Pesticides and Human Health – An Economic Approach to Evaluation

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Dedication

Für Johannes, Maria und Eva

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Abstract

Pesticide poisoning is a major health problem for farmers in developing countries. In order to assess different strategies to recide pesticide poisoning among farmers and to be able to design more effective policies, an economic evaluation of pesticide health risks is needed. The objective of this dissertation is to provide an economic evaluation of the health costs of pesticides from the farmers' perspective in the case of Nicaraguan vegetable producers and to analyse their choices concerning pesticide use and adoption of alternative pest management technology.

An analysis of pesticide exposure and incidence of pesticide poisoning is provided, based on data from a season-long production input monitoring survey of 191 vegetable farmers. The relationship between pesticide exposure and the number of poisoning symptoms reported by the farmers could be established using a zero-inflated Poisson regression model.

A second survey, designed as recall survey of a sample of 433 farmers, provided the data base to address the questions of the adoption of alternative pest control practices and the valuation of pesticide health costs using a willingness-to-pay approach.

The analysis of the farmers' valuation of pesticide health risks revealed that farmers would be willing to pay a premium of about 23% of current pesticide expenditure to avoid pesticide health risks if that possibility existed. The validity of farmers' valuation of health risks could be established in a series of tests showing the consistency of the results with economic theory.

The effect of pesticide health costs on the adoption of alternative pest management practices was analysed using poisson regression methods. Adoption was measured in two levels, the number of practices a farmer had tested on his farm and the number of practices adopted into current practice after the testing. The results of the adoption models revealed that previous experiences with pesticide poisoning increased the number of practices tested by the farmer but had no effect on the current use of practices. This shows that the adoption of IPM practices depends more on the feasibility and effectiveness for pest control as established during the testing phase.

The use of some alternative pest control practices led to reductions in insecticide use and also stimulated farmers to shift from hazardous to less toxic pesticides, which confirms potential health benefits of the technology. However, other practices had no effect and some even increased insecticide use.

The presented study shows that farmers are aware of pesticide health risks and have a positive willingness to pay to avoid both chronic and acute pesticide poisoning. Health concerns can be a motivation for farmers to change their behaviour and test alternative pest control practices. However, they need more and better information about health effects of specific active ingredients and pesticides. This would allow farmers to make their informed choices and to identify safer alternatives to the currently used hazardous products.

For the evaluation of rural health policies or the welfare effects of bans of widely used and highly hazardous pesticides, further studies are needed to provide a value estimate of pesticide health costs on a national level.

Keywords:

Pesticide poisoning, willingness-to-pay approach, adoption of alternative pest control practices, poisson regression, Nicaragua

Kurzfassung

Pflanzenschutzmittelvergiftungen stellen nach wie vor ein wesentliches Gesundheitsrisiko für landwirtschaftliche Haushalte in Entwicklungsländern dar. Das Ziel der vorliegenden Arbeit ist eine ökonomische Analyse der Gesundheitsrisiken von Pflanzenschutzmitteln und deren Auswirkungen auf das Entscheidungsverhalten bezüglich des Pflanzenschutzes im Gemüsebau im Falle von Kleinbauern in Nicaragua.

Zunächst wurde der Zusammenhang zwischen der Pflanzenschutzmittelbelastung und dem Auftreten von Vergiftungssymptomen analysiert. Die Datengrundlage dazu bildete eine Haushaltsbefragung von 191 Betrieben mit monatlich wiederholten Interviews zu Eckdaten der Produktion und des Pflanzenschutzmitteleinsatzes.

Eine zweite Erhebung von Primärdaten lieferte die Daten für eine Zahlungsbereitschaftsanalyse der Gesundheitskosten von Pflanzenschutzmitteln und der Adoption von alternativen Pflanzenschutzmaßnahmen. Sie umfasste eine Stichprobe von 433 Gemüsebaubetrieben.

Die Ergebnisse der Zahlungsbereitschaftsanalyse zeigen, dass die Befragten Mehraufwendungen von etwa 23% der derzeitigen Pflanzenschutzmittelkosten akzeptieren würden, wenn sie damit die chronischen und akuten Gesundheitsrisiken von Pflanzenschutzmitteln vermeiden könnten.

Mittels Poissonregressionen wurde der Einfluß der Einstellung der Landwirte zu den Gesundheitsrisiken von Pflanzenschutzmitteln auf die Übernahme von alternativen Pflanzenschutzmaßnahmen modelliert. Zwei verschiedene Indikatoren wurden verwandt, um die Adoption dieser Techniken auf zwei Ebenen darzustellen; zum einen die Anzahl der Maßnahmen die der Landwirt praktisch getestet hatte, zum anderen die Anzahl der Maßnahmen, die im vorhergehenden Jahr angewandt worden waren. Die Ergebnisse der Modelle zeigen, dass vorherige Erfahrungen mit Pflanzenschutzmittelvergiftungen die Zahl der getesteten Maßnahmen erhöhte, jedoch keinen Einfluß auf die derzeitige Verwendung hatte.

Eine Reduzierung des Insektizidaufwandes, und somit potentielle Verbesserungen für die Gesundheit der Landwirte aufgrund der Verwendung von nicht-chemischen Pflanzenschutzmaßnahmen, konnte teilweise festgestellt werden. Für einige dieser Pflanzenschutzmaßnahmen wurde jedoch kein Effekt gefunden, andere wiederum schienen den Insektizideinsatz sogar zu erhöhen.

Die vorgestellte Arbeit zeigt, dass die Landwirte sich der Gesundheitsrisiken von Pflanzenschutzmitteln bewußt sind. Sie haben eine positive Zahlungsbereitschaft für die Vermeidung chronischer und akuter Vergiftungen und Gesundheit stellt für sie eine Motivation für Verhaltensänderungen wie z. B. das Experimentieren mit neuen Technologien dar. Es werden jedoch mehr und bessere Informationen über die spezifischen Gesundheitsrisiken der verschiedenen Pflanzenschutzmittel benötigt. Dies würde den Landwirten ermöglichen, sichere Alternativen zu den derzeitig genutzten giftigen Mitteln zu identifizieren.

Zur Bewertung und Planung von gesundheitspolitischen Maßnahmen im ländlichen Raum sind weitere Studien erforderlich, die ökonomische Bewertung von Gesundheitsrisiken durch Pflanzenschutzmittel auf nationaler Ebene vornehmen.

Schlagwörter:

Pflanzenschutzmittelvergiftungen, Zahlungsbereitschaftsanalyse, Poisson-Regressionsmodelle, alternative Pflanzenschutzmaßnahmen, Nicaragua

Zusammenfassung

Pflanzenschutzmittelvergiftungen stellen nach wie vor ein wesentliches Gesundheitsrisiko für landwirtschaftliche Haushalte in Entwicklungsländern dar. Das Ziel der vorliegenden Arbeit ist eine ökonomische Analyse der Gesundheitsrisiken von Pflanzenschutzmitteln und deren Auswirkungen auf das Entscheidungsverhalten bezüglich des Pflanzenschutzes im Gemüsebau im Falle von Kleinbauern in Nicaragua.

Der Literaturüberblick im ersten Kapitel zeigt, dass die Vergiftungsraten in der landwirtschaftlichen Bevölkerung in Entwicklungsländern weltweit auf ähnlichem Niveau liegen. Jedoch sind die Daten über die Gesundheitseffekte von Pflanzenschutzmitteln insgesamt lückenhaft und ein Großteil der Pflanzenschutzmittelvergiftungen wird nicht in den offiziellen Gesundheitsstatistiken erfasst. Die Gründe für mangelhafte Dokumentierung von Pflanzenschutzmittelvergiftungen von Landwirten umfassen z. B. die oft lückenhafte medizinische Grundversorgung in ländlichen Gebieten, unzureichendes Wissen über chronische Effekte und die Schwierigkeit der Zuordnung von Vergiftungssymptomen zu spezifischen Pflanzenschutzmitteln, da die Bauern für gewöhnlich einer Vielzahl von verschiedenen Produkten ausgesetzt sind. Internationale Organisationen, Regierungen, sowie Nicht-Regierungsorganisationen und die Pflanzenschutzmittel-industrie verfolgen unterschiedliche Strategien zur Reduzierung von Pflanzenschutzmittelvergiftungen von Landwirten, die allerdings bisher nur wenig Erfolg erzielt haben. Um verschiedene Ansätze zu evaluieren und effektivere Maßnahmen zur Minimierung der Vergiftungsraten zu entwickeln, ist eine ökonomische Bewertung der Gesundheitsrisiken von Pflanzenschutzmitteln erforderlich. In Kapitel eins werden Forschungslücken insbesondere im Bereich der umfassenden quantitativen Bewertung der Gesundheitskosten der Pflanzenschutzmittel, der Analyse der individuellen Auffassungen über die Gesundheitsrisiken seitens der Bauern und der daraus folgenden Entscheidungen über die Verwendung von Pflanzenschutzmitteln und alternativer Pflanzenschutzmaßnahmen identifiziert.

Aufbauend auf der Diskussion von bisher verwandten Methoden der Bewertung von Gesundheitskosten von Pflanzenschutzmitteln, wird im Kapitel zwei der methodische Ansatz für die vorgelegte Forschungsarbeit entwickelt. Die Kosten von Pflanzenschutzmittelvergiftungen werden zunächst gemessen in Form von Ausgaben

zur Behandlung der Vergiftung, sowie der Opportunitätskosten für die verlorene Arbeitszeit. Außerdem wird eine Zahlungsbereitschaftsanalyse angewandt. Diese Methode erlaubt es, auch nicht-monetäre Kosten für die menschliche Gesundheit einzubeziehen, und die Kosten chronischer Gesundheitsbeeinträchtigungen aus der Sicht der Bauern zu schätzen. Der Einfluss der individuellen Auffassungen der Bauern über die Gesundheitsrisiken auf die Verwendung von alternativen, nicht-chemischen Pflanzenschutzmaßnahmen wird untersucht und so die Verbindung hergestellt zwischen der persönlichen Wahrnehmung und beobachtetem Verhalten in bezug auf die Pflanzenschutzmittelverwendung. Die Analyse stützt sich auf Primärdaten aus zwei Erhebungen auf Haushaltsebene. Zunächst wurden monatlich detaillierte Produktionsdaten, einschließlich Pflanzenschutzmittelaufwand und Arbeitszeiten für die Ausbringung, sowie Gesundheitsbeeinträchtigungen, Vergiftungssymptome und Aufwendungen für Gesundheit über einen Zeitraum von 7 Monaten (zwei Anbauperioden) erhoben. Die Daten aus dieser Erhebung bilden die Grundlage der Analyse der Zusammenhänge zwischen der Pflanzenschutzmittelbelastung der Landwirte und den von ihnen angegebenen Vergiftungssymptomen. In einer zweiten Erhebung wurden landwirtschaftliche Haushalte zur Verwendung von Pflanzenschutzmitteln, nicht-chemischen Pflanzenschutzmaßnahmen und ihrer Zahlungsbereitschaft für die Vermeidung von Gesundheitsrisiken durch Pflanzenschutzmittel befragt. In dieser Befragung wurden insbesondere auch frühere Erfahrungen mit Pflanzenschutzmittelvergiftungen thematisiert.

Im dritten Kapitel werden drei Forschungsfragen beantwortet, erstens, ob und wieweit die Landwirte sich der Gesundheitsrisiken von Pflanzenschutzmitteln bewusst sind, zweitens, wie hoch die aktuelle Pflanzenschutzmittelbelastung für Landwirte im Gemüsebau ist und drittens, wie stark sie von Gesundheitsbeeinträchtigungen und Vergiftungssymptomen durch Pflanzenschutzmittelkontakt betroffen sind. Die Ergebnisse zeigen, dass die Belastung von nicaraguanischen Gemüsebauern mit Pflanzenschutzmitteln in der Tat hoch ist: Im Untersuchungszeitraum 2003/04 brachte ein Landwirt im Durchschnitt 7.7 kg Pflanzenschutzmittel in zwölf Anwendungsvorgängen aus. Von dieser Menge fallen 44% in die Kategorie Ia, Ib oder II, d.h. gefährlich für die menschliche Gesundheit, gemäß der Klassifizierung durch die Weltgesundheitsorganisation. Der Preis der Pflanzenschutzmittel war negativ mit der Giftigkeit korreliert, d.h. je giftiger desto preiswerter. Die Landwirte hatten ein grundlegendes Bewusstsein über die Gesundheitsrisiken, z. B. berichteten 5.6% der Befragten, dass sie im Untersuchungszeitraum eine akute Vergiftung erlitten hatten, und insgesamt 43% der Befragten bzw. ihrer Familienmitglieder waren mindestens einmal im Leben an akuter Pflanzenschutzmittelvergiftung erkrankt. Die Kosten für die betroffenen Haushalte waren im Durchschnitt 26.5 USD bei einer mittelschweren Vergiftung, bei der der Erkrankte maximal eine Woche arbeitsunfähig war. Bei schweren Vergiftungsfällen, mit längerem Arbeitsausfall und der Verlegung in ein Krankenhaus, fielen im Mittel Kosten in Höhe von 51.9 USD für den Haushalt an. Die Häufigkeit, der von den Bauern berichteter Vergiftungssymptome, entsprach der individuellen Belastung mit Pflanzenschutzmitteln. Der Zusammenhang zwischen der Anzahl der Symptome und der Intensität der Pflanzenschutzmittelbelastung konnte mit Hilfe der Zero-Inflated-Poisson-Regressionsmethode modelliert werden. Die Modellergebnisse zeigten, dass die Anwendungshäufigkeit, die Giftigkeit der verwendeten Pflanzenschutzmittel, gemessen als durchschnittlicher gewichteter Preis, und das Mischen verschiedener Mittel in einer Anwendung, wesentliche Risikofaktoren für das Auftreten von Vergiftungssymptomen darstellten.

Im Kapitel vier wird die vierte Forschungsfrage, nach der ökonomischen Bewertung der Gesundheitskosten von Pflanzenschutzmitteln aus der Sicht der nicaraguanischen Gemüseproduzenten behandelt. Eine Zahlungsbereitschaftsanalyse wurde durchgeführt zur Quantifizierung der monetären und nicht-monetären Kosten von akuten und chronischen Gesundheitsbeeinträchtigungen. Die Landwirte wurden nach dem maximalen Preis gefragt, den sie für eine ungiftige Version ihres bevorzugten Pflanzenschutzmittels zu zahlen bereit wären. Dabei wurde die gleiche Pflanzenschutzeffizienz sowie die im Vorjahr aufgewendete Menge dieses Mittels zugrunde gelegt. Die Analyse ergibt, dass die Landwirte Mehrkosten in Höhe von 23% ihrer aktuellen Aufwendungen für Pflanzenschutzmittel für die Vermeidung von Gesundheitsrisiken akzeptieren würden, insofern es diese Möglichkeit gäbe. Mit einer durchschnittlichen Zahlungsbereitschaft von 25.8 USD für die Vermeidung von chronischen Krankheiten und 61.6 USD für chronische und akute Risiken zusammen, liegen die Beträge über den vorher berechneten durchschnittlichen Ausgaben im Falle akuter Pflanzenschutzmittelvergiftungen. Es wurde überprüft, ob die ermittelten Werte in bezug auf ökonomische Theorie plausibel und gültig sind. Dazu wurde die Zahlungsbereitschaft für verschiedene Szenarien, in denen unterschiedlich viele Risiken vermieden werden konnten, verglichen. Die Befragten nannten signifikant höhere Werte, wenn chronische und akute Gesundheitsrisiken vermieden werden konnten, verglichen mit dem Szenario, in dem nur auf chronische Risiken Bezug genommen wurde. Die Variation in der Höhe der Zahlungsbereitschaft konnte, wie erwartet, mit Unterschieden in der Ressourcenverfügbarkeit zwischen den Befragten erklärt werden. So hatten z. B. Landwirte, die Zugang zu Kredit hatten oder über eine höhere Gemüseanbaufläche verfügten, eine relativ höhere Zahlungsbereitschaft als solche mit weniger Ressourcen. Diese Ergebnisse bestätigen, dass die hypothetischen Werte, welche die Befragten nannten, gültige Schätzungen der Zahlungsbereitschaft für die Vermeidung von Pflanzenschutzmittelvergiftungen darstellen.

In Kapitel fünf wird die Frage untersucht, was die Landwirte unternehmen, um Pflanzenschutzmittelvergiftungen zu vermeiden und ob die Kosten für die menschliche Gesundheit in der Übernahme von nicht-chemischen Pflanzenschutztechniken eine Rolle spielen. Mittels Poissonregressionen wurde die Anzahl der von den Landwirten übernommenen alternativen Techniken modelliert. Zwei verschiedene Indikatoren wurden verwandt, um die Adoption dieser Techniken auf zwei Ebenen darzustellen, zum einen die Anzahl verschiedener Maßnahmen die der Landwirt praktisch getestet hatte, zum anderen die Anzahl der Maßnahmen, die im vorhergehenden Jahr angewandt worden waren. Da die Stichprobe sowohl Landwirte, die an einem Projekt zum Integrierten Pflanzenschutz teilgenommen hatten, umfasste, als auch solche, die nicht teilgenommen hatten, wurde ein zweistufiges Poissonmodell geschätzt. Dieses erlaubt es, einer Verzerrung der Ergebnisse durch die möglicherweise nicht-randomisierte Auswahl der Projektteilnehmer zu korrigieren. Die Ergebnisse zeigen, dass vorherige Erfahrungen mit Pflanzenschutzmittelvergiftungen unterschiedliche Effekte auf die zwei Ebenen der Technikübernahme. Landwirte, die von vorherigen Vergiftungen berichtet hatten, hatten mehr alternative Pflanzenschutzmaßnahmen getestet als solche ohne vorherige Gesundheitsprobleme. Kein Einfluss dieser Variablen gab es jedoch wenn die aktuelle Verwendung dieser Pflanzenschutzmaßnahmen betrachtet wurde. Dies zeigt, dass bei der Entscheidung über die Verwendung von alternativen Pflanzenschutzmaßnahmen die in den Tests ermittelte Effektivität und praktische Umsetzbarkeit eine wichtige Rolle spielt.

Der Einfluss der Anwendung von alternativen Pflanzenschutzmaßnahmen auf den Pflanzenschutzmittelverbrauch wurde mittels linearer Regression untersucht. Zwei verschiedene Effekte wurden modelliert, zum einen eine Veränderung in der angewandten Menge von Pflanzenschutzmitteln, zum anderen eine Verschiebung in der Mittelauswahl, hin zu weniger giftigen Mitteln, gemessen als Mengenanteil von als gefährlich klassifizierten Pflanzenschutzmitteln am Gesamtaufwand. Am Beispiel von Weißkohl konnte gezeigt werden dass bestimmte nicht-chemische Maßnahmen sowohl zu einer Verminderung im Insektizidaufwand als auch zu Reduzierung des Anteils hochgiftiger Mittel führten. Andere Maßnahmen hatten keinen Einfluss, während eine dritte Gruppe von Maßnahmen sogar zu einer Erhöhung des Insektizidaufwandes führte. Diese Ergebnisse veranschaulichen dass der Pflanzenschutzmittelaufwand in der intensiven Gemüseproduktion und die Durchführbarkeit nicht-chemischer Pflanzenschutzmaßnahmen von vielen Faktoren abhängig und schwer vorhersehbar sind. Es konnte jedoch auch gezeigt werden, dass es Möglichkeiten der Einsparung von Pflanzenschutzmitteln gibt und es damit auch möglich ist, die Gesundheitsrisiken von Pflanzenschutzmitteln durch die Anwendung nicht-chemischer Pflanzenschutzmaßnahmen zu verringern.

Insgesamt führen die Ergebnisse der vorgelegten Studie zur Schlussfolgerung dass nicaraguanische Gemüseproduzenten sich der Gesundheitsrisiken von Pflanzenschutzmitteln bewusst sind und bereit wären, für die Vermeidung dieser Risiken zu zahlen, wenn es diese Möglichkeit gäbe. Eine Erklärung dafür, dass sie trotz dieser Einstellungen weiterhin giftige Pflanzenschutzmittel verwenden, könnte darin liegen, dass sie nicht ausreichend darüber informiert sind, welche Risiken mit welchen Mitteln verbunden sind, und welche konkreten Möglichkeiten der Risikovermeidung bestehen. Zukünftige Maßnahmen zur Vermeidung von Pflanzenschutzmittelvergiftungen in der ländlichen Bevölkerung sollten über allgemeine Risikoaufklärung hinausgehen und stärker auf die Nutzen und Risiken einzelner chemischer und nicht-chemischer Pflanzenschutzmaßnahmen eingehen. Dabei sollten den Landwirten konkrete und leicht anwendbar Möglichkeiten der Risikovermeidung aufgezeigt werden.

Zur Bewertung und Planung von gesundheitspolitischen Maßnahmen im ländlichen Raum sind weitere Studien erforderlich, die ökonomische Bewertung von Gesundheitsrisiken durch Pflanzenschutzmittel auf nationaler Ebene vornehmen. Dazu müsste die Analyse auf Bevölkerungsschichten ausgeweitet werden, die primär subsistenz-orientierte Landwirtschaft betreiben. Es ist wahrscheinlich, dass in diesem Sektor die Gesundheitsrisiken anders bewertet werden als von der Gruppe der stärker kommerziell ausgerichteten Gemüseproduzenten, die in der vorgelegten Arbeit untersucht wurde.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CATIE	Tropical Agricultural Research and Higher Education Centre by its Spanish acronym
CV	Contingent Valuation
FAO	Food and Agricultural Organization
INTA	Nicaraguan Institute for Agricultural Technology by its Spanish acronym
IPM/AF	Integrated Pest Management and Agroforestry
IPM	Integrated Pest Management
PAHO	Pan American Health Organization
PIC	Prior Informed Consent
RESSCAD	Conference of Health Sector in Central America and Dominican Republic by its Spanish acronym
UNEP	United Nations Environmental Program
WHO	World Health Organization
WTP	Willingness to pay

1 Pesticides and Human Health – An Introduction to the Economic Analysis

1.1 Introduction

Pesticide use continues to increase worldwide (PAHO 2002; DASGUPTA et al. 2005a; PRANEETVATAKUL et al. 2007; LEE and ESPINOSA 1998), and pesticide poisoning remains a major health problem among farmers in developing countries. The WHO (1990) published first estimates of pesticide poisoning on the global level of 1 million of victims per year. Studies that estimate the incidence among farmers based on survey data report rates of severe acute poisoning of about 5-7% per year in different developing countries. This figure does not seem to have changed over time, considering for example findings of about 7% of the exposed farmers in Sri Lanka (JEYARATNAM et al. 1987), the study of AJAYI (2000) in Ivory Coast and the more recent estimates of SOHN and CHOI (2001) in Korea and CORRIOLS (2002) in Nicaragua.

In this first chapter, existing evidence on the health effects of pesticides among farmers is reviewed and different strategies to reduce pesticide poisoning are discussed. Typical constraints and problems encountered when studying pesticide poisoning in developing country agriculture that are relevant to this research are identified. This leads to the overall objective of the study and the specific research questions. Finally an overview of the structure of this dissertation is given.

1.2 Data sources on pesticide poisoning

Estimates of the incidence of pesticide poisoning are obtained from two main types of data sources: first, there is surveillance or public monitoring data. Surveillance refers to data that is collected through the public health system, where cases of pesticide poisoning are separately registered and reported. Second, surveys and case studies provide information on pesticide exposure and health outcomes for specific situations, points of time or particular groups within the population.

Surveillance systems for pesticide poisoning exist in many countries. The objective is to assess the development and dynamics of pesticide poisoning incidence rates through regular updates about the situation. The information from surveillance can, for instance, be used to identify high-risk regions and hazardous situations and thus help in the design of policies to avoid pesticide health risks. One example of the use of surveillance data is the initiative of health ministries in Central America[1] in requesting the ministries of agriculture to re-evaluate the registration of the 12 pesticides causing most of the poisoning cases in the region (MURRAY et al. 2002). In another case in Nicaragua, surveillance of pesticide poisoning helped to detect a poisoning epidemic due to cheap imports of a highly hazardous insecticide in a formulation that exacerbated exposure for the farmers and workers during application (MCCONNELL and HRUSKA 1993).

However, reliable statistics can only be expected from a surveillance system based on a functioning public health system, where the victims of poisoning have good access to health care, and where health workers are trained to recognize, treat and report these cases (MURRAY and TAYLOR 2000; LONDON and BAILIE 2001). These conditions are commonly not met in developing countries. Farmers in remote areas often have no access to public health care, or health workers are not trained to recognize poisoning. As a result, it can be assumed that public surveillance tends to underestimate the incidence of pesticide poisoning. In Nicaragua, an estimation of underreporting of pesticide poisoning through the public health system revealed that 98% of the cases were not included in the surveillance data (CORRIOLS et al. 2001). Even in developed countries, surveillance data from public health statistics were found to lack accuracy (MILIGI et al. 2005). For example, in the USA, the Environmental Protection Agency (EPA) has “no capability to accurately determine national incidence or prevalence of pesticide illnesses that occur in the farm sector” (U.S. General Accounting Office (GAO), 1993, cited in REEVES and SCHAFER 2003). Surveillance data commonly over represent the mortality from acute pesticide poisonings as compared to less severe health outcomes. Also, as DINHAM (1993) points out, surveillance data tend to overemphasize suicides as the cause of pesticide-related death. The reason is that suicide victims are more often transferred to a hospital and the cause of the emergency is often more obvious than for victims of occupational accidents. Moreover, it has been observed that in Brazil, for example, pesticide-related deaths are routinely associated with suicide, without considering other possible reasons (DINHAM 1993).

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[1] The Conference of Health Ministries includes the following countries: Panama, Costa Rica, Nicaragua, Republica Santo Domingo, Honduras, El Salvador, Guatemala and Belize.

In summary, the variation in the estimates of poisoning cases based on surveillance data is high (Table 1.1), indicating the difficulties in assessing the health risks of pesticides on a larger scale. Also, fluctuations in rates of pesticide poisonings over time could be related to changes in the surveillance efforts rather than to changes in the health situation of the population (PAHO 2002). In most cases the figures will represent only lower bound estimates of the real extent of the problem, while chronic health impairments due to pesticide exposure are rarely included at all in surveillance data.

Table 1.1: Estimates of pesticide poisoning incidence from public surveillance data

Country	Reference year	Estimated rate	Source
World	1985	20/100,000	WHO 2000
Guatemala	1997	5/100,000	HURST 1999
Costa Rica	2006	16/100,000	MINISTERIO DE SALUD 2006
Sri Lanka	1979	79/100,000	JEYARATNAM et al. 1982
Nicaragua	2000	> 35/100,000	PAHO 2002
Japan	2000	<1/100,000	NAGAMI et al. 2005

Source: own presentation

Surveys and case studies are often used to complement or assess surveillance data. An example is the study of CORRIOLS et al. (2001) in Nicaragua. Their results revealed that, compared to survey data, only 2% of poisoning cases were reported by the public surveillance system. Another reason to conduct surveys on pesticide poisoning is to study specific risk factors for poisoning for different target groups, to estimate costs of poisoning or to analyse the effects of pesticide policies on farmers' health. In Table 1.2, poisoning estimates from surveys are reported. For Guatemala, HURST (1999) reports large differences in poisoning estimates, when comparing surveillance data to survey data (Table 1.1 and 1.2).

Approaches to the measurement of pesticide poisoning in surveys and case studies include different medical checks, recall questions for self-reporting of pesticide poisoning and observation of poisoning signs and symptoms. The most detailed and reliable data about the health status of the population are obtained from clinical tests, comparing groups exposed to pesticides and non-exposed reference groups. A relatively simple test is the check of blood concentration of the enzyme cholinesterase, which decreases with increasing exposure to organophosphates, thus indicating poisoning (HRUSKA and CORRIOLS 2002; DASGUPTA et al. 2005). A more comprehensive medical assessment of the outcomes of pesticide exposure includes examination of skin effects, neurobehavioral effects, respiratory tract, cardiovascular effects, the gastrointestinal tract and neurological effects (COLE et al. 1998). While medical tests are the most reliable method for determining the health effects of pesticides, they are expensive and are therefore applied only to small samples.

Self-reporting of past poisoning events based on recall surveys is used to assess more generally the incidence of pesticide health effects in a population. The resulting estimates of the proportion of the population affected by pesticide poisoning differ largely according to the definition of pesticide poisoning applied in the respective study. For example, acute poisoning as reported by farmers often refers to severe cases, when the victim seeks medical treatment or is unable to work for some days (JEYARATNAM et al. 1982; JEYARATNAM et al. 1987; SOHN and CHOI 2001). The incidence rates of acute poisoning range between 5% and 7% of farmers per year. As additional indicators, in many studies, data on different typical poisoning signs and symptoms are collected. These include headaches, dizziness, vomiting, skin irritation, and other symptoms that occur during or shortly after pesticide use and usually disappear after one day (see e.g. CORRIOLS et al. 2001; DASGUPTA et al. 2005; MANCINI et al. 2005). The incidence of such poisoning indicators is often found to be high (see Table 1.2). For example, a study in China found that 20% of rice farmers reported these signs and symptoms (HUANG et al. 2000). Similar results were found for Vietnam (DUNG et al. 1999); and in a study from Indonesia the share of women farmers affected was about 66% (MURPHY et al. 1999).

Which method of data collection should be used depends on the research question: different objectives are pursued using different methods. Clinical tests provide details on the epidemiology and toxicological effects of pesticides, while the focus of self-reporting studies is on farmers' perceptions and knowledge about pesticide health risks.

Table 1.2: Estimates of pesticide poisoning incidence from surveys and case studies.

Country	Reference population	Estimate of incidence	Indicator	Source
Ivory Coast	Farmers	8% / 37%[1]	Rate of acute poisoning	AJAYI 2000
Guatemala	Total population	267/100,000	# of poisonings/year	HURST 1999
Ecuador	Rural population	171/100,000	Rate of acute poisoning	COLE et al. 2002
		20.5/100,000	Mortality Rate	
Nicaragua	Farmers	6.3%	Rate of acute poisoning	CORRIOLS 2002
Nicaragua	Farmers	5.3%	Rate of acute poisoning	LABARTA and SWINTON 2005
Sri Lanka	Farmers	7.1%	Rate of acute poisoning	JEYARATNAM et al. 1987
Malaysia		7.3%		
Indonesia		0.3%		
Indonesia	Farmers	9%	Rate of incidence of symptoms	KISHI et al. 1995
Korea	Farmers	6.9%	Rate of severe poisoning (medical attention)	SOHN and CHOI 2001
Vietnam	Vegetable farmers	27.1-33.9%	Rate of incidence of symptoms	DUNG et al. 1999
Indonesia	Pesticide using women	66%	Rate of incidence of symptoms	MURPHY et al. 1999
China	Farmers	20%	Rate of incidence of symptoms	HUANG et al. 2000
		4-69%	Abnormal laboratory tests, different indicators	

[1] in different survey regions

Source: own presentation

1.3 Approaches to reduce pesticide poisoning

Recognizing the high incidence of pesticide poisoning among farmers in developing countries, different strategies to pesticide health risks have been developed to reduce pesticide poisoning in farming communities. In principle, the strategies focus either on a reduction of the overall amount of toxic pesticides used, or aim at reducing direct exposure through safer handling practices. Reductions in pesticide use can be achieved through substitution with products of low human toxicity or through the use of non-chemical pest control methods. Safer handling of pesticides includes the use of appropriate protective equipment, safe storage of pesticides and avoidance of hazardous practices when handling the products.

There are three different levels where strategies to reduce pesticide poisoning are designed and implemented:

1. International Agreements on pesticide trade
2. Agricultural policies by national governments
3. Actions of private and non-governmental organizations.

In this section these levels of interventions and their specific strategies are briefly discussed.

1.3.1 International Agreements

A general framework covering pesticide use and trade and policy instruments on the international level is the International Code of Conduct on the Distribution and Use of Pesticides, first accepted by the Food and Agriculture Organization (FAO) of the United Nations in 1985 and updated and revised in 2002 (FAO 2003). It provides “voluntary standards of conduct for all public and private entities engaged in or associated with the distribution and use of pesticides, particularly where there is inadequate or no national legislation to regulate pesticides.” (FAO 2003, Article 1.1).

National governments and the pesticide companies are requested to take measures to avoid negative effects from pesticides on human health and environment. These measures include the banning of hazardous pesticides of the WHO classes Ia and Ib, appropriate labelling and adequate information provision for the farmers. The code also makes reference to the Rotterdam Convention on the Prior Informed Consent (PIC) procedure for pesticides in international trade (FAO/UNEP 1998), which states that any country has to give explicit consent if chemicals are to be imported that are listed under the PIC procedure, and that the exporting country should ensure that no exports take place against the consent of the importing country.

The FAO code and the PIC procedure constitute policy instruments that aim to reduce hazards from pesticides and to raise awareness of particular hazardous products (DINHAM 1993). However, the effectiveness of these agreements depends on the effective collaboration of governments and especially the pesticide industry (DINHAM 1993), whose commitment is naturally limited by their own interests. An important constraint is the lack of the capacity of many developing countries to implement and supervise the standards established in the Code of Conduct (KONRADSEN et al. 2003).

1.3.2 Agricultural policies by national governments

On the national level, in most countries pesticide use and trade are subject to government regulation. Pesticide regulations include: registration of pesticides, banning of dangerous pesticides, restrictions on the use of pesticides with respect to certain crops or certain application techniques, e.g. restrictions on the use in aerial spraying or application only by specially trained applicators. Sometimes, regulations include standards for pesticide sales with respect to education and training of pesticide sales agents and the location of a sale. Other policy instruments on the national level are taxes and subsidies on pesticides and measures to promote alternative pest control practices.

There are examples of successful reduction of pesticide poisoning through banning of pesticides in developing countries. KONRADSEN et al. (2003) report about case studies in different countries, where the number of deaths through pesticide poisoning was significantly reduced after a ban of the most hazardous products. A recent example is the Nicaraguan case of pills of aluminium phosphate, used as an insecticide in stored grain, which were prohibited in 2004. Poisoning cases had included suicides, as ingestion of the pills is extremely easy, as well as accidental cases, since treated grains often are stored in farmers' homes. Two years after the prohibition, the number of lethal poisoning cases had been reduced from 150 per year before the ban to less than 50 (MINSA 2006). In Sri Lanka, the organophosphates monocrotophos and methamidophos were banned in 1995, which resulted in a reduction of poisonings by these products; however, poisoning with endosulfan increased until this product was also banned in 1998 (ROBERTS et al. 2003). This case shows that the ban has to be accompanied by the introduction of non-hazardous alternatives to avoid the problem shifting to another product or the continued illegal use of the banned pesticides (see also DINHAM 1993).

Taxes as policy instruments to reduce pesticide use have been discussed in different studies: AGNE (2000) pointed out that a tax on pesticides should be designed to take into account the environmental impact of different products in order to be effective. Directly addressing pesticide poisoning, results of a simulation of pesticide taxes from the Philippines and Ecuador show that the increases in production costs due to a tax would be offset by cost reductions through the positive effects on the health status of farmers (ANTLE and PINGALI 1995; ANTLE et al. 1998).

Besides specific pesticide regulation, other agricultural policies can also have an impact on pesticide use: If a pesticide-based system of agricultural production is favoured and implemented through direct subsidies or a focus on pesticides in national agricultural research and extension, the result is probably overuse of pesticides (FLEISCHER et al. 1999) and thus higher poisoning rates. Other conditions implying a pro-pesticide bias in agricultural policies are less obvious, such as lack of transparency in the regulatory decision-making process and lack of accounting for health effects and external costs of pesticide use. AGNE et al. (1995) provide a framework for analysis of factors that promote overuse of pesticides and hence contribute to the problem of pesticide poisoning.

1.3.3 Projects of Private and Non-governmental Organizations

A number of studies report that farmers in the developing world use highly toxic pesticides in an unsafe and hazardous manner, describing the lack or non-use of protective clothing, mixing pesticides with bare hands, using leaking backpack sprayers, storing of pesticides in kitchens or bedrooms, re-using pesticide bottles for drinking water and children playing with empty containers (see e.g. (DINHAM 1993; MURPHY et al. 1999; AJAYI 2000; MANCINI et al. 2005). Different explanations are offered for this observed behaviour and hence different solutions are proposed. Lack of awareness of pesticide health effects may be one reason, as mentioned by AJAYI (2000). CROPPER (1994) argues that although most farmers know about the detrimental effects of pesticides on human health in principle, they may be ignorant about chronic effects. Also, farmers may be unaware of the different exposure pathways, for example the absorption of toxic substances through the skin. This leads to underestimation of the health risks and unsafe handling of pesticides. According to this view, information and awareness campaigns are needed in order to change farmers' unsafe behaviour.

Another factor relates to attitudes determined by culture. In a study of a project with potato farmers in Ecuador, COLE et al. (2002) described the belief that only “weak” men needed protection against pesticides poisoning. In this project the aim therefore was to change attitudes and encourage people to accept safe use practices. One method to achieve a change in behaviour was to encourage women to warn their husbands of the dangers of pesticides and not put the economic bases of their families at risk (COLE et al. 2002).

Another explanation why farmers use pesticides in a hazardous manner is given by ZILBERMAN and CASTILLO (1994). They suggest that the phenomenon of cognitive dissonance may be a reason why farmers use pesticides in an unsafe manner. Farmers know in principle that they put themselves at risk when applying toxic pesticides; however, after frequent applications they develop subjective perceptions that underestimate the health risks of pesticides. This view is supported by the findings of AJAYI (2000), that farmers get used to pesticide exposure and poisoning symptoms, which leads to underestimation of health risks.

As a response to widespread evidence of unsafe and hazardous handling of pesticides, campaigns to promote their safe and rational use have been initiated. One example is the initiative of the Global Crop Protection Federations with three pilot projects on safe use of pesticides that were implemented in Kenya, Guatemala and Thailand (HURST 1999). More than 260,000 farmers and farm workers, 20,000 retailers, health workers, teachers and schoolchildren were trained to be aware of pesticide health risks and the practices needed for safe use. While recognizing that this approach could contribute to the creation of a positive awareness towards safer use of pesticides in different groups of the society who are potentially exposed to pesticides, HURST (1999) criticized the training concepts and implementation as too short and top down. Other researchers point out that the evaluation of the pilot projects focused on demonstrating the project efforts, but changes in behaviour in the long term and significant reductions in pesticide poisoning of farmers could not yet be shown (MURRAY and TAYLOR 2000; MURRAY and TAYLOR 2001).

Another example of training in safe use of pesticides was the programme on Safe and Effective Use of Crop Protection Products in Developing Countries financed by the Novartis Foundation[2] (ATKIN and LEISINGER 2000). It was implemented in Mexico, Zimbabwe and India and included the training of farmers and other groups of the society such as medical doctors, pesticide retailers and school children. In this programme, a variety of training methods was used, such as farmer meetings, demonstration plots and radio programmes. A focus was given to approaches specific to the cultural context of the target regions, i.e. using theatre plays in Zimbabwe or cartoon books in Mexico. Results of accompanying impact studies showed mixed effects from the programme. Farmers' knowledge on pesticide health risks and safe practices was increased. However, the translation of knowledge into practice was limited to simple procedures that did not require expenses and additional clothing. Adoption of these practices after the end of the programme was found to be low. ATKIN and LEISINGER (2000) therefore point out that safe use training in farmer communities should be a long-term activity of pesticide manufacturers in order to achieve sustainable risk reductions.

That farmers are reluctant to adopt specific protective clothing for pesticide application has been explained by its inappropriateness for tropical environments. This makes it highly inconvenient for farmers to use (MCCONNELL and HRUSKA 1993; MURRAY and TAYLOR 2000). Also, HRUSKA and CORRIOLS (2002) did not find a positive effect in the use of protective gear to reduce exposure to pesticides and point out that gloves or rubber boots may even have adverse effects if they become damaged or contaminated. In this case, exposure to pesticides would be even higher.

In view of the limited effects of the promotion of the safe use of pesticides, different authors classified this approach as the "least effective" as compared to the elimination of hazardous products, and programmes that aim at reducing pesticide use (MURRAY and TAYLOR 2000; COLE et al. 2002; KONRADSEN et al. 2003).

The major approach to achieving a general reduction in pesticide use is the implementation of Integrated Pest Management (IPM). The objective of IPM is to reduce the dependency on chemical pesticides by introducing a knowledge-based management of the cropping system with more emphasis on alternative pest control measures (WAIBEL et al. 1998). Information is the most important factor in IPM because farmers can decide on pest control based on close

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[2] "This research programme was undertaken as part of the Risk Fund set up by Novartis (then Ciba-Geigy) in 1988 to support its business activities in the Third World. The fund is intended for commercially oriented projects that require especially extensive services or preparations or expensive support" (ATKIN, JOHN and KLAUS M. LEISINGER (2000). Safe and Effective Use of Crop Protection Products in Developing Countries. New York, USA., Preface, p. vii.)

observation of their crops and considering the relationships among crop, pest and agro-ecosystem (STAVER 2004). Positive effects on farmer health can be expected due to either a reduction in pesticide use or a shift towards less hazardous pesticides (SMITH and CALVERT 1976).

Different studies on the impact of IPM programmes on pesticide use show that the majority of farmers adopting this technology have reduced their pesticide use significantly (see e.g. VAN DEN BERG 2004). In the case of one of the largest training programmes in IPM, the FAO Farmer Field School Programme in rice production in Indonesia (KENMORE 1996), large effects on pesticide use have been claimed. However, some of the results have generated controversy (FEDER et al. 2004). So far, empirical evidence on the health benefits of IPM programmes is scanty. The lack of large-scale adoption may be one reason for the low impact on pesticide poisoning incidence rates on national or regional levels. MORSE and BUHLER (1997; p. 91) point out that only about 0.05% of Asian rice farmers are practising IPM and that adoption of IPM in Latin America has remained low so far. The high cost of IPM training, especially of the Farmer Field Schools (a method that relies on season-long training with participatory methods and field based learning) means that this is not always cost effective. Also, little diffusion of knowledge from training participants to non-participants occurred, as found in a case study in the Philippines (ROLA et al. 2002). Other constraints on widespread adoption of IPM include policy factors and promotion of pesticides by private and public institutions (MORSE and BUHLER 1997).

Specifically designed impact assessment studies including potential health benefits of IPM are rare. In their Zimbabwean case study, MAUMBE and SWINTON (2003) did not find an impact of farmer training in IPM on the incidence of health symptoms from pesticides. Also, in the Bangladesh study of DASGUPTA et al. (2007), evidence on health effects of IPM cannot be confirmed empirically. Especially in studies that use self-reporting to measure health effects, IPM training and adoption may have two opposite effects: the reduction of health risks through reductions in pesticide use and the increased awareness of pesticide health risks leading to increased reporting of poisoning symptoms. On the other hand, DASGUPTA et al. (2007) raised the question of to what extent the awareness of pesticide health risks constitutes an incentive to adopt a pesticide-saving technology like IPM. LABARTA and SWINTON (2005) found a positive impact of prior experiences with pesticide health symptoms on the adoption of key practices of IPM among Nicaraguan bean farmers and a negative correlation with insecticide use. However, pesticide use in bean production is generally rather low and the health effects that are actually achieved through IPM in that case study were small (LABARTA 2005).

1.4 Research gaps

The review of literature has revealed that ample evidence exists about the severity of the pesticide-poisoning problem among farmers in the developing world. However, actual estimates of the numbers of farmers affected through acute poisoning are likely to represent a lower bound of the real figures. In particular, the chronic health effects of pesticides remain a widely undocumented phenomenon so far. Also, the estimates of health costs of pesticides are likely to reflect the lower bounds of actual costs, especially with regards to chronic illnesses. In order to determine socially optimal pesticide use levels and design effective policies to reduce pesticide poisoning it is necessary to account for the full health costs of pesticides.

The health costs of pesticides are closely interlinked with the decision-making about pesticide use and alternative pest control practices. Hence, the methodological challenge is to analyse the effects of three main factors, namely pesticide use, the health costs of pesticides and the adoption of alternative pest control measures (Figure 1.1).

As a starting point, these factors can be viewed in a sequence: pesticide use is the cause of pesticide poisoning, expressed as health costs. The reduction of pesticide use through adoption of IPM then is a possible solution to the poisoning problem. However, the analysis has to consider different linkages between these aspects: while pesticide use determines the health risks of pesticide poisoning, the health costs of pesticides can also be assumed to influence decisions on pesticide use with respect to quantities used and the toxicity levels of products. But the empirical evidence that farmers reduce pesticide use because of health costs is weak. Some studies find an effect of personal experience with pesticide poisoning on pesticide use (WILSON and TISDELL 2001; LABARTA and SWINTON 2005). In other cases, health variables were shown to have no effect on pesticide use levels (MAUMBE and SWINTON 2000). Unawareness or lack of knowledge of the pesticide health risks has often been mentioned as the driving factor in pesticide poisoning, e.g. in the case of Philippine rice farmers who use pesticides; although returns are negative if health costs are considered (ROLA and PINGALI 1993). Contrary to these views, ample evidence exists that farmers in developing countries are aware of at least the acute health risks of pesticides, through their own experience with pesticide poisoning or as indicated through a positive willingness to pay to avoid them (WARBURTON et al. 1995; CUYNO et al. 2001).

Studies of the health costs of pesticides have mainly focused on quantifying the health costs and relating them to the extent of pesticide use as the main risk factor for poisoning. So there is a research gap concerning the question of why farmers continue to incur substantial health risks through pesticide use. Therefore an analysis of the relationship between pesticide use and their health costs is needed. The issue to be addressed includes a description of current pesticide use patterns and exposure, which then can be linked to the health effects as perceived by farmers. Then the question as to whether and to what extent farmers are aware of pesticide health risks can be addressed.

Also, there is still a lack of comprehensive evaluations of health costs from the farmers' point of view, including the market costs – as cost of illness – and the non-market costs, which depend highly on farmers' individual perceptions. A detailed discussion of methods to quantify pesticide health costs is provided in chapter 2.

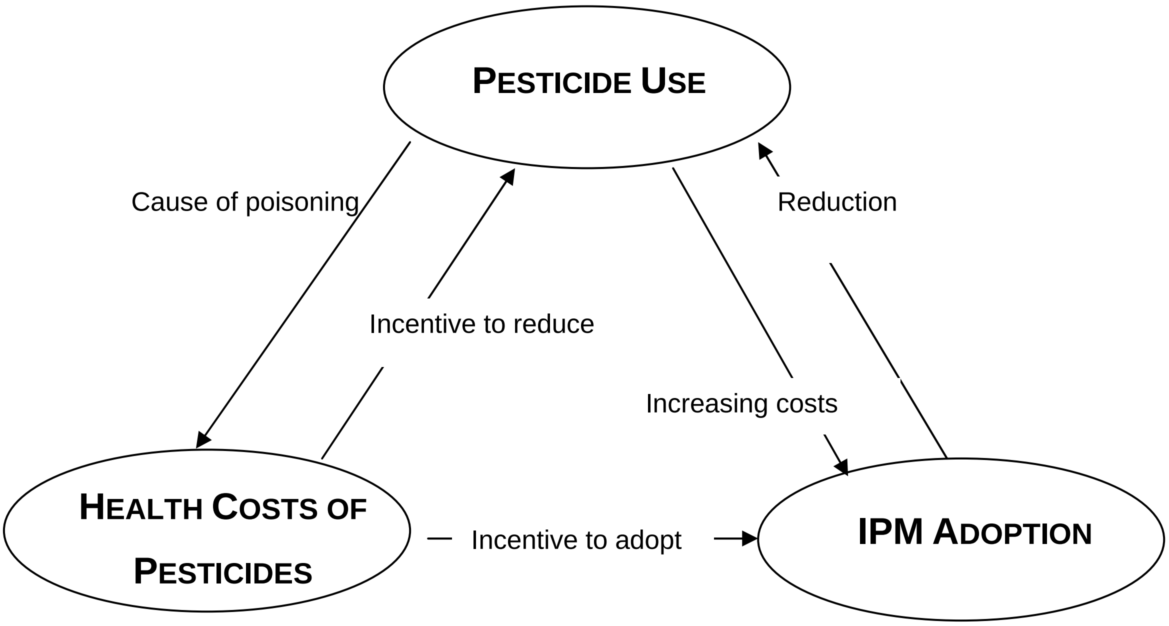


Figure 1.1: Relationships between pesticide use, health costs and adoption of IPM.

Source: Own presentation.

The relationship between pesticide use and the adoption of IPM is partly reciprocal. In IPM, alternative, non-chemical methods of pest control are used to substitute for pesticides, leading to reductions in the use of chemicals. On the other hand, the level of pesticide use can also impact on the adoption of IPM: if pesticides are used at very high levels, it is likely that natural mechanisms of pest control, such as beneficial insects, become less effective. In this situation, agricultural production becomes increasingly dependent on the input of more pesticides, since pest pressure typically increases and natural control becomes inefficient and the costs to adopt IPM increase. This phenomenon has been described as the “pesticide treadmill”, using the concept of path dependency. Each pesticide application contributes to the need for the next application. As a consequence, the costs of restoring the balance between pests and their natural enemies increase as compared to systems with low initial pesticide use. Hence, pesticide use may have negative impacts on the adoption of IPM.

The effect of IPM adoption on pesticide use is the essential factor in its impact on pesticide health costs. Adopters of IPM are assumed to reduce their risk of pesticide poisoning because they reduce their pesticide use or shift to less toxic products. However, high health costs of pesticides may be an incentive to adopt IPM as a strategy to reduce pesticide exposure.

While many studies show that farmers are aware of pesticide health risks to some extent, the link between awareness and actual behaviour has rarely been addressed (LABARTA 2005).

There is still a research gap with respect to the different incentives for farmers when deciding on pest control techniques and pesticide use. The question whether pesticide health costs are a reason for farmers to reduce pesticide use and adopt non-chemical pest control technologies has so far been addressed in two studies with opposing results (MAUMBE and SWINTON 2000; LABARTA and SWINTON 2005). This factor is important for the planning of policies aiming to introduce new pest control technology and reduce pesticide poisoning.

1.5 Objective of the thesis and research questions

Based on the review of evidence of pesticide poisoning among farmers in developing countries and the identified research gaps, the objective of this dissertation is to analyse the extent of the pesticide-poisoning problem, to quantify the health costs of pesticides and assess their effect on the adoption of IPM practices in the case of Nicaraguan vegetable farmers.

The dissertation addresses six specific research questions:

1. What is the extent of pesticide use among Nicaraguan vegetable farmers with respect to the range of products, their toxicity and the time span of exposure?
2. What are the effects of pesticide exposure on the health of Nicaraguan vegetable farmers and what is the relationship between pesticide exposure and self-reported health impairments?
3. Are Nicaraguan vegetable farmers aware of the pesticide health risks?
4. What are the market and non-market health costs of pesticides?
5. What strategies do farmers employ to avoid pesticide poisoning?
6. Do pesticide-related health costs represent incentives for farmers to adopt Integrated Pest Management practices?

These questions will be addressed in a series of papers as outlined in the next section.

1.6 Outline of the thesis

This dissertation presents a collection of four papers that address the research questions raised above and contribute to the methodology needed to answer these questions.

The first essay (Chapter 2) reviews and analyses methodologies applied in previous studies on the evaluation of the health effects and health costs of pesticides. The basic concepts and approaches used in this dissertation are outlined. This paper provides the basis for answering the research questions and explains data needs and data collection for the empirical analyses in this study.

The second paper (Chapter 3) addresses the first three research questions. It provides a detailed picture of the current situation of Nicaraguan vegetable growers, considering details about farmers' perceptions about health risks, perceived health impairments and pesticide use and exposure. Pesticide use patterns are analysed with respect to potential substitution of highly hazardous products by less toxic compounds. The relationship between pesticide exposure and the incidence of pesticide poisoning is established, confirming the viability of using self-reporting as a measure of the incidence of acute poisoning among farmers.

The third paper (Chapter 4) deals with the valuation of non-market costs of pesticide-related health, addressing research questions 3 and 4. It presents an application of contingent valuation to the case of health costs of pesticides among Nicaraguan vegetable growers. The methodology includes a series of validity tests in order to assess the valuation results. Farmers’ willingness to pay statements are assumed to be valid, since they vary with the amount of benefits presented in valuation scenarios and increase with increasing health risks. Also, the indicators of income and wealth show the effects suggested by economic theory. The evaluation and quantification of health costs of pesticides from the farmers’ perspective is important information in understanding the incentives that play a role in decision making about pest control.

In order to answer the last two research questions, the paper presented in chapter 5 analyses in depth the question of adoption of alternative plant protection measures such as IPM. The role of pesticide-related health in farmers’ choices on the use of pesticides and alternative pest management practices is analysed considering two stages in the adoption process: first, the experimentation phase or testing of practices and second, the decision phase, when the farmer decides on adoption or non-adoption of the different practices. The rationale is that health considerations will only have an influence on IPM adoption if health benefits are indeed realized, and no influence will be observed if IPM practices do not lead to reductions in pesticide use. Hence, this methodology allows the identification of potential effects of health costs in the adoption process, which may be overlooked in simpler models.

The last paper (Chapter 6) is a synthesis of the studies presented in this dissertation. It is shown how each of the studies gives answers to the research questions addressing different aspects of the overall theme of the economics of pesticide-related health. The results are summarised and conclusions are drawn. Based on these results, recommendations for further research are presented.

2 The costs of pesticide health effects among small-scale farmers in Nicaragua: a conceptual framework for data collection

2.1 Introduction

As shown in the introductory chapter, pesticide poisoning is a major health problem for the rural population in developing countries. Pesticide poisoning causes costs to farmers and their family members. For example, PINGALI et al. (1994) estimated that the health costs of pesticides for Philippine rice farmers are about USD0.50 to USD1 per dollar of the insecticide costs. Pesticides are also a major factor for the public health system. In a recent study from Nicaragua, a rough estimation indicated that costs totalled about USD2.2 million in the year 2000 or 14% of the expenditure for agricultural expenditure for pesticides (CORRIOLS et al. 2001).

The estimation of health costs includes major challenges. The problems of data availability and quality for measuring the incidence of acute and chronic pesticide poisoning, outlined in the previous chapter, also affect the assessment of pesticide-related health costs. Additionally, there are specific methodological challenges, because the evaluation of health costs of pesticides is necessarily connected to the question of the value of human health in general.

Addressing this question on the basis of welfare theory, the utility an individual derives from his own health is the appropriate reference measure. Hence, in the agricultural context, different value aspects of health can be identified (Table 2.1). The production value of health is derived from the fact that health is the basic condition for an individual to provide labour, a critical input in agricultural production. Besides, individuals derive utility from being healthy, which can be interpreted as the value of wellbeing as such. In analogy to the concept of the total economic value of natural resources (PEARCE and TURNER 1990), the value of pesticide-related health can be described as the sum of the production value and the value of wellbeing.

Table 2.1 illustrates the different value components of health and the valuation approaches. Generally, the production value of health is represented by the cost of illness caused by pesticides. Its valuation is based on market prices and includes productivity effects such as yield loss or decreased supply of family labour, and cost effects such as the cost of treatment of pesticide poisoning or wage premiums for pesticide application. For the assessment of the value of wellbeing, market as well as non-market based methods are used. For example, the farmers' efforts to avoid or mitigate pesticide health risk, spending on protective equipment, hired labour or alternative pest control, can be valued using market prices. Finally, individual wellbeing can be evaluated more directly using stated willingness to pay measures, in which respondents evaluate hypothetical market scenarios (Mitchell and Carson 1989). The underlying assumption for these types of approaches is that farmers have preferences for economic goods and non-market goods such as health, which are unobservable in the markets, but which would be observed if market choices existed.

Table 2.1: Aspects of value of human health and indicators for measurement.

Criteria	**Value of labour**		**Value of wellbeing**	
Basis of measurement	**Prices of market goods**			**Hypothetical prices**
Type of costs	**Productivity effects**	**Cost effects**	**Risk mitigation and substitutes**	**Willingness to pay**
Examples	Effects on farm productivity, Supply with family labour, Management skills	Treatment costs, Drugs, pharmacy, consultancy fees, wage premiums for pesticide application	Protective clothing, Investment in IPM training and implementation, Hired labour instead of family labour	Contingent valuation, Willingness to pay for reduction of health risks

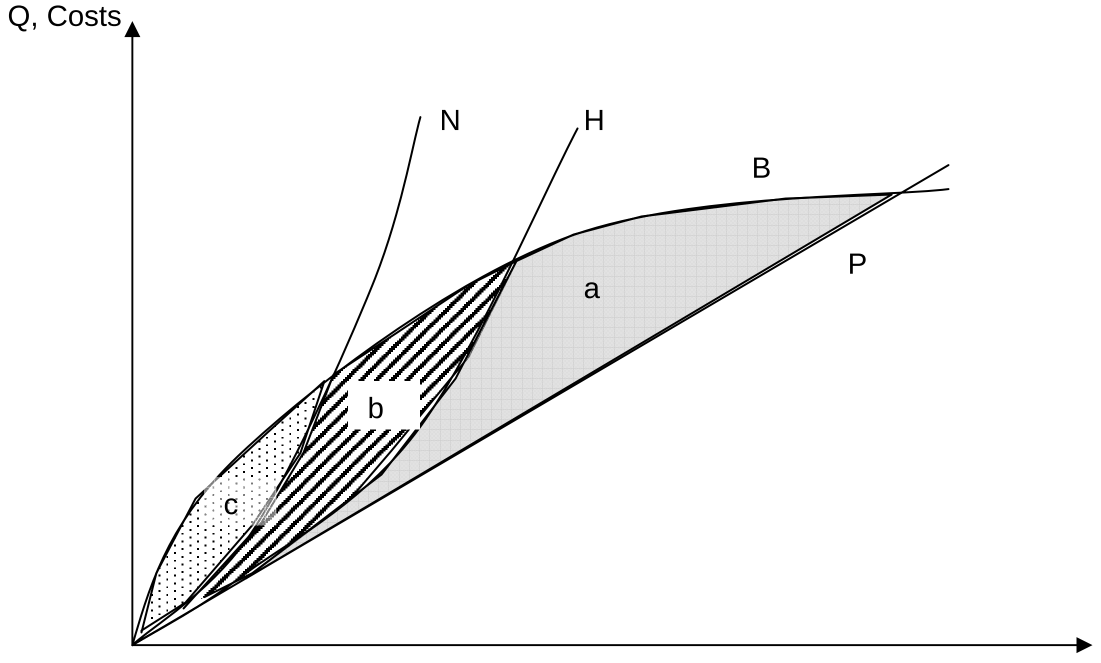
Source: adapted from Zander 2001

In the literature, two main types of studies valuing the health costs of pesticides can be found; studies focussing on the costs of illness, which in the categorization of Table 2.1 include the productivity and cost effects, and studies on the willingness to pay for health, either revealed willingness to pay as measured by surrogate market methods or stated willingness to pay using contingent valuation techniques.

This paper provides an overview of the different approaches to the evaluation of health costs of pesticides applied so far. Methodological challenges and data needs are identified. Based on this analysis, the conceptual framework of data collection used in the presented studies to evaluate the health costs of pesticides for Nicaraguan vegetables is outlined and described.

2.2 Evaluation of health costs of pesticides

The evaluation of health costs of pesticides has two main purposes: (1) To inform policy makers to take these costs into account in cost benefit analysis as a means of evaluating agricultural policies that affect pesticide use. These include registration, taxes and subsidies, and policies in the rural health sector, including for example, special training of health workers. (2) To assess the economically optimal level of pesticide use with and without health costs. This is illustrated in Figure 2.1. The effects of pesticide use in plant production are measured by the prevented loss of revenue. The area between the revenue and cost curves represents the benefits of pesticide use. If health costs are not considered, the benefit of pesticide use comprises the sum of areas a, b and c. There are two possible cost curves for the health costs. Curve H shows the market cost of illness, e.g. labour lost due to sickness and expenditure for treatment. Considering these costs reduces the benefits of pesticides to the areas b and c. The inclusion of non-market effects raises the costs to curve N and the benefits decrease to area c, which therefore represents the “true” benefits of pesticide use.



X = Pesticide use

Q = Potential Yield Loss Prevented by Pesticides

B = Yield loss prevented by pesticide use

P = Pesticide costs without health costs

H = Pesticide costs including market costs of pesticide poisoning

N = Pesticide costs including market and non-market health costs

Figure 2.1: Impact of human health costs on benefits from pesticide use.

Source: adapted from Ajayi 2000

2.2.1 Cost of illness approaches

Most studies on pesticide health costs so far have concentrated on measuring the cost of illness due to pesticide exposure, applying a range of different techniques.

Ajayi (2000) provides the framework of a cost accounting approach, defining different cost categories: damage acceptance, preventive costs, mitigation costs and unknown costs. Damage acceptance costs include productivity loss of family labour and increased farm production risk; mitigation costs comprise all costs of treatment of the illness, including travel, medication, fees and materials for self-administered cures. Cost of protective clothing and preventive treatments are summarised as preventive costs. Chronic illness is assigned to unknown costs, and is not included in the accounting. Ajayi (2000) argues that the optimum level of pesticide use, determined by their costs and benefits, would be lower if farmers were aware of and considered the full health costs of pesticides. A similar methodology of cost accounting to estimate pesticide health costs was used by HUANG et al. (2000) in their Chinese case study and MAUMBE and SWINTON (2003) for Zimbabwean cotton farmers. Cost accounting is useful for the evaluation of severe acute poisoning. However, chronic effects, which represent an important health risk, are not included. ROLA and PINGALI (1993) tried to quantify these costs based on clinical data, from which the cost to restore farmers' health up to a level of a non-exposed reference population was estimated.

The cost of treatment of pesticide poisoning included in the accounting approaches depends on a number of factors. AJAYI (2000) pointed out that farmers seem to get used to poisoning symptoms over the years of exposure and accept them as common side effects from spraying. In the survey region where pesticides had been used only for short time, farmers' expenditure on mitigation of poisoning was significantly higher than in the region with many years of pesticide use. Another important aspect is the access to health services. Where no such service is available, illnesses remain untreated and no costs are included in the accounting.

A different approach to measure the production value of pesticide-related health is the health production function approach (ANTLE and PINGALI 1995; ANTLE et al. 1998). With this methodology, the impact of health impairments due to pesticides on the production cost of rice in the Philippines and potatoes in Ecuador was analysed. Their model includes the estimation of health impairments caused by exposure to pesticides and the production costs, dependent on prices of inputs, expected yield and health impairments. Results show that pesticide-related health impairments increased overall production costs, implying that the farmers' capacity to manage the crop efficiently was affected by pesticide health effects. This methodology avoids the bias of non-inclusion of costs when illnesses remain untreated for some reason or in the case of chronic health effects. In these cases, farmers' health is impaired for a longer time period, during which productivity is affected. Hence this cost is included as increase in production costs. However, in the application of this approach the data requirements to establish the relationship between pesticide use and health impairments are high. Medical checks and tests to separate pesticide effects from other factors that affect health conditions have to be carried out.

2.2.2 Willingness to pay approaches

A comprehensive evaluation of health costs of pesticides would include not only the market costs of illness but also the non-market value of health such as the cost of pain or the risk of non-treated chronic illnesses that lead to decreased life expectancy. Assuming utility maximising behaviour and perfect markets and information, farmers' valuation of pesticide-related health would be observable from their choices on how much and which pesticide to use, trading off between health risk of pesticides and income generation (LOHR et al. 2000). Additionally, farmers may use strategies to decrease pesticide exposure while maintaining the level of agricultural production. The concept of trade off and the effect of risk avoiding strategies are illustrated in Figure 2.2. Assuming that agricultural output is linked to the intensity of pesticide use, improvements in human health are achieved by reducing agricultural output and farmers choose their level of output and health according to their preferences: for instance, operate on the level H_0 following the trade-off curve T_o. If strategies to avoid pesticide exposure are employed, such as the use of protective equipment or alternative pest control, the trade-off curve T_1 is relevant, allowing for better health status on the same level of agricultural production. Note that the part T** of the curves implies that at a very low health status, agricultural production may be affected by the reduced capacity to provide labour (ANTLE et al. 1998).

Following the concept of the trade-off between health and income generation through agricultural production, the value of pesticide-related health including market and non-market aspects is defined by the amount of income an individual farmer is willing to forego or to pay in order to increase his health status.

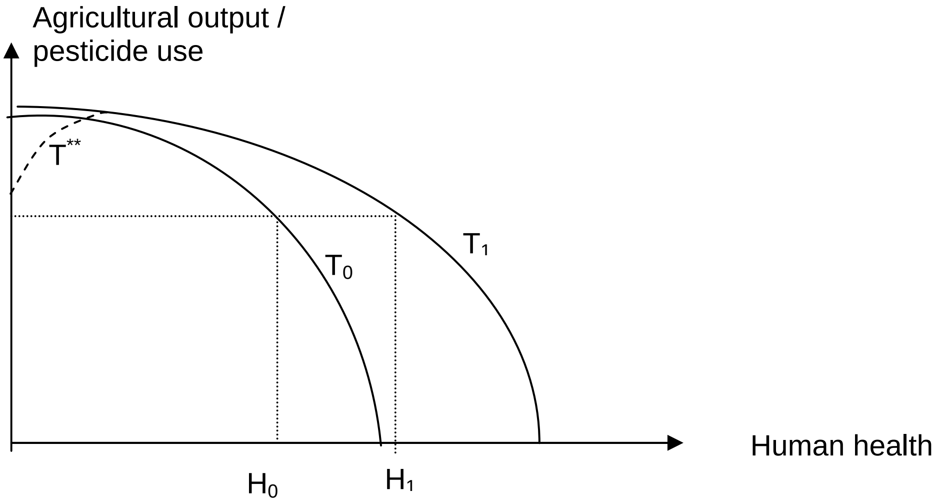


Figure 2.2: Trade-off between human health and agricultural production and the effect of mitigation of health risks.

Source: adapted from Crissmann et al. (1998)

Willingness to pay approaches include both revealed willingness to pay for surrogate products and stated willingness to pay in hypothetical market scenarios.

The surrogate products approach measures farmers' expenditure on goods that prevent pesticide poisoning, including the strategy of hiring labour for pesticide application instead of using family labour, expenses on personal protective equipment or investment in alternative technology of pest control without pesticides. COLE et al. (2002) report that participants of a training programme on pesticide use and health were willing to purchase protective equipment, hence revealing their valuation of pesticide health risks. WARBURTON et al. (1995) used the surrogate product of protective equipment in a hypothetical market scenario, analysing farmers' willingness to pay for protective equipment among Philippine rice farmers and found it to be positively correlated with income variables and education. However, there are problems in using the willingness to purchase and use protective equipment as proxies for the valuation of health. While farmers generally can be assumed to be somehow aware of pesticide health risks (WARBURTON et al. 1995), the appropriateness and effectiveness of protective equipment under the common conditions in tropical climates may be questionable. ANTLE et al. (1998) point out that additional costs of inconvenience related to the use of protective clothing affects the adoption of these items, hence, observed expenditure represents only a share of farmers' real willingness to pay for health. This would be one possible explanation of the frequent observation that farmers in developing countries rarely use full protective equipment (see e.g. GOMES et al. 1999; MAUMBE and SWINTON 2003;

JIRACHAIYABHAS et al. 2004). Hiring labour for the application of pesticides is another possible strategy for avoiding pesticide health risks for the farm household. LABARTA (2005) found that some evidence that experience with pesticide poisoning led to increases in the demand of hired labour for spraying. Yet one limitation of this approach for measuring revealed willingness to pay for health risks is the issue of substitutability of family and hired labour for this task. If the farmer controls the effective application of the pesticide, he may still be exposed to the product while supervising. Commonly, farmers prefer to mix the pesticides themselves, hence they still are left with the most hazardous part of the application.

Given these limitations of the valuation based on revealed willingness to pay for surrogate products and preventive expenditure, stated willingness to pay approaches or contingent valuation techniques have been proposed to evaluate non-market health costs of pesticides (HIGHLEY and WINTERSTEEN 1992). Contingent valuation uses hypothetical market situations, where the evaluated good is described in detail to survey respondents who give a statement at what price they would be willing to buy the good (MITCHELL and CARSON 1989).

So far, few studies have applied this method to quantify the non-market health costs of pesticides. FLORAX et al. (2005) used 15 studies in their meta-analysis that provided monetary estimates of willingness to pay for reducing pesticide risks, most of which referred to consumers, who are potentially exposed to pesticides through contaminated food. The valuation scenario chosen for consumer surveys is usually the purchase of pesticide-safe food, like fresh vegetables (VANIT-ANUNCHAI 2006). MULLEN et al. (1997) refer more generally to the respondents' monthly grocery bill as the starting point for the valuation of pesticide effects on environment and human health. With respect to farmers' health risks from pesticides, the valuation scenario often refers to the willingness to pay for a pesticide that is safe for human health. For instance, the study of OWENS et al. (1998) analysed US farmers' willingness to pay for a safe herbicide substituting for the herbicide atrazine, considering health effects of pesticides for farmers and other environmental effects such as leaching to groundwater and fish toxicity. The results showed that farmers were most concerned about on-farm effects, with the highest willingness to pay for human health and groundwater effects. LOHR et al. (2000) studied US farmers' valuation of insecticide risks on environment and human health, asking directly for the trade-off between yield and reduction of risks. This approach differs from the previously mentioned contingent valuation studies, because rather than using a hypothetical product like a safe pesticide, farmers stated how much yield they would be willing to sacrifice in order to reduce health risks from one pesticide application. This setting is probably closer to the theoretical concept of a trade-off between the production of agricultural output and human health.

A contingent valuation study with farmers in a developing country was carried out by CUYNO et al. (2001) studying the case of Philippine vegetable farmers in order to evaluate an IPM programme with expected reductions in pesticide use. Like the studies from the US, farmers were asked to value a range of risks to different environmental categories, including human health. In this study, farmers were again asked to state their willingness to pay for a safe pesticide. Results showed that willingness to pay for human health is higher than for the other categories, summing up to about 22% of current pesticide expenditure. WILSON (2002), in his study in Sri Lanka, did not use the safe pesticide scenario, but asked farmers the direct question how much would they be willing to pay in order to avoid the costs of pesticide poisoning.

There are some critical issues in contingent valuation studies, which have been discussed extensively (HAUSMAN 1993). One main point is the validity of value judgements based on hypothetical questions. However, CHAMP et al. (2003) argue that this is not an issue questioning the method as such, pointing out that each individual study should be assessed using a set of validity tests. MITCHELL and CARSON (1989) describe different aspects of validity of contingent values and methods for their evaluation. Another important aspect, which is especially relevant in the above cited studies, is the question how the valuations of different non-market goods are interlinked, e.g. how values are affected if pesticide effects on human health and other environmental categories are evaluated in separate scenarios. This can lead to problems when aggregating stated willingness to pay, e.g. in order to obtain estimates of the health benefits of projects.

2.2.3 Overview of applications of valuation approaches

Recent studies evaluating the health effects of pesticides are summarized in Table 2.2. Cost accounting studies have been used for different purposes. One is the assessment of pesticide health costs accruing to the farmers and an explanation of farmer decision making (AJAYI 2000; HUANG et al. 2000). COLE et al. (2000) used this farmer level information for subsequent project interventions and for community training purposes, while the analysis of CORRIOLS (2002) aims at estimating health costs accruing on a national level.

Compared to the cost accounting studies, the health production function approach provides important additional information by linking the health costs directly to the amounts of pesticides used and by including chronic and untreated illnesses. This allows the establishment of models for the analysis of different policies. Some studies simulated the effects of taxing pesticides on the production costs (ANTLE and PINGALI 1995; ANTLE et al. 1998). Assuming price elasticities for the demand of pesticides, a tax led to decreases in pesticide use. This reduction in pesticide use then resulted in better health among farmers, and lower health costs. The effects on the net change in production costs were different in the analysed production systems. In the Philippine rice growing system, taxes on pesticides caused reductions in health costs that overcompensated for foregone production at lower pesticide use levels, implying an increase in social welfare. In the higher intensity potato cropping system in Ecuador, the effects of pesticide taxation were more differentiated and more strongly linked to the health risks of specific pesticides because of higher yield losses at lower pesticide use levels (ANTLE et al. 1998). While a general tax on pesticides improved farmers' health status, net reductions in production costs and health benefits overcompensating yield losses were only achieved by a specific tax on the most hazardous pesticide Carbofuran.

The willingness to pay approaches allows the valuation of not only the cost of illness but also the intrinsic non-market value of health. Therefore, contingent valuation studies have been used to include health costs of pesticides in a quantitative manner in cost benefit studies of programmes promoting, for example, Integrated Pest Management (BRETHOUR and WEERSINK 2001; CUYNO et al. 2001; MULLEN et al. 1997). Another important aspect in willingness to pay studies is that they provide information about the farmers' perceptions of health costs of pesticides. This type of valuation contributes to the understanding of the incentives that are involved in their decision making about pesticide use, which can be helpful in assessing the feasibility of programmes aiming to change pesticide use patterns. However, the question of practical implications of stated willingness to pay for farmers' decision making about technology and pesticide use has so far not been investigated.

Table 2.2: Studies on health costs of pesticides.

Country	Crop	Acute effects	Chronic effects	Approach	Source
Cote d'Ivoire	Cotton	Yes	No	Cost accounting	AJAYI 2000
China	Rice	Yes	No	Cost accounting	HUANG et al. 2000
Ecuador	Potato	Yes	No	Cost accounting	COLE et al. 2000
Nicaragua	Agriculture	Yes	No	Cost accounting	CORRIOLS 2002
Zimbabwe	Cotton	Yes	No	Cost accounting	MAUMBE and SWINTON 2003
Philippines	Rice	Yes	Yes	Costs to restore health	ROLA and PINGALI 1993
Philippines	Rice	Yes	Yes	Health production function	ANTLE and PINGALI 1995
Ecuador	Potato	Yes	Yes	Health production function	ANTLE et al. 1998
USA	Maize	Yes	Yes	Willingness to pay	OWENS et al. 1998
Philippines	Onion	Yes	Yes	Willingness to pay	CUYNO et al. 2001
Sri Lanka	Agriculture	Yes	Yes	Willingness to pay	WILSON 2002
USA	Apples	Yes	Yes	Willingness to pay (Consumers)	RAVENSWAAY VAN and WOHL 1995
USA	Grocery	Yes	Yes	Willingness to pay (Consumers)	BRETHOUR and WEERSINK 2001

Source: own presentation

2.3 Methodological concept and framework of data collection

In this dissertation, pesticide health costs are evaluated using both main approaches described above (cost accounting of the market cost of illness, and willingness to pay) to assess the full health costs, including non-market value components as perceived by farmers.

The evaluation of health costs is based on the characterisation of pesticide exposure and health effects. In order to answer the research questions on farmer awareness and the role of health costs in the decision making on pest control, the relevant measure are farmers' perceptions on pesticide health effects and costs. Therefore, the causal relationship between pesticide use and health effects is established using regression methods.

While pesticide use and the resulting health effects can be studied based on cross-sectional data, the question of the effect of health costs on pesticide use and other pest control methods can only be answered if different time periods are considered. For example, present pesticide use can be assumed to be influenced by previously experienced pesticide poisoning. These kinds of time effects were accounted for in the data collection process. Primary data was collected using household surveys (Figure 2.3). These included intensive monitoring of actual pesticide use and perceived health effects as well as a set of recall questions to capture previous experiences with pesticide poisonings. Pesticide poisoning is a severe health outcome that most likely will be remembered over a long period of time; hence responses to these questions should be highly reliable. Two measures of health costs are established in this dissertation: the market costs accounting for all expenses and lost labour that farmers incurred due to acute poisoning, and the non-market costs as estimated from the farmers' willingness to pay in a contingent valuation survey.

The case of small-scale vegetable farmers in Nicaragua has been selected for this study for a number of reasons. Nicaragua is a country with relatively high pesticide use and high poisoning rates among farmers (PAHO 2002). Secondary data about pesticide poisoning incidence is available through the public health monitoring system of the Ministry of Health and a recent study on the underreporting of pesticide poisoning in the public statistics (CORRIOLS et al. 2002). An agricultural census was carried out in Nicaragua in 2001 (Cenagro III), providing information about land holdings, land use, access to resources and agricultural activities.

In vegetable production, pesticide use intensity is especially high as compared to food grain production. Also, vegetables are cash crops sold to the local markets, hence farmers are connected to the commercial sector, they use different information sources and are familiar with a large range of different pesticides from which they choose the inputs used in their crops. It can be assumed that crop management and input use is highly variable in vegetable production and farmers deal with pest control and pesticide health risks using different strategies.

In Nicaragua, IPM has been promoted by different programmes over a long time period. One of the largest IPM programmes in Nicaragua is the CATIE IPM/AF programme, started in 1989 in response to pest outbreaks in vegetable and coffee production. In different project phases it evolved from a research and technology development programme to develop participatory research approaches and finally organized large-scale participatory IPM training of producers of coffee, vegetables and food grains all over the country until 2003. The programme cooperated closely with governmental and non-governmental agricultural organisations, intervening at different hierarchical levels in order to achieve broad support for the implementation of IPM in Nicaragua[3]. As a consequence, by now there are a number of different sources of information about IPM and alternative pest control methods available to farmers in Nicaragua. For example, the public extension service (INTA[4]) as well as a number of NGOs, promote alternative pest control and pesticide reduction among farmers (LABARTA 2005) and related topics are also disseminated through radio and newspapers. This provides a good background in which to study the adoption of this alternative pest control technology.

The CATIE IPM programme hosted the fieldwork for the presented studies. For one part of the data collection the participation in the training organised by this programme was used for the stratification of the sample. In the other main part of data collection however, the variable “participation in IPM training” is not restricted to CATIE training and comprises IPM training by different organisations.

The data collection framework was designed to account for different data requirements in order to answer the research questions and in order to minimise bias from the data collection method. As outlined in Figure 2.3, two surveys were carried out, one designed as a monitoring survey focussing on details about vegetable production, pesticide use and exposure as well as precise descriptions of health conditions and poisoning episodes. The other was implemented as recall survey covering IPM adoption and the valuation of health costs through willingness to pay.

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[3] Another relatively large IPM programme in the country is called PROMIPAC, organising IPM training for small-scale producers following the Farmer Field School training approaches. The focus of the training however is IPM in food grain production.

[4] Nicaraguan Institute for Agricultural Technology by its Spanish acronym: Instituto Nicaragüense de Tecnología Agropecuaria.

MONITORING SURVEY

Sample

Participants of IPM training (105 respondents)	Non-participants of IPM training (86 respondents)

Department	Matagalpa	Estelí	Madriz	Jinotega
Municipality	Sébaco	Condega Pueblo Nuevo	San Lucas	Jinotega
Villages	Sabana Verde Ampompoá La China Carreta Quebrada	Santa Teresa Motolín Los Calpules	El Tablón Las Culebras La Playa	Chagüite Grande Sisle Tomatoya Corinto

Data

Socio-economic data of household

Production monitoring (biweekly)

- Pesticide use, time spent for application, related health symptoms per application
- Fertilizer use and other inputs
- Labour use
- Yield and prices

Health cost survey (monthly)

- General illnesses of household members and costs
- Pesticide-related illnesses and costs
- Lost labour due to illnesses

RECALL SURVEY

Sample

Departments	Matagalpa	Estelí	Jinotega	South Pacific (Masaya/Granada)
Municipality	5	5	3	3
Villages	25	35	18	9
Farmers	110	120	151	52

Data

Socio-economic data of household

Production recall questions (previous cropping season, approx. last year)

- Input use, Fertilizer and Pesticides
- Gross returns / Yields & Prices

Health indicators (last year)

- General illnesses of household members and costs
- Pesticide-related illnesses and costs
- Lost labour due to illnesses
- Perceptions about pesticide health risks
- Previous poisoning events and related costs

Willingness to pay to avoid health risks

Adoption of IPM practices

Figure 2.3: Framework of data collection.

Source: own presentation

The monitoring survey was based on regular visits to the participating farmers over seven months, including the two main cropping seasons in Nicaragua from June 2003 to January 2004. Four survey regions with intensive vegetable production were selected. Within these regions, municipalities with high incidences of pesticide poisoning were selected (Table 2.4), namely the municipality of Sébaco in the department of Matagalpa, Condega and Pueblo Nuevo in the department of Estelí, San Lucas in the department of Madríz and Jinotega in the department of Jinotega. The sample was stratified with respect to farmer participation in IPM training, and villages were purposively selected. The selection criterion for the villages was that IPM training had taken place in the village for vegetable IPM in two subsequent years. In total, 191 farmers in 14 villages were included in the monitoring sample. Detailed data on pesticide use, labour for pesticide application and poisoning symptoms were collected using record sheets, where farmers kept notes, supported by regular visits (weekly to biweekly) of enumerators. Also, data on yields, output prices and other inputs such as labour, irrigation and materials were collected. Additionally questionnaires were used to gather data on household characteristics, other income sources, land tenure, educational levels and project participation. A questionnaire on health-related variables was filled out every month.

Table 2.3: Incidence of acute pesticide poisoning according to public health monitoring system. [Rate per 100,000 inhabitants]

Department	Municipality	2000	2001	2003	2004
Boaco		28	31	26	25
Carazo		18	20	23	15
Chinandega		54	58	45	41
Chontales		12	14	15	16,5
Estelí		74	53	49	40
	Condega	*66*	*66*	*138*	*74*
	Pueblo Nuevo	*57*	*77*	*81*	*26*
Granada		28	48	26	17
Jinotega		48	45	55	52
	Jinotega	*65*	*56*	*81*	*84*
Leon		28	25	23	16
Madriz		52	46	43	31
	San Lucas	*54*	*125*	*82*	*40*
Managua		13	14	10	10
Masaya		25	20	12	10
Matagalpa		58	46	43	34
	Sebaco	*104*	*76*	*51*	*41*
Nueva Segovia		71	66	80	81
Rio San Juan		24	19	15	40
Rivas		56	44	42	28

Source: BERROTERÁN 2002; BERROTERÁN 2005

While this data from intensive monitoring provides an important and detailed insight in the actual situation of vegetable farmers, a second survey was designed to measure the non-market health costs based on farmers' willingness to pay for health and analysis of the adoption of IPM. This survey was carried out from May to July 2004, covering the four main vegetable growing regions in Nicaragua. In these regions, the villages were randomly selected and within the village, a complete enumeration of vegetable farmers was carried out. The sample size was 430 farmers. Those villages where the monitoring survey had been carried out were excluded from the recall survey, in order to avoid bias that might result from increased awareness of pesticide-related health due to regular questions during the monitoring survey. The recall survey, based on one interview per respondent acquired data on pesticide use and agricultural production, pesticide-related health impairments and attitudes towards pesticides and pesticide health risks and questions about farmers' willingness to pay to avoid pesticide health risks. Also, data on knowledge, testing and adoption of IPM practices was collected.

Climatic conditions of vegetable production were similar in both surveys, including hot, semi-arid lowlands and cooler, humid highlands. Also, the range of crops was similar: hot climate for fruit vegetables like tomato and bell pepper, highland climate for leafy vegetables and tuber crops.

2.4 Summary

In the literature on pesticide health costs to date, the focus has been on the evaluation of market costs using different approaches to measure the cost of illness. Cost accounting of expenditure on medical attention of poisoning victims and lost labour is a relatively simple valuation method, yielding estimates of minimum costs of acute poisoning cases. More comprehensive approaches included a valuation based on clinical tests that then were used as a basis to estimate the costs to restore farmers' health as compared to a non-exposed population. This allows accounting for chronic effects as well. A special application of these estimates of the cost of illness is the health production function approach, directly measuring the effect of pesticide exposure of farmers on the productivity of their farms.

In order to obtain a full valuation of health costs of pesticides, including market and non-market costs, contingent valuation surveys have been proposed to elicit farmers' willingness to pay to reduce health risks from pesticides. These studies can help to understand to what extent farmers are aware of pesticide health risks and what the consequences are for choices on pest control. A number of contingent valuation studies of pesticide health costs have been conducted so far. They show that this method provides plausible results for farmers in developed countries (see for example OWENS et al. 1998) as well as in developing countries (CUYNO 1999; WILSON 2002). The results were then used, for example, in cost benefit studies of IPM programmes. The link between farmer awareness of health costs and actual pesticide use practices has not been addressed in these studies.

In this dissertation, a comprehensive approach to the evaluation of human health risks related to pesticide use is applied, including the analysis of pesticide exposure and perceived health effects, market and non-market valuation methods to assess pesticide health costs and an assessment of the effect of perceived health costs on pesticide use and the adoption of alternative pest control practices.

Data collection comprised an in-depth production monitoring survey of 191 vegetable farmers to describe pesticide use patterns and farmer exposure and relate this to pesticide health risks. A second survey of 433 farmers was conducted to estimate farmers' willingness to pay to avoid health risks and to analyse their decision to adopt non-chemical pest control practices.

3 Pesticides and Human Health – Evidence from Nicaraguan Vegetable Farmers[5]

3.1 Introduction

In Central America, pesticide poisoning among farmers has been reported to be a major health problem (PAHO 2002). In Nicaragua, evidence of pesticide poisoning is generated through a surveillance system, which was established in the mid eighties (MCCONNELL and HRUSKA 1993). Pesticide poisoning information is derived from reports from public health stations and hospitals. In this system, many cases remain unreported as revealed in a countrywide representative survey conducted in 2000. The results of the survey showed that underreporting is likely to be in the order of 98% (KEIFER et al. 1996; CORRIOLS et al. 2001). The study also found that in the survey year, 7% of farmers suffered from pesticide poisoning.

Measuring pesticide poisoning in developing countries is not an easy task. Generally two types of approaches are used: a) clinical checks of the target population (see e.g. PINGALI et al. 1995; COLE et al. 1998; HRUSKA and CORRIOLS 2002) and b) surveys, where respondents are asked to self-report poisoning incidents and symptoms that they perceive as related to pesticide exposure (KISHI et al. 1995; CORRIOLS et al. 2001; MANCINI et al. 2005). Typical poisoning symptoms are, for instance, headaches, dizziness, vomiting, eye irritations and skin rashes or irritations, which occur within 24 hours after the exposure to pesticides.

Both approaches of measuring pesticide poisoning have their advantages and drawbacks. It has been observed for instance that self-reporting can result in overestimation (DASGUPTA et al. 2005b). On the other hand, some authors argue that self-reporting may lead to underreporting if farmers are unaware of pesticide health risks, or become used to poisoning symptoms and accept them as a normal side effect from spraying (AJAYI 2000). Clinical health checks are expensive and therefore can only be applied to a relatively small sample. Thus representativeness of the results cannot be assured.

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[5] This chapter is a modified version of: GARMING, HILDEGARD and HERMANN WAIBEL (2008): Pesticides and Human Health – Evidence from Nicaraguan Vegetable farmers. Submitted to: International Journal of Occupational Health.

To address the problem of attributing health effects to pesticide exposure and to identify different risk factors for pesticide poisoning, different empirical models have been applied. For example, HUANG et al. (2000) use logistic regression linking poisoning events reported by farmers to risk factors like pesticide exposure and smoking and drinking habits. The specification of variables as indicators for pesticide exposure varies in different applications. For example, the total amount of pesticides is used in HUANG et al. (2000) , while in other studies the frequency of spraying is used as indicator (ANTLE and PINGALI 1995; DUNG and DUNG 1999; SOHN and CHOI 2001) or the toxicity of products used by the farmers (MANCINI et al. 2005). Logistic regression models, based on a binary measure of pesticide poisoning can provide information on basic risk factors. Other approaches applied so far include linear regression models of health costs of pesticide poisoning (ROLA and PINGALI 1993; HUANG et al. 2000), or of a severity index of pesticide poisoning (MANCINI et al. 2005). One typical problem for empirical models linking pesticide poisoning to measures of pesticide exposure is that the distribution of the dependent variable is often strongly skewed towards zero. In this study, the particularity of a high share of zero observations in the dependent variable is accounted for by using a zero-inflated Poisson regression approach.

In Nicaragua pesticide poisoning has been addressed in a few studies so far. However, these studies either concentrated on the analysis of the reporting system and a descriptive analysis of frequency of poisoning and risk factors (MURRAY et al. 2002; PAHO 2002) or dealt with pesticide use and pesticide poisoning in staple food production (HRUSKA and CORRIOLS, 2002). These studies demonstrate that the use of highly hazardous insecticides is common among Nicaraguan producers of maize and beans. This study is the first to be applied to small-scale vegetables producers in Nicaragua.

This paper aims to provide evidence for the health effects of pesticide use among small-scale farmers in developing countries. The overall objective is to assess these effects among vegetable producers in Nicaragua. The specific objectives are 1) to describe pesticide use practices, including quantity and toxicity of the products used, 2) to measure the incidence of pesticide poisoning and 3) establish a relationship between pesticide use and exposure and farmers' perceptions of pesticide poisoning.

3.2 The Model

To establish the relationship between exposure to pesticides and self-reported pesticide poisoning, previous studies used logistic regression models (DUNG and DUNG 1999; HUANG et al. 2000) or probit models (LABARTA and SWINTON 2005). Such models can explain the probability of an individual suffering from pesticide poisoning or a specifically defined health condition based on a set of exposure variables and personal characteristics. Problems in the use of these binary models can arise when the dependent variable is strongly skewed towards one outcome, i.e. is invariant (MENARD 1995). For pesticide poisoning, as defined as illness that leaves the victim unable to work for at least one day (CORRIOLS et al. 2001), the expected incidence in the sample based on previous studies is about 5 – 7%, implying a strongly skewed distribution towards zero.

Therefore, in the analysis performed in this paper, pesticide poisoning is measured quantitatively as the number of symptoms reported during a pesticide use monitoring survey. This is a count variable consisting of non-negative integer values, which allows the application of count regression models. One problem is that the distribution of the number of symptoms reported by a farmer may be skewed towards zero. There are two reasons for this: (1) Farmers may not become poisoned because absorption of the toxic substance is below the dose that would cause health effects; (2) they are poisoned but do not associate the symptoms with the pesticide exposure. To overcome this problem a zero inflated negative binomial regression model can be used (CAMERON and TRIVEDI 1998). This model is an extension of the standard Poisson regression for count data. It has two characteristics that are relevant for the present analysis. First, it allows for a distribution of the dependent variable, which is concentrated at zero. Second, it allows for overdispersion, i.e. 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).

In the zero inflated count models, firstly the probability φ of the dependent variable y_i being zero is specified as follows:

(3.1) $$\Pr ob(y_i = 0) = \varphi + (1-\varphi)e^{-\mu_i}$$

Following the approach of LAMBERT (1992), φ is specified as a logistic function with explaining variables z_i and coefficients γ_i:

(3.2) $$\varphi = \frac{\exp(z_i\gamma_i)}{1+\exp(z_i\gamma_i)}$$

The probability of the dependent variable taking any positive value r is then determined by φ and the negative binomial distribution with the conditional mean μ and the dispersion parameter α (CAMERON and TRIVEDI 1998).

(3.3)
$$\Pr ob(y_i = r) = (1-\varphi)\frac{\Gamma(r+\alpha^{-1})}{\Gamma(r+1)\Gamma\alpha_{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{r} \quad ,$$

r = 1,2 ,….,k

The parameter μ presents the expected value of the distribution and is parameterised as a function of explanatory variables x_i and coefficients β_i.

(3.4)
$$E(y_i|x_i) = \mu = \exp(x_i{}' \beta_i)$$

The empirical model for the expected value of the number of symptoms (No_of_symp) is specified as follows:

(3.5) E(No_of_symp) = f(*nspray, app, mix, edu, age, IPM, fveg, lveg, bveg, fgr*)

To estimate the coefficients γ, α and β, the maximum likelihood estimation procedure for zero – inflated negative binomial regression in Stata Version 9.2 is used.

As explanatory variables, measures of exposure to pesticides as well as farmer and cropping system characteristics were included.

nspray:	As a proxy for the exposure to pesticides, the number of applications during the whole cropping season was considered, a variable found to influence the incidence of pesticide poisoning in previous studies (ANTLE and PINGALI 1995).
app:	As an indicator for the quality and the human toxicity of the insecticides used; the weighted average price of insecticides used by a farmer was included in the model. Prices are assumed to be highly correlated with the toxicity of a pesticide formulation according to the classifications of the WHO (WHO 2002), as shown in Table 3.4. Compared to these classifications, the price variable is a continuous measure with higher variability.
mix:	An indicator for the exposure to pesticides is defined as the number of sprays with a mixture of different pesticides. The mixing and application of these “pesticide cocktails” has been identified as a highly hazardous practice in the study of Corriols et al. (CORRIOLS et al. 2001).

edu: Of the farmer characteristics, education as measured in years of school attended by the farmer, and is assumed to have an effect on pesticide poisoning. More highly educated farmers are more likely to read and follow the safety instructions on the pesticide labels.

age: Age may have an effect as well. Older farmers may be more susceptible to pesticide poisoning because of a poorer general health status. However, with longer experience in using pesticides, they also might be more cautious and hence report less symptoms.

IPM: The expected effect of farmer participation in training in integrated pest management on pesticide poisoning is negative. If farmers learn about pesticide health risks and how to avoid them, fewer symptoms will be reported.

As cropping system characteristics, dummy variables are included for the different crop groups:

fveg: fruit vegetables,

lveg: leafy vegetables,

bveg: bulb vegetables and

fgr: food grains.

The rationale for including these variables is that exposure is assumed to be linked to the crop characteristics, i.e. intensity of contact with the treated plants depends on the height of the crop when treated with pesticides. As an example, maize as the major food grain is much higher than leafy vegetables.

For estimation of the zero-inflated model, the explanatory variables z_i include the dummy on participation in IPM training, the total amount of pesticides used by the farmer, the number of pesticide cocktails and a dummy variable indicating whether the farmer uses one of the two pesticides causing the highest number of pesticide poisonings, Methamidophos and Carbofuran.

3.3 The Data

Measurement of pesticide use in small-scale vegetable production poses a challenge for data collection. Frequent sprays with a large variety of different pesticides in highly varying doses are typical for these systems. Hence such data are difficult to remember for farmers in a recall survey at the end of the cropping season (PEMSL 2006). Therefore, in this study data collection consisted of a monitoring survey during two cropping seasons, namely the two rainy seasons in Nicaragua[6]. Farmers were requested to keep records on input applications and the time used for the application in each of their crops using simple forms provided as booklets. In initial workshops they were trained to use the forms. Field enumerators visited the farmers every two weeks to check the data and complete the information if necessary. Since farmers use different small containers for measuring the dose of pesticide per knapsack sprayer, they were asked to keep the records based on their own measures. These measures were then verified using a pocket scale. When the crop was harvested, the enumerators collected additional data on labour use and other costs as well as on yields and gross returns. As an incentive to participate and provide reliable data, copies of the input records and information on calculated gross margins and returns to labour were provided as feedback to the farmers, which they used for reference in discussions with extension workers and other farmers. In order to obtain data on total pesticide exposure, the input monitoring included not only vegetable crops, but also any other crops the farmer grew during the monitoring period.

The survey was carried out during the 2003/2004 growing seasons. The sample included 191 small-scale farmers in four regions representing different agro-ecological zones (MARÍN and PAUWELS 2001). The survey regions comprise parts of the northern highlands in the department of Jinotega, with a cool and humid climate where traditionally leafy vegetables and roots are grown. The second survey region was the valley of Sébaco in the department of Matagalpa, with a hot semi-arid climate. This region is a traditional vegetable growing area where mainly fruit vegetables like tomatoes, bell pepper and to a lesser extent cucumbers are grown. The third region, Pueblo Nuevo and Condega in the department of Estelí have similar agro-ecological conditions as in Sébaco. Finally three villages in the semi-arid highland zone of San Lucas in the department of Madríz were included in the sample, where traditionally food grains are grown. The reason for including this region was that IPM training

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[6] The main cropping seasons in Nicaragua are “primera” – the first rainy season from May to August and “postrera” – the second rainy season from September to December. With irrigation, some farmers grow vegetables also during the dry season, delaying the crop for harvesting in February. These were also included in the survey.

in vegetable production had been carried out for two previous years and vegetable management practices were expected to be different from those in the traditional vegetable growing regions. However, in the survey year farmers in this region did not grow vegetables and hence the data include only food crop production. Within the three survey regions, the villages selected were those where IPM training in vegetable production had been carried out within the CATIE IPM program[7]. In the villages, all vegetable growers were included in the sample, subject to their willingness to participate in the monitoring. The sample size was 191, composed of 105 participants as identified through lists provided by the IPM program, and 86 non-participants.

In order to determine total pesticide exposure for each farmer, efforts were made to include all crops grown by the farmer including vegetable crops and food grains like beans and maize. However, this was not achieved in all cases: A number of respondents were not willing to continue the monitoring after the first cultivation period. A total of 94 respondents provided data for one crop only, while 97 respondents reported two or more crops.

3.4 Results

The results are structured into three sections. The first two sections deal with the description of variables used in the model, which is presented in the third section. First, pesticide use among Nicaraguan vegetable farmers and exposure to pesticides is characterized. In the second section, pesticide poisoning incidence and farmers' perceptions of health risks from pesticides are described. Finally, the results of the model used to establish a relationship between pesticide exposure and health effects are presented.

3.4.1 Exposure to pesticides

The monitoring of crop management practices showed that all except four farmers were exposed to chemical pesticides. A large variety of active ingredients and products were used in different groups of vegetable crops. For example, insecticide use in fruit, leafy and bulb vegetables is shown in Table 3.1. In all crops a high proportion of products classified as

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[7] In Nicaragua Integrated Pest Management (IPM) has been promoted since the 1980s by different institutions, including CATIE, PROMIPAC, CARE. It includes research and technology development as well as large-scale farmer training. This study was carried out in collaboration with the CATIE IPM program.

extremely or highly hazardous for human health (WHO category Ia) was applied, including the widely used products Methamidophos, Carbofuran and Metomyl. They constituted the largest share of insecticides used in leafy vegetables. In fruit and bulb vegetables, the main share of insecticides belonged to the WHO II category. This included popular products like Endosulfan, Cypermethrin, Paraquat and Chlorpyriphos.

Table 3.1: Number and active ingredients of insecticides used by WHO toxicity class and type of vegetables.

Crop group	**Fruit vegetables**$^{1)}$	**Leafy vegetables**$^{2)}$	**Bulb vegetables**$^{3)}$
No. of products	39	29	23
No. of active ingredients	25	20	15
Use by WHO toxicity category			
Ia “extremely hazardous” [%]	14.4	5.9	16.7
Ib ”highly hazardous“[%]	35.9	50.6	24.4
II ”moderately hazardous“[%]	40.0	35.2	56.3
III/U “slightly hazardous”$^{4)}$ [%]	9.7	8.2	2.6

$^{1)}$ cabbage, lettuce, celery, broccoli; $^{2)}$ tomato, bell pepper, chili, cucumber; $^{3)}$ onion, carrot, beetroot, potato; $^{4)}$ category III: slightly hazardous, category U: unlikely to present hazard in normal use.

Source: own survey data

Total pesticide exposure during the two monitored cultivation periods in 2003/04 is shown in Table 3.2. In order to indicate the skewness of the distribution of some of the exposure indicators, quartiles are presented.

The survey respondents are small-scale farmers, with less than 2 ha planted to vegetables and food grains in both cultivation periods, and a median even below 1 ha. As a result, pesticide exposure per farmer seems to be moderate. Yet it has to be noted that these data present but a lower bound of pesticide exposure, since not all crops grown by the farmers may have been reported, as explained in section 3.3. The average number of crops reported by a farmer was 1.8.

The total time spent for pesticide applications and hence exposure to pesticides, was highly variable among farmers. Between 30% and 45% of the total time allocated for spraying was performed by hired laborers.

Many farmers applied mixtures of different pesticides; so-called “pesticide cocktails”. From a farmer’s point of view this practice has two main purposes: they want to save time for pesticide application and they believe that effectiveness of the pesticides will be increased. Mixtures with up to five different products, including mixing fungicides and insecticides, were observed. In this indicator the distribution is strongly skewed: the lower quartile is zero, implying that more than 25% of respondents did not use mixtures at all, while another 25% used them more than seven times during the survey period.

The quantities of pesticides used by the farmers varied widely. On average, more non-hazardous than hazardous products are used. However, this difference is a result of high amounts of the category II and U products used by relatively few farmers. For the lower quartile and the median, the amounts of hazardous products exceed those classified as non-hazardous.

Table 3.2: Exposure to pesticides per farmer in 2003/04, N=191.

Exposure Indicator	**Mean**	**Std. Dev.**	**Quartiles**		
			25	**Median**	**75**
Total crop area [ha][1)]	1.5	1.9	0.4	0.7	1.8
Time spent for pesticide applications [mandays]	11.7	13.4	3.9	8.0	14.1
Share of hired labour for pesticide application [%]	39.0	47.0	29.0	38.0	45.0
Total number of sprays	12.4	10.9	5.0	8.0	16.8
Total number of “pesticide cocktails”	4.8	6.5	0.0	2.0	7.0
Total amount of pesticides WHO I&II [kg]	3.4	4.1	0.7	2.3	5.0
Total amount of pesticides WHO III&U [kg]	4.3	7.7	0.0	1.4	5.3

[1)] Calculated as the sum of plots reported in the monitoring survey.

Source: own survey data

The differences in total pesticide exposure among respondents were related to the crop mix they grow. The comparison of pesticide use on a per hectare basis for different crop groups (Table 3.3) shows that pesticide use intensity was high in vegetables as compared to food grains. The highest amounts of insecticides and fungicides were used in fruit vegetables. Also, spraying frequency was highest in this vegetable group, with sprays about every week and frequent use of pesticide cocktails. Bulb vegetables, including onions, carrots, beetroots and potatoes showed the highest herbicide applications. About 50% of the herbicides used belong to the WHO toxicity categories I or II. For the insecticides, non-hazardous products are rarely used at all, with a share of hazardous products of 88% and more, while fungicides are usually found in the non-hazardous group. In food grains, only a few sprays are usually applied, but they are almost exclusively hazardous pesticides in this crop group.

Table 3.3: Exposure to pesticides per hectare by type of vegetable.

	Leafy vegetables[1)]	**Fruit vegetables**[2)]	**Bulb vegetables**[3)]	**Food grains**[4)]
No. of observations	85	70	28	158
No. of pesticide applications	7.6	15.0	10.6	1.5
	(3.7)	*(9.8)*	*(9.0)*	*(1.5)*
Time spent spraying [man-days]	12.7	21.8	16.3	1.7
	(9.4)	*(17.8)*	*(33.0)*	*(1.9)*
Share of hired labour for spraying [%]	25	43	43	42
Amount insecticides [kg/ha]	3.8	7.6	4.6	0.5
	(3.8)	*(7.5)*	*(4.7)*	*(1.0)*
Share insecticides WHO I/II [%]	93	87	88	94
Amount herbicides [kg/ha]	1.2	0.7	3.3	1.0
	2.7	*1.6*	*12.9*	*1.2*
Share herbicides WHO I/II [%]	49	46	80	98
Amount fungicides [kg/ha]	6.1	10.0	8.5	<0.01
	7.4	*11.2*	*11.0*	<0.01
No. of pesticide cocktails	4.4	5.8	3.6	0.1
	3.5	*5.6*	*6.2*	*0.3*
Average weighted price of insecticides [USD/kg]	20.5	38.8	10.5	2.3
	(25.7)	*(54.1)*	*(16.4)*	*(2.5)*
Average weighted price of fungicides [USD/kg]	7.1	14.5	11.5	
	(6.2)	*(20.2)*	*(14.1)*	

1) cabbage, lettuce, celery, broccoli; 2) tomato, bell pepper, chili, cucumber; 3) onion, carrot, beetroot, potato; 4) maize, beans, sorghum.

Standard deviations in brackets

Source: own calculations

An additional indicator for the toxicity of the pesticides used is the weighted average price of products. In general, the more expensive pesticides tend to be less hazardous for human health (see Table 3.4). The average prices differ by crop groups. They are relatively low in food grains, while the highest average pesticide prices were observed for fruit vegetables (see Table 3.3).

Table 3.4: Prices of the five[8] most used insecticides for each WHO toxicity class.

Trade name of product	USD/kg	WHO classification
Terbufoc	2.1	Ia
Counter	2.5	Ia
Metil	2.7	Ia
Metamidofos	3.0	Ib
Turbo	4.3	Ib
Rimidofos	5.0	Ib
Tamaron	5.7	Ib
Lorsban	6.0	II
Endosulfan	7.3	II
Cipermetrina	8.0	II
Vexter	8.7	II
Dipel	10.0	U
Evisect	16.7	II
Vidate	17.3	Ib
Abacmatina	140.0	U
Spintor	144.0	U
Vertimec	173.3	U

Source: own survey data

The comparison of the cost of the recommended dose with the farmers' actual cost of application in the sample shows that farmers tend to use lower doses than recommended by the manufacturers (Table 3.5). Whether this practice affects the effectiveness of pest control, especially for the low toxicity products where differences are comparatively high, cannot be determined from the data.

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[8] In the WHO category Ia only three different insecticides were found, in category U four.

Table 3.5: Cost of dose recommended by manufacturer, and farmer practice.

Trade name of product	WHO classification	Cost of recommended dose[1] USD/ha	Cost of actual dose[2] USD/ha
Counter	Ia	19	15.5
Metamidofos	Ib	4.3 – 6.5	3.2
MTD	Ib	4.3 - 6.5	4.6
Tamaron	Ib	5.6 - 8.5	3.0
Lorsban	II	4.0 - 10	9.4
Endosulfan	II	14.6	6.6
Thionex	II	14.6	7.7
Muralla	II	11.5 - 21.6	10.0
Avaunt	II	11.1 - 15.9	12.6
Spintor	U	28 - 43	16.8
Abacmatina	U	70 - 140	20.8
Vertimec	U	86 - 173	37.9

1) based on application rates recommended by manufacturer; 2) based on average rate applied by farmers

Source: own survey data

3.4.2 Pesticide poisoning incidence

In the survey year 2003, 5.6% of the respondents reported at least one poisoning incident. Also, 43% of the respondents or members of their households reported suffering from acute poisoning at least once in their life. In most of the cases (90%) poisoning was related to applications and occurred either while spraying or mixing the pesticide. Accidents with pesticides within the household amounted to 5%, and another 5% were suicides. The share of suicides is much lower than reported in global statistics based on hospital records, which range between 40% and 80% (see e.g. DINHAM 1993). However, the survey data include relatively more poisoning incidents that do not result in hospital attendance, and hence the figures cannot be directly compared to hospital records. In the following analysis, the suicides are not included.

In addition to poisoning cases explicitly reported as pesticide poisoning incidents, "light" poisoning was considered in this study, defined as the coincidence of three or more typical poisoning symptoms related to a pesticide application as recorded in the pesticide use monitoring sheets in 2003/04. Table 3.6 gives an overview of the total number and severity of the poisoning cases in 2003/04 and the related costs for the households. The cases are classified into light, medium and severe, according to the number of working days lost due to the illness, following the methodology of Corriols (CORRIOLS et al. 2002). Intoxication is classified as light poisoning, when the victim recovers in one day of rest. No expenses for medicine are usually made in these cases; instead farmers treat themselves by taking indigenous medicine. If the victim is unable to work for two to five days due to the poisoning, the case is classified as medium. Usually some attention by medical staff in the community health care center or the district capital is sought. If the victim is left unable to work for more than five days, the case is considered a severe intoxication. Costs include emergency transport to the hospital and treatment by health staff. This occurred twice in 2003 among the survey respondents. Lost labour is valued at the rate of hired short time workers at USD2.70 per day.

In addition to the monetary costs of health, other disutilities of poisoning must be taken into account. Even light poisoning cases are linked to considerable inconvenience. In addition, the chronic effect of pesticides is an additional cost of poisoning (GARMING and WAIBEL 2007).

Table 3.6: Poisoning cases and costs according to severity in 2003/04.

	Severity		
	Low	**Medium**	**High**
Number of cases	38	4	2
Percent of intoxication cases [%]	86.4	9.1	4.5
Average number of lost working days	0	3	7
Average private cost per case [USD]	0	26.5	51.9
Range of costs per household per case [USD]	0	5.3 - 66.5	29.3 - 74.6

Source: own survey data

Table 3.7 gives an overview of the products that farmers reported as a cause for poisoning events. This includes all cases of poisoning at any time in a farmer’s life. The major pesticides reported are Metamidophos, Carbofuran and Methomyl. The observations of the respondents seem reasonable as all these compounds belong to the WHO Ib category. These pesticides also belong to the group of 12 pesticides causing most poisoning cases in Central America and which the Conference of Health Ministries of the seven countries in

Central America and the Dominican Republic (RESSCAD[9]) proposed to ban (MURRAY et al. 2002). Despite its potential harm Metamidophos is still one of the most used pesticides in Nicaragua, although several farmers mentioned that it was no longer effective and they considered it to be harmful to them. The only plausible explanation for its continued use is the perceived lack of alternatives.

Table 3.7: Poisoning events by active ingredient as reported by farmers in number of cases and percent.

Active Ingredient	WHO category	No. of cases	%
Metamidophos	Ib	22	25.3
Carbofuran	Ia	18	20.7
Methomyl	Ib	14	16.1
Paraquat	II	5	5.7
Mancozeb	U	4	4.6
Malathion	III	4	4.6
Metylparathion	Ia	2	2.3
Prophenophos	II	2	2.3
Cypermethrin	II	2	2.3
Aluminium phosphate	FM1)	2	2.3
Imidacloprid	II	1	1.1
Deltamethrin	II	1	1.1
Chlorpyriphos	II	1	1.1
		9	10.3
Total		87	100

1) Fumigant: not classified “these compounds are of high hazard and recommended exposure limits for occupational exposure have been adopted … in many countries” (WHO 2002, p. 40)

Source: survey data

Figure 3.1 shows the numbers of poisonings reported in recent years. It shows that farmers more easily remember the most recent poisoning events, with more than 50% of the poisoning cases reported for the period of five years prior to the survey year. In 1993 there is again a peak in the number of poisonings. This could be related to farmers’ inability to

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[9] By its Spanish acronym: Reunión del Sector Salud de Centroamérica y República Dominicana

remember the exact date of a poisoning event and instead they reported “about 10 years ago”. Hence caution needs to be applied in perceptions of trends of pesticide poisoning over time. However, Figure 3.1 shows that farmers do perceive pesticide poisoning as a problem.

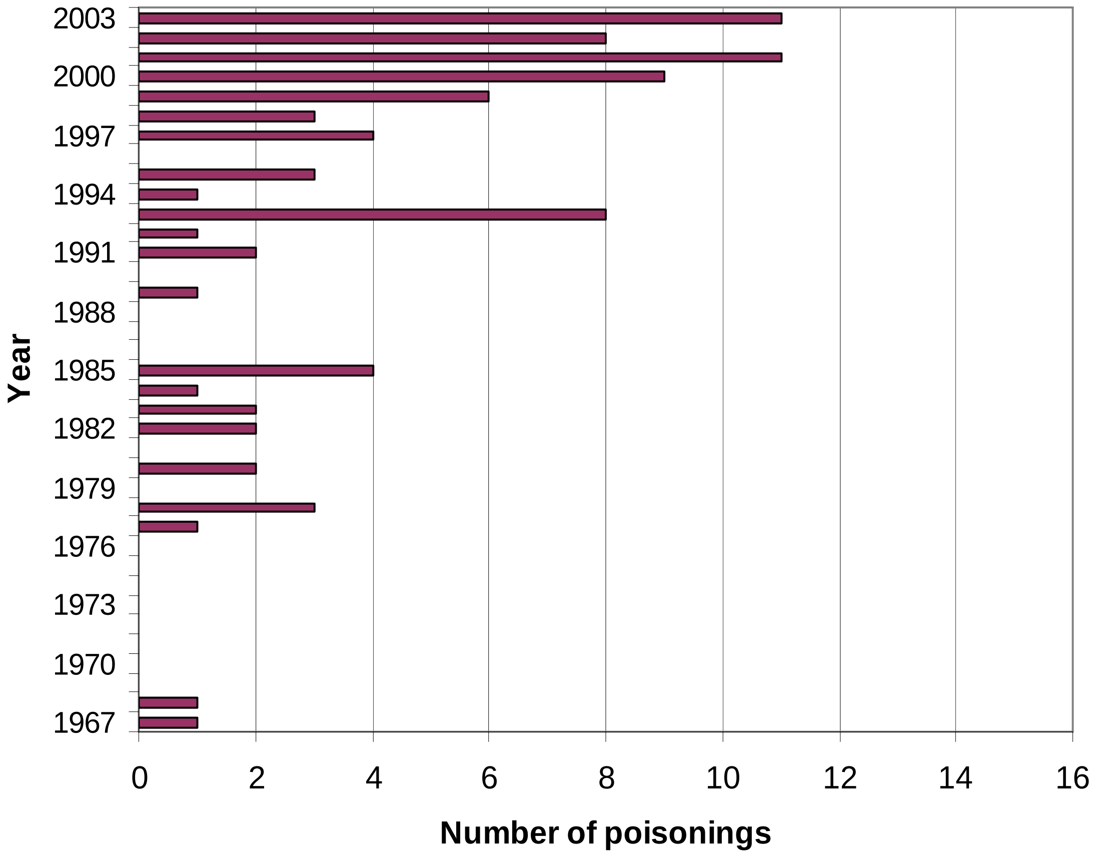

Figure 3.1: Number of past poisonings according to time interval.

Source: own presentation.

For the survey year, farmers also reported health symptoms they perceived to be related to pesticide application in the input monitoring sheets during 2003/04. Table 3.8 shows the frequency of the reported different health symptoms and the pesticides that farmers believed to have caused these symptoms. Except for Thiometoxam and Cypermethrin all listed pesticides belong to the group of 12 pesticides that are recommended by the RESSCAD to be banned or restricted. Again, Metamidophos, as the most used product is also most frequently reported to cause typical poisoning symptoms. This product frequently provokes headaches and dizziness. The herbicide Paraquat is commonly used for land preparation in food grain production and causes headaches and eye irritation. The insecticide Cypermethrin is often referred to as a “hot” pesticide, and farmers typically complain about skin irritation when using this product.

The number of poisoning symptoms reported by a farmer during the input monitoring is the dependent variable in the Poisson model used to establish the relationship between pesticide exposure and health effects of pesticides. The average number of poisoning symptoms is 1.5, but the distribution is strongly skewed towards zero, with about 60% of farmers not reporting any symptom.

Table 3.8: Frequency of health symptoms by pesticide compound observed by farmers after spraying in 2003/04.

Name of pesticide compound	Head-ache	Eye irritation	Dizzi-ness	Skin rashes/ irritation	Difficulty to breathe	Stomach ache / vomiting	Others
Metamidophos	38	13	10	1	2	1	2
Paraquat	25	7	3	3	1	1	0
Cypermethrin	13	5	4	17	1	1	0
Thiometoxam	10		1			1	0
Methomyl	6	1	5	2			1
Chlorpyriphos	6		1			1	0
Terbuphos	5		1		1	4	0
Others	40	16	16	18	1	5	21

Source: own survey data

3.4.3 Model results

The results of the Poisson regression model show that the reported incidence of poisoning symptoms among farmers is mainly explained by variables related to the exposure to pesticides (Table 3.9). More frequent spraying during the cropping season significantly increases the number of symptoms reported. An additional factor is the application of mixtures of pesticides. Increasing the number of pesticide cocktails leads to more poisoning symptoms. The average price of insecticides as a proxy for the toxicity of the pesticides used is significant. Farmers who use lower priced pesticide products, implying higher toxicity, tend to report more poisoning symptoms.

Among farmer characteristics, age has a significant positive effect, i.e. the number of symptoms reported is higher for older farmers. This is contrary to previous studies, where younger farmers were more frequently affected (SOHN and CHOI 2001). The reason could be that older farmers tend generally to have more health problems and are more susceptible to pesticide health effects. Based on the model results, formal education does not influence the probability of poisoning, although it could be expected that the more educated farmers are more likely to read safety information on pesticide labels and may actually practise safety measures (ATKIN and LEISINGER 2000). In this sample however, formal education level is generally low, with an average of only three years of school attendance, which may not be enough to make a difference.

Also, participation in IPM training had no significant effect on the number of poisoning symptoms reported. There is no information about training contents, so no conclusions can be drawn about whether information about pesticide poisoning was conveyed in the training.

To assess the statistical quality of the model, the likelihood ratio test is used. The dispersion parameter alpha is greater than zero; indicating that the negative binomial model is appropriate. Finally, in order to compare the zero-inflated model to the standard Poisson application, the Vuong test is used (VUONG 1989). The Vuong test statistic is greater than 1.96, which is an indication that the zero-inflated model is superior to the simple version.

In order to test the robustness of the estimates, the model was recalculated using different specifications. The reduced form of the model, including only those variables that had a significant effect on the dependent variable, shows that the model results are robust (Table 3.9).

Table 3.9: Results of the zero-inflated negative binomial regression model on the count of symptoms reported during input monitoring.

N	181						
Non-zero observations	53						
Zero observations	128						
	Complete model				**Reduced model**		
	Coef.		**S.E.**	**z-value**	**Coef.**	**S.E.**	**z-value**
Farmer characteristics							
Age	0.022	**	0.009	2.41	0.021***	0.008	2.600
Years in School	0.014		0.042	0.34			
IPM training	-0.142		0.214	-0.66			
Cropping system characteristics							
Fruit vegetables	0.017		0.317	0.05			
Bulb vegetables	-0.259		0.501	-0.520			
Food grains	-0.469		0.409	-1.15			
Exposure to pesticides							
Total number of sprays	0.020	**	0.009	2.12	0.025***	0.008	3.120
Average price of insecticides	-1.131	***	0.382	-2.96	-0.927***	0.331	-2.810
Number of pesticide cocktails	0.048	**	0.019	2.46	0.066***	0.016	4.170
Constant	0.524	*	0.560	0.94	0.151	0.366	0.410
Model information							
/lnalpha	-1.546	***	0.474	-3.26	-1.315***	0.448	-2.930
alpha	0.213		0.101		0.268	0.120	
Vuong test	2.65	***			2.98***		
Log likelihood	-215.26				-216.73		
LR chi2	34.61	***			31.67***		

*** significant at 0.01 level; ** significant at 0.05 level; * significant at 0.1 level

Source: own calculations

3.5 Summary and Conclusions

The results of this study largely confirm previous research on pesticide poisoning among farmers in developing countries. The incidence of pesticide poisoning of 5.6% found in this study is similar to results of previous studies in Nicaragua and the findings from other countries (LABARTA and SWINTON 2005; CORRIOLS et al. 2002; KISHI et al. 1995). The majority of poisoning cases was caused by pesticides classified in WHO category Ia or Ib, namely Methamidophos, Carbofuran and Methomyl. Additionally, 27% of the farmers reported one or more health symptoms after spraying during the survey period. Again, Methamidophos is responsible for most of the symptoms reported, followed by Cypermethrin and Paraquat, both classified as WHO category II. The most frequently reported symptoms were headache, dizziness, and eye and skin irritations. The pesticides that farmers most frequently associated with health symptoms are largely congruent with those products known to cause most of the poisoning cases in Central America (PAHO 2002).

Farmers' pesticide exposure is characterized by a large variety of different products. The use of extremely toxic insecticides, belonging to WHO category Ia, is still common. The majority of insecticides are hazardous to human health, belonging to the WHO categories I or II. In the comparison of pesticide use in different crop groups, fruit vegetables were shown to be most pesticide-intensive crops, followed by bulb vegetables. In food grains, although the total amounts of pesticides were rather low, they consisted almost entirely of hazardous products.

The large share of hazardous pesticides used by the farmers may be linked to the price differences of the products. It was shown that prices are correlated with human health risks of the products, the cheapest insecticides being the most toxic.

Using a zero-inflated Poisson model, the relationship between pesticide exposure and self-reported health symptoms from pesticides for small-scale vegetable farmers in Nicaragua was established. Special emphasis was given to the measurement of pesticide poisoning as the number of health symptoms reported during an intensive input use monitoring survey. Using a different approach to that of previous studies where logistic or linear regression models were applied (ROLA and PINGALI 1993; DUNG and DUNG 1999; HUANG et al. 2000; MANCINI et al. 2005), the model used here accounts for the large share of zero observations in the dependent variable, which is a common characteristic for pesticide poisoning data. Hence the validity of empirical findings could be increased. The model results show that the main determinants of health risks from pesticides are the number of applications and the toxicity of the products as measured by the weighted average price of insecticides. Additionally, in this study the use of "pesticide cocktails" was found to increase the incidence of health symptoms from pesticides.

The findings of this study hint at some starting points for policies aiming to reduce pesticide poisoning among farmers. Firstly, the results support the notion that a general reduction in the use of the most toxic pesticides can be expected to significantly reduce health risks for farmers. This tends to support the proposal of MURRAY et al. (2002) to ban and restrict the 12 pesticides causing most of the poisoning cases in Central America. Recently, the registration of these pesticides has been evaluated by the Ministry of Agriculture, resulting in the prohibition of two products, namely a fumigant used in food grain storage, aluminum phosphate as tablets and Monocrotophos. For the other evaluated pesticides that were found to be commonly applied by the respondents in this study, restrictions on the use were decreed (GARCÍA 2006). While the prohibition of aluminum phosphate is considered to be a successful measure in reducing the number of deaths through pesticide poisoning in Nicaragua (BERROTERÁN 2006), the benefits of restrictions imposed on the use of pesticides seem to be more difficult to achieve. For example, Metamidophos use is restricted to rice and sorghum only, and users should be subject to regular blood tests for cholinesterase. However, this pesticide continues to be the most used product in maize production and is still widely available in pesticide shops. It is therefore also applied to vegetable crops (GARCIA 2006).

Other possible measures are changes in the prices of pesticides in order to reduce the incentives to use hazardous products. For the Philippines, ANTLE and PINGALI (1995) found that taxation of pesticides would reduce the average production costs of rice when health costs are included. In the case of potato production in Ecuador, policy simulations show 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). AGNE and WAIBEL (2005) found that for coffee production in Costa Rica, taxes could be an effective tool to reduce pesticide use, as the effects on gross margins at farmer level are small.

Further analysis of price differences between insecticides of different toxicity classes and modeling of pesticide demand based on price elasticities is warranted in order to show whether pesticide taxation would be an economically efficient instrument of health policy in the case of Nicaraguan small-scale vegetable producers.

Overall the study shows that self-reporting of health symptoms by small-scale farmers in developing countries is a useful means of assessing pesticide health risks. This study should be considered as the starting point for further research on the economic evaluation of the health effects of pesticides and the implications for farmers’ choices of pest control practices.

4 Pesticides and Farmer Health in Nicaragua – a willingness-to-pay approach to evaluation[10]

4.1 Introduction

Pesticide poisoning is a major health risk in developing countries. Poisoning incidence has been monitored in different parts of the world for more than 20 years. The estimates of the share of farmers affected every year are similar in different countries and over a long time horizon (WHO 1990; HUANG et al. 2000). Among the first to publish estimates about the poisoning incidence among farmers was JEYARATNAM et al. (1987) with data from Malaysia and Sri Lanka. His estimates of about 7% of the farming population affected by poisoning every year have later been confirmed for different countries. In Nicaragua, pesticide poisoning has been well documented (see e.g. CORRIOLS 2002; KEIFER et al. 1996; MURRAY et al. 2002). Recent estimates of the number of farmers suffering from pesticide poisoning every year range between 5.4% and 6.3% of the farming population of Nicaragua (PAHO 2002). Recent survey data from Nicaraguan vegetable growers revealed that 30% had experienced acute poisoning at least once in their life as farmers. However, chronic effects from long-term exposure are often not recognized and are rarely documented (REEVES and SCHAFER 2003).

To address this situation, many strategies have been proposed and some implemented. In particular, training farmers on the safe use of pesticides and the promotion of protective gear have both been considered as means to reduce farmers' exposure to pesticides (ATKIN and LEISINGER 2000). But the long-term benefits of safe use campaigns have been questioned (HURST 1999; MURRAY and TAYLOR 2000).

The correlation between the level of use of toxic pesticides and the severity of health risks has been widely documented (KISHI et al. 1995; PINGALI and ROGER 1995; CRISSMAN et al. 1998). Therefore, reduction of pesticide use is seen by many as a strategy for improving the health status of the rural population. Integrated Pest Management (IPM) has been promoted as a technology that aims to reduce the dependence on chemical pesticides and to increase the use of non-chemical methods of plant protection. Here, a thorough understanding of the agro-ecosystem and regular field observations are crucial (MORSE and BUHLER 1997). While in many programmes a reduction in pesticide use has been achieved (VAN DEN BERG 2004;

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[10] An earlier version of this chapter has been published as: GARMING, HILDEGARD and HERMANN WAIBEL (2008): "Pesticides and Farmer Health in Nicaragua – a willingness-to-pay approach to evaluation". European Journal of Health Economics, forthcoming.

GARMING and WAIBEL 2005), scientific evidence of positive health effects of IPM has so far been mixed. While some studies could not establish significant effects of participation in IPM training on the incidence of health effects (MAUMBE and SWINTON 2000; LABARTA and SWINTON 2005), the study of HRUSKA and CORRIOLS (2002) showed reductions in pesticide poisoning after IPM training in Nicaragua, based on blood tests.

Economic evaluation of health costs of pesticides is required to design effective rural health policies to reduce pesticide poisoning cases among the farm population. Here, the methodological approach has to take into account the fact that health includes market and non-market value components. Evaluations of health costs of pesticides so far have focused on the market components, estimating the costs of illness (AJAYI 2000; HUANG et al. 2000). However, a more comprehensive analysis of the health costs of pesticides has to also consider the non-market value of human health. For this purpose, the contingent valuation (CV) method has been proposed, which was found to be suitable in obtaining a valuation of individuals' preferences for health (HIGHLEY and WINTERSTEEN 1992). However, only few studies have applied contingent valuation to the topic of pesticides and human health. Most of these studies were conducted for IPM programs in US agriculture (FLORAX et al. 2005), either as consumer surveys (see e.g. MULLEN et al. 1997; BRETHOUR and WEERSINK 2001), or through the analysis farmers' WTP for reducing the negative effects of pesticides (OWENS et al. 1998). Only few studies on farmers' WTP for health have been carried out in developing countries, namely in the Philippines (CUYNO et al. 2001), Sri Lanka (WILSON 2002) and Nepal (ATREYA 2005). No such study has been conducted so far in Central America although pesticide use and related health risks in this region are among the highest in the world (PAHO 2002).

This paper presents a contingent valuation approach to estimate the health costs of pesticides among vegetable farmers in Nicaragua. The objective is to assess farmers' willingness to pay for pesticide-related health improvements. This information can assist in the design of programmes to effectively reduce the negative effects of pesticides.

4.2 Theoretical background

Contingent Valuation (CV) is a technique for the valuation of non-market goods and has widely been applied in health economics (KARTMAN et al. 1996; O'BRIEN and GAFNI 1996; DIENER et al. 1998; OLSEN and SMITH 2001; SHACKLEY and DONALDSON 2002; HANLEY et al. 2003; MATARIA et al. 2004). The underlying theoretical framework is welfare economics in the case of valuation of public goods. An individual's health can be considered primarily as a private good (SMITH 2005), which is evaluated in the framework of household theory. In CV, a constant individual utility is taken as the basis for evaluating a change in the supply of a non-market good, applying the concept of Hicks compensated demand functions. The appropriate welfare measure for the evaluation of a pesticide-related health outcome is compensating variation, which refers to the utility level before the change. In Figure 4.1, the concept of compensating variation (C) is illustrated: The utility of the farm household (U_0) is represented as the sum of health (H_0) and other goods, summarized as income (I_0). If supply with health is improved to H_1, keeping income constant, for example through a new pest management technology (I_0=I_1), farmers move to a higher utility level (U_1). The value of the improvement in health is defined as that amount of income that the farmer is willing to forgo (WTP) in order to be as well off as before the change in health i.e. to remain on his initial utility level U_0 with H_1, I_2.

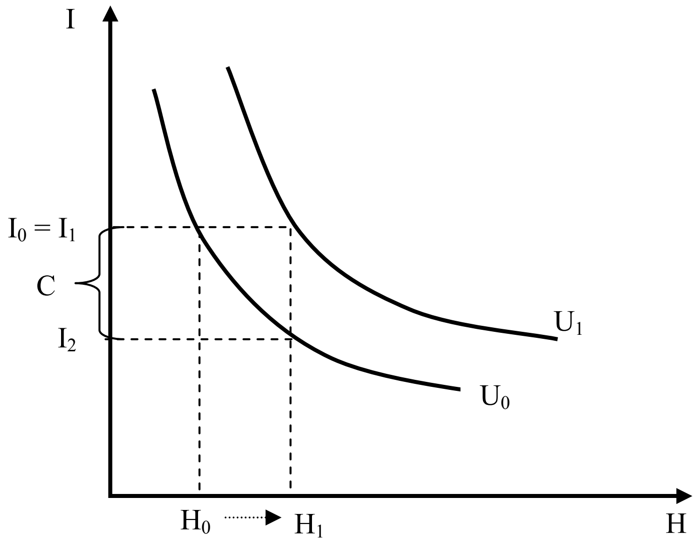

Figure 4.1: Compensating variation for an improvement in pesticide-related health.

Source: adapted from MARGGRAF and STREB 1997

The elicitation of WTP is based on surveys, in which respondents evaluate the non-market good in hypothetical market situations. Since CV relies on stated preferences instead of behaviour observed in real markets, a controversial discussion about the question of whether or not CV can produce valid results (HAUSMAN 1993) was provoked. Studies comparing values elicited in hypothetical settings with those found in transactions involving cash payments raised the concern that the hypothetical values may generally be higher than what respondents are willing to pay in the real market (CUMMINGS et al. 1995). Addressing these concerns, valuation experiments with consumers based on non-hypothetical payments have been tested (NAYGA et al. 2006). Nevertheless, the feasibility of these kinds of experiments may depend on the case to be studied and the respondents involved. Recent literature on CV therefore emphasizes the importance of creating scenarios that are as realistic as possible and of conducting validity tests as quality indicators for each application (CHAMP et al. 2003, p. 155).

MITCHELL and CARSON (1989) identify three main types of validity assessments: a) Content validity is achieved through careful design of the survey instrument. The definition of the good and the scenarios should ensure that the correct values are measured. Bias can result if the amount of benefit of the scenario is not clear or if the means of payment is not plausible to respondents. Careful survey design, pre-tests and focus group discussions are tools to enhance content validity. b) Convergent validity compares valuations of the same good obtained by different measures. If the values are correlated and tend to converge, they are assumed to be valid. However in a specific application, it may be difficult to obtain other measures, as CV is usually applied in cases where market-based prices (for example) are not available. c) Theoretical validity applies the concept that the demand for non-market goods follows the same rules as the demand for market goods. For example, the valuation should be sensitive to the amount of the good supplied, which is tested in scope tests. Also, willingness to pay should vary with income and attitudes towards the good. This is tested by regressing the obtained values on a number of variables that are expected to determine willingness to pay, based on economic theory. In the present study the hypothesis is tested that (1) concerns about pesticide poisoning, (2) experience of illness, (3) income variables and (4) risk measures like intensity of pesticide use, are relevant predictors for the valuation of health. In the following section, the design and the conduct of the CV survey with Nicaraguan small-scale vegetable farmers is described. Next, a description is provided of how the evidence of validity was established.

4.3 Methodology and Model

The CV study evaluated the WTP of small-scale vegetable farmers for avoiding health risks from pesticides. The survey was implemented in face-to-face interviews with 433 respondents in the four main vegetable growing regions in Nicaragua. The design of the survey instrument was guided by the data requirements for the elicitation of WTP and the tests on the validity as summarized in Table 4. 1

Table 4.1: Methods of assessment of validity of willingness to pay applied in the survey.

Validity	**Implementation in survey**	**Assessment**
Content validity		Response rates Analysis of comments of respondents with zero-bids.
Definition of the good	Pesticide without health risks	
Payment vehicle	Pesticide price	
Familiarity	Purchase of pesticide, Farmers' most used pesticide according to production recall questions	
Acceptance of the questionnaire	Modifications after pre-tests	
Criterion validity	No objective measure of the value available.	Not used.
Construct validity		
Convergent validity	Costs of acute poisoning Adoption of IPM practices Use of personal protective equipment	Compared to stated WTP – lower bound of WTP Frequency of IPM adoption Not used after pre-tests
Theoretical validity	Valuation in two scenarios Questions on ❑ Household characteristics ❑ Income variables ❑ Pesticide exposure and health	Scope test: less benefits = less WTP? Logistic regression: Payer / Non-payer Regression model on WTP

Source: own presentation

The description of health for the valuation scenario was based on the approach used by CUYNO (1999). Health was represented as an attribute of a pesticide. In a hypothetical purchase situation, the respondents were offered a pesticide with low human toxicity but with the same pest control efficiency as their currently most used pesticide. The difference between the current market price for the toxic version and the price that respondents would be willing to pay for the low-toxic version of the pesticide was established as the willingness to pay (WTP) for the health attribute. This method was selected because farmers are most familiar with pesticide-based pest control. Other possible descriptions of the good “health” would have included, for example, the willingness to invest in IPM or the purchase of protective equipment. However, in pre-tests and discussions with farmers both options were rejected. IPM comprises a number of different pest management practices that are applied in a highly variable manner, according to specific farm conditions and the range of crops grown. Consequently, it was not feasible to define a standard IPM application with determined reductions in health risks that could have been used for the valuation of health costs. Protective equipment is often perceived as inconvenient and of questionable effectiveness. Hence, for the farmers, the health benefits were not plausible enough. Thus the low-toxicity pesticide option proved to be the most feasible description of health for the CV survey.

The survey instrument gradually familiarized the farmers with the problem of pesticide-related health, asking them to recall pesticide use in the previous growing period and experiences with poisoning and poisoning symptoms. Then information was given about the possible health effects of pesticides, using a list identifying the most commonly applied pesticides as high, medium or low risk following WHO classification (WHO 2002). High risk pesticides include the WHO categories Ia, Ib and II, medium comprise category III and low risk category U. The distinction between acute and chronic health risks was explained. Subsequently, WTP was established for two scenarios: a pesticide avoiding chronic risks and a pesticide avoiding both chronic and acute risks. The comparison of WTP in these scenarios was used for a scope test, indicating whether respondents understood and valued the differences in the extent of health benefits. The elicitation of the WTP was designed as an open ended bidding game, starting with a 100% price premium, then lowering or increasing the price depending on the farmer’s response. After two bidding rounds, the farmer was asked to rethink his decision and the WTP question was repeated. Total WTP was calculated as the product of price premium and the purchased amount of the pesticide.

In order to compare WTP to related measures of health costs of pesticides, the costs of acute poisoning and general health costs of the household were also collected in the survey. Theoretical validity was assessed in a two-step methodology, first identifying the factors determining whether a respondent had a positive WTP, then analysing the variation of the

WTP amounts. In the first step, a binary logistic regression was applied, where the probability of a positive WTP (p) is regressed on explaining variables (x_i), following a logistic probability distribution:

$$(4.1)\qquad p = \frac{e^{\alpha+\beta_1 x_1}}{1+e^{\alpha+\beta_1 x_1}},$$

For an interpretation similar to the linear regression model, in the logistic regression, the odds ratio of the probabilities for the two possible outcomes of the dependent variable is calculated, which in its logarithmic transformation is a linear function of the explaining variables, α representing the intercept and β' the vector of coefficients of the explaining variables.

$$(4.2)\qquad \operatorname{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \alpha + \beta' x.$$

Since the distribution of positive WTP values (Y) was skewed, as frequently observed in health care data (MANNING et al. 2005), in the second step a semilog or log-linear regression model (GUJARATI 1995, p. 169) was used for the analysis.

$$(4.3)\qquad \ln(Y) = \alpha + \beta' x_i$$

The vector of explanatory variables (x_i) included personal and household characteristics, socio-economic, health-related and pesticide exposure related variables. Respondents' age could have a positive effect on WTP, assuming that older farmers have a longer history of pesticide exposure and have a generally lower health status. However, it is also possible that older farmers are less concerned about future chronic health effects from pesticides. Formal education, as measured in the number of years the respondent attended school, is expected to be positively linked to WTP. For larger households, the supply of family labour can be expected to be higher, hence knowledge and adoption of alternative pest control is expected to increase WTP for avoiding health risks from pesticides. An IPM index is used, capturing the number of alternative pest control practices a farmer uses. Also, a dummy variable on participation in IPM training is included. There may be regional differences in the awareness and WTP for health risks of pesticides, due to access to information, activities of public and non-governmental rural organizations and health infrastructure. Therefore, dummy variables for the survey regions are included in the analysis.

WTP is expected to increase with higher wealth and income of a respondent. The net returns of agricultural production in the survey year and off-farm income are used as income indicators. Farm size is an indicator for wealth. However, the farm acreage can include fallow land and extensively used pastures. Therefore, as an indicator for the intensity of vegetable production, the area planted to vegetables and food grains is included. Another indicator for economic resources is the type of finance used by the respondent: Wealthier farmers have access to formal credit systems from banks, cooperatives or non-governmental organizations, while poorer farmers prefer informal lending as "sharecroppers". In these agreements, the lender supplies external inputs and is paid with a fixed share of output[11]. Sharecroppers usually have little bargaining power about the type of pesticides provided and would be expected to have a lower WTP for safe pesticides.

Attitudes towards health are expected to be the most important explanatory variables determining WTP. However, measuring personal beliefs and attitudes can be difficult. LICHTENBERG and ZIMMERMAN (1999) found that experience with health problems and self-reported poisoning significantly influenced perceptions of health risks of pesticides. In this study, previous experience with pesticide poisoning was classified into three severity categories and used as an indicator for perceptions of health risks. Often, farmers report less severe health symptoms related to pesticide application without considering it as a poisoning. In this study the reported number of symptoms is also included as an indicator for the respondents' attitudes towards health risks of pesticides. The intensity of pesticide use is included in the model to account for actual pesticide exposure. The preferred source of information on pest control is expected to influence farmers' perceptions as well. Those who rely on the advice of pesticides sales agents probably have a lower WTP than those asking extension officers of the public extension service or non-governmental organizations.

Finally, the reference price of the pesticide used in the elicitation of WTP is included in the model, to test whether WTP depends on the starting price.

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[11] This way of finance is rather expensive, but is preferred by poor farmers since risks are shared in the case of crop loss.

4.4 Results and Discussion

Results of the valuation for the two scenarios “chronic” and “chronic and acute” are presented in Table 4.2. The average price increments are 69% and 157% for the scenario “chronic” and “chronic and acute” respectively. Eight percent of the sample was excluded because these respondents did not use any high-risk pesticides, another 15% refused to answer the WTP questions. In total, 362 valid WTP answers were obtained, of which 22% had a zero WTP for the scenario “chronic” and 19% for both scenarios. The reasons given for zero bids included budget constraints (70% of non-payers) and the perception of using sufficient protection to avoid health risks in the status quo (15%). About 15% of the non-payers indicated that they had not had any health problems from pesticides so far.

A first indicator for the validity of WTP responses is the difference in WTP between the scenarios. The benefits from the scenario “chronic and acute” are higher than “chronic”, thus WTP is expected to be higher as well. To confirm this, t-tests were used, which showed a highly significant difference, indicating that the respondents understood the nature of health benefits offered in the two scenarios.

Table 4.2: Median and mean WTP in two valuation scenarios.

Indicator	Unit	Mean (S.E.)	25 Quartil	Median	75 Quartil	Skew.
Total WTP "chronic"	USD	25.8 (3.7)	0	6.00	20.3	6.2
Total WTP "chronic and acute"	USD	61.6 (9.6)	6.0	20.75	50.0	7.8

Source: own calculation

Taking into account the fact, that most respondents are resource-poor small-scale farmers, the stated contingent values seem relatively high. However, variation is very high and the distribution is skewed, so for a first assessment of plausibility of the values, WTP is compared to family expenditure for general health care and individual household income and pesticide expenditure (Table 4.3). Mean WTP for low-toxic pesticides is about 23% higher than the total pesticide expenditure in the survey year. This may appear high when considering that most farmers (63%) need external finance for buying pesticides and fertilizer. Also, pesticide use and expenditure data in this study are based on a recall survey and consequently absolute values have to be interpreted with caution. Nevertheless, the accepted increase in pesticide costs for avoiding health risks is similar to findings from the Philippines of CUYNO (1999), where farmers’ WTP for health was about 22% of pesticide costs. In other studies much higher WTP figures were found, e.g. above 100% of pesticide costs in Nepal (ATREYA 2005) and the US (OWENS et al. 1998).

On the other hand, when comparing WTP with household income, the share is much lower, with a median of 1.2% and a mean of 3.1%. Also, actual expenditure on family health care per year is higher than the mean WTP for avoiding health risks from pesticides. In conclusion, the values obtained for avoiding pesticide health risks are reasonable by these plausibility indicators.

Table 4.3: WTP as share of pesticide expenditure and income.

	Unit	Mean (S.E.) 1)	25 Quart.	Median	75 Quart.
Pesticide expenditure/year	USD	608.7 (61.7)	95.2	222.5	618.8
WTP “chronic and acute” / pesticide expenditure	%	22.6 (2.5)	1.0	5.9	20.0
Agricultural net income / year	USD	1846.5 (228.4)	143.3	666.7	1851.7
Household income / year	USD	2096.0 (235.6)	265.0	904.7	2257.3
WTP “chronic and acute” / household income	%	3.1 (1.6)	0.07	1.2	3.8
Family expenditure for health care	USD	97.8 (14.3)	0	30	66.7

1) Note that the displayed values are the means of the ratios calculated on individual basis over the sample.

Source: own calculations

In Table 4.4 the results for the logistic regression on positive WTP in the scenario “chronic effects” are shown[12]. Of the personal and household characteristics, the coefficients for respondents’ age and number of household members are significant, and they have the expected negative sign. This result is reasonable as one can expect that the older the farmer, the less he will be concerned about future chronic effects of pesticides, particularly if he has not suffered from illnesses so far. The negative sign of the coefficient for larger households could be related to a relatively higher supply of family labour and consequently lower health risks for the individual.

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[12] A logistic regression model was also estimated for the scenario “chronic and acute effects”. However, overall model fit as assessed using a likelihood ratio test was poor, therefore only the model for the scenario “chronic effects” is shown.

There are differences in WTP among the survey regions: In the Northern highlands, Jinotega and Matagalpa, fewer respondents have a positive WTP as compared to the region of Pacifico Sur. This region close to the capital is more densely populated, has a better road and education infrastructure and more exchange of information from any sources. That may cause farmers to be more aware of health risks and more interested in alternatives to toxic pesticides. Income and wealth indicators have a minor effect on the probability of a positive WTP. Only sharecropping has a significant negative effect (at 0.1 level) as expected.

Of the health and exposure-related variables, the number of poisoning symptoms reported by the farmers is positively related to their attention to health aspects and therefore to a positive WTP.

Table 4.4: Logit model for positive willingness to pay in the scenario “chronic effects”.

Variable	Variable Description	Coeffic.	Odds ratio	Sig.
Household characteristics				
Age of respondent	[years]	-0.022	0.978	**
School	[years attended]	-0.001	0.999	
HH members	Number of persons living in household	-0.116	0.890	**
IPM Index	Knowledge and adoption of practices	-0.024	0.976	
Trained	Participation in IPM training	0.330	1.391	
Survey regions1)				
Pac_Sur	South Pacific region	0.230	1.258	
Matag	Matagalpa	-1.094	0.335	***
Jinotega	Jinotega	-1.022	0.360	***
Income and wealth				
Credit	Acess to formal credit	0.190	1.209	
Sharing	Sharecropper	-0.507	0.602	*
Net return	Agricultural net returns [$]	<0.001	1.000	
Off-farm	Off-farm income [$]	<0.001	1.000	
Farm size	[mz2)]	-0.014	0.986	
Crop area	[mz]	-0.331	0.718	
Subsistence	Food grain production for home consumption	0.190	1.209	

Exposure to pesticides and health problems				
Severity	Severity of poisoning experience	0.004	1.004	
Symptoms	Reported number of symptoms after spraying	0.117	1.124	*
WHO I & II	Total amount of pesticide of this category used [kg/mz]	0.003	1.003	
WHO III & IV	Total amount of pesticide of this category used [kg/mz]	-0.005	0.995	
Sales agent	Information source pesticide shop	-0.346	0.708	
Extension	Information source extension service (public or NGO)	-0.218	0.804	
Reference price	Current price of reference pesticide [C$/kg]	0.001	1.001	
Constant		2.981	19.702	
Model Summary				
-2 Log likelihood		446.502		
Nagelkerke R Square		0.168		
Percentage Correct		65.565		
Chi-square		48.357		***

1) omitted variable: Estelí; 2) Central American Unit of area: 1 manzana = 0.7 ha

***: significant at 0.01 level; ** significant at 0.05 level; * significant at 0.1 level;

Source: own calculations

Table 4.5 shows the results of the log-linear regression model for the WTP in the scenario “chronic and acute effects”.[13] Of the respondents’ and household characteristics, formal education has a significant and negative effect on WTP. A possible explanation for this could be that higher educated farmers tend to read and understand pesticide labels and feel more confident about coping with pesticide health risks. As expected, the adoption of IPM practices captured in the IPM index is positively correlated with WTP, indicating that IPM farmers have higher awareness of pesticide health risks. Corresponding with the findings of the logit model, respondents in the South Pacific Region gave a higher WTP than the other regions.

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[13] A log-linear model was also calculated for the scenario “chronic effects”, with similar results: significant variables with same sign as shown in Table 4.5 were: Pac_Sur, credit, farm size, crop area, severity of poisoning, pesticide use per mz.

The results also reveal that budget constraints are important: The variable access to formal credit is highly significant and has a positive effect on WTP. These farmers usually face less cash constraints than those working as sharecroppers or without any lending. The effects of the variables farm size and cropped area on WTP are opposite. Land ownership can be interpreted as an indicator of wealth, but owners of larger farms including fallow land, pastures and coffee may be less affected by pesticide health risks as compared to farmers with small areas and intensive vegetable production. Hence, the reported area planted with vegetable or food grain crops, which is more related to full-time farming with a high input of family labour, has a highly significant and positive effect on WTP. The variables net returns from agricultural activities and off-farm income were supposed to increase demand for health and lead to a higher WTP, however they are not significant in this model. This could be explained by the fact that in vegetable production net returns are highly variable, so that results of a specific year may not bear much relationship to the farmer's valuation of health effects.

Table 4.5: Log linear regression on stated WTP for scenario "chronic and acute effects".[14]

Variable	Unstand. Coeff.	Std. Error	Stand. Coeff.	T-value	Sig.
Household characteristics					
Age [years]	<0.001	0.007	0.004	0.061	
School [years]	-0.061	0.030	-0.141	-2.010	**
HH members	-0.044	0.042	-0.066	-1.062	
IPM Index	0.029	0.015	0.141	1.995	**
Trained	-0.290	0.196	-0.110	-1.474	
Survey regions1)					
pac_sur	0.696	0.281	0.193	2.474	**
Matag	-0.134	0.234	-0.041	-0.571	
Jinotega	0.197	0.217	0.068	0.909	

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[14] For detection of possible multicollinearity in the model, the variance inflation factors (VIFs) [12] (p. 338) were calculated. These are smaller than 2 for all variables, indicating that correlation between explaining variables may not affect the estimation of coefficients.

Income and wealth					
Credit	0.632	0.198	0.221	3.195	***
Sharing	0.177	0.209	0.062	0.848	
Net return [$]	<0.001	<0.001	-0.029	-0.414	
Off-farm [$]	<0.001	<0.001	0.033	0.460	
Farm worker	-0.352	0.230	-0.095	-1.530	
Farm size [mz$^{2)}$]	-0.008	0.004	-0.123	-1.914	*
Crop area [mz]	0.120	0.031	0.302	3.905	***
Subsistence	-0.237	0.175	-0.088	-1.357	
Exposure to pesticides and health experiences					
Severity	0.165	0.081	0.135	2.049	**
Symptoms	0.079	0.048	0.107	1.669	*
WHO I & II [kg/mz]	0.011	0.005	0.144	2.127	**
WHO III & IV [kg/mz]	0.006	0.003	0.135	2.105	**
Sales agent	-0.082	0.191	-0.029	-0.431	
Extension	-0.158	0.217	-0.053	-0.727	
Reference price	<0.001	0.001	0.008	0.137	
Intercept	5.283	0.515		10.248	***
Model					
R Square	0.401				
Adjusted R Square	0.326				
Regression F-value	5.334				***
Number of observations	208				

[1] omitted variable: Estelí; [2] Central American Unit of area: 1 manzana = 0.7 ha

***: significant at 0.01 level; ** significant at 0.05 level; * significant at 0.1 level

Perceptions of health risks of pesticides and exposure variables have a positive effect on stated WTP. Previous experience with pesticide poisoning is highly significant. The more severe the poisoning as perceived by the respondent, the higher the WTP. The reported number of symptoms is also positively related to the valuation of health risks, although the correlation is weaker than with the poisoning variable. The intensity of pesticide use, an indicator for health risks through exposure, is a highly significant predictor of WTP as expected.

4.5 Conclusions

The results of this contingent valuation study demonstrate that Nicaraguan vegetable farmers are well aware of pesticide health risks. This is also reflected in a positive willingness to pay for avoiding these risks.

Compared to pesticide expenditure, the WTP for avoiding risks for human health found in this study confirms the results of a previous study from the Philippines (CUYNO 1999). However, it is considerably lower than the results found in similar studies from the US (HIGHLEY and WINTERSTEEN 1992), Sri Lanka (WILSON 2002) and Nepal (ATREYA 2005). This indicates that the values probably represent a lower bound of the farmers' evaluation of pesticide-related health. Nevertheless, it can be observed that farmers still use substantial amounts of highly toxic pesticides, which tend to be cheaper than more benign alternatives. One reason for this can be assumed to be the farmers' lack of knowledge about the actual toxicity of specific pesticides and their difficulties in attributing the perceived health problems to these. Also, many farmers may still not be aware of less risky pesticides available for particular pest problems and therefore resort to the more familiar products despite the related health risks. However, the majority of the respondents are aware of the health risk associated with pesticides and therefore can imagine the value of a safe (albeit hypothetical) pesticide as designed for the purpose of the bidding game. So, the theoretical validity of the stated WTP could be established. Respondents gave higher values to the scenario "chronic and acute effects," which provided higher benefits. Also WTP increased with previous experience with pesticide poisoning and the number of symptoms, as well as increased health risks represented by current pesticide use intensity. Respondents considered cash constraints and paying capacity when stating WTP, as indicated by the significant effect of access to credit in the regression models.

This paper presents an approach to the quantification of the health costs of pesticides and hence the estimation of the benefits of programmes that directly or indirectly reduce pesticide poisoning. Estimations of health costs of pesticides are important information for policy makers. Firstly, these values can be used to more realistically assess the benefits of IPM programmes. Generally if an IPM program is effectively contributing to the reduction of toxic pesticides as has been established in a number of cases (see e.g. van den Berg 2004) the rate of return of such programs is higher than previously assumed in many studies. In this regard IPM programs should be considered under the banner of rural health policies in addition to their role as agricultural technology. Secondly, information about pesticide health costs can serve as a basis for government decision-making for investments in rural health infrastructure. Thirdly, the fact that farmers value their health demands that information about health issues of agricultural technologies should be more effectively incorporated in general agricultural extension programs. It is thus recommended that agricultural policies should look beyond the “modern input- productivity paradigm” and encompass a more comprehensive approach in agricultural education.

With respect to the finding that farmers with a higher level of IPM adoption have a higher WTP for better health, further research should address the question of to what extent better health can serve as an incentive for farmers to adopt technologies that reduce pesticide use.

5 Farmer Health and Adoption of Integrated Pest Management Practices

5.1 Introduction

This study is motivated by the fact that pesticides continue to be a major health risk for farmers in developing countries. Ample evidence exists that pesticides cause human health problems and that the health risks of farmers are closely correlated to the doses and toxicity of the pesticides they use (KISHI et al. 1995; CRISSMAN et al. 1998; HUANG et al. 2000). It has been estimated that 5-7% of farmers in developing countries are victims of acute pesticide poisoning every year (JEYARATNAM et al. 1987). These early estimates have been confirmed by more recent studies in different parts of the world (KISHI et al. 1995; AJAYI 2000; PAHO 2002; LABARTA and SWINTON 2005). Many efforts to reduce health risks from pesticides in developing countries have shown little success. For example, projects promoting the use of personal protective devices during spraying often have only short term effects and farmers return to their old practices after some time (ATKIN and LEISINGER 2000).

For several decades Integrated Pest Management (IPM) has been promoted as a safer alternative to routine pesticide spraying. In IPM, an important factor is knowledge of how to manage the crop and the crop environment in such a way that the use of external inputs, especially chemical pesticides, can be significantly reduced. Knowledge is required on both the use of non-chemical practices and need-based pesticide use. On a global scale the diffusion of the IPM technology has been lower than expected (WAIBEL and PEMSL 2000). Despite its potential benefits, demonstrated in numerous studies (see, e.g. VAN DEN BERG 2004), adoption of IPM by farmers in developing countries has been low so far (MORSE and BUHLER 1997; p. 91). One of the reasons could be that the promoters of IPM were focussing mostly on its benefits in terms of productivity and costs. However, some studies showed that there might be other factors that can drive the adoption of this technology. For example, PRANEETVATAKUL and WAIBEL (2006) found that Thai rice farmers reduced their pesticide use after IPM training, even though there was no significant income effect.

In order to analyze adoption of this technology, the aspects of knowledge acquisition and learning by doing can be assumed to be especially important because IPM practices have to be adjusted to the specific conditions of the farmers' cropping system (NORTON et al. 2005).

In many adoption models, learning has been included as an important explanatory variable. For example, FOSTER and ROSENZWEIG (1995) found that the profitability of high yielding varieties increased with experience in cultivation, and concluded that learning by doing was an important factor. MOSER and BARRETT (2006) determined that learning, especially learning from others, was an important factor in the adoption of a low input rice intensification system among Malagasy farmers. In their model they treated adoption as a two-stage process and predicted the farmers' decision to continue using the technology after they had tested it. Accordingly, learning by doing became an important determinant of final technology adoption. Different approaches have been used to model the learning process during the adoption of new technologies. In their study of organic agriculture in Greece, DIMARA and SKURAS (2003) developed a two-stage model of adoption. The first stage was defined as the awareness stage, during which a farmer becomes aware of the technology and decides to search for more information, while the second stage is the ultimate adoption decision. In their sequential model, the authors first estimated awareness of the technology and subsequently modelled the adoption decision. Their results indicate that different variables may have an impact on different stages of adoption, which would not be observable in a one-stage model.

An important aspect of studies on the adoption of technologies is the definition and measurement of adoption. As FEDER et al. (1985) point out, the measurement of adoption at farm level must consider whether the technology is divisible or not. Adoption of divisible technologies such as fertilizer use or high yielding varieties can be measured quantitatively as the degree of use, i.e. land planted to the variety, quantity of fertilizer applied. For non-divisible technologies the binary measure of use or non-use is commonly applied (DIMARA and SKURAS 2003). Also, in the case of technologies consisting of a package of innovations, different components of the package may be adopted at different times, which further complicates the definition of adoption (FEDER et al. 1985). In his review Doss (2006) describes how the definition of an adoption measure can influence the results of an adoption study because the determinants of adoption can differ between a binary and quantitative model for the same technology. It is also pointed out that adoption of management practices in the context of sustainable agricultural practice is especially complicated to define (DOSS 2006). In this study, the issue of measurement of adoption is addressed following the methodology used in previous studies (MAUMBE and SWINTON 2000; RAMIREZ and SHULTZ 2000; PARK and LOHR 2005). The number of typical practices adopted by the farmer is used as an operational measure of IPM adoption and a proxy for the degree of adoption.

Several studies showed that farmers in developing countries are aware of pesticide health risks (NTOW et al. 2006; GARMING and WAIBEL 2007). However, it is not yet clear whether the awareness of health risks is sufficient motivation for farmers to adopt IPM. Some studies showed that health is an important factor in adoption while others could not confirm this. For example, LABARTA and SWINTON (2005) found some evidence that bean farmers' prior experience with pesticide poisoning symptoms reduced the demand for pesticides and increased the adoption of different IPM practices. On the other hand, results from a study on IPM in cotton in Zimbabwe (MAUMBE and SWINTON 2000) showed no significant impact of attitudes towards health on adoption of IPM.

In the theoretical literature on adoption and diffusion of innovations (e.g. SUNDING and ZIVIN 2000; ROGERS 2003) adoption is described as a process of information, experimentation, decision, implementation and evaluation. Hence, different factors may influence the adoption decision in different stages of the adoption process. In the case of the adoption of IPM practices, a model is needed that takes into account the testing of practices as a crucial activity before the decision on adoption is made. Since there are many IPM practices, farmers need to choose those that best suit their circumstances. Hence the decision to finally adopt a practice is conditional on the process of testing and adaptation.

The objective of this paper is to analyze the relationship between farmers' perceptions of pesticide health risks and their choices with regard to pest control. It investigates the effect of farmers' experiences with pesticide poisoning and perceptions of health risks of pesticides on the adoption process of IPM practices, considering two levels of adoption: the testing of IPM practices and the adoption. In a second step of the analysis, the effects of adopting IPM practices on the amount and the toxicity of pesticides, and hence on potential health risks, are studied.

The paper is organized as follows: section 2 explains the conceptual framework of analysis and models used. In section 3 the data collection is briefly explained and the descriptive analysis of the model variables is presented. Section 4 presents the model results, followed by conclusions in section 5.

5.2 Conceptual framework and model

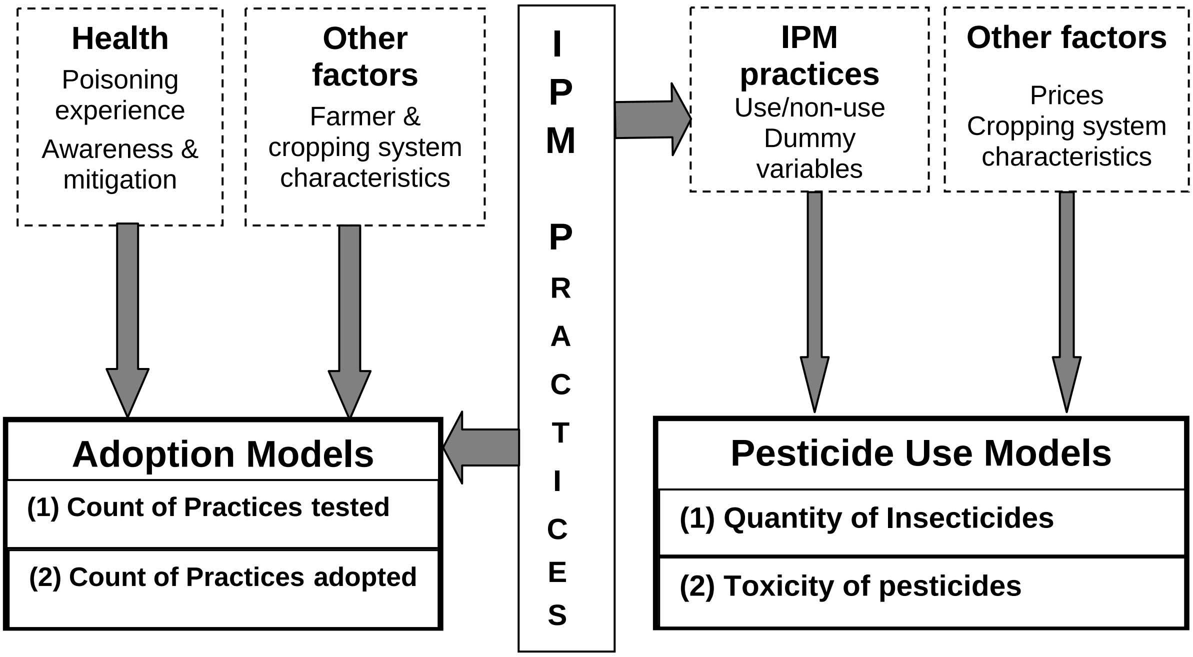
The adoption of new technologies by farmers is influenced by different factors and constraints. Basic factors that cause an individual to become aware of a new technology and to consider its adoption are the perceptions of having a problem or some degree of dissatisfaction (ROGERS 2003). Farmers' potential problems with pest control technologies include their technical effectiveness and the perceptions of health risks of pesticides, which may motivate them to search for alternative pest control technologies.

Analysis of the adoption of IPM practices is based on household theory, which suggests that the driving force of new technology adoption is the expected gain in farmers' utility. For simplification this is often equated to profit. However, for small-scale farmers in developing countries, it is reasonable to assume that households derive utility not exclusively from income but also from non-monetary benefits such as health. Hence, improvements in health may constitute incentives for farmers to adopt IPM practices. The adoption of IPM practices can have positive effects on farmer health if as a consequence the use of pesticides can be reduced, and therefore the risk of pesticide poisoning decreases. Also, farmers applying IPM practices may shift from pesticides with high human toxicity towards modern products with specific effects on pests and low toxicity for humans, with resulting reductions in the health risks.

In this study, the relationship between farmers' perceptions of pesticide health risks and their choices with regard to pest control is analyzed in two steps as illustrated in Figure 5.1. In the first step two separate adoption models are estimated: one for the testing of practices and the second one for the actual use of practices. Both models are of the Poisson type and rely on the count of practices as the dependent variable. The explanatory variables for both models include the respondent's experience of pesticide poisoning and his/her perceptions of pesticide health risks as well as farmer and cropping system characteristics (Figure 5.1). The second step of the analysis is to investigate the effect of the use of IPM practices on the amount and toxicity of pesticide used by the respondents (Figure 5.1). A set of dummy variables representing the different practices, as well as pesticide prices and cropping system characteristics, are included as explanatory variables in these models.

In the following section the adoption models are presented first, followed by a description of the pesticide use models.

Figure 5.1: Overview of models used in the analysis.



Source: own presentation

For the model of adoption of IPM practices, a quantitative measure of adoption is established as the dependent variable. The number of practices tested or used by a farmer out of a set of typical practices is counted, assuming that the more practices a farmer uses, the higher the degree of adoption. The count of IPM practices used can take on only integer and non-negative values, including zero. Poisson regression models are commonly applied in the analysis of count data (CAMERON and TRIVEDI 1998; WOOLDRIDGE 2006). Hence, for analyzing the effect of farmers' experiences with and perceptions about pesticide-related health on the two levels of adoption, two Poisson regression models were fitted with the dependent variable being a) the count of practices tested by a farmer and b) the count of practices actually used by the farmer.

Therefore, the count of practices y_i is assumed to be Poisson distributed and the probability that a farmer uses a certain number of practices Y_i on his farm can be expressed as:

$$(5.1) \qquad \Pr ob(Yi = y_i) = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!} \; ; \; y_i = 0,1,2,...11$$

The conditional mean of the count μ_i is equal to the variance of the distribution and depends on a vector of explanatory variables x_i.

(5.2) $$E(y_i|x_i) = Var(y_i|x_i) = \mu_i = \exp(x_i \beta')$$

The empirical specification of (5.2) is as follows:

(5.3) μ_I= f (*intox, prem, age, edu, lod, lveg, fveg, bveg, fgr, ccr, ord, crd, particip*)

For estimation of the parameters β the maximum likelihood estimation procedure is used.

Table 5.2 gives an overview of the explanatory variables.

Previous experience with poisoning is expected to have a positive effect on the adoption of IPM practices because it increases awareness of the negative effects of pesticide use, which may lead the farmer to search for alternative pest control technology. A dummy variable is used indicating whether the farmer has suffered from pesticide poisoning before ***(intox)***. Perceptions of health risks were measured through the presence or absence of the practice of a farmer to pay a wage premium to hired labour for pesticide application ***(prem)***. This variable aims to capture both the mitigation of health risks, and the higher labour costs when using pesticides, both factors expected to increase the adoption of IPM practices.

Different farmer characteristics include respondent's age ***(age),*** the number of years the farmer attended school ***(edu)*** and a dummy indicating whether the farmer owns the land he is cultivating ***(lod).*** Older farmers have been found to adopt innovations at a lower rate than younger farmers (FEDER and UMALI 1993), so the expected sign of the coefficient for age is positive. Also, education is usually a positive factor for the adoption. For land tenancy it is expected that a farmer operating on his own land adopts more IPM practices, because these practices aim at a long-term positive effect on the agro-ecosystem in contrast to pesticide applications.

The use of IPM practices is not specifically targeted to single crops, with typical examples for practices affecting the whole cropping system being the use of crop rotation or green manure to increase soil fertility. However, different practices may be preferably used in different crop groups. Therefore, as cropping system characteristics, the crop portfolio is considered in the model as dummy variables for different crop groups. The crops are grouped into leafy vegetables ***(lveg)*** including cabbage, celery and lettuce; fruit vegetables ***(fveg)*** including tomatoes, bell pepper, cucumber and chilli; and bulb vegetables ***(bveg)*** including potatoes, onions, carrots and beets. In addition to vegetable production, a number of farmers also produce beans and maize ***(fgr)*** for home consumption. Among the vegetable farmers, most farmers grow vegetables from the same crop group; however it is also possible that a farmer grows crops belonging to more than one of the crop groups. The number of different crops grown by a farmer ***(ccr)*** is included as an indicator of the diversity of the cropping system. It is expected that adoption of IPM practices grows with increasing crop diversity.

Farmers using their own finance ***(ord)*** often have tighter cash constraints as compared to those with access to formal credits ***(crd)***. Cash constraints can be expected to encourage the adoption of IPM practices, which generally are more labour intensive but require less cash expenditures, e.g. for pesticides. In Nicaragua, agreements referred to as sharecropping contracts by farmers ***(scd)*** are another way of finance. In these arrangements typically the farmer obtains a loan from a supplier of inputs and pays back the loan as a fixed proportion of his produce. Pesticide use is mainly determined by the lender, who is not concerned about potential health costs, which accrue to the farmer.

Finally a dummy variable is included, indicating whether or not the farmer participated in an IPM training program ***(particip)***. Doing so is expected to increase the adoption of IPM practices. The inclusion of this variable leads to a potential self-selection problem. IPM training participants may not be selected randomly in a village, i.e. usually the better connected, wealthier farmers tend to participate in the training. If there is a systematic difference between trained and non-trained farmers, e.g. in farm assets, education and social status, the estimates of the training effects will be subject to selection bias and may be overestimated. To correct for this, a two-stage Poisson model is estimated and compared with the results of the individual adoption models. In the first stage, logistic regression is used to model the probability that a farmer will participate in IPM training p(particip) as a function of a set of explanatory variables x_i.

(5.4) $$p\,(\text{particip}) = \frac{e^{\alpha+\beta_1 x_1}}{1+e^{\alpha+\beta_1 x_1}},$$

(5.5) p (*particip*) = f (*edu, lod, ord, scd, hhs, mtd, jtd, etd*)

The explanatory variables include education ***(edu)*** and land tenancy ***(lod)*** as well as access to credit ***(ord, scd)***. Since the participation in training has opportunity costs of labour, the number of family members ***(hhs)*** is included as a proxy for availability of family labour. The survey regions ***(mtd, jtd, etd)*** are included to explain training participation in order to capture differences in the implementation of training, which is organized on the level of the departments. The estimated participation is included as an explanatory variable in the Poisson model at the second stage. For the testing of model coefficients in this two stage maximum likelihood model, the Murphy-Topel variance estimator is used, following a method described by (HARDIN 2002).

The second major part of the analysis deals with actual pesticide use, modelled as a function of the adoption of IPM practices. If adoption reduces actual pesticide use or leads farmers to use pesticides with lower human toxicity, this would indicate that there are potential health benefits related to the adoption of IPM practices.

Among the different categories of pesticides, insecticides carry more potential health hazards than fungicides or herbicides. Therefore, the effect of IPM practices on the quantities of insecticide use was estimated, using linear regression. In a second model the shift towards pesticides with lower human toxicity was analyzed. Here the dependent variable was the ratio of hazardous pesticides to the total amount used. The hazard classification was based on the WHO grouping of pesticides according to human toxicity (WHO 2002). Following the classification used by CRISSMAN et al. (1998) in his Ecuadorian study, all products belonging to the categories "extremely", "highly" or "moderately hazardous", categories Ia, Ib and II, were included in this group.

(5.6) $Ins\_use(crop) = f\,(IPM\_1, IPM\_2, \ldots IPM\_11, fert, app, psd, exd, ccd)$

(5.7) $Share\_tox(crop) = f\,(IPM\_1, IPM\_2, \ldots IPM\_11, fert, psd, exd, ccd)$

The pesticide use and toxicity models are estimated separately for different vegetable crops. As explanatory variables, the binary measures of adoption of the different IPM practices ***(IPM_1 to IPM_11)*** are included as dummy variables (Figure 5.2). Other determinants of pesticide use are the level of productivity and expected yields and prices. As a proxy, the amount of fertilizer applied to the crop per hectare ***(fert)*** is included as an explanatory variable. The weighted average price of pesticides ***(app)*** is also included in the pesticide use functions. Additionally, a dummy on information sources is included, indicating whether the farmer relies on recommendations of a pesticide sales agent ***(psd)****,* which is expected to increase pesticide use. The number of different crops grown by a farmer ***(ccd)*** is an indicator for the diversity of the cropping system and is expected to be negatively correlated with pesticide use.

5.3 The Data

The analysis is based on data from a survey of 433 small-scale vegetable farmers in four regions in Nicaragua; namely Matagalpa, Jinotega, Estelí and the South-Pacific Region. Within these regions, villages with vegetable production were randomly selected from lists provided by the national extension service (INTA[15]) and local agricultural organizations. Within the villages, complete enumeration of vegetable growers was conducted. Every farmer who had grown at least 0.175 ha[16] of vegetables in the previous cropping season, was considered a vegetable farmer and was therefore included in the survey. The distribution of survey respondents among the survey regions (Table 5.1) was based on the relative

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[15] By its Spanish acronym: Instituto Nacional de Tecnología Agropecuaria

[16] Equivalent to 0.25 manzana, the local unit for area.

importance of vegetable growing in the different regions according to experts from INTA and a large scale IPM training programme by the Tropical Agricultural Research and Higher Education Centre (CATIE by its Spanish acronym[17]). The farmers were interviewed about IPM knowledge and adoption, experience with pesticide-related health, pesticide use and profits in the previous cropping season, using structured questionnaires.

Table 5.1: Number of respondents by region included in the survey.

Region	**Matagalpa**	**Estelí**	**Jinotega**	**South Pacific Region**
Municipality	5	5	3	3
Villages	25	35	18	9
Farmers	110	120	151	52

Source: own presentation

The respondents are small-scale farmers with about 2 ha of area planted to annual crops (Table 5.2). On this area, an average of 2.3 crops are grown per year, usually one or two vegetable crops and one crop staple crop such as maize or beans. The education level is generally low; in most cases farmers have not completed primary school. With more than 40% of the farmers having participated in IPM training, coverage of training projects among vegetable farmers seems relatively high.

Experience with pesticide poisoning is common among vegetable farmers; about one quarter of them reported having suffered from pesticide poisoning before the survey year. This excludes those 5.3% who experienced poisoning in the survey year.

A number of farmers pay wage premiums of up to 25% to hired labour for spraying pesticides. These may be in-kind or cash.

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[17] Centro Agronómico Tropical de Investigación y Enseñanza

Table 5.2: Descriptive statistics of model variables.

Variable	Description of variable [unit]	Mean *(Std. Dev.)*
Farmer characteristics		
age	Farmer age [years]	41.4 *(12.9)*
edu	Years of school attended [years]	3.6 *(3.0)*
IPM	IPM training [% of sample]	43.3
hhs	Household size [persons]	5.3 *(2.0)*
lod	Land owner [% of sample]	71.3
psd	Advice from pesticide shop [% of sample]	35.3
exd	Advice from extensionist [% of sample]	25.9
Experiences with poisoning and perceptions of health risks		
intox	Poisoning before survey year [%]	25.9
prem	Wage premiums paid to hired pesticide applicator [%]	12.2
Cropping system characteristics		
cah	Area planted to annual crops [ha]	2.1 *(2.5)*
ccr	No. of crops per year	2.3 *(1.5)*
fgr	Farmer grows food grains [% of sample]	40.9
lveg	Farmer grows leafy vegetables [% of sample]	63.4
bveg	Farmer grows bulb vegetables [% of sample]	69.7
fveg	Farmer grows fruit vegetables [% of sample]	64.8
app	Weighted average pesticide price paid by the respondent [$/kg]	14.4 *(12.3)*
Financial resources		
scd	Sharecropping [% of sample]	37.0
ord	Own finance only [% of sample]	36.0
crd	Uses formal credit [% of sample]	27.0
Survey regions		
mtd	Matagalpa [% of sample]	25.2
etd	Esteli [% of sample]	28.1
jtd	Jinotega [% of sample]	34.7
psd	South Pacific Region [% of sample]	12.0

Source: own survey data

In cross-sectional studies it is difficult to account for learning processes and the determinants of adoption at different stages. Hence, and as suggested by BESLEY and CASE (1993), in this study recall questions on the different stages of adoption, namely testing and final adoption, were included in the data collection procedure. A set of 11 typical IPM practices was defined based on the consultation of national experts in Nicaragua[18]. For each of the practices, the respondent indicated whether he knew about the practice, had tested it and whether he was actually using it (Table 5.3).

Table 5.3: IPM practices and share of farmers per adoption category for each practice.

Practice	Not known [%]	Known [%]	Tested [%]	Adopted [%]
Yellow sticky trap	25.0	75.0	32.9	16.9
Botanical pesticides	30.9	69.1	29.7	12.1
Covered seedbeds	33.6	66.4	30.3	18.7
Remove infested fruits/plants	12.8	87.2	72.8	64.2
Hedges	12.8	87.2	62.3	42.3
Trap crops	62.6	37.1	16.2	10.2
Soil treatment (lime or ash)	11.8	88.2	75.9	67.6
Crop rotation	7.0	93.0	88.2	85.6
Animal manure	15.0	85.0	41.9	17.8
Green manure	60.3	39.7	16.7	5.6
Organic fertilizer for spraying on leaves (home made)	63.6	36.4	18.6	8.1

Source: own survey data

Practices that are directly targeted at decreasing pest pressure, such as botanical pesticides and yellow sticky traps are widely known, but their adoption among vegetable farmers in Nicaragua remained relatively low. Of these practices only the removal of infested fruits and plants to avoid further spread of the pest is used by more than 60% of the farmers. A reason for the lower adoption rate of the other practices may be that additional inputs, such as equipment to prepare botanical pesticides or nets to cover seedbeds, are required. Additionally, labour-intensive practices like the planting of hedgerows to retain pests and the use of trap crops, which attract pests and where they can be sprayed easily, are rarely used. As a general agronomic practice, crop rotation is adopted by most of the farmers. Since

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[18] The study was carried out in collaboration with the CATIE IPM programme, which developed IPM options for different crops and provided large-scale farmer training.

many of them plant different vegetable crops and additional staple crops, this measure is easily implemented. Soil treatment with lime or ash is widely used, since it has been promoted to reduce soil borne diseases. The use of manure to replace mineral fertilizer and to improve soil quality is not very common, although it is known to most of the farmers. However, only few farmers keep livestock and therefore manure is scarce. On average, the farmers are using 3.6 out of 4.9 practices tested, i.e. 73% (Table 5.4).

Table 5.4: Average counts of practices in three levels of adoption.

Levels of Adoption	Mean	Std. Deviation
Number of practices tested	4.9	2.74
Number of practices actually using	3.6	2.25

Source: own survey data

While IPM practices are targeted towards the whole cropping system, the use of external inputs such as mineral fertilizer or pesticides can be measured separately for each crop. An overview of the use of external inputs in major vegetable crops is given in Table 5.5. The descriptive statistics show that the amounts of external inputs vary widely between the vegetable crops. Cabbage crops received relatively little pesticide inputs compared to tomato and potato production, which used three to five times more insecticides and fungicides. In general, the share of hazardous pesticides is lower in potatoes than in cabbage or tomatoes. However, the variation among farmers is substantial as indicated by the standard deviations.

Table 5.5: Input use in major vegetable crops.

Variable	Description of variable [unit]	Mean	Std. Deviation
Cabbage	Number of farmers growing cabbage	108	
fert	Amount of fertilizer [kg/ha]	138.6	103.8
Ins_use	Amount of insecticides [kg/ha]	3.0	2.9
Fung_use	Amount of fungicides [kg/ha]	1.5	1.8
Share_tox	Ratio pesticides WHO I&II / total amount of pesticides [%]	45.6	31.5
Tomato	Number of farmers growing tomatoes	199	
fert	Amount of fertilizer [kg/ha]	205.2	184.0
Ins_use	Amount of insecticides [kg/ha]	14.3	14.0
Fung_use	Amount of fungicides [kg/ha]	19.6	2.4
Share_tox	Ratio pesticides WHO I&II / total amount of pesticides [%]	49.1	28.3
Potato	Number of farmers growing potatoes	98	
fert	Amount of fertilizer [kg/ha]	741.3	443.6
Ins_use	Amount of insecticides [kg/ha]	15.3	20.1
Fung_use	Amount of fungicides [kg/ha]	25.4	19.7
Share_tox	Ratio pesticides WHO I&II / total amount of pesticides	35.1	23.9

Source: own survey data

5.4 Results

The results of the Poisson model for testing of practices (Table 5.6) show that prior experience with pesticide poisoning tends to stimulate farmers to test IPM practices. Also, farmers who pay extra remuneration to workers for applying pesticides tested significantly more different IPM practices. The latter is also a factor in the decision whether or not to continue using IPM practices (Table 5.7). Apart from a farmer’s awareness of pesticide health risks, this variable also captures the additional costs of labour for spraying operations, therefore representing a motivation to adopt alternative practices.

A higher education level leads to more experimentation and adoption of IPM practices, as expected. The age of the respondents is positively correlated with experimentation but not with adoption. Considering that age is a proxy for farming experience it is obvious that older farmers with longer farming experience have tested more different practices compared to younger farmers. Additionally, the participation in IPM training is a significantly positive factor for the testing and adoption of IPM practices.

Land tenure status is an important aspect for the use of different practices. Since the basis of IPM practices is to change the production system on a long-term perspective compared to the immediate action of pesticides, landowners are more likely to adopt alternative pest control methods than those who only rent the land. The access to credit and agreements on the financing of crops have no effect on either stage of adoption.

There are significant differences among the different groups of vegetables; for example, farmers growing leafy vegetables test and adopt more IPM practices than those growing bulb and fruit vegetables or food grains. Possible reasons could be differences in production technology and crop ecology.

To test the robustness of the models, two different model specifications were estimated and the results compared. Table 5.6 and 5.7 each show the full model, including all expected predictors of adoption, and a reduced model, where only significant predictors are included. The comparison of the coefficients and standard errors shows that the estimates are robust.

Table 5.6: Results of Poisson regression on count of practices tested by farmers.

	Full model			**Reduced model**		
	Coef.	S.E.	z-value	Coef.	S.E.	z-value
Farmer characteristics						
Age	0.003 *	0.002	1.65	0.004 **	0.002	2.23
Schooling	0.033 ***	0.008	4.12	0.033 ***	0.008	4.25
Land owner	0.040	0.057	0.70			
Trained	0.392 ***	0.047	8.38	0.386 ***	0.046	8.32
Experiences with poisoning						
Intox before	0.092 *	0.049	1.87	0.086 *	0.048	1.78
Wage premiums	0.298 ***	0.060	4.96	0.275 ***	0.059	4.68
Financial resources						
Sharecropper	0.024	0.059	0.41			
Own finance	0.036	0.055	0.65			
Cropping system characteristics						
No. of crops	-0.024	0.018	-1.29			
Leafy vegetable	0.245 ***	0.056	4.40	0.238 ***	0.056	4.27
Bulb vegetable	-0.076	0.059	-1.29	-0.079	0.059	-1.34
Food grains	-0.009	0.051	-0.17	-0.041	0.047	-0.87
_cons	0.988 ***	0.124	7.99	0.975 ***	0.105	9.31
Model statistics						
Wald chi2(10)	198.010			188.930		
Prob > chi2	0.000			0.000		
Pseudo R2	0.087			0.085		
Log pseudolikelihood	-950.064			-958.050		

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

Table 5.7: Results of Poisson regression on count of practices used by farmers.

	Full model			Reduced model		
	Coef.	S.E.	z-value	Coef.	S.E.	z-value
Farmer Characteristics						
Age	-0.001	0.003	-0.36			
Schooling	0.028***	0.010	2.72	0.030***	0.010	3.16
Land owner	0.127*	0.065	1.95	0.138**	0.061	2.24
Trained	0.327***	0.058	5.62	0.329***	0.056	5.81
Experiences with poisoning						
Intox before	0.085	0.059	1.44			
Wage premiums	0.252***	0.070	3.62	0.241***	0.065	3.72
Financial resources						
Sharecropper	-0.051	0.069	-0.74			
Own finance	0.029	0.069	0.41			
Cropping system characteristics						
No. of crops	-0.025	0.023	-1.09			
Leafy vegetable	0.224***	0.065	3.42	0.167**	0.066	2.54
Bulb vegetable	-0.152**	0.066	-2.31	-0.111**	0.055	-2.00
Food grains	-0.073	0.061	-1.21			
_cons	0.958***	0.153	6.25	0.889***	0.082	10.80
Model statistics						
Wald chi2 (16)	114.5					
Prob>chi2	0.000					
Pseudo R2	0.060					
Log pseudolikelihood	-880.406			-888.422		

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

The results of the two-stage maximum likelihood model, accounting for possible selection bias in the dummy variable of participation in IPM training (Table 5.8), illustrate that participation in training may be associated with higher education. Access to finance as an indicator for resource constraints has also an effect. Farmers without access to formal credit, and sharecroppers, are less likely to participate in training than those with access to credit.

The results of the second stage Poisson models on testing and adoption of IPM practices show that the estimated participation in IPM training has a positive and significant effect on both levels of adoption (Table 5.9). The coefficients of the other variables included in the adoption models are similar to those obtained in the one-stage models shown above, thus confirming the robustness of the estimation results.

Table 5.8: Two-stage Poisson model: Results for logistic regression on training participation.

	Coef.		Robust S.E.	Wald chi2
Schooling	0.063	*	0.034	1.850
Land owner	0.269		0.233	1.160
Share cropper	-0.962	***	0.279	-3.440
Own finance	-0.421	*	0.259	-1.620
Family members	0.033		0.047	0.690
Wage premiums	0.452		0.351	1.290
Jinotega	0.143		0.347	0.410
Matagalpa	-0.325		0.358	-0.910
Esteli	0.408		0.349	1.170
_cons	-0.502		0.435	-1.150
Wald chi2	32.75			
Prob > chi2	<0.001			
Pseudo R2	0.059			
Log pseudolikelihood	-275.547			

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

Table 5.9: Two-stage Poisson model: Results for Poisson regression models on adoption of IPM practices at two adoption levels.

	IPM_test			**IPM_use**		
	Coef.	Mtopel S.E	z-value	Coef.	Mtopel S.E.	z-value
Farmer characteristics						
trained est.	0.778***	0.206	3.770	0.977***	0.242	4.610
Age	0.003*	0.002	1.760	0.018	0.002	0.090
Schooling	0.026***	0.009	3.000	0.062	0.010	1.510
Experiences with poisoning						
Intox before	0.086*	0.049	1.760	0.088	0.057	1.300
Benefits	0.209***	0.067	3.140	0.124***	0.080	1.370
Cropping system characteristics						
Leafy vegetable	0.239***	0.051	4.690	0.204***	0.059	3.400
Bulb vegetable	-0.005	0.053	-0.100	-0.091	0.061	-1.290
Food grains	0.002	0.045	0.040	-0.066	0.054	-1.220
_cons	0.814***	0.124	6.570	0.644***	0.145	4.320

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

The linear regression models show that insecticide use and the share of hazardous pesticides can be explained for cabbage production but not for other crops. This is probably related to the observation that more IPM practices are used in leafy vegetables, among which cabbage represents the most important crop.

In cabbage production, several IPM practices have an effect on insecticide use (Table 5.10). The application of yellow sticky traps is directly targeted at reducing pest pressure in the crop and shows the expected negative sign. The planting of hedges that retain insect pests also helps to reduce insecticide use. A more general practice for reducing insecticide use is crop rotation, which avoids the accumulation of pests and diseases over several cultivation periods. The use of leafy fertilizer aims mainly at making plants more resistant towards infestation by pests and diseases, and its impact on pesticide use is negative, as expected.

Contrary to expectations, the practice “application of lime” is correlated with higher amounts of insecticide use. This application has two main objectives: the control of soil-borne pests and diseases and an adjustment of soil acidity to enhance the uptake of nutrients and hence increase the effect of fertilizer application. This second aspect could explain the positive sign in the model; fertilizer use also has a positive impact on pesticide use, reflecting a generally higher level of input use.

Two of the IPM practices, namely trap crops and green manure, have an unexpected positive effect on insecticide use. No data is available to analyze the reason for this result.

The amount of fertilizer used in cabbage production is strongly correlated with insecticide use, as expected. Fertilizer use is a proxy for the expectations of the farmers about yields and prices and reflects their choice of the level of input use. Insecticide use decreases with increasing crop diversity on a farm, indicated by the number of crops grown in the survey year. An explanation might be that pest pressure tends to be lower in diversified cropping systems compared to monoculture.

Finally, the use of pesticide retailers as the primary information source for pest problems has no effect on the use of insecticides. One reason for this result could be that the other information sources, namely extension service and other farmers, tend to focus on chemical pest control as well. Consequently, the difference between the information sources is not significant.

When the model is re-estimated with different specifications and dropping insignificant variables, the estimates of the coefficients are robust, as shown in the results for the reduced model (Table 5.10).

Table 5.10: Insecticide use in cabbage production.

	Full model			Reduced model		
	Coef.	S.E.	T-value	Coef.	S.E.	T-value
(Constant)	2.084***	0.597	3.489	1.840***	0.504	3.648
Fertilizer	0.815***	0.103	7.949	0.827***	0.097	8.547
Pesticide price weighted	-0.021	0.014	-1.531			
Number of crops	-0.340***	0.121	-2.812	-0.351***	0.114	-3.066
Pesticide shop	0.258	0.348	0.740			
Yellow traps	-1.205**	0.569	-2.118	-0.862*	0.491	-1.756
Hedges	-0.757**	0.354	-2.139	-0.641*	0.335	-1.914
Crop rotation	-0.946**	0.467	-2.028	-0.887**	0.447	-1.984
Leafy fertilizer	-2.162***	0.723	-2.991	-2.102***	0.602	-3.494
Lime	0.820**	0.375	2.184	0.874**	0.350	2.498
Trap crops	1.427*	0.741	1.925	0.838	0.641	1.308
Fertilizer crops	1.333*	0.772	1.728	2.022***	0.628	3.218
Manure	-0.141	0.508	-0.277			
Organic pesticides	0.532	0.595	0.894			
Covered seedbeds	-0.662	0.490	-1.350			
Scouting	0.626	0.382	1.638			
Adjusted R Square	0.478			0.473		
F	7.224***			11.582***		

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

The results of the model explaining the share of hazardous pesticides to the total amounts used in cabbage production are shown in Table 5.11. Hazardous pesticides are often those with effect on a broad spectrum of pests, while the non-hazardous pesticides are directed only to specific target pests. In general, hazardous pesticides are cheaper than non-hazardous products.

Three of the considered practices lead to a decrease in the use of hazardous pesticides: leafy fertilizer, crop rotation and covered seedbeds. The use of trap crops leads to a higher share of hazardous pesticides. A possible explanation is that farmers might use broad-spectrum pesticides on these trap crops, which are usually not for human consumption and which attract a broad spectrum of insects.

It is not clear why the use of manure has a positive coefficient in this model. Some practices that reduce pesticide use, like yellow traps and hedges to retain pests, have a negative sign in this model; however, no significant effect on the share of hazardous pesticides can be established.

There is no effect on the types of pesticides applied when lime is used, which supports the above explanation that the primary objective in the application of lime is to improve soil fertility rather than to reduce pests. This is associated with the general level of input use, but is not related to pest control measures. Similarly, the use of fertilizer has no effect on the choice of different pesticides, whereas the diversity of the cropping system not only reduces the amount of pesticide used, but also the share of hazardous products. On the other hand, the effect of pest scouting (which is expected to reduce the share of hazardous pesticides because need-based application becomes possible) was not significant. Also, advice from pesticide retailers, which in theory could lead farmers to purchase the more expensive and less hazardous pesticides, could not be confirmed by the model results.

The comparison between the full and reduced models show that the estimation results are robust.

Table 5.11: Results of linear regression model on the share of hazardous pesticides used in cabbage production.

	Full model			**Reduced model**		
	Coef.	S.E.	T-value	Coef.	S.E.	T-value
(Constant)	0.761***	0.103	7.364	0.754***	0.093	8.106
Fertilizer	0.024	0.019	1.242	0.028	0.019	1.527
Number of crops	-0.081***	0.023	-3.493	-0.078***	0.022	-3.590
Pesticide shop	0.067	0.066	1.009			
Leafy fertilizer	-0.300**	0.138	-2.182	-0.283**	0.118	-2.395
Crop rotation	-0.196**	0.089	-2.205	-0.170**	0.080	-2.136
Covered seedbeds	-0.187**	0.093	-2.006	-0.150*	0.089	-1.680
Manure	0.162*	0.097	1.673	0.159*	0.088	1.797
Trap crops	0.308**	0.130	2.371	0.311**	0.121	2.578
Organic pesticides	0.093	0.113	0.820			
Lime	0.035	0.072	0.489			
Hedges	-0.104	0.067	-1.542			
Yellow traps	-0.127	0.107	-1.193	-0.120	0.095	-1.269
Fertilizer crops	0.024	0.144	0.169			
Scouting	0.079	0.072	1.091			
Adjusted R Square	0.182			0.183		
F	2.623 ***			3.967***		

* significant at 0.1 level, ** significant at 0.05 level, *** significant at 0.01 level

Source: own calculations

5.5 Conclusions

This study confirms findings in the literature that farmers are aware of the health risks of pesticides and search for alternatives to reduce them. The findings generally correspond with those of an earlier paper that found a positive willingness to pay to avoid health risks (GARMING and WAIBEL 2007). It is striking that farmers who have experience with pesticide poisoning are more motivated to test IPM practices as alternative pest control measures. However, such testing activities do not necessarily lead to adoption, and thus testing is just an effective means for identifying feasible and non-feasible practices.

Another important conclusion is that that the role of health perceptions is likely to be underestimated in single-stage adoption models, which focus on actual use of IPM practices (MAUMBE and SWINTON 2000; LABARTA and SWINTON 2005). This was demonstrated clearly by the comparison of factors influencing the adoption decision in the two stages of the adoption process.

In general, the overall amount and application of different pesticides in vegetable production in conjunction with the awareness of health issues, is difficult to establish. However, in this study, insecticide use and the share of hazardous pesticides could be modelled for cabbage production. Farmers' expectations of productivity, as represented by the level of fertilizer used in the crop, are an important determinant of insecticide use. Also, for several IPM practices, a reduction in insecticide use and the toxicity of pesticides used could be shown. Hence, in the case of cabbage production, the adoption of IPM practices has potential benefits for the health of the farmer through the reduction of pesticide use levels and by stimulating a shift to less hazardous compounds.

The paper also shows that in addition to profit, non-monetary indicators such as health aspects are important for farmers and motivate them to seriously consider ways to reduce the use of hazardous pesticides.

While previous studies focussed on determining the health costs of pesticides (CRISSMAN et al. 1998; PINGALI et al. 1994; AJAYI 2000) this study has investigated how farmers make decisions on whether to test and employ IPM practices and how it can affect pesticide usage. The study highlights the importance of farmers' experiences of poisoning and their perceptions of health risks of pesticides. Both factors were found to influence farmers' choices in pest control and can also lead to changes in their behaviour. Such findings have implications for the design of health policies in agriculture and for the implementation of IPM programs. For example, it will be important in the future that health aspects are given more leverage in the design of agricultural extension programs. Also more information than simply warning signs on pesticide bottles could be provided. For example, health effects of different pesticide compounds, the costs associated with poisoning and the health benefits of particular IPM practices could be included in pest management information. Yet, simply providing more information may not be sufficient, especially as its character is rather technical. The translation of technical knowledge into practice is not necessarily straightforward among farmers, as experiences with large-scale training programmes to promote the safe use of pesticide show. Although they had started to adopt a number of safe use practices, farmers did not continue to apply these safety rules over time (ATKIN and LEISINGER 2000). The results of the study presented here can be interpreted as an indication that farmers' experiences and perceptions of health risks should be given more focus in programmes aiming to reduce pesticide poisoning.

6 Summary and Synthesis

The overall objective of this dissertation is to analyse the impact of health costs of pesticides on farmers' choices concerning pesticide use and adoption of alternative pest management technology in the case of Nicaraguan vegetable farmers.

6.1 Summary

The review of literature presented in Chapter one showed that pesticide poisoning continues to be a major health problem for farmers in developing countries. The incidence rates of pesticide poisoning among farmers seem to be similar throughout the developing world. However, data on pesticide health effects are often scarce and a large proportion of poisoning incidents remain underreported in official health statistics. Farmers' lack of access to health facilities, inadequate reporting procedures, lack of knowledge on chronic health effects and difficulties in attributing health problems to specific pesticides due to the large number of pesticides used by farmers, are reasons why pesticide poisoning is often poorly documented. Different actors, namely international organizations, national governments, private and non-governmental organizations have pursued different approaches to reduce pesticide poisoning among farmers with only limited effects so far. In order to assess different approaches and to be able to design more effective policies for reducing pesticide poisoning among farmers, an economic evaluation of pesticide health risks is needed. The research gaps, as identified in Chapter one, include the analysis of farmers' perceptions of health risks of pesticides and their decisions on pesticide use, the comprehensive and quantitative evaluation of pesticide health costs and the implications for their choices on the adoption of non-chemical pest control measures.

Based on a review of methods for the evaluation of health costs applied in previous studies, the approach of analysis used in this research was derived in Chapter two. Pesticide health costs were firstly measured as cost of illness, such that the farmers' private expenses for treatment of poisoning and their costs in terms of lost labour are considered. In addition to that, a willingness to pay approach was applied, allowing to include the costs of chronic illnesses and to account for non-market values related to human health. By analysing the effects of farmers' perceptions about pesticide health costs on the use of alternative, non-chemical pest control practices, the link between farmers' perceptions and their observed choices with respect to pesticide use can be established.

The data collection comprised two household surveys. First, in a season-long production monitoring survey detailed data on crop production, pesticide use, labour for spraying, poisoning symptoms and health expenditure was collected. The data from this survey allow analysing the relationship between farmers' reporting of pesticide poisoning and actual exposure to pesticides. The second survey was designed as a recall survey on the adoption of alternative pest control practices and the valuation of pesticide health costs using a willingness-to-pay approach. Specific questions on previous experiences with pesticide poisoning were included in this survey in order to link these with choices in pest control.

Chapter three answered three research questions, namely farmers' awareness of pesticide health risks, their actual exposure to pesticides in vegetable production and perceptions about health effects as a result from pesticide exposure. The results showed that pesticide exposure of Nicaraguan vegetable farmers is very high. On average, a farmer applied 7.7 kg of formulated pesticides in about 12 applications during the 2003/04 cropping season, 44% of which are classified as hazardous to human health by WHO. The price of a pesticide was negatively correlated with its toxicity, i.e. the more toxic products tended to be the cheapest. Farmers were generally aware of the health risks of pesticides, as 5.6% of respondents reported acute poisoning during the survey period and a total of 43% of respondents or their household members had suffered pesticide poisoning at least once in their life. The costs that the farmers incurred, were USD26.5 in case of a medium pesticide poisoning incident, i.e. a maximum of one week illness and USD51.9 for severe cases, i.e. when the victim had to be transferred to hospital and was unable to work for more than one week. Farmers' reporting of health symptoms caused by pesticides during the survey period corresponded with exposure. The relationship between pesticide exposure and the number of poisoning symptoms could be established applying a zero-inflated Poisson regression model. The results of this model show that the frequency of spraying, the toxicity of products as measured by the weighted average price and the practice of mixing different pesticides in one sprayer were major risk factors for pesticide poisoning symptoms.

Chapter four dealt with the fourth research question as outlined in chapter one. It presented the results of the assessment of health costs from pesticides by Nicaraguan vegetable farmers. A willingness to pay approach was used to quantify the market and non-market costs of acute and chronic pesticide poisoning. Farmers were asked to state the maximum price they would pay for a non-toxic version of their favourite pesticide, assuming the same pest control efficiency of the product and the same quantity as purchased in the year before the survey. This study revealed that farmers would be willing to pay a premium of about 23% of current pesticide expenditure to avoid pesticide health risks if that possibility existed. In absolute figures, average willingness to pay was higher than the previously calculated expenses for pesticide poisoning, with a mean of USD25.8 for avoiding chronic illness and USD61.6 for avoiding both, acute and chronic health risks. The validity of farmers' valuation of health risks was tested on consistency with economic theory by comparing willingness to pay for different scenarios with different amounts of benefits offered. Farmers stated significantly higher values if both, chronic and acute health risks could be avoided simultaneously, as compared to a scenario where respondents were only given the option to avoid chronic risks. The stated amounts for the non-toxic pesticides varied according to budget limitations of farmers and their previous experiences with pesticide poisoning as expected, i.e. farmers with access to credit, larger vegetable areas or previous poisoning were willing to pay more. These findings confirm that the stated, hypothetical values are valid estimates of farmers' willingness to pay for avoiding pesticide poisoning.

Chapter five investigated the questions of what farmers do to avoid pesticide poisoning and whether pesticide health costs are a factor in the adoption of alternative pest management practices. Poisson regression methods were used to model the number of alternative pest control practices adopted by a farmer. Adoption was measured in two levels, the number of practices a farmer has tested on his farm and the number of practices adopted into current practice after the testing. As the sample included farmers who participated in an IPM project and non-participants, potential selection bias due to non-random sampling of project participants was corrected for by using a two-stage Poisson model. The results of the adoption models showed that previous experiences with pesticide poisoning had different effects on the two levels of adoption. Farmers who had experienced pesticide poisoning before had tested more IPM practices than others without such experience. However, there was no apparent effect of experiences with pesticide poisoning on the current use of practices. This shows that the adoption of IPM practices depends more on the feasibility and effectiveness for pest control as established during the testing phase.

The effects of adoption of IPM practices on pesticide use for selected crops were analysed applying linear regression models. Two different effects were modelled: a change in quantities of pesticides used and a shift towards less toxic pesticides, measured as the share of hazardous pesticides of total pesticide use. In the example of cabbage, the use of certain IPM practices led to a reduction in insecticide use and also to a shift towards less hazardous products. Other practices had no effect and some even increased insecticide use. These results illustrate that pesticide use in intensive vegetable production and the feasibility of alternative pest control practices depends on many factors and is difficult to predict. However there is a potential for reducing pesticide use and hence for reducing pesticide health risks through the adoption of IPM practices.

6.2 Conclusions and Recommendations

The results of this study allow drawing a number of conclusions, which are important for policy makers, concerned with the health conditions of farmers in developing countries. First, contrary to many other studies and common perceptions farmers are aware of pesticide health risks. Also, they are able to attribute health impairments to pesticide exposure and the perceived pesticide poisoning symptoms correspond to actual exposure to hazardous products. In a study in Vietnam, only a weak correlation between farmers reporting of poisoning symptoms and observed pesticide poisoning measured through blood tests was found, which led the authors to conclude that self-reporting was not a reliable measure for pesticide poisoning (DASGUPTA et al. 2005b). However, the results from this study of Nicaraguan vegetable farmers suggest that farmers' perceptions of pesticide health effects as reported in the survey conducted by the author can be considered valid indicators for pesticide poisoning incidence, since they are clearly related to exposure variables.

The second conclusion is that a majority of farmers would be willing to pay to avoid pesticide health risks if the possibility existed. The amounts of money farmers are willing to pay to avoid pesticide health risks are higher than the expenses they incur in case of pesticide poisoning. This suggests that small farmers in developing countries value their health higher that what can be concluded from their level of expenditures. While previous studies have focused on the acute pesticide poisoning (see for example KISHI et al. 1995; AJAYI 2000; KISHI 2002; WILSON 2002; MANCINI et al. 2005), the results of this study show that farmers are aware and willing to pay for the avoidance of chronic illnesses as a consequence of pesticide exposure. On the other hand the stated preferences of the respondents do not translate into more benign pesticide use practices. This study could not completely answer the question why farmers continue to use highly toxic pesticides although less hazardous products but higher priced products are available in the market. A possible explanation to this puzzle could be that farmers do not have sufficient knowledge about the precise health risks related to specific pesticides. Farmers are aware of pesticide health risks in general but they are perhaps unable to identify effective alternatives to avoid health risks. Thus the hypothetical situation which respondents were confronted with in the valuation of willingness-to-pay bid differed somewhat from their actual decision making situation. In the survey experiment respondents were confronted with a specific pesticide with known effect on the pests and the crop. The specific health risks were explained and also the specific benefits of the hypothetical non-toxic pesticide. This may contradict to the real world situation where there is less information about health risks of specific pesticides. In the real world the trade-off is more complex. For a pesticide there are more parameters to consider than toxicity and price. For example other product traits like the required frequency of application or the spectrum of pests that can be controlled may play a role also. Other authors have also pointed out such difficulty e.g. WARBURTON et al. (1995) in the Philippines or DASGUPTA et al. (2005a) in Bangladesh.

The information about possible health hazards provided on the pesticide labels does not seem to reach the farmers, as also shown in a study with farmers in the Brazilian Amazon (WAICHMAN et al. 2007). Even farmers with higher education stated that they found pesticide labels confusing and thus did not read them. As a consequence they underestimated the health risks of many pesticides.

In addition to the valuation of health effects in a hypothetical pesticide purchase situation, Chapter five provides evidence that farmers' awareness of pesticide health risks has observable effects on actual behaviour and influences the choices of pesticides and non-chemical pest control practices. Previous experience with pesticide poisoning motivated farmers to search for alternatives to pesticides and to test IPM practices. The fact that there was no effect of previous experience with pesticide poisoning on the final adoption of these practices, once more suggests that given the information at hand, farmers may have difficulties to identify pest control measures that are both, effective and safe.

The study suggests some conclusions for future rural health policies in developing countries. Primarily there is a need for more and better information about health effects of pesticides. This information has to go beyond the promotion of a general awareness about pesticide health risks, and indicate the risks of specific active ingredients and pesticides. For example, health effects of different pesticide compounds, the costs associated with poisoning and the health benefits of particular IPM practices could be included in pest management information. This will allow farmers to make their informed choices and to identify safer alternatives to the currently used hazardous products. Based on the results of the studies presented here, instead of relying on transferring technical information, farmers' experiences and perceptions about pesticide poisoning should be given more emphasis in agricultural extension programmes, in order to achieve an impact on their actual behaviour.

This study identifies some opportunities for further research. For example, in order to design more effective programs for reducing pesticide use and introducing non-chemical pest management practices, the question has to be answered, why the effects of adoption of these practices on the reduction of pesticide use in vegetable production were low. This is especially puzzling because farmers showed their interest in alternative pest management practices and were motivated to test them. Further analysis will have to clarify whether there is a technology gap, i.e. the available practices are not appropriate for crops, such as vegetables, where high levels of pesticides are commonly applied, or a knowledge gap i.e. farmers need more training on the effective use of the technology.

For the evaluation of rural health policies or the welfare effects of bans of widely used and highly hazardous pesticides, the valuation of pesticide health costs needs to be estimated on a national level. This also requires to include farmers who do not mainly produce for the market but who are subsistence-oriented producer of food. It is likely that their willingness to pay for avoiding health costs is different from farmers who are better connected to markets and whose farming systems are commercialised.

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Annex A: Survey instruments for monitoring survey

A.1 Input Monitoring Record Sheets

Departamento: ______________________ Comunidad: ______________________
Nombre del Productor:______________________ Nombre de la Finca: ________________
Nombre de la parcela: ______________________
Cultivo: _______________________ Variedad: ______________________
Fecha de siembra del semillero:______________ Tamaño del semillero: ______________
Fecha del transplante: ______________________ Cuántas manzanas: ________________

Registro de aplicaciones en el cultivo

Fecha de la aplicación		
Cuándo hizo recuento		
Para qué plaga o enfermedad		
Nombre del producto		
Cantidad del producto		
Cantidad de agua		
Quién hizo la aplicación Parentesco o mozo		
Cuántas horas trabajó cada quién		
Hubo algún malestar en la salud Quién		

A.2 Format for labour input, yields and prices

Labores e insumos Nombre del productor: ______________________ Fecha de tomar datos: ________ Cultivo: ______________

Labores realizadas	**Fecha**	**Mano de obra**			**Insumos y servicios externos**			
		Días-persona familiar	Días-persona contratada		Tipo	Cantidad	Precio U.	Costo Total
			Días	Costo/día				
Total en la parcela								
Total por mz:								

Beneficios de la parcela

Tipos de productos (principal y otros)	**Cantidad cosechada** (rendimiento/mz)	**Pérdida** post-cosecha	**Cantidad disponible**	**Usos y beneficios**	**Precio unit.(C$)**	**Producción total**

A.3 Health questionnaire, first visit

Cuestionario por aspectos de la salud

Nombre del Productor:_____________________________________

Fecha de encuesta____

1. ¿En su opinión, que pasa con una persona que se intoxica de plaguicidas?

____

2. ¿Usted o un miembro de la familia se ha intoxicado con plaguicidas una vez en su vida?

_________________, ¿Cuando?__________________

3. ¿Cómo fue eso? ____

En caso que sí pase por pregunta 5.

4. ¿Alguien que trabaja en la finca aplicando plaguicidas sintió uno de los siguientes malestares después de aplicar?

Problemas	Si	¿Quién?	fecha	cultivo	con qué producto
Dolor de cabeza					
Vista turbia					
Salivación					
Mareos					
Ganas de vomitar					
Vómitos					
Dificultad respiratoria					
Calambres musculares					
Asma					
Cansancio					
Picazón en la piel					
Quemadura en la piel					
Piel irritada					
Infecciones en la piel					
Daños en las uñas					
Salpicadura en los ojos					
Falta de concentración					
Debilidad muscular					
Tristeza					
Desanimo					
Otros ¿ cuáles?					

5.1 Días laborales perdidos por enfermarse por plaguicidas

¿**Quién** se enfermó y tuvo que dejar de trabajar?	
¿ **Días** laborales perdido?	
¿**Fecha** de la enfermedad?	
¿Con qué **producto** fue?	
Quién lo estuvo cuidando en la casa	
Días laborales perdido por cuidar al enfermo	
Costo mano de obra perdido	

5.2. ¿Qué se hizo para curarlo /ayudarlo?

Nada	
Receta casera:	
Adonde fue para buscar ayuda	
líder de salud, curandero o partera	
un puesto o centro de salud	
hospital	
médico privado	
Qué le dieron	
Cuantos días en el hospital	

6. ¿Cuánto gasto por la comida?_________________
7. ¿Cuánto gasto por la medicina? _______________
8. ¿Cuánto gasto por el transporte?_______________
9. ¿Usted gastó en total ______________________por la intoxicación

10.1 Salud familiar en general

¿Algún miembro de la familia tuvo se enfermó en este año? **¿Quién**?		
¿Cuál fue el **problema**?		
Días laborales perdidos		
Cuando fue		
Quién lo estuvo cuidando en la casa		
Días laborales perdidos para cuidar al enfermo		

Costo mano de obra perdido		

10.2. ¿Qué se hizo para curarlo /ayudarlo?

Nada	
Receta casera:	
Adonde fue para buscar ayuda	
líder de salud, curandero o partera	
un puesto o centro de salud	
hospital	
médico privado	
Qué le dieron	
Cuantos días en el hospital	

11. ¿Cuánto gasto por la comida? _________________

12. ¿Cuánto gasto por la medicina? _______________

13. ¿Cuánto gasto por el transporte? _______________

14. ¿Usted gastó en total _______________________ por enfermedad?

A.4 Health questionnaire, monthly visit

Cuestionario por aspectos de la salud en el mes pasado

1. ¿Alguien que trabaja en la finca aplicando plaguicidas sintió uno de los siguientes malestares después de aplicar?

Problemas	Si	¿Quién?	fecha	cultivo	con qué producto
Dolor de cabeza					
Vista turbia					
Salivación					
Mareos					
Ganas de vomitar					
Vómitos					
Dificultad respiratoria					
Calambres musculares					
Asma					
Cansancio					
Picazón en la piel					
Quemadura en la piel					
Piel irritada					
Infecciones en la piel					
Daños en las uñas					
Salpicadura en los ojos					
Falta de concentración					
Debilidad muscular					
Tristeza					
Desanimo					
Otros ¿ cuáles?					

2.1 Días laborales perdidos por enfermarse por plaguicidas

¿**Quién** se enfermó y tuvo que dejar de trabajar?	
¿ **Días** laborales perdido?	
¿**Fecha** de la enfermedad?	
¿Con qué **producto** fue?	
Quién lo estuvo cuidando en la casa	
Días laborales perdido por cuidar al enfermo	
Costo mano de obra perdido	

2.2. ¿Qué se hizo para curarlo /ayudarlo?

Nada	
Receta casera:	
Adonde fue para buscar ayuda	
líder de salud, curandero o partera	
un puesto o centro de salud	
hospital	
médico privado	
Qué le dieron	
Cuantos días en el hospital	

3. ¿Cuánto gasto por la comida?_________________

4. ¿Cuánto gasto por la medicina? _______________

5. ¿Cuánto gasto por el transporte?_______________

6. ¿Usted gastó en total ______________________por la intoxicación

7.1 Salud familiar en general

¿Algún miembro de la familia tuvo se enfermó en este año? **¿Quién**?		
¿Cuál fue el **problema**?		
Días laborales perdidos		
Cuando fue		
Quién lo estuvo cuidando en la casa		
Días laborales perdidos para cuidar al enfermo		
Costo mano de obra perdido		

7.2. ¿Qué se hizo para curarlo /ayudarlo?

Nada	
Receta casera:	
Adonde fue para buscar ayuda	
líder de salud, curandero o partera	
un puesto o centro de salud	
hospital	
médico privado	
Qué le dieron	
Cuantos días en el hospital	

8. ¿Cuánto gasto por la comida? _________________

9. ¿Cuánto gasto por la medicina? _______________

10. ¿Cuánto gasto por el transporte? _______________

11. ¿Usted gastó en total __________ ____________ por enfermedad?

A.5 Questionnaire on general household and farm characteristics

1. Nombre del productor(a)__________________ edad ____ sexo _______
2. Otro oficio____
3. Ingreso de otros trabajos anual_________________________________
4. Nivel escolar____
5. ¿Quienes viven en la finca?

Parentesco	Sexo	Edad	Nivel escolar	Otros oficios	Ingreso de otros oficios anual

6. ¿Qué ha cultivado en este año?

7. ¿De quien era la tierra?

Tierra	En verano Cultivo ---- área	Primera Cultivo ---- área	Postrera Cultivo ---- área
propia			
Alquilada			
Prestada			

7.1 Si alquila tierra: ¿cuanto pagó por cosecha? ________________________________

7.2 Si es prestada o otro, ¿cual fue el acuerdo? ________________________________

8. ¿Con que recursos trabaja usted?

☐ Recursos propios ____

☐ Con crédito ¿de que parte? ________________ tasa de interes______________

☐ A medias ¿con quién? _________________ (grado de parentesco)

¿Cual es el acuerdo? ____

9. ¿Cuanto tiempo tiene de trabajar con hortalizas? _____________________________
10. ¿Con que hortalizas ha trabajado? _ ______________________________________
11. ¿Cual hortaliza le gusta mas? ____
12. ¿Porqué? ____

13. ¿Ha dejado de cultivar alguna hortaliza? Si __ No __

En caso de si:

14. ¿Cual? 15. Y ¿porqué?

- ☐ por plagas y enfermedades cultivo ____________________
- ☐ por mercado cultivo _____________________
- ☐ por que requiere mucha inversión cultivo _____________________
- ☐ por problema del suelo cultivo _____________________
- ☐ Otros____

16. ¿Ha trabajado con algún tipo de asistencia técnica? Si ____ No____

En caso de si:

17. ¿Con quién (o quienes) _______________________________________

18. ¿Desde cuando? __ ____
19. En este año que técnico(a) lo esta visitando ____________________________
20. ¿De que organización? ____
21. ¿Usted o miembro de la familia ha trabajado con algún proyecto que no sea de agricultura? Si_______ no______

En caso de si:

22. ¿quién? (parentesco) ____

23. ¿Cuándo? ____
23. ¿Que proyecto, qué institución? _______________________________________
24. ¿Cuando tiene problema con el cultivo, a quién busca para resolverlo?

____

25. ¿Que producto ya no ocupa porque le hizo algún daño o le dio malestares?

Producto: _______________________ Malestar: ______________________

26. ¿Hay productos que le dan algún malestar pero sigue aplicando?

Producto: _______________________ Malestar: ______________________

27. ¿Normalmente, quién hace las aplicaciones en el cultivo?

Si no es el productor:

28. ¿Porqué no lo hace personal?

____

Gracias

Encuestador/a____

Annex B: Survey instrument willingness to pay survey

Evaluación económica del impacto de MIP en la salud de agricultores

Cuestionario de segunda fase de campo

Fecha: ___________________ Comunidad: _________________

Departamento: ___________________ Municipio: _________________

Encuestador: ___________________

1. Nombre del productor(a):

____

i. Edad: ____________ Sexo: ________________

2. Otro oficio

____

3. Ingreso de otros trabajos anual: ____

4. Nivel escolar: ____

5. Estado civil: ____

6. ¿Quienes viven en la finca?

Parentesco	Sexo	Edad	Nivel escolar	Otros oficios	Ingreso de otros oficios anual

7. ¿Hay familiares que viven fuera de la comunidad y quienes apoyan a su familia económicamente? ¿Quienes? ____

8. ¿Cuánto contribuyen por mes o año? _______________________________________

9. Tamaño de la finca: ____

Terreno propio: __________________________________

Terreno alquilado mz/año: __________________________

Precio por alquilar: ________________________________

10. ¿Usted trabaja al día? Si ____ No: _____

11. ¿Cuantos días trabajó en el año pasado? _______________________________

12. ¿Cuánto vale un día de trabajo? ____

13. Producción y uso de insumos en el año pasado (2003):

Para sacar ingreso, preguntar si la ganancia es de él o si todavía tiene que pagar al mediero.

Cultivo	Área	Cuanto fue la inversión que hizo	A como vendió	Insumos utilizados Plaguicidas y fertilizante	Cantidad aplicada	Cuantas aplicaciones le dio al cultivo

11. ¿Cuáles son los problemas en la salud que afectan a su familia, puede poner en orden, cuáles son importantes y cuales menos importantes?

A) ____

B) ____

C) ____

D) ____

E) ____

12. ¿Puede estimar, cuanto gastó por salud de toda la familia en el año pasado?

Parentesco	Enfermedad	Costo consulta	Medicina	Transporte	Dias laborales	Costo total

13. ¿Usted, alguien de la familia o alguien que trabaja en la finca se ha intoxicado alguna vez en la vida? Si: ________ No: ___________

¿Quién?____________________ ¿Cuándo? ____________________________

¿Cómo fue eso? ____

¿Cuántos días no pudo trabajar?____

¿Tuvo que ir al hospital? Si: _______ No: __________________

¿Cuánto gastó en hospital, medicina y transporte? _____________________________

14. ¿Normalmente, quién hace las aplicaciones en el cultivo? ______________________

Si no es el productor:

¿Porqué no lo hace personal? ____

15. ¿Cuándo contrata a alguien para fumigar, como es el acuerdo normalmente?

- ☐ Día de trabajo normal

- ☐ Por tarea, precio: ____
- ☐ Otros: ____

16. ¿Quiénes son los que trabajan en la parcela? Grado de parentesco
    ____

17. ¿Usted ha sentido algún de los siguientes malestares cuando aplicaba plaguicidas? ¿O conoce a alguién?

Problemas	¿Quién?	cuando	cultivo	con qué producto
Dolor de cabeza				
Mareos				
Asco/ Vómitos				
Afecta los ojos o la vista				
Salivación				
Dificultad respiratoria				
Piel afectada				
Calambres musculares				
Cansancio				
Otros ¿ cuáles?				

18. ¿Hay algún producto que ya no ocupa porque le hizo algún daño o le dio malestares

    Producto:________________________ Malestar: ___________________________

19. ¿Hay productos que le dan algún malestar pero sigue aplicando?
    Producto:________________________ Malestar: ___________________________

Explique clasificación de los plaguicidas según riesgo en la salud en pagina adjunta:

20. *Identificar en el cuadro 2 el producto de riesgo 3 que el productor ha aplicado en mayor cantidad.*
    Manifeste:
    El producto que utiliza mas en hortalizas con alto riesgo de salud es

    ____

21. ¿Cuál es el precio que usted paga actualmente por ese producto?

    ____

Si no hay producto de riesgo 3, sigue con pregunta 26

22. Si hubiera un mismo producto, con la diferencia que este no tenga efectos en su salud a largo plazo, es decir que no produce cáncer o esterilidad, pero puede causar una intoxicación inmediata si no se cuida cuando esta manipulando el producto.

23. ¿Usted pagaría mas por este producto?

Si No

24. ¿Cuánto mas pagaría, lo compraría si valdría el doble del precio actual?

Anote valor doble del precio actual:

C$ _____________________? Si: _____ No: _____

En caso que si: Aumente por 50C$ y pregunte de nuevo, si pagaría
C$ _____________________? Si: _____ No: _____
En caso que no: Reduce por 50C$ y pregunte de nuevo, si pagaría
C$ _____________________? Si: _____ No: _____

25. ¿Cuanto es el precio maximal que usted estaría dispuesto a pagar para este producto?: C$ _________________

26. Y si el producto no tendría ningún efecto peligroso en la salud humana pero el efecto en la plaga siempre quede igual. Usted pagaría mas que _____________ (precio confirmado en pregunta 25)?

Si: _____ No: _____

27. *En caso que si: Aumente por 50C$ y pregunte de nuevo, si pagaría*
C$ _____________________? Si: _____ No: _____
En caso que no: Reduce por 50C$ y pregunte de nuevo, si pagaría
C$ _____________________? Si: _____ No: _____

28. ¿Cuanto es el precio maximal que usted estaría dispuesto a pagar para este producto?: C$ _________________

En caso que no acepta un precio mas alto:

29. ¿Porque no? ____
____

30. ¿Con qué recursos trabaja usted?

Cultivo	Recursos propios	Crédito ¿De quien?	A medias ¿Con quien?	Acuerdo a medias

____

31. ¿Cuanto tiempo tiene de trabajar con hortalizas? ________________________

32. ¿Con que hortalizas ha trabajado? _ __________ ______________________ _

33. ¿Cuando tiene problema con el cultivo, quién es que más le puede ayudar y que busca para resolverlo? ____

34. Ha trabajado con algún tipo de asistencia técnica?
Si: ____ No:____

En caso de si:

35. ¿Con quién (o quienes)?____

¿Cuándo? ________ ____

36. ¿Usted hace monitoreo o recuento de plagas o enfermedades en sus cultivos?
Si: ____ No:____

En caso que si:

37. ¿Cómo lo hace? ¿Y qué hace con los resultados del recuento?
____

38. Si lo hace: ¿dónde lo aprendió? ____

39. ¿Cuáles son las practicas no-químicas/MIP que conoce?

Leer una por una de las siguientes prácticas.

Practica	Conoce	Ha probado	Actualmente aplica
Abono orgánico			
Abono verde			
Biofertilizante			
Preparaciones caseras de repellentes/ insecticidas			
Semillero tapado			
Preparación del suelo con cal / ceniza			
Rotación de cultivo			
Recolección de frutas dañadas			
Barreras vivas			
Cultivos trampas			
Trampas amarrillas			
Otras no mencionadas			

40. Aquí tenemos un pequeño agradecimiento para usted por su paciencia y por ayudarnos. ¿Qué prefiere?

- ❑ una pachita de aceite Nim para probarlo,
- ❑ una recompensa de 20 Córdobas.
- ❑ una jeringa de 50 cc,
- ❑ una revista Enlace sobre hortalizas.

Muchas GRACIAS