmer)	45
Treatment expenses (US$/head/farmer/year)	9
Mortality rate of intoxicated animals (%)	11
Average cost of livestock loss (US$/farmer/year)	118

[a)] All calculations based on the 13% of the farmer who experienced livestock poisoning from pesticide used in vegetables production
Source: Own survey

Additional losses occurred when the milking animals (cows and goats) were not milked or the milk from the poisoned animals was disposed of because of being unhealthy for consumption. However, due to the lack of more detailed information those additional losses were not considered in this study.

[3] Third administrative unit of Kenya.

7.3.1.4 Collection and disposal of empty pesticide containers

Empty pesticide containers are considered as hazardous waste, unless they are well drained, rinsed, and disposed of appropriately. The best way to dispose of empty pesticide containers is to take them to a pesticide containers collection site. Containers taken to these sites can later be recycled. However, this method of disposal does not exist in Kenya and many small scale farmers either throw them in latrines, crop fields, or water bodies (wells, dam, river, and pond), burry them, or reuse them. Shallow burial of empty containers as most of the farmers did, might lead to pesticides eventually leaching into the soil and buildup of pesticide waste underground, which implies that the environmental fate is unclear. This is both, a health and a safety risk, because it is difficult to understand whether a burial site is close to underground water sources as ground water levels in Kenya changes between rainy and dry seasons.

In 2007, Crop Life Kenya with assistance of Crop Life International conducted a Container Survey. The objective of the survey was to assess empty pesticide container handling, disposal, and management in Kenya. It found 24,783,062 empty containers across the country's major horticultural production areas, which were projected to increase to 32,509,953 containers in the year 2010 (AAK, 2008).

The field observation module of the farm household survey of 2008 investigated the mode of empty pesticide container disposal, and showed approximately 536 freshly used pesticide containers either lying in the vegetable field or in the farm compound of the 425 farmers surveyed. With a conservative assumption that this represents practices of vegetable farmers in general, and with two crops per year this accumulates to 2.5 empty containers per farmer per year. The cost of collection of these containers can be estimated at US$ 0.34/farmer/year, based on the deposit-refund of US$ 0.13/container[4], which is currently being applied for soda bottles in Kenya. Since this deposit is collected at the point of sale for soda bottles, it would imply that farmers themselves take the empty pesticide containers to the agrochemical dealers just like the soda consumers. In a deposit–refund system, farmers pay deposits that are added to the price of the pesticide and receive refunds when they return the empty container. Since farmers dispose empty pesticide

[4] Most of the containers were made of glass, metal, or plastic containers, in range of 200 ml to 500 ml. This is almost equivalent to soda bottles of 300-500 ml. The container can be recycled into "New" pesticide containers, but farmers should do the thorough cleaning prior to taking them back to reduce costs of recycling.

containers in an inappropriate manner, the deposit here is used to recover the externality. However, the benefit associated with pesticide container return is the externality reduced plus the reuse value and cost saving from alternative disposal methods, while the cost is generated from the return process. Fullerton and Kinnaman (1995) concluded that fees for waste collection should be priced as if disposal and recycling are the only two main disposal options.

7.3.1.5 Cost of Government regulation and research

The budget allocated by the government to avoid pesticide side effects represents a proxy for pesticide externalities. There are two main bodies empowered by Kenyan Laws to register and control the use of pesticides in Kenya. These are the Agrochemical Association of Kenya (AAK) and the Pest Control Products Board (PCPB).

An estimation was made to indicate as to what proportional expenses are made to regulate pesticide use through the fraction of the pesticides estimated as being used in vegetable production (570 metric tonnes) to the average import of 2004-2006 (6,999 metric tonnes) (PCPB, 2004-2006).

Table 7.5 shows the approximate budget share by the vegetable sub-sector from AAK and PCPB. Although, in principle these budgets are required even for the registration and control of less harmful bio-pesticides and biological controls they can as well be minimized if the external costs of pesticides are reduced. Assuming that 30% (Conservative estimate based on the budget for training and controls for proper use) of the average costs calculated for the vegetable sub-sector (US$ 60,382) can be reduced if the pesticide related external costs are minimized gives US$ 18,115.

Table 7.5: Government regulation budgets to prevent pesticide risks

Organization	Budget in (US$)			Budget for vegetables [a)]
	2006	2005	Average	
AAK	263,680	274,719	269,200	21,924
PCPB	499,405	445,048	472,227	38,458
Total	763,085	719,767	741,426	60,382

[a)] Own calculation
Source:AAK, 2005-2006 and PCPB, 2006

Further to these bodies, local extension officers at sub-location levels also give advice and information concerning pesticide use. Pesticide companies also allocate considerable resources to launch media campaigns, farm-based demonstrations, regular farmer visits, workshops and farmers' meetings. They also promote research combined with demonstrations to highlight pesticide efficacy aspects, mainly to prove the superiority of their products. Among the 4,805 active Non-Governmental Organizations (NGOs) who work in the country (Directory of NGOs in Kenya, 2005) 74 were involved in the agricultural extension activities. The expenditures incurred by pesticide companies are not included as an externality or indirect effect, because they do so to promote pesticide use and the impact of their activities were already estimated in terms of health damages, livestock loss, and residues in vegetables. The NGOs and extension officers have small budgetary allocation to impart training on pesticides, and were hence not accounted for.

7.3.2 Quantified Pesticide side effects

7.3.2.1 Effects of pesticides on beneficial arthropods and birds

From the farm household survey of 2008 about 21%, 37%, 35% and 6% of the interviewed farmer had observed dead bees, natural enemies, soil biota, and birds respectively in their vegetable fields during or within 24 hours after spraying pesticides between 2003 and 2008. Excluding the farmers from the total sample, who had not checked the vegetable plot for dead beneficial insects or birds after spraying and those that did not re-enter the field within 24 hours almost doubles the frequencies (bees 37%, natural enemies 60%, soil biota 61%, and birds 11%).

When asked which pesticides they had sprayed prior to their observation dimethoate (Dimeton 40EC) was the main pesticide, followed by cyhalothrin (Karate 25C), cyfluthrin (Bull dock 25EC), fenpyroximate (Ogor 40EC), and carbofuran (Furadan). In general, all the pesticides that farmers listed are reported by Mineau et al. (1999) to be very toxic to beneficial arthropods and birds. Some farmers even explained how they observed earthworms dying as they emerged from the contaminated field and that the birds that ate the earthworms died too.

In general, the majority of the farmers reported to have observed very few dead bees, natural enemies, soil biota, and birds per spraying. However, 11% had also observed many (over 1000) dead ladybird beetles (Table 7.6). An average of 10%, 15%, 17%, and 8% of the interviewed farmers had also heard neighboring farmers having witnessed dead bees, natural enemies, soil biota and birds respectively in their vegetable plots 24 hours after spraying. The extent of kills of these organisms is difficult to determine because most of them are often highly mobile, and birds often live far from sprayed fields and can as well die on the way or in inconspicuous locations. Equally difficult is the counting of arthropods of which surveyed farmers just gave a rough estimate.

Table 7.6: Farmers observation of dead beneficial arthropods and birds (%)

Estimates[a)]	Bees	Natural enemies				Soil biota			Birds
		Ants	Bee-tles	Drago-n flies	Spi-ders	Cri-ckets	Earth-worms	Milli-pedes	
Very few	74	74	78	88	78	81	72	97	71
Few	11	10	8	3	11	9	12	3	17
Many	4	4	2	0	1	3	3	0	0
Too many	0	0	11	0	3	0	1	0	0
Dont know	11	13	2	8	8	7	13	0	13

[a)] Very few (<50), Few (50-100), Many (101-1000), Too many (≥1001)
Source: Own survey

Over 66% of the total farmers interviewed perceive that the presence of bees, natural enemies, soil biota, and birds in their vegetable fields had decreased. On the other hand, 17% of farmers perceive an increase (Figure 7.1). The majority of farmers mainly attributed the decrease to increased use of pesticides. However, birds decrease was least associated with the increased use of pesticides (Figure 7.2)

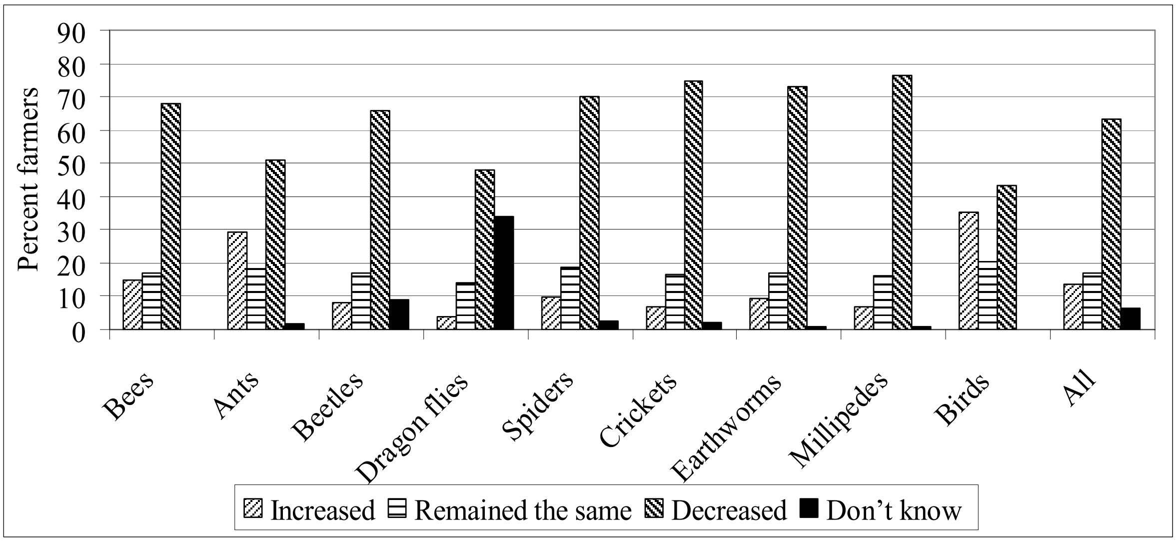

Figure 7.1: Farmers perception of the presence of beneficial arthropods and birds in vegetable fields as compared from 2003 to 2008
Source: Own survey

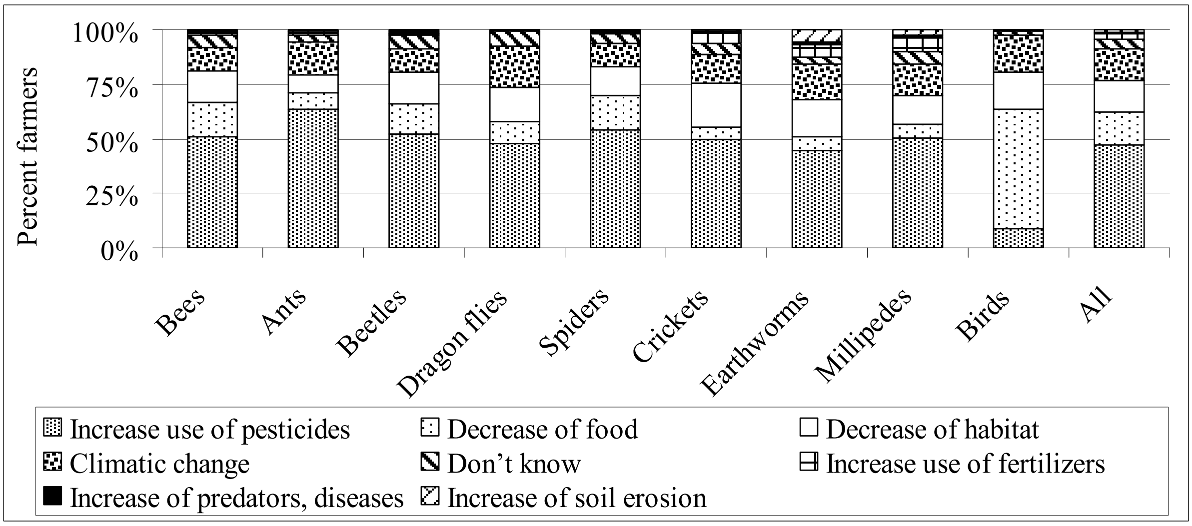

Figure 7.2: Farmers perception of the factor associated with decline of beneficial arthropods and birds in vegetable fields as compared from 2003 to 2008
Source: Own survey

With conservative assumption that on average a farmer observes about 25 dead beneficial arthropods and birds in a single application, and assuming that this occurs only twice in a season this comes to about 7.32[5] million beneficial insects and birds lost in a year.

Many insects are beneficial to man and ecology. Honeybees and wild bees are vital for pollination of crops including vegetables. Globally, of the approximated 300 commercial crops, about 84% are insect pollinated (Williams, 1996). Bees are responsible for pollination of over 80–85% of most of the cultivated crops, representing approximately one-third of global food production mostly pollinated by bees (Klein *et al.,* 2007). A study by Kasina (2007) in Kenya found that bees through pollination increases yield of vegetables by over 25%. Similarly, the study also reported a 56% increase in the fruit weight and size of capsicum due to cross-pollination as a result of bees pollination. Besides the pollinating services, bees also provide honey and wax.

Natural enemies like ladybird beetles, praying mantis, spiders, dragonflies, and fire ants play a major role in keeping populations of many pests under control. In situations where they are eliminated, secondary pest out break may occur (Dent, 1991). In such a case, additional pesticide treatments have to be made in order to prevent yield losses. The extra costs of pesticide used can in this case be taken as the pesticide externality. Fungicides also can accelerate the pest outbreaks when they reduce fungal pathogens that are naturally parasitic on many insect pests. Soil biota like earthworms, millipedes, and crickets play a key role in trash burial, nutrient cycling, soil aeration, and drainage. Earthworms particularly aid in bringing new soil to the surface at a rate of up to 200 tonnes/ha/year in US (Pimentel *et al.,* 1993). This action improves soil formation and structure for plant growth and makes various nutrients more available for absorption by plants. However, they are as well sensitive to a range of agricultural pesticides (Park *et al.,* 1999).

Birds are also very important in the ecosystem. They support dispersion and distribution of tree and wildflower seeds, support in pollination, reduce pollution by eating dead animals they find, and they provide revenue through the bird watching ecotourism. In 2007, approximately 2 million tourists visited Kenya and this generated revenues of about US$ 0.9 million. Though no official statistics for ecotourism exist, more and more increasingly,

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[5] The estimated number of dead beneficial insects was extrapolated with 40% of the number of farmers estimated in the vegetable sub-sector (183,021) and multiplied by 2 representing two crop seasons per year.

tourists are said to come purposely for bird watch (CBS, 2007). Giving indication of the 'unvalued' massive costs, associated with the use of pesticides.

7.3.2.2 Pesticides resistance

Over 50% of the farmers reported that they had at one time experienced a problem with pests which could not be controlled even when using the right pesticides at its appropriate quantity (the recommended rate) and quality (not expired), although these pesticides had been working fine before. When asked what they did: 37% reported they increased the spraying frequency, 28% changed to different products, 20% increased concentration, and 15% mixed pesticides. Answering the question on how they perceive the pest control power of the current pesticides in the market, over half (52%) responded that they are weak.

Chemical resistance in Diamond Back Moth (DBM) has been confirmed in Kenya (Kibata, 1997; Cooper, 2001). Globally, about 520 insect species, 150 plant pathogenic species, and about 273 weeds species are now resistant to pesticides (Stuart, 2003). In Sri Lanka in the Matale district, land was abandoned because pesticides became ineffective in protecting crops (Wilson and Tisdell, 2001).

7.3.3 Expert Consultation

The main objectives were to validate, extrapolate, and substantiate available empirical findings of some of the pesticide externalities from farmers' estimates. The consultation during the expert workshop confirmed the results presented in the preceding section as realistic and rather conservative. Experts ranked natural enemies as the major organism being negatively affected by pesticide use in the vegetable sub-sector followed by people through direct human health impairment, livestock, farm birds, aquatic organisms, and bees in the order of frequencies. Water quality and residues in vegetables were the least frequent mentioned external and indirect effect (Table 7.7).

Table 7.7: Expert rating of pesticide externalities in Kenyan vegetable sub-sector (% of responses)

Category	Cannot say	Not severe	Moderate	Severe	Very severe
Human health	0	4	24	28	44
Domestic animals	0	8	40	44	8
Farmland birds	8	20	24	40	8
Honeybee and wild bee	16	4	28	28	24
Natural enemies (spiders, beetles, dragon flies, ants)	0	8	16	16	60
Soil biota (earthworms, millipedes and crickets)	16	24	16	20	24
Aquatic organisms (frogs and fish)	8	8	28	32	24
Pesticide residue on vegetables	0	52	28	12	8
Water quality	4	8	32	36	20

Source: Own survey

Seventy four percent of the experts also identified pesticide runoff as the main essential cause of water pollution in the current vegetable production systems and 66% expect negative effects on their own health due to pesticide residues on the vegetables they consume.

7.3.4 Summary of the externalities costs in the sub-sector

Table 7.8 summarizes the indirect and external costs associated with pesticide use in vegetable production in Kenya. Extrapolation of the human health costs to the entire vegetable sub-sector with the total number of vegetable farmers estimated at 183,021 gives a welfare loss of US$ 0.65 million/year. Similarly, livestock loss of US$ 13.45/farmer/year and costs of avoided pollution through a deposit-refund system for empty pesticide containers of US$ 0.34/farmer/year extrapolated to include all vegetable farmers raised the costs significantly (Table 7.8).

Overall, indirect costs borne by farmers themselves summed up to US$ 3.11 million/year. Dividing this cost by the direct cost of pesticides use in the vegetable sub-sector of US$

5.06 million[6] gives a ratio of 1: 0.6 indicating that when a farmer spent 1 US$ in direct costs, it also costs him or her US$ 0.6 indirectly. Including other related external costs leads to a ratio of 1:2.5.

Table 7.8: Total estimated external costs from pesticides in the vegetable sub-sector in Kenya

Type of costs	US$/ farmer/ year	Million US$/ year	Other effects identified, but not quantified
Health impact	3.54	0.65	Chronic health effects of farmers, deaths, effects on hired labour and consumers
Livestock	13.45	2.46	Produce loss
Vegetable loss	52.67	9.64	Higher consumer prices due to low supply
Collection and disposal of empty pesticide containers	0.34	0.06	
Government regulations to prevent damage	0.10	0.02	Costs of administration by pesticide-related research at universities and environmental agencies
Loss of natural enemies	NQ	NQ	Loss of natural enemies
Cost of pesticide resistance	NQ	NQ	Cost of extra pesticides for the control of red spider mite that farmers claimed it was resistant to pesticides and they increased the number of applications and application rates to counter it
Honeybee and pollination losses	NQ	NQ	Loss of honey and honey bees
Bird losses	NQ	NQ	Loss of farmland birds
Indirect costs	16.99	3.11	
External costs	53.11	9.72	
Direct costs	27.66	5.06	
Ratio (indirect: direct)		0.62	
Ratio (external: direct)		2.54	

NQ= Effects not valued

Source: Own survey

[6] The direct cost of US$ 14 was multiplied by 2, assuming two crop seasons per year and then extrapolated with the total number of farmer estimated in the sub-sector.

7.3.5 Farmers' response to pesticide prices

The existence of externalities in vegetable production indicates that current levels of use of pesticides are above the social optimum level. In addition, the application methods are inappropriate. Thus, pesticide reductions as well as changes in application techniques are necessary for reducing human and environmental externalities. In theory, there are several possibilities how this can be achieved. One such possibility is by introducing a pesticide tax to internalize the external costs. The aim of such a tax would be to alter pesticide consumption, inducing shifts to other pest control technologies like integrated pest management or other more benign products and less toxic pesticides, which in this case are taxed less and thus comparatively cheaper. Such a tax can then generate revenues that can be used as support to research and development of environmentally friendly technologies as well as training and extension systems of disseminating such technologies.

In order to assess the possibilities of such a tax toward reductions and shifts in pesticides consumption, farmers were asked for pesticide amount and price of their favorite or the most frequently used pesticide. By hypothetical price changes farmers were then asked the amounts they would be willing to buy to ascertain their response to price changes. This approach is a contingent valuation method, with a modified open-ended elicitation technique. For the analysis, responses were then categorized as follow:

- Increase by ≥50%, (if farmer would increase the current amount by more than half but less than double),
- Current amount 100%, (if the farmer would buy the same amount),
- Reduce by <50%, (if the farmer responded that he/she would buy more than half but less than the current amount),
- Reduce by ≥50%, (if the farmer responded that he/she would buy less than half of the current amount),
- Not buy, (if the farmer responded that he/she would change to cheaper pesticides, would not buy at all, or would turn to use of other pests control practices like use of concoctions such as Mexican marigold and neem extracts, use of ash, physical killing, and spraying pure water for insect pests.

Of the 425 farmers interviewed, only 15% farmers said they would reduce their pesticide use by ≥50% or not buy at all if the pesticide price was raised by 50% (Table 7.9). Even if the pesticide prices were to be doubled, only 59% of the farmers would reduce their pesticide use or shift to other pest control methods. Further increasing the pesticide price up to 200% would still have no effect on the decision of 20% of the farmers on their choice of pesticide use. A sizeable number of farmers would increase their pesticide demand if the prices were reduced, supporting findings elsewhere that pesticide subsidies result in high pesticide use (Dasgupta *et al.,* 2001). However, about 2% would not buy at all even when price were reduced by over 50%. These farmers feared that the price drop would be a sign of fake pesticides.

Table 7.9: Farmers' response to hypothesized pesticide price changes (%)

Use of pesticides	Increase ≥50%	Current amount	Reduce by <50%	Reduce by ≥50%	Not buy
Price increase by:					
50%	3	80	1	9	6
100%	2	37	1	35	24
200%	1	20	1	22	55
Price decrease by:					
50%	26	63	7	1	2
75%	36	56	2	4	1

Source: Own survey

On average, the decision on the amount of the pesticides by about 86% of the farmers was price responsive. This very high price responsiveness of pesticide use indicates that tax and price adjustments can be effective instruments to achieve socially optimal levels of pesticide use under current Kenyan conditions. In Philippines, Antle and Pingali (1995) found that taxation of pesticides would reduce the average production costs of rice when health costs are included, while in Ecuador, policy simulations showed that average production costs would be lower if a tax was applied to the most hazardous pesticide used by potato farmers (Antle *et al.,* 1998). In Costa Rica, Agne and Waibel (2005) found that, taxes could be an effective tool to reduce pesticide use for coffee production.

7.4 Summary

In this chapter, the indirect costs posed by pesticide use in the vegetable production were presented. The total additional costs including indirect costs and the externalities of pesticides used in vegetable production in Kenya were estimated at US$ 12.83 million/year or 58 US$ per ha. When analyzing the composition of the additional costs of pesticides it is shown that the highest share was accounted by potential vegetable losses, followed by livestock losses, human health costs, disposal of empty pesticide containers and damage prevention costs.

Indirect costs borne by the farmer in terms of health costs and livestock loss were calculated at US$ 3.11 million. Dividing this by the direct costs of US$ 5.06 million, result in a ratio of 1:0.6 indicating that when a farmer spent US$ 1 in direct costs, it also costs him or her US$ 0.6 indirectly. Including the other potential external costs lead to a ratio of 1:2.5. In addition, although not valued over 58% of the farmers had also observed mortality of beneficial arthropods and birds 24 hours after spraying pesticides, and about 80% had witnessed a cumulative decline of the same species populations in their sprayed fields, of which they attributed to the pesticides sprayed. It was estimated that about 7.32 millions beneficial insects and birds are lost in a year due to pesticide use. These beneficial arthropods are very important for the ecosystem and contribute substantially to the ‘economy’. Thus implies that the ‘true’ cost of pesticides is currently grossly understated.

If externalities were incorporated in the market price of pesticide products, a switch to more human and environmental health friendly pest control methods, such as use of less toxic products and switch to integrated pest management (IPM) practices would be more favorable as supported by the farmer response to hypothetical pesticides price adjustments. However, design and implementation would benefit from evaluation of such systems under the current pest control conditions.

Lessons from bio control based IPM for cabbage as an alternative to chemical control have already been found to decrease negative human health effects associated with pesticide use (Jankowski, 2007). Other pest management strategies such as intercropping (Legutowska *et al.,* 2002), tillage type and crop rotation (Hummel *et al.,* 2002) have also been shown to significantly reduce pests. These strategies are cost-effective and environmentally friendly thus there is a need to bring to the attention of farmers of these pests control methods. In addition, a deposit-refund system where a pesticide container charge (the deposit) is left with the pesticide vendors until the container is taken back (refund) is suggested to reduce the unsafe disposal observed. The container can then be recycled into "New" pesticide containers, fencing posts and others.

The pesticide residue testing findings support recommendations for routine monitoring of these pollutants in vegetables to minimize human health risks of consumers. Mechanism to facilitate formal documentation of pesticide related cases of poisoning of both human and livestock should be put in place, as this would help greatly in the monitoring of the extend of the hazard. This may be done by advocating free medical assistances in medical and veterinarian centers for those affected. The costs for these services could be recovered from an appropriate tax imposed on the pesticides that cause most damage. This would further stimulate the development and adoption of safer alternatives.

Further research is recommended to value the effects that could only be identified but not quantified *e.g.* the health costs should cover all individuals exposed to pesticides, *i.e.* pesticide traders, hired workers and consumers and incorporate pesticide-induced chronic illnesses and deaths.

8 Summary, conclusions and recommendations

8.1 Summary

The objectives of this study were to: i) identify pesticide use and handling practices by small scale farmers and evaluate their determinants, ii) examine incidences of acute pesticide poisoning symptoms and associated health costs over time, and iii) quantify and value the magnitude of pesticide negative externalities in vegetable production.

This research has addressed these objectives using data collected by means of farm household surveys, vegetable pesticide residue analysis, and expert interviews. The data were also supplemented with information from inventory and secondary data collected from research organizations and government institutions.

Chapter two clearly indicates that vegetable production and pesticide consumption have increased over time. There are a number of institutions, both governmental, semi-government and private members associations, which directly or indirectly contribute, toward improving the vegetable sub-sector. Of notable influence is the Pest Control Products Board that is involved with registration of all agricultural chemicals imported or distributed in Kenya. Other bodies involved in pesticide regulation include the Agrochemicals Association of Kenya, National Environment Management Authority, Kenya Plant Health Inspectorate Service, and the Kenya Environment Secretariat. However, in spite of many governments agent involved in pesticides regulation and use, evidence from many reports indicates illegal and inappropriate use of pesticides, suggesting a dysfunctional regulatory framework. This increases the danger of human poisoning and damage to the environment.

The data collection framework and data collection methods employed for this research were presented in chapter three. The chapter first introduced the general framework and the challenges involved in externalities evaluation. Earlier studies were grouped into three broad categories: i) those that follow an 'accounting approach' based on actual market prices with scientific evidence of the externalities, ii) those which utilize the 'economic approach' and make use of hypothetical and surrogate markets, and iii) those that combine the two approaches. This study followed a modification of the accounting approach in three stages. The first stage involved identification of the externalities relevant in the vegetable sub-sector that was captured by literature review, group discussions and expert debates. In the second stage, quantification and valuation was conducted by analyzing existing information, farm household surveys, and pesticide residue analysis. In the final stage, the estimates were validated in expert workshops.

The fourth chapter looked at pesticide use at farm level. It gave a detailed analysis of pesticide use in terms of types of products used, pattern of application, and the associated risks. Results showed that in vegetable production pesticide products had increased, with about 19 new products applied in 2008 as compared to 2005. There was also a significant increase in the application rate, and intensity of use. Potatoes and tomatoes were the most pesticide-intensive crops. Approximately, 570 metric tonnes of pesticides applied were estimated in 2008, of which 61% are classified as bad actor chemicals (PANNA, 2009). Similarly, according to World Health Organization risk classification, 7% of the pesticides commonly used are extremely hazardous (WHO Ia and WHO Ib) and 36% moderately hazardous (WHO II).

Mean EIQ–value for all the pesticides was calculated at 18, 10 and 77 for farm workers, consumers and the environment respectively with an overall average at 35. These results indicate that the sub-sector potentially has negative external effects, especially in the environmental dimension. The EIQ field use rating clearly demonstrated that different pesticide product pose different risks to the environment and those that pose low threat could be chosen to manage pests.

Chapter five reported pesticide-handling practices and factors associated with those practices. Although majority of farmers (81%) were aware of the risks involved in pesticide use, an equivalent proportion (85%) still inappropriately handled pesticides, mainly through, unsafe storage (23%), unsafe disposal of leftover either sprays solutions, rinsate and empty pesticide containers (40%), failure to wear the required minimum protective gear (68%), or over-dosed pesticides (27%).

An econometric model to explain pesticide-handling practices demonstrated that record keeping of vegetable production activities could significantly reduce the inappropriate pesticides handling practices. On the other hand, handling pesticides categorized as WHO II and receiving advice on pesticides use from pesticide traders significantly increased inappropriate pesticides handling practices. This suggests the need for more participatory and targeted outreach programmes, which deal specifically on promotion of record keeping and reduction on use of pesticides, particularly those falling in WHO II. Contrary to theoretical expectations, farmers' pesticide risk perceptions and previous experiences of a negative pesticide impact did not influence farmers' pesticide handling practices. This point to the fact that learning from experiences is not supported. Perhaps farmer accepts these impacts as normal risks of farming and they get used to them. The results further suggest widespread inappropriate handling of pesticides in Kirinyaga and Makueni districts. The district of Meru appears to be less prone to these practices perhaps due to record keeping. Further research on specific location differences may provide more useful insights.

In chapter six, the analysis of pesticides related health effects are presented. The findings in this chapter indicates that the incidences of pesticide related acute illness increased by over 70% with about 34% of the farmers reporting at least one pesticide-related acute symptom in 2008 as compared to 20% in 2005. New episodes were calculated at 55%, indicating persistence of the problem to many farmers. Majority used home remedies to cure the symptoms and they only visited the health clinic if the symptoms either persisted or became serious. This evidence seems to suggest that many farmers treat acute pesticide related acute illness as minor problems that do not warrant medical attention.

Pesticide related health costs were calculated on average at US$ 3.54/farmer/year. These costs are about 47% of mean household pesticide expenditures. However, it is of value to note that these costs are the lower boundary because the chronic diseases resulting from long-term pesticide exposure, the costs to restore health status completely and non-monetary costs like suffering are not accounted for.

The link between health costs and the pesticide related acute symptoms was established through the Tobit panel model. The results of this model also point out that the severity of the symptom is an important factor influencing the health costs. In a different model, inappropriate handling of pesticides and handling different pesticide products were major risk factors for pesticide poisoning symptoms. Level of education, record keeping of production activities and use of protective equipments, particularly apron/coat and facemask, considerably reduce these symptoms.

The indirect costs posed by pesticide use in the vegetable production were presented in chapter seven. These costs were estimated at US$ 12.83 million/year or 58 US$ per ha. The bulk of the costs were accounted by potential vegetable losses, followed by livestock losses, human health costs, disposal of empty pesticide containers and damage prevention costs. Indirect costs borne by the farmer in terms of health costs and livestock loss were calculated at US$ 3.11 million. A ratio of 1:0.6 was calculated when these costs were compared to the direct costs of pesticide use, indicating that when a farmer spent US$ 1 in direct costs, it also costs him or her US$ 0.6 indirectly. Including other external costs puts the ratio at 1:2.5, showing that the external costs are quite higher than the currently paid price at the farm gate level. It is thought that if these externalities could be incorporated in the market price of pesticides, a switch to more human and environmental health friendly pest control methods, such as use of less toxic products and switch to integrated pest management (IPM) practices, would be more favorable as supported by the farmers' responses to hypothetical pesticide-price-adjustments. Besides, although not valued, over half of the interviewed farmer had observed mortality of beneficial arthropods and birds 24 hours after spraying pesticides. It was estimated that about 7.32 millions beneficial insects and birds are lost in a year due to the use of pesticides. These beneficial arthropods are very important for the ecosystem and contribute substantially to the economy.

8.2 Conclusions

The findings of this study revealed that the pesticide use intensity in the vegetables production has increased. Results further indicate that majority of farmers inappropriately handle pesticides. Such heavy use of pesticides accompanied with unsafe handling increased the risks of exposure not only to the farm workers, but to the entire society as well.

The regression results confirm that record keeping of production activities by farmers can play a significant role in the reduction of inappropriate pesticide handling practices, while handling pesticides in WHO II and receiving advice on pesticides use from pesticide traders significantly increases those unsafe practices.

The lack of an association between previous experience of a negative pesticide impact and pesticide handling practices support the study by Kishi *et al.* (1995) and Ajayi (2000) which found that pesticide applicators tend to accept a certain level of illness as an expected and normal part of farming. Corroborating the findings, only few farmers among those who reported pesticide-related health problems sought medical attention at a local health facility. Thus, many farmers treat pesticide related acute illness as minor problems that do not warrant medical attention. This trend is worrying because not only the health of farmers is affected but also the whole family is endangered. Furthermore, the effect on entire society is likely since water sources and the entire ecosystem is affected.

Findings also point to specific districts like Kirinyaga and Makueni experiencing higher prevalence of unsafe practices while Meru Central district appears to be less prone to those practices. There are also strong indications that wearing of protective equipments actually reduces significantly the pesticide related health problems.

An overall estimation of pesticide related indirect costs shows that they are quite higher than the current price paid by farmers. Meaning that, the 'true' cost of pesticides is currently grossly understated. If these costs were incorporated in the market price of pesticide products, a switch to more human and environmental health friendly pest control methods, such as use of less toxic products and integrated pest management practices would be more favorable. This is also in line with farmers' responses to hypothetical pesticides price adjustments. However, design and implementation would benefit from evaluation of such systems under the current pest control conditions. Lessons from bio control based IPM for cabbage as an alternative to chemical control have already been found to be very helpful by decreasing risks to human health (Jankowski, 2007). Other pest management strategies such as intercropping (Legutowska *et al.,* 2002), tillage type and crop rotation (Hummel *et al.,* 2002) have also been shown to significantly reduce pests. These strategies are cost-effective and environmentally friendly. Thus, there is a need to raise farmers' attention about these pests control methods.

Finally, there are several ways in which this study has contributed to academic literature. The research has provided the first estimates of external costs of pesticide use in the Kenyan vegetable sub-sector contributing to the on-going concerns of the pesticide harmful effects in the developing countries. The procedure developed can easily be applied in the assessment of externalities in the entire agriculture sector or in other developing countries.

The second critical issue addressed in this study is the understanding of the inappropriate pesticide handling practices at farm level in Kenya. Finally, the study highlights the need for panel data in estimating the pesticide related health costs and acute symptoms.

8.3 Recommendations

Based on the findings in this study, the following recommendations are made:
First, given the widespread inappropriate pesticides handling practices identified, it is suggested that policymakers to design effective, more participatory and targeted outreach programmes, which deal specifically on promotion of record keeping of farming activities by farmers, this was demonstrated by econometric analysis to be an effective tool to raise farmers' awareness.

Second, more information on the broader long-term negative effects of pesticides to the human health and to environment should be disseminated. In addition, promotion of the use of personal protective equipments seems to be very relevant.

Third, the indirect costs estimated should be made known to a broader audience and explicit to everybody. This would provide an opportunity for entering into a policy dialogue. As a starting point, these costs could be indicated on the pesticide labels particularly the more hazard ones (WHO Iab and II). This would allow farmers to make informed choices. In a similar note, an effort to discourage cheap availability of these toxic pesticides to farmers is also suggested.

Fourth, a deposit-refund collection system, whereby a pesticide container charge (the deposit) is left with the pesticide vendors until the container is taken back (refund) could be establishment. This would reduce the unsafe disposal of empty pesticide containers.

Fifth, mechanism to facilitate formal documentation of pesticide related cases of poisoning of both human and livestock should be put in place. This may be stimulated by advocating free medical assistances for pesticide poisoning in medical and veterinarian. The costs for these services could be recovered from an appropriate tax imposed on the pesticides that cause most damage. The taxation could also stimulate the development and adoption of safer pest control alternatives involving integrated pest management (IPM). In addition, it is necessary to include an intensive residue monitoring system particularly on domestic vegetables.

Sixth, in view of the increasing trends in pesticide use and the results of the residue testing, continuous monitoring for pesticides residues is needed in the vegetables in order to protect the consumers from health hazards involved.

Finally, it is recommended that further research be carried out to come up with more specified policy recommendations. However, it is believed that this study has opened the door for more studies related to pesticide externalities in developing countries. Such studies are very important particularly in Africa where pesticide externalities could make people more vulnerable to poverty.

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List of Appendices

Appendix A: List of Banned Pest Control Products with date of ban

Common name	Use	Year
2,4,5 T (2,4,5 – T)	Herbicide	1986
5 Isomers of Hexachlorocyclo-hexane	Fungicide	1986
Aldrin	Insecticide	2004
Benomyl, Carbofuran/Thiram combinations	Dustable powder formulations containing a combination of Benomyl above 7%, Carbofuran above 10% and Thiram above 15%	2004
Binapacryl	Miticide/Fumigant	2004
Captafol	Fungicide	1989
Chlordane	Insecticide	1986
Chlordimeform	Insecticide	1986
Chlorobenzilate	Miticide	2004
DDT (Dichlorodiphenyl Trichloroethane)	Agriculture	1986
Dibromochloropropane	Soil Fumigant	1986
Dieldrin	Insecticide	2004
Dinoseb and Dinoseb salts	Herbicide	2004
DNOC and its salts (such as Ammonium Salt, Potassium salt & Sodium Salt)	Insecticide, Fungicide, Herbicide	2004
Endrin	Insecticide	1986
Ethyl Parathion	Insecticide, All formulations banned except for capsule suspensions	1988
Ethylene dibromide	Soil Fumigant	1986
Ethylene Dichloride	Fumigant	2004
Ethylene Oxide	Fumigant	2004
Fluoroacetamide	Rodenticide	2004
Heptachlor	Insecticide	1986
Hexachlorobenzene (HCB)	Fungicide	2004
Mercury Compounds	Fungicides, seed treatment	2004
Methyl Parathion	Insecticide, All formulations banned except for capsule suspensions	1988
Monocrotophos	Insecticide/Acaricide	2004
Pentachlorophenol	Herbicide	2004
Phosphamidon	Insecticide, Soluble liquid formulations of the substance that exceed 1000g active ingredient/L	2004
Toxaphene (Camphechlor)	Insecticide	1986

Source: PCPB, 2007

Appendix B: List of Restricted Pest Control Products

Common name	Remarks
Benomyl, Carbofuran/Thiram combinations	Dustable powder formulations containing a combination of Benomyl below 7%, Carbofuran below 10% and Thiram below 15%
DDT (Dichlorodiphenyl trichloroethane)	Insecticide, restricted use to Public Health for mosquito control in mosquito breeding grounds. Banned for agricultural use
Ethyl Parathion	Insecticide, capsule suspension formulations allowed in 1998
Lindane-pure gamma – BHC	Insecticide, restricted use, for seed dressing only
Methyl parathion	Insecticide, capsule suspension formulations allowed in 1998
Monocrotophos	Insecticide/Acaricide, soluble liquid formulations of the substance that are below 600g active ingredient/L
Phosphamidon	Insecticide, Soluble liquid formulations of the substance that is below 1000g active ingredient/L

Source: PCPB, 2007

Appendix C: Survey questionnaire for farmers' interviews

Universität Hannover

International Centre of Insect Physiology and Ecology
Tropical Insect Science for Development
icipe

Farmer awareness, knowledge and perceptions of pesticides negative externalities in vegetable production in Kenya

1. Name of household head ____

2. Main respondent (if different from head) ________________________________

3. District ______________________________

4. Location _____________________________

5. Sub-location __________________________

6. Locality______________________________

7. Interviewer name ____

8. Start time _____________end ____________

9. Previous survey participated in ____________

10. Old questionnaire number_______________

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:________**

Number	Question	Coding/response	Response
	Section A: Bio data		
1.	Gender of the respondent	1) Male 2) Female	
2.	Age of the farm-decision maker		
3.	Education of the farm-decision maker	0) None 1) Pre-primary school 2) Primary school 3) Secondary school 4) College	
4.	Years worked as an agricultural and as a vegetable farmer	Agricultural: Vegetable farmer:	
5.	Total size of the land you cultivate for all crops (acres)		
	Section B: Basic farming practices		
6.	Which kind of vegetables did you grow this year and what are the average plot sizes under them?	Code: A | Acreage: Dry, Rainy (Current) | Code: A | Acreage: Dry, Rainy (Current)	
7.	Do you irrigate your vegetable crops?	1) Yes 2) No if no, go to No. 10	
8.	Which method of irrigation do you use?	1) Bucket 2) Furrow 3) Sprinkler 4) Drip 5) Basin 6) Pipe 7) 8)	
9.	What are the main sources of water for irrigation?	1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 9) Dam 10) Pond 11)	

Code A: 1) French beans 2) Spinach 3) Carrots 4) Kales 5) Cabbage 6) Peas 7) Baby corn 8) Tomatoes 9) Leeks 10) Onions 11) Capsicums 12) Okra 13) Asian vegetables 14) Valore 15) Tuwer 16) Turia 17) Tindori 18) Snaps 19) Butternuts 20) 21) 22) 23)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
10.	What types and quantity of pesticides did you use in different vegetables this season?		

Crop code (Code: A)	Product name (Code: B)	ml or g / pump	Size of the pump (lt)	No of pumps	No of times	PHI (Days)	Price per package	
							Package size	Price (Ksh)

Code A: 1) French beans 2) Spinach 3) Carrots 4) Kales 5) Cabbage 6) Peas 7) Baby corn 8) Tomatoes 9) Leeks 10) Onions 11) Capsicums 12) Okra 13) Asian vegetables 14) Valore 15) Tuwer 16) Turia 17) Tindori 18) Snaps 19) Butternuts 20) 21) 22) 23)

Code B:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>11.</td><td>When was spraying of pesticide started in this farm? (Respondent should be allowed to consult with the old people in the household. For those who have bought the land and no information can be derived from the neighbors. Indicate, bought and year bought)</td><td></td><td></td></tr>
<tr><td>12.</td><td>Which types of pesticides did you use 6 years ago?</td><td></td><td></td></tr>
<tr><td>13.</td><td>Which are the major three pesticides did you use 6 year ago?
(Rank them in order of frequency of use)</td><td>1.
2.
3.</td><td></td></tr>
<tr><td>14.</td><td>Do you practice soil fumigation?</td><td>1) Yes 2) No if no, go to No. 16</td><td></td></tr>
<tr><td>15.</td><td>Which chemicals do you use?</td><td>1) Furadan 2) Mocap 3) Nemacur 4) 5)</td><td></td></tr>
<tr><td>16.</td><td>Which are the major three pesticides you use currently?
(Rank them in order of frequency of use)</td><td>1.
2.
3.</td><td></td></tr>
<tr><td></td><td colspan="2">Section C: Water and fish farming</td><td></td></tr>
<tr><td>17.</td><td>What are the current main sources of water for domestic use?</td><td>1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 9) Dam 10) Pond</td><td></td></tr>
<tr><td>18.</td><td>Rank the main sources of water for domestic use in terms of the most frequently used in the last five years?</td><td>1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 9) Dam 10) Pond</td><td></td></tr>
<tr><td>19.</td><td>How far are the nearest rivers, streams, wells, boreholes and ponds from your vegetable fields and how many are they?</td><td><table>
<tr><th>Source</th><th>Distance (feet/m/km)</th><th>Number</th><th>Location Code C: 1) Uphill 2) Downhill)</th></tr>
<tr><td>Rivers/streams</td><td></td><td></td><td></td></tr>
<tr><td>Ponds</td><td></td><td></td><td></td></tr>
<tr><td>Wells</td><td></td><td></td><td></td></tr>
<tr><td>Boreholes</td><td></td><td></td><td></td></tr>
<tr><td>Dams</td><td></td><td></td><td></td></tr>
</table></td><td></td></tr>
</table>

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
20.	How many are in your farm?	<table><tr><td>Source</td><td>Distance (feet/m/km)</td><td>Number</td></tr><tr><td>Rivers/Streams</td><td></td><td></td></tr><tr><td>Ponds</td><td></td><td></td></tr><tr><td>Wells</td><td></td><td></td></tr><tr><td>Boreholes</td><td></td><td></td></tr><tr><td>Dams</td><td></td><td></td></tr></table>	
21.	Did you notice changes in the watercolor, smell or taste five year ago?	1) Yes 2) No 101) Not applicable	
22.	How can you rate the water quality (freshness) in your ponds/ wells/dams in the last five years?	<u>**Read:**</u> 1) Increased 2) Decreased 3) Remained the same If decreased, go to No. 24. Remained the same No. 25	
23.	If increased what are the possible factors you can attribute the increase to?	1) Climatic change 5) Decrease use of pesticides 6) Decrease use of fertilizers 7) 8) 9) 99) Don't know	
24.	If decreased what are the possible factors you can attribute the declines to?	1) Climatic change 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
25.	According to your observation, is the water quality in this area been negatively affected by pesticide use?	1) Yes 2) No 3) Partly 99) Don't know	
26.	Why do you say so?		
27.	How can you rate the water quality deterioration in the locality?	<u>**Read:**</u> 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	
28.	How do you perceive the abundance of frogs in the last five years?	<u>**Read:**</u> 1) Increased 2) Decreased 3) Remained the same If decreased, go to No. 30. Remained the same No. 31	
29.	If increased what are the possible factors you attribute the increase to?	1) Climatic change 2) Increase of food 3) Increase of habitat 4) Decrease of predators and diseases 5) Decrease use of pesticides 6) Decrease use of fertilizers 7) 8) 9) 99) Don't know	
30.	If decreased what are the possible factors you can attribute the declines to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>31.</td><td>Have you ever observed dead frogs in the ponds/wells/dams/rivers?
If yes, how many were they and when was it?</td><td><table><tr><td>Source</td><td>1) Yes
2) No</td><td>Number: Code:
1 ≤50 2) ≤100 3) ≤1000
4) ≥1001 99) Don’t know</td><td>Time of the years</td></tr><tr><td>Ponds</td><td></td><td></td><td></td></tr><tr><td>Wells</td><td></td><td></td><td></td></tr><tr><td>Dams</td><td></td><td></td><td></td></tr><tr><td>Rivers</td><td></td><td></td><td></td></tr></table>If all no, go to No. 33</td><td></td></tr>
<tr><td>32.</td><td>What did you attribute the death of the frogs to?</td><td>1) Climatic change 2) Decrease of food 3) Decrease of habitat
4) Increase of predators and diseases 5) Increase use of pesticides
6) Increase use of fertilizers 7) 8)
9) 99) Don’t know</td><td></td></tr>
<tr><td>33.</td><td>Do your fellow farmers have ponds, wells or dams?</td><td>1) Yes 2) No 99) Don’t know if no, go to No. 36</td><td></td></tr>
<tr><td>34.</td><td>Have you heard them talk of observing unusual death of frogs in their ponds?</td><td>1) Yes 2) No if no, go to No. 36</td><td></td></tr>
<tr><td>35.</td><td>What did they attribute the death of the frogs to?</td><td>1) Climatic change 2) Decrease of food 3) Decrease of habitat
4) Increase of predators and diseases 5) Increase use of pesticides
6) Increase use of fertilizers 7) 8)
9) 99) Don’t know</td><td></td></tr>
<tr><td>36.</td><td>Do you have fish in your ponds?</td><td>1) Yes 2) No if no, go to No. 46</td><td></td></tr>
<tr><td>37.</td><td>How do you perceive the abundance of fish in the last five years?</td><td><u>Read</u>: 1) Increased 2) Decreased 3) Remained the same
If decreased, go to No. 39. Remained the same No. 46</td><td></td></tr>
<tr><td>38.</td><td>If increased what are the possible factors you attribute the increase to?</td><td>1) Climatic change 2) Increase of food 3) Increase of habitat
4) Decrease of predators and diseases 5) Decrease use of pesticides
6) Decrease use of fertilizers 7) 8)
9) 99) Don’t know</td><td></td></tr>
<tr><td>39.</td><td>If decreased what are the possible factors you can attribute the declines to?</td><td>1) Climatic change 2) Decrease of food 3) Decrease of habitat
4) Increase of predators and diseases 5) Increase use of pesticides
6) Increase use of fertilizers 7) 8)
9) 99) Don’t know</td><td></td></tr>
<tr><td>40.</td><td>Do you eat them or sell them?</td><td>1) Eat 2) Sell 3) Both</td><td></td></tr>
</table>

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
41.	Have you ever experience fish death in the ponds?	1) Yes 2) No if no, go to No.46	
42.	What did you attribute the death of the fish to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
43.	Did you consult anybody? (e.g. extensionist)	1) Yes 2) No if no, go to No. 45	
44.	What did they attribute the death to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
45.	What was the amount lost due to the fish death? (Ksh)		
46.	Do you know farmers who practice fish farming in the locality?	1) Yes 2) No if no, go to No. 49	
47.	Have you heard any farmer complains of unusual fish death in the locality?	1) Yes 2) No if no, go to No. 49	
48.	What was the cause?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
49.	According to your observation and what you have heard from other people how can you rate the occurrence of death of fish and frogs due to pesticides in the locality?	**Read:** 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	
50.	How can you rank these types of water pollution in the locality starting with the most damaging?	(see ranking table below)	

Read:	Rank
Fertilizer runoff or leaching	
Pesticide/chemical runoff or leaching	
Livestock waste	
Sewage/human waste	
Factories	
Deforestation	
Others	

Questionnnaire Number: ____________ Date:________________ Interviewer Number:_______

Number	Question	Coding/response	Response
	Section D: Livestock		
51.	Did the household raise any livestock during the last five year (2003-2008)?	1) Yes 2) No if no, go to No.60	
52.	How far are your horticultural fields in relation to where the household graze or get the fodder for the livestock most of the time?	**<u>Read</u>:** 1) ≤5 feet to hort crops 2) 5-10 feet to hort crops 3) 10-20 feet to hort crops 4) ≥20 feet to hort crops	
53.	Where does the household water livestock most of the time?	1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 9) Dam 10) Pond	
54.	Do you practice tick control?	1) Yes 2) No if no, go to No. 58	
55.	What type of tick control do you use most?	**<u>Read</u>:** 1) Dipping 2) Spraying 3) 4) 5)	
56.	If spraying, which chemicals do you use?	1) Triatix 2) 3) 4) 5) 6)	
57.	If spraying, do you use the same sprayer you use to spray the crops?	1) Yes 2) No	
58.	Do you feed your livestock with vegetable residues?	1) Yes 2) No	
59.	If yes, which ones?	Crop code A	
60.	Did you experience livestock poisoning due to pesticides used in the vegetable crops from 2003-2008?	1) Yes 2) No if no, go to No. 68	

<u>Code A:</u> 1) French beans 2) Spinach 3) Carrots 4) Kales 5) Cabbage 6) Peas 7) Baby corn 8) Tomatoes 9) Leeks 10) Onions 11) Capsicums 12) Okra 13)Asian vegetables 14) Valore 15) Tuwer 16) Turia 17) Tindori 18) Snaps 19) Butternuts 20) 21) 22) 23)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
61.	Which livestock were poisoned and what were the symptoms?	Code D: 1) Cattle 2) Oxen 3) Sheep 4) Goats 5) Donkeys 6) chicken 7) 8) Code: D | Symptom	
62.	How many livestock were poisoned?	Code: D | Number	
63.	How did it happen?	Code: D | Story, try to get pesticide product name	
64.	In these instances of poisoning, did you consult a veterinary officer?	1) Yes 2) No	

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>65.</td><td>How many times did you consult a veterinary officer?</td><td></td><td></td></tr>
<tr><td>66.</td><td>How much did it cost on average for treatment and transport cost?</td><td></td><td></td></tr>
<tr><td>67.</td><td>How many of those animals received treatment or died and how many times did it happen?</td><td><table>
<tr><td>Code: D</td><td>Number</td><td>Died:
1) Yes
2) No</td><td>Market cost</td><td>Number of times</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table></td><td></td></tr>
<tr><td>68.</td><td>Have you heard other neighboring farmers complain of livestock poisoning?</td><td>1) Yes 2) No if no, go to No. 70</td><td></td></tr>
<tr><td>69.</td><td>How did it happen?</td><td><table>
<tr><td>Code: D</td><td>Story, try to get pesticide product name</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table></td><td></td></tr>
<tr><td>70.</td><td>According to your observation and what you have heard from other people how can you rate the occurrence of livestock poisoning in the locality?</td><td><u>Read</u>: 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don’t know</td><td></td></tr>
</table>

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
	Section E: Bees		
71.	How do you perceive the presence of bees in your vegetable fields in the last five years? (2003-present)	**Read:** 1) Increased 2) Decreased 3) Remained the same If decreased, go to No. 73. Remained the same No. 74	
72.	If increased what are the possible factors you attribute the increase to?	1) Climatic change 2) Increase of food 3) Increase of habitat 4) Decrease of predators and diseases 5) Decrease use of pesticides 6) Decrease use of fertilizers 7) 8) 9) 99) Don't know	
73.	If decreased what are the possible factors you can attribute the declines to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
74.	Have you ever observed dead bees in your vegetable field 24hrs after spraying?	1) Yes 2) No 101) Not applicable if no, go to No. 77	
75.	If yes, which year, how many were they and what type of pesticides had you sprayed before?	(see sub-table below)	

Year	Number: Code: 1 ≤50 2) ≤100 3) ≤1000 4) ≥1001 99) Don't know	Pesticide code: B

Code B:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17)Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>76.</td><td>How frequent did you observe dead bees each time you sprayed those pesticides?</td><td><table><tr><td>Pesticide code: B</td><td><u>Read</u>: 1) Rarely 2) Occasionally
3) Frequently 4) Often 5) Always</td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>77.</td><td>Have you heard your fellow farmers talk of observing unusual death of bees in their field after spraying?</td><td>1) Yes 2) No if no, go to No. 79</td><td></td></tr>
<tr><td>78.</td><td>If yes, which year and what type of pesticide had they sprayed before?</td><td><table><tr><td>Year</td><td>Farmer</td><td>Pesticide code: B</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>79.</td><td>Do you own hives?</td><td>1) Yes 2) No if no, go to No. 81</td><td></td></tr>
<tr><td>80.</td><td>How many do you own?</td><td></td><td></td></tr>
</table>

<u>Code B</u>:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17)Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
81.	Have you ever observed dead bees near the hives?	1) Yes 2) No if no, go to No. 86	
82.	Who own those hives?	1) Own 2) Fellow farmers 3) Communal hives 4)	
83.	What did you attribute the death to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
84.	Do you eat honey or sell it?	1) Eat 2) Sell 3) Both	
85.	How much do you think you lose due to death of honeys bees?		
86.	Do you practice intercropping in the vegetable fields?	1) Yes 2) No if no, go to No. 88	
87.	If yes, which crops do you intercrop with vegetables?	1) Maize 2) Fruit 3) Sorghum 4) Chick pea 5) Sweet potatoes 6) Beans 7) Irish potato 8)	
88.	Do you normally check for the presence of other blooming plants and weeds which might attract bees before treating a field with pesticides?	1) Yes 2) No 3) Not applicable	
89.	If yes, do you spray even after observing bees in the vegetable field?	1) Yes 2) No 3) Not applicable	
90.	Do you know farmers who are bee keepers?	1) Yes 2) No if no, go to No. 93	
91.	Have you heard them say that they have observed unusual dying of bees or regular dying of bees?	1) Yes 2) No if no, go to No. 93	
92.	What did they attribute the death to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
93.	According to your observation and what you have heard from other people how can you rate the occurrence of death of honey bees due to pesticide in the locality?	**Read:** 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

Number	Question	Coding/response	Response
	Section F: Birds		
94.	How would you assess changes in overall farmland bird numbers and presence on your vegetable farm in the last 5 years? (2003-present)	**Read:** 1) Increased 2) Decreased 3) Remained the same If decreased, go to No. 98. Remained the same No. 99	
95.	Are there some season that they decline or increase?	1) Yes 2) No 99) Don't know 101) Not applicable	
96.	What species have declined or increased? (local names okay)	Declined /season | Increased /season (blank table, 6 rows)	
97.	If increased what are the possible factors you attribute the increase to?	1) Climatic change 2) Increase of food 3) Increase of habitat 4) Decrease of predators and diseases 5) Decrease use of pesticides 6) Decrease use of fertilizers 7) 8) 9) 99) Don't know	
98.	If decreased what are the possible factors you can attribute the declines to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 9) 99) Don't know	
99.	Have you ever observed dead birds in your field 24 hrs after spraying?	1) Yes 2) No 101) Not applicable if no, go to No. 103	
100.	If yes, which birds were they and which year was it? (local names allowed)	Bird name | Year | Bird name | Year (blank table, 7 rows)	

Table for question 96:

Declined /season	Increased /season

Table for question 100:

Bird name	Year	Bird name	Year

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>101.</td><td>If yes, how many birds were they and what type of pesticides had you sprayed before?</td><td><table><tr><td>Year</td><td>Farmer</td><td>Number: Code:
1 ≤50 2) ≤100 3) ≤1000
4) ≥1001 99) Don’t know</td><td>Pesticide code:
B</td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>102.</td><td>How frequent did you get dead birds each time you sprayed those pesticides?</td><td><table><tr><td>Pesticide code: B</td><td>Bird name</td><td><u>Read</u>: 1) Rarely
2) Occasionally 3) Frequently
4) Often 5) Always</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>103.</td><td>Have you heard your fellow farmers’ talk of observing dead birds in their field after spraying?</td><td>1) Yes 2) No if no, go to No. 105</td><td></td></tr>
<tr><td>104.</td><td>If yes, which year, how many birds were they and what type of pesticide had they sprayed before?</td><td><table><tr><td>Year</td><td>Farmer</td><td>Number: Code:
1 ≤50 2) ≤100 3) ≤1000
4) ≥1001 99) Don’t know</td><td>Pesticide code:
B</td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>105.</td><td>According to your observation and what you have heard from other people how can you rate the death of farmland birds due to pesticide in the locality?</td><td><u>Read</u>: 1) Very high 2) high 3) Moderate 4) Low 5) Very low
99) Don’t know</td><td></td></tr>
</table>

Code B:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td></td><td>Section G: Natural enemies</td><td></td><td></td></tr>
<tr><td>106.</td><td>Do you know any of these insects?
(An insect zoo to be shown to the farmer to state which one they know)</td><td>
<table>
<tr><td>Insect</td><td>1) Yes
2) No</td><td>Insect</td><td>1) Yes
2) No</td><td>Insect</td><td>1) Yes
2) No</td></tr>
<tr><td>1) Spider</td><td></td><td>3) Dragon</td><td></td><td>5)</td><td></td></tr>
<tr><td>2) Beetle</td><td></td><td>4) Ants</td><td></td><td>6)</td><td></td></tr>
</table>
if no to all, go to No.111</td><td></td></tr>
<tr><td>107.</td><td>If ‘yes’ what kind of insects are they?</td><td>
<table>
<tr><td>Insect</td><td>Code: E</td><td>Insect</td><td>Code: E</td><td>Insect</td><td>Code: E</td></tr>
<tr><td>1) Spider</td><td></td><td>3) Dragon</td><td></td><td>5)</td><td></td></tr>
<tr><td>2) Beetle</td><td></td><td>4) Ants</td><td></td><td>6)</td><td></td></tr>
</table></td><td></td></tr>
<tr><td>108.</td><td>How do you perceive the abundance of these insect in your vegetable fields over the last five years? (2003-present)</td><td>
<table>
<tr><td>Insect</td><td>Code:
<u>Read</u>: 1) Increased 2) Decreased
3) Remained the same, if decreased, go to No. 110. Remained the same No. 111</td></tr>
<tr><td>1) Spider</td><td></td></tr>
<tr><td>2) Beetle</td><td></td></tr>
<tr><td>3) Dragon flies</td><td></td></tr>
<tr><td>4) Ants</td><td></td></tr>
</table></td><td></td></tr>
<tr><td>109.</td><td>If increased what are the possible factors you attribute the increase to?</td><td>
<table>
<tr><td>Insect</td><td>1) Climatic change 2) Increase of food
3) Increase of habitat 4) Decrease of predators and diseases 5) Decrease use of pesticides 6) Decrease use of fertilizers
7) 8) 99) Don’t know</td></tr>
<tr><td>1) Spider</td><td></td></tr>
<tr><td>2) Beetle</td><td></td></tr>
<tr><td>3) Dragon flies</td><td></td></tr>
<tr><td>4) Ants</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table></td><td></td></tr>
</table>

<u>Code E</u>: 1) Harm the crop 2) Help to control the pests 3) 4) 5)

Questionnnaire Number: ____________ Date:________________ Interviewer Number:________

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>110.</td><td>If decreased what are the possible factors you can attribute the declines to?</td><td>
<table>
<tr><td>Insect</td><td>1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) 8) 99) Don’t know</td></tr>
<tr><td>1) Spider</td><td></td></tr>
<tr><td>2) Beetle</td><td></td></tr>
<tr><td>3) Dragon flies</td><td></td></tr>
<tr><td>4) Ants</td><td></td></tr>
<tr><td>5)</td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>111.</td><td>Have you ever observed any of these insects dead in your field 24 hrs after spraying? (show the farmer the insects in the zoo)</td><td>1) Yes 2) No 101) Not applicable if no, go to No. 114</td><td></td></tr>
<tr><td>112.</td><td>If yes, which year, how many insect were they and what type of pesticide had you sprayed before?</td><td>
<table>
<tr><td>Year</td><td>Insect:
1) Spiders
2) Beetles
3) Dragon
4) Ants 5)</td><td>Number: Code:
1 ≤50 2) ≤100
3) ≤1000 4)≥1001
99) Don’t know</td><td>Pesticide code: B</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
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</table>
</td><td></td></tr>
</table>

<u>Code B:</u>1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

<table>
<tr><th colspan="2">Questionnnaire Number: ____________ Date:________________</th><th>Interviewer Number:_______</th><th></th></tr>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>113.</td><td>How frequent did you observe dead insects each time you sprayed those pesticides?</td><td><table>
<tr><td>Pesticide code: B</td><td>Insect: 1) Spiders 2) Beetles 3) Dragon 4) Ants 5)</td><td><u>Read</u>: 1) Rarely 2) Occasionally 3) Frequently 4) Often 5) Always</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table></td><td></td></tr>
<tr><td>114.</td><td>Have you heard your fellow farmers talk of observing dead insect in their field after spraying?</td><td>1) Yes 2) No</td><td></td></tr>
<tr><td>115.</td><td>If yes, which were they and what type of pesticides had they sprayed before?</td><td><table>
<tr><td>Farmer</td><td>1) Spiders 2) Beetles 3) Dragon 4) Ants</td><td>Pesticide code: B</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table></td><td></td></tr>
<tr><td>116.</td><td>Have you ever experienced an outbreak of a vegetable pest which was initially under control?</td><td>1) Yes 2) No if no, go to No. 118</td><td></td></tr>
</table>

<u>Code B</u>:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17)Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________		**Interviewer Number:_______**	
Number	**Question**	**Coding/response**	**Response**
117.	If yes, which year was it and what pest was it?	Year | Pest | Crop/vegetable infected | | | | | | | |	
118.	According to your observation and what you have heard from other people how can you rate the death of these insect (Show the insect zoo) due to pesticides in the locality?	**Read:** 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	
	Section H: Soil biota		
119.	How do you rate the change in abundance of earthworms, millipedes and crickets in your vegetable fields over the last five years, which you have observed during ploughing and weeding?	**Read:** 1) Increased 2) Decreased 3) Remained the same If decreased, go to No. 122. Remained the same No. 123 Earthworms | Millipedes | Crickets |	
120.	Are there seasons when they are high? If yes, when?	1) Yes 2) No 99) Don't know Season___________________	
121.	If increased what are the possible factors you can attribute the increase to?	1) Climatic change 2) Increase of food 3) Increase of habitat 4) Decrease of predators and diseases 5) Decrease use of pesticides 6) Decrease use of fertilizers 7) Decrease of soil erosion 8) 9) 10) 99) Don't know Earthworms | Millipedes | Crickets |	
122.	If decreased what are the possible factors you can attribute the declines to?	1) Climatic change 2) Decrease of food 3) Decrease of habitat 4) Increase of predators and diseases 5) Increase use of pesticides 6) Increase use of fertilizers 7) Increase of soil erosion 8) 9) 10) 99) Don't know Earthworms | Millipedes | Crickets |	
123.	Have you ever observed dead earthworms, millipedes or crickets 24 hrs after spraying?	1) Yes 2) No if no, go to No. 126	

<table>
<tr><td colspan="2">Questionnnaire Number: ____________ Date:________________</td><td>Interviewer Number:_______</td><td></td></tr>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>124.</td><td>If yes, which year, how many were they and what type of pesticides had you sprayed before?</td><td>
<table>
<tr><td>Year</td><td>Code:
1) Earthworm
2) Millipedes
3) Crickets</td><td>Number: Code:
1 ≤50 2) ≤100
3) ≤1000
4)≥1001
99) Don’t know</td><td>Pesticide code: B</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>125.</td><td>How frequent did you get dead earthworms, millipedes or crickets each time you sprayed those pesticides?</td><td>
<table>
<tr><td>Pesticide
code: B</td><td>Code:
1) Earthworm
2) Millipedes
3) Crickets</td><td><u>Read</u>: 1) Rarely
2) Occasionally
3) Frequently
4) Often 5) Always</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td></tr>
</table>
</td><td></td></tr>
<tr><td>126.</td><td>If you did not observe any of the above insects, what is the reason in your opinion?</td><td>1) Does not go back to the field to check 2) Pesticides are not harmful to them 3) 4) 5)</td><td></td></tr>
</table>

<u>Code B:</u>1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ | **Interviewer Number:_______**

Number	Question	Coding/response	Response
	Section A: Bio data		
127.	Have you heard your fellow farmers talk of observing dead earthworms/millipedes/ crickets in their field after spraying?	1) Yes 2) No if no, go to No.129	
128.	If yes, which year, and what type of pesticide had they sprayed before?	(see sub-table below)	
129.	According to your observation and what you have heard from other people how can you rate of death of earthworms, millipedes and crickets due to pesticides in the locality?	**<u>Read</u>:** 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	
	Section I: Pesticide residues in vegetables		
130.	Do you think the vegetables you harvest contain pesticides residues?	1) Yes 2) No 3) Partly 99) Don't know 101) Not applicable	
131.	Why do you think so?		
132.	Where do you sell your produce?	**<u>Read</u>:** 1) Domestic market 2) Exporters 3) Both	

Sub-table for 128:

Year	Farmer	1) Earthworm 2) Millipedes 3) Crickets	Pesticide code: B

<u>Code B:</u>1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:_______**

Number	Question	Coding/response	Response
133.	Out of the 10 kg of harvest (*e.g.* cabbage-heads) what fraction does your buyer reject to buy because of different reasons?	Dry season | Rainy season	
134.	What are these reasons?	1) Pests, diseases 2) Pesticide residues 3) Damaged 4) Over supply 5) 6) 7) Dry season | Rainy season	
135.	If you produce for domestic market, who is the first and second major buyer?	1) Consumer at local market 2) Middleman/ Brokers 3) Restaurants 4) Local industry 5) Supermarket 6) Hospitals 7) Schools 9) Neighbours 10) 11) 12)	
136.	Do the household consume the same produce you sell?	1) Yes 2) No	
137.	Why yes/ no?		
138.	Do you grow an extra plot for home consumption?	1) Yes 2) No if no, go to No. 143	
139.	Why do you grow an extra plot for home consumption?	1) Different type of vegetables 2) 3) 4) 5) 6)	
140.	Do you spray that extra plot?	1) Yes 2) No if no, go to No. 142	
141.	If yes, do you spray the same pesticides as the crops you sell?	1) Yes 2) No if no, go to No. 143	
142.	If not, why?		

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:_______**

Number	Question	Coding/response	Response
	Section J: Pest resistance		
143.	Have you ever experience a problem with pests, which could not be controlled even when using the right pesticide at its appropriate quantity (the recommended rate) and quality (not expired) although this pesticide worked fine before?	1) Yes 2) No if no, go to No. 146	
144.	Which year was it, what pest was it, what pesticide had you used and what did you do?	(see table below)	
145.	For how long had you used those pesticides	(see table below)	
146.	Have you heard other farmers talk of experiencing a problem with pests which could not be controlled even when using the right pesticide at the recommended rate and quality (not expired) although this pesticide worked fine before?	1) Yes 2) No if no, go to No. 148	

Question 144:

Year	Pest	Pesticides Code: B	What you did Code: F

Question 145:

Pesticide Code: B	Number of years

Code F: 1) Mix pesticides 2) Increase concentration 3) Spray more often 4) 5) 6)
Code B:1) Dimethoate 2) Karate 3) Decis 25 EC 4) Bulldock 5) Penncozeb 6) Dithane 7) Wetsulf 8) Thiovit 80WP 9) Antracol 70 WP 10) Atom 2.5 EC 11) Achook 12) Bestox 20 EC 13) Brigade 14) Champion 15) Copper 16) Cyclone 17) Danadim 18) Diazinon 19) Dipel 20) Dynamic 21) Electis 22) Equation pro 23) Farm-X 24) Fastac 25) Folicur 26) Fungaran 27) Gramoxane 28) Gausho 29) Kocide 30) Lannate 90 31) Metasystox 32) Milraz 33) Ogor 34) Omex 35) Ortiva 36) Oshothane 37) Poltricin 38) Polytrin 39) Ridomil 40) Sancosen 41) Selecron 42) Talstar 43) Thuricide 44) Topsin 45) Tristar 46) Agrinate 47) Dursban 48) Ippon 49) Vapcothion 50) Mithane Super 51) Alfatox 52) Tata Alfa 53) Methomex 54) Anvil 55) Copper fungicide 56) Ambush 57) Cosavet 58) Cobox 59) Daconil 60) Aflix 61) Phosvit 62) Malathion TK 63) Furadan 64)

Questionnnaire Number: ____________ Date:________________ | **Interviewer Number:_______**

Number	Question	Coding/response	Response
147.	If yes, how many out of 10 in the last five years?		
148.	Have you changed your use of pesticides in the vegetable production during the last 2 year?	1) Yes 2) No if no, go to No. 150	
149.	Why did you change your use of pesticides?	1) Problem with resistant pests 2) Increased number of pest 3) New pesticide coming up 4) 5)	
150.	Why not?	1) They are still strong 2) 3)	
	Section K: Health		
151.	Have you (or the family member who sprays) experienced pesticide related health problem within 24hrs after spraying during this season?	1) Yes 2) No if yes, fill the table below	

152.

Person? 1) You 2) Wife 3) Son 4) Daughter 5)	Symptoms (Code: G)	How severe were the symptoms? 1) Mild 2) Severe 3) Very severe	How long did the symptoms prevail? (Days)	Which medical treatment did you use? (Code: H)	Did the treatment work? 2) No	How much did the treatment cost (including transport)?	Were you able to work during this time? 1) Yes 2) No	If No, how many days you did not work?	Number of time in the season

Read: Code G: 1) Headache 2) Sneezing 3) Vomiting 4) Stomach ache 5) Backache 6) Skin rash 7) Dizziness 8) Blurred vision 9) Diarrhea 10) eye irritation 11) Fever 12) Shortage of breath 13) Heart trouble 14) 15) 16) 17)
Read: Code H: 1) Clinic 2) Health center 3) Hospital 4) Use of tablets from the shops 5) Traditional

Questionnnaire Number: ____________ Date:________________		**Interviewer Number:_______**	
Number	**Question**	**Coding/response**	**Response**
153.	Have you heard/ observed other farmers intoxicated by pesticides?	1) Yes 2) No	
154.	According to your observation and what you have heard from other farmers, how do you rate human illness or injury arising from various pesticide exposure scenarios in this village?	**Read:** 1) Very high 2) high 3) Moderate 4) Low 5) Very low 99) Don't know	
	Section L: Farmer opinion on pesticide externalities	**Use cue cards for No.155-178**	
155.	In your opinion, what is the effect of pesticide on water, frogs and fish?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
156.	Why do you think so?	1) 2) 3)	
157.	In your opinion, what is the effect of pesticide on livestock?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
158.	Why do you think so?	1) 2) 3)	
159.	In your opinion, what is the effect of pesticide on birds?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
160.	Why do you think so?	1) 2) 3)	
161.	In your opinion, what is the effect of pesticide on bees?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
162.	Why do you think so?	1) 2) 3)	
163.	In your opinion, what is the effect of pesticides on beneficial insects?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
164.	Why do you think so?	1) 2) 3)	
165.	In your opinion, what is the effect of pesticide to human?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
166.	Why do you think so?	1) 2) 3)	

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:_______**

Number	Question	Coding/response	Response
167.	In your opinion, what is the effect of pesticide on earthworms, millipedes, and crickets?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
168.	Why do you think so?	1) 2) 3)	
169.	In your opinion, what is the link between use of pesticides and resistance of pests to pesticides?	**Read:** 1) Beneficial 2) Somewhat beneficial 3) No effect 4) Somewhat harmful 5) Harmful 99) Don't know	
170.	Why do you think so?	1) 2) 3)	
171.	"Pesticides always result in good produce" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
172.	"Pesticides harm the environment" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
173.	"Pesticides always result in death of insects including the beneficial ones like bees" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
174.	"Pesticides can harm human health" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
175.	"Pesticide is a must in vegetable production" Do you??	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
176.	"The more pesticides the better" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
177.	"Over time, there will be a demand for pesticide-free vegetables in this locality" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
178.	"Killing beneficial insect like dragon fly, ants beetles etc will increase pest infestations" Do you?	**Read:** 1) Strongly agree 2) Agree 3) Neither agree nor disagree 4) Disagree 5) Strongly disagree	
	Section M: Pesticide application practices, handling, and storage		
179.	How do you determine when to apply pesticides?	1) Whenever I see pests 2) When advised by the buyer's staff 3) Only after scouting for pests 4) When a neighbor sprays 5) Using spray calendar/program 6) When advised by other farmers 7) Extension recommendations 8)	
180.	Did you keep records of the use of chemicals in your last crop of vegetable production?	1) Yes 2) No	

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:________**

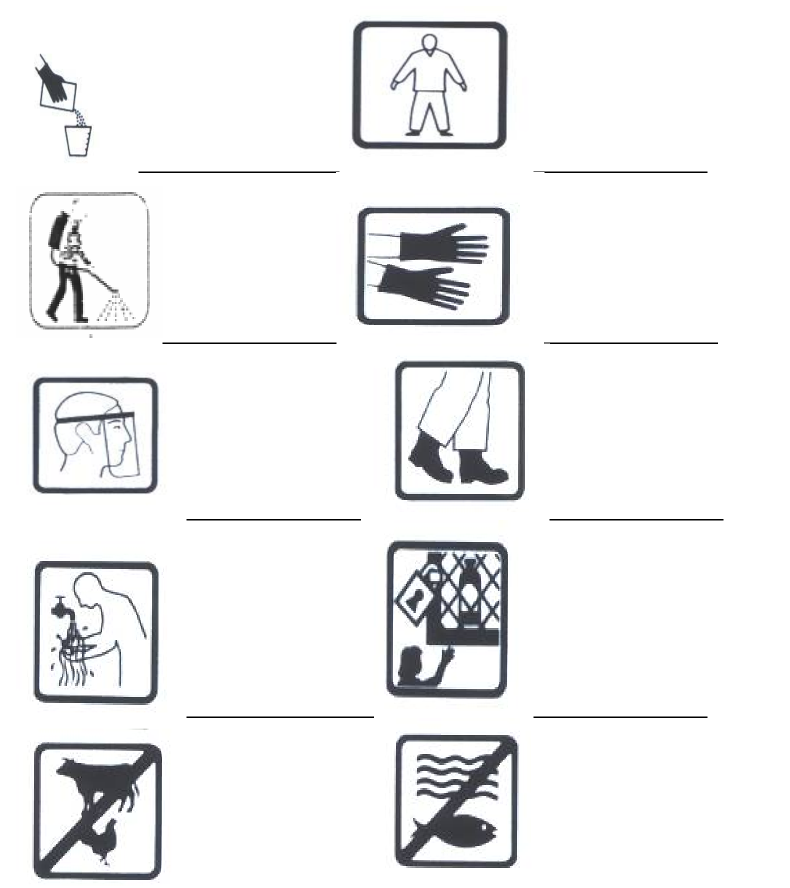
Number	**Question**	**Coding/response**	**Response**
181.	Who is the primary mixer and applicator of pesticides used in your vegetable production?	1) Myself 2) Spouse 3) Son 4) Daughter 5) Hired laborer 6) 7) 8)	
182.	What container do you use for mixing pesticide?	1) Cooking pot 2) Drinking-water bucket 3) Sprayer tank 4) Special container for mixing pesticide 5) Bathing basin/trough 6)	
183.	How does the mixer determine the amount of water to use for mixing pesticides?	1) Extension recommendations 2) From other farmers 3) Using the labels 4) 5) 6)	
184.	What protective measures do you adopt during pesticide spraying and how often?	(see sub-table below)	
185.	Do you read the pesticides product labels each time you spray?	1) Yes 2) No	
186.	If no, why not?		
187.	What is the meaning of color band on the pesticide container?	(see sub-table below)	

Question 184:

Read:	1) Yes 2) No	**Read:** 1) Rarely 2) Occasionally 3) Frequently 4) Often 5) Always
Long-sleeved overall		
Rubber gloves		
Gumboots		
Nose mask/cloth		
Goggles		
Hat/headscarf		

Question 187:

Color	Code: **Read:** 1) Harmful 2) Slightly harmful 3) Harmful 4) Very harmful 99) Don't know
Blue	
Red	
Yellow	
Green	

Questionnnaire Number: ____________ Date:________________		**Interviewer Number:_______**	
Number	**Question**	**Coding/response**	**Response**
188.	Do you know the meaning of these pesticides pictograms? If yes, what do they mean?		
189.	How do you evaluate the recommended dosage given in labels of pesticide products?	**<u>Read</u>:** 1) Adequate 2) Too little 3) Too much 99) Don't know	
190.	Do you apply more/less pesticide than recommended dosage given in labels of pesticide products?	1) About same levels 2) Same level 3)Apply more 4) Apply less 99) Don't know	
191.	Why do you apply more/less pesticide than recommended dosage given in labels of pesticide products?		

Questionnnaire Number: ____________ Date:________________		Interviewer Number:_______	
Number	**Question**	**Coding/response**	**Response**
192.	Where do you store your pesticides?	1) Chemical store 2) Kitchen 3) Bedroom 4) Wardrobe 5) Grading shed 7) Cattle feed 8) Kitchen 9) Farm store 10) Outside 11) 12) 13) 14)	
193.	In this place where do you keep the pesticides?	1) On ground 2) On shelves up 3) 4)	
194.	On average, for how long do you store the chemicals after opening?	1) Less than a week 2) 2 weeks 3) 1 month 4) 3 month 4) 6 months 5) A year 6) More than a year 7)	
195.	Do you read the expiry date of the chemicals before using them?	1) Yes 2) No	
196.	What do you do with the chemical after it has expired?	9) Dispose into the disposal pit 10) Continually used in the same field 11) dispose in the field 12) Dispose in the toilet 14) Use on another crop 15) 16) 17) 101) Not applicable	
197.	What do you do with empty pesticide containers/bottles?	1) River 3) Well 4) Reservoir 7) Dam 8) Pond 9) Dispose into the disposal pit 10) Wash and use domestically 11) Destroy and burn or bury 12) Throw in the toilet 13) Wash and use for paraffin 14) 15) 16) 17) 101) Not applicable	
198.	How do you dispose of remaining pesticides in sprayer?	1) River 3) Well 4) Reservoir 7) Dam 8) Pond 9) Dispose into the disposal pit 10) Continually used in the same field 11) dispose in the field 12) Dispose in the toilet 14) Use on another crop 15) 16) 101) Not applicable	
199.	Where do you wash your sprayers?	1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 7) Dam 8) Pond 9) Don't wash 10) 11)	
200.	How do you dispose of the water you use to wash sprayer?	1) River 2) Tap 3) Well 4) Reservoir 5) Bore hole 6) Pipe 9) Dam 10) Pond 11) 12) 13)	
201.	How do you dispose of crops residue?	1) Stack along ponds, rivers 2) Use as fuel 3) Burn in field after drying 4) Feed to animals 5) Compost 6)	
	Section N: General		
202.	Are you aware of any environmental problems in the community during the last 5 years?)	1) Yes 2) No if no, go to No.204	

Questionnnaire Number: ____________ Date:________________ | **Interviewer Number:_______**

<table>
<tr><th>Number</th><th>Question</th><th>Coding/response</th><th>Response</th></tr>
<tr><td>203.</td><td>If yes, which ones?</td><td></td><td></td></tr>
<tr><td>204.</td><td>Which pest control managements do you know?</td><td>1) Crop rotation 2) Use of resistant variety 3) Mulching
4) Physical killing 5) Uproot and burn/burry infected plants
6) Alternating pesticide to slow resistance 7) Pest scouting 8) Use of safer and less toxic pesticides 9) Adjusting application rate, timing and frequency to protect beneficial organisms 10) Use trap crops 11) Use of biological/natural pesticides 12)
13) 14) 15)</td><td></td></tr>
<tr><td>205.</td><td>Which ones do you practice?</td><td>1) Crop rotation 2) Use of resistant variety 3) Mulching
4) Physical killing 5) Uproot and burn/burry infected plants
6) Alternating pesticide to slow resistance 7) Pest scouting 8) Use of safer and less toxic pesticides 9) Adjusting application rate, timing and frequency to protect beneficial organisms 10) Use trap crops 11) Use of biological/natural pesticides 12)
13) 14) 15)</td><td></td></tr>
<tr><td>206.</td><td>Have you ever been EUREPGAP certified? For which period did you hold the cert? Start year end year. (Remember to explain what EUREPGAP is)</td><td><table><tr><td>Certified: 1) Yes 2</td><td>Year start</td><td>Year end</td></tr><tr><td></td><td></td><td></td></tr></table></td><td></td></tr>
<tr><td>207.</td><td>Do you apply the EUREPGAP practice also for domestic market produces?</td><td>1) Yes 2) No if no, go to No. 209</td><td></td></tr>
<tr><td>208.</td><td>If so, which practice?</td><td></td><td></td></tr>
<tr><td>209.</td><td>What is your most important source of pesticides use information for your agricultural production?</td><td>1) Radio 2) Newspapers 3) Labels 4) Traders at the market
5) Traders who came to the farm 6) Fellow farmers 7) Extension officers 8) Agro vet 9) 10)</td><td></td></tr>
<tr><td>210.</td><td>How often did you obtain this information and how do you rate its usefulness for your vegetable production?</td><td><u>Read</u>: 1) Once a week 2) 2 - 3 times a month 3) Once a month
4) Once in three months 5) Once in a season<table><tr><td>Source</td><td>Times information received</td><td><u>Read</u>: 1) Very important 2) Important 3) lightly important 4) Somehow important 5) Not important</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr></table></td><td></td></tr>
</table>

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:_______**

Number	**Question**	**Coding/response**	**Response**
211.	Are you satisfied with the quality of this information?	1) Yes 2) No 3) Partly 4)	
212.	What was the main reason why you are not satisfied with the quality of this information?	1) Infrequent information 2) Inaccurate information 3) Interest not covered 4) Livestock not covered 5) Too complex information	
213.	How do you obtain most of your pesticide?	1) Do not use any 2) Own retention 3) Trader at farmstead 4) Out-growing arrangements 5) Agro vet 6) Gifts 7) 8) 9)	
214.	What do you say about the pesticides available these days?	**Read:** 1) Stronger 2) Weaker 3) Are the same as in the past	
215.	What makes you think so?		
216.	How many kg or liters of pesticide do you use per crop season on average?	<table><tr><td></td><td>Dry season</td><td>Rainy season</td><td>Total</td></tr><tr><td>kg</td><td></td><td></td><td></td></tr><tr><td>litres</td><td></td><td></td><td></td></tr></table>	
217.	How much money do you use for pesticide per crop season on average?	<table><tr><td>Dry season</td><td>Rainy season</td><td>Total</td></tr><tr><td></td><td></td><td></td></tr></table>	
218.	Do you have a preference for any brand of pesticides?	1) Yes 2) No if no, go to No. 220	
219.	If yes, which ones and why?		
220.	If no, why?		
221.	Taking a situation when pesticide prices are increased by 50%, what amount would you buy?	**(Ask the farmer the quantity and the price of one of the pesticide he or she uses most/ favorite and use it as an example for No. 221-225**	
222.	What if the pesticide prices were to be doubled, what amount would you buy?		

Questionnnaire Number: ____________ Date:________________ **Interviewer Number:_______**

Number	Question	Coding/response	Response
223.	What if the prices are increased up to 200%, what amount would you buy?		
224.	What if the prices were decrease by: 50%, what amount would you buy?		
225.	What if the prices were decrease by: 75%, what amount would you buy?		
226.	What is the trend of your pesticide use during the past 5 years?	**<u>Read</u>:** 1) Increasing 2) The same 3) Decreasing	
227.	What are the reasons why the trend is so?		
	Section O: Field observation		
228.	Location and number of lying pesticide containers. On farm. (Walk through the entire farm and visually count the number of lying empty pesticides containers)	(see table below)	
229.	Questions asked or comments by the farmer		

Coding/response for question 228:

Place	1) Yes 2) No	Number	Comments
In vegetable field			
Near vegetable field			
Well			
Dam			
Pond			
Near home stead			
Near bee hives			

Thank you!

Appendix D: A complete list of all the pesticides farmer used with EIQ values, application rate, field use rating and estimated volumes (n=839, 2005 and 425, 2008)

Active ingredient	Trade name	Family name	WH-O [a)]	EIQ [b)]				% farmer		Rate (kg/ha) [c)]		Field use	Vol [d)]
				F	C	E	A	2005	2008	2005	2008		
Insecticides													
Acetamiprid	Tristar 70WSP	Inorganic	NL	7	8	72	29	<1		0.42 (0.14)		13	
Azadirachtin	Achook	Tetranortriterpen o-id	NL	6	6	25	12	6	1	1.58 (0.21)	1.64 (0.49)	12	0.96
Bifenthrin	Brigade 25EC	Pyrethroid	II	14	8	112	44	<1	5	0.50 (0.00)	2.84 (0.8)	11	4.92
Bifenthrin	Talstar 50EC	Pyrethroid	II	14	8	112	44	1		0.28 (0.12)		22	
B. thuringiensis	Dipel	Microbial	U	7	3	30	13	5	5	0.89 (0.31)	0.62 (0.00)	3	0.04
B. thuringiensis	Thuricide HP	Microbial	U	7	3	30	13	2	5	1.45 (0.00)	1.74 (0.44)	4	5.04
Carbofuran	Furadan	Carbamate	IB	20	11	82	51		<1		4.08 (3.04)	31	0.62
Chlorpyriphos	Dursban 4EC	Organophosphate	II	18	4	109	44	1	1	0.67 (0.13)	4.11 (01.85)	3	2.22
Cyfluthrin	Bulldock 25EC	Pyrethroid	II	7	4	108	39	10	20	2.24 (0.52)	1.70 (0.22)	5	19.05
Cypermethrin	Bestox 100EC	Pyrethroid	II	21	22	62	36	1	22	0.26 (0.03)	1.51 (0.20)	11	17.44
Cypermethrin	Cyclone 505EC	Pyrethroid	II	21	22	62	36	6	11	0.79 (0.08)	1.56 (0.20)	91	10.08
Cypermethrin	Fastac 10EC	Pyrethroid	II	21	22	62	36	1	3	0.49 (0.14)	0.63 (0.21)	1	0.58
Cypermethrin	Polytrin 200EC	Pyrethroid	II	21	22	62	36	<1		0.30 (0.10)		72	
Cypermethrin	Tata Alfa 10EC	Pyrethroid	II	21	22	62	36	4	5	0.39 (0.09)	0.99 (0.26)	1	3.06
Deltamethrin	Atom 2.5EC	Pyrethroid	II	18	2	65	28	1	1	1.10 (0.33)	0.48 (0.22)	0	0.32
Deltamethrin	Decis 25EC	Pyrethroid	II	18	2	65	26	12	14	0.44 (0.05)	0.69 (0.10)	3	7.36
Deltamethrin	Farm-X	Pyrethroid	II	18	2	65	26	13	<1	0.36 (0.04)	2.28 (0.00)	13	0.29
Deltamethrin	Keshet 2.5EC	Pyrethroid	II	18	2	65	26		<1		1.58 (0.00)	0	0.57
Demeton methyl	Metasystox	Organophosphate	IB	43	13	73	43	1	<1	0.23 (0.04)	3.56 (0.00)	43	0.50
Diazinon	Alfatox	Organophosphate	II	7	2	122	44	1	11	0.08 (0.00)	1.31 (0.29)	44	5.25
Diazinon	Diazinon 60EC	Organophosphate	II	7	2	122	44	1	4	0.92 (0.29)	1.39 (0.30)	26	5.08
Diazinon	Diazol EC	Organophosphate	II	7	2	122	44		<1		2.23 (0.00)	44	0.15
Dichlorodiphenyl-trichloroethane	DDT	Organochlorine	IA						<1		6.66 (5.68)		0.18

Active ingredient	Trade name	Family name	WH-O [a)]	EIQ [b)]				% farmer		Rate (kg/ha) [c)]		Field use	Vol [d)]
				F	C	E	A	2005	2008	2005	2008		
Dichlorvos	Phosvit	Organophosphate	IB	41	18	100	54	<1		2.52 (1.04)			
Dimethoate	Danadim 40EC	Organophosphate	II	31	12	101	34	3	4	1.15 (0.12)	2.31 (0.51)	14	7.16
Dimethoate	Dimet 400EC	Organophosphate	II	31	12	101	34		<1		0.87 (0.72)	136	0.18
Dimethoate	Dimeton 40EC	Organophosphate	II	31	12	101	34	37	48	1.79 (0.24)	1.93 (0.11)	14	61.23
Fenitrothion	Sumithion	Organophosphate	II	78	6	58	47		<1		2.28 (2.17)	47	0.53
Fenpyroximate	Ogor 40EC	Pyrazole	NL					1	11	0.70 (0.16)	1.71 (0.26)		9.85
Formothion	Aflix	Organophosphate	O	72	9	141	74	<1		0.40 (0.00)		37	
Imidacloprid	Gausho	Chloro-nicotinyl	II	7	10	93	37	<1		1.11 (0.19)		11	
Lambda cyhalothrin	Duduthrin	Pyrethroid	II	21	3	108	44		3		3.96 (1.81)	44	1.53
Lambda cyhalothrin	Karate 2.5WG	Pyrethroid	II	21	3	108	44	27	27	1.44 (0.26)	2.47 (0.26)	16	41.78
Lambda cyhalothrin	Tata umeme 2.5EC	Pyrethroid	II	21	3	108	44		<1		1.50 (0.50)	11	1.53
Malathion	Marathion 50EC	Organophosphate	III	9	5	58	24	<1	<1	1.11 (0.58)	7.37 (3.11)	24	2.50
Methomyl	Agrinate 90SP	Carbamate	IB	6	11	49	22	1	2	1.49 (0.18)	5.03 (1.39)	10	1.71
Methomyl	Lannate 90SP	Carbamate	IB	6	11	49	22	3	4	0.52 (0.06)	0.54 (0.70)	40	30.07
Methomyl	Methomex 90	Carbamate	IB	6	11	49	22	<1	<1	0.10 (0.00)	3.95 (0.00)	10	0.48
Permethrin	Ambush 25DC	Pyrethroid	II	12	5	72	30	<1	<1	0.28 (0.08)	0.59 (0.00)	2	0.14
Profenophos/ cypermethrin	Polytrin 440EC	Organophosphate / Pyrethroid	II	8	3	168	60	1	2	1.62 (0.62)	2.72 (0.92)	264	1.85
Fungicide													
Azoxystrobine	Ortiva SC	Strobilurin	U	8	3	67	27	3	7	0.93 (0.13)	0.53 (0.08)	27	1.02
Bupirimate	Nimrod 25EC	Pyrimidine	U						<1		0.33 (0.04)		0.07
Chlorothalonil	Daconil W75	Chloronitrile	U	20	11	81	38	1		0.88 (0.00)		57	
Copper hydroxide	Champion	Inorganic	III	24	5	85	39	<1	<1	0.48 (0.01)	0.79 (0.39)	23	0.06
Copper hydroxide	Funguran 50WP	Inorganic	III	24	5	85	39	<1		0.16 (0.14)		6	

Active ingredient	Trade name	Family name	WHO [a)]	EIQ [b)]				% farmer		Rate (kg/ha) [c)]		Field use	Vol [d)]
				F	C	E	A	2005	2008	2005	2008		
Copper hydroxide	Kocide DF	Inorganic	III	24	5	85	39	<1	<1	0.62 (0.05)	2.37 (0.00)	39	0.46
Copper oxychloride	Cobox	Inorganic	III	8	4	51	21	<1		0.59 (0.00)		42	
Copper oxychloride	Cuprocaffaro WP	Inorganic	III	8	4	51	21		2		1.11 (0.27)	42	0.86
Copper sulfate	Copper	Inorganic	II	24	13	148	62	3	<1	0.54 (0.14)	2.92 (1.13)	124	2.61
Cuprous oxide	Copper Nordox	Inorganic	II	12	5	83	33	3	4	1.45 (1.01)	4.09 (0.63)	66	8.82
Cymoxanil	Milraz 76WP	Acetamide	III	6	6	14	9	1	22	0.94 (0.22)	2.71 (0.25)	14	73.52
Famoxadone	Equation pro	Oxazolidinedione	U	9	3	20	11	2		1.37 (0.31)		4	
Hexaconazole	Anvil	Azole	U	27	54	41	40	<1	<1	0.18 (0.10)	1.11(0.04)	16	0.17
Hexaconazole	Cotaf 5EC	Azole	U	27	53	41	40		<1		0.92 (0.00)	2	0.16
Iprodione	Ippon	Dicarboximide	U	16	9	48	24	<1		0.89 (0.69)		36	
Mancozeb	Agrithane 80WP	Carbamate	U	20	5	49	26		2		3.9 (0.49)	37	1.35
Mancozeb	Dithane M45	Carbamate	U	20	5	49	26	14	18	2.51 (0.34)	3.56 (0.36)	18	99.55
Mancozeb	Milthane Super	Carbamate	U	20	5	49	26	1	1	0.95 (0.29)	3.26 (2.01)	26	5.95
Mancozeb	Oshothane 80WP	Carbamate	U	20	5	49	26	<1	5	1.44 (0.62)	3.05 (0.68)	21	15.56
Mancozeb	Penncozeb 80WP	Carbamate	U	20	5	49	26	1	4	1.09 (0.11)	5.76 (1.28)	21	11.59
Mancozeb	Sancozeb 80WP	Carbamate	U	20	5	49	26	<1	<1	0.29 (0.1)	2.24 (1.99)	21	1.40
Mancozeb	Electis 75 WG	Carbamates	U	32	13	94	47	<1		0.05 (0.00)		63	
Metalaxyl	Ridomil MZ68	Carbamate	III	8	12	38	19	<1	8	0.89 (0.20)	2.16 (0.44)	26	65.56
Profenofos	Selecron 720EC	Organophosphate	II	8	3	168	59	1	<1	0.56 (0.07)	0.45 (0.15)	425	0.29
Propineb	Antracol 70WP	Inorganic	U	9	3	39	17	1	2	0.67 (0.08)	3.07 (0.67)	24	2.68
Sulphur	Cosavet DF	Inorganic	U	10	6	121	46	<1		0.79 (0.00)		92	
Sulphur	Kumulus DF	Inorganic	U	10	6	121	46		4		1.79 (0.45)	92	0.27
Sulphur	Thiovit 80WP	Inorganic	U	10	6	121	46	1	9	2.17 (0.47)	2.51 (0.53)	110	6.28

Active ingredient	Trade name	Family name	WH-O [a]	EIQ [b]				% farmer		Rate (kg/ha) [c]		Field use	Vol [d]
				F	C	E	A	2005	2008	2005	2008		
Tebuconazole	Folicur 250EW	Triazole	III	20	31	70	40	<1	10	0.67 (0.26)	1.18 (0.23)	100	6.01
Tebuconazole	Orius 25EW	Triazole	III	20	31	70	40		4		1.19 (0.22)	10	2.05
Thiophanate - methyl	Topsin M	Carbamate	O	16	12	40	24	<1	2	0.49 (0.00)	2.78 (0.72)	19	2.23
Triadimefon	Bayleton WP25	Triazole	III	16	21	55	31		<1		2.16(1.27)	16	0.64
Tributyltin oxide	Biomet	Tributyltin	NL						<1		1.77 (0.00)		0.01
Trifloxystrobin	Flint 50WG	Strobilurin	NL	12	10	70	31		<1		0.28 (0.00)	8	0.06
Sulphur	Wetsulf WP	Inorganic	U	10	6	121	46	1	5	1.01 (0.14)	3.18 (0.76)	92	6.97
Herbicide													
Linuron	Farmuron 50WP	Phenylurea	U	11	7	41	19		2		1.39 (0.24)	19	0.66
Metribuzin	Sencor 70WP	Triazinone	II	8	8	69	28		5		1.36 (0.35)	10	6.71
Paraquat	Gramoxone	Bipyridylium	II	8	5	80	31	<1	<1	1.36 (0.26)	5.63 (0.03)	37	1.39
Acaricide													0.00
Abamectin	Dynamec	Avermectin	NL	36	5	73	38	1	2	0.28 (0.06)	0.95 (0.37)	8	0.69
Propargite	Omite	Organosulfurs	III	20	8	177	67	<1		0.95 (0.00)			
Tetradifon	Vapcothion	Chlorodiphenyl	U	11	4	38	18	<1		0.25 (0.00)			
Average				18	10	77	35			1.23 (0.07)	2.01 (0.06)	39	569.83 [e]
Median				18	6	70	36			0.59	1.19	21	
Mode				20	5	49	44			0.40	1.19	11	

[a] Ia = extremely hazardous; Ib = highly hazardous; II = moderately hazardous; III = slightly hazardous; U = unlikely to present acute hazard in normal use; O = obsolete as pesticide; NL = not classified

[b] F = farm worker component; C = consumer component; E = ecological component; A = average

[c] Figures in brackets are standard errors

[d] Estimated volumes of pesticides used in 2008 in metric tonnes.

[e] Total

Source: Own survey

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Hierdurch erkläre ich, dass ich meine Dissertation mit dem Titel

NEGATIVE EXTERNALITIES OF PESTICIDE USE IN THE VEGETABLE SUB-SECTOR IN KENYA

selbstständig verfasst und alle benutzten Hilfsmittel und Quellen vollständig angegeben habe.

Die Dissertation wurde nicht schon als Masterarbeit, Diplomaarbeit oder für andere Prüfungsarbeiten verwendet.

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Macharia Ibrahim Ndegwa