Economic and Environmental Consequences of Agrochemical Use for Intensive Rice Cultivation in the Mekong Delta, Vietnam

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List of Abbreviations

AW	autumn-winter
CLRRI	Cuu Long Rice Research Institute
CMEA	Council of Mutual Economic Assistance
COI	cost of illness
CPI	Consumer Price Index
CPRGS	Comprehensive Poverty Reduction and Growth Strategy
CVM	Contingent Valuation Method
DANIDA	Danish Development Agency
EEPSEA	Economy and Environment Programme for Southeast Asia
EEU	Environmental Economics Unit
EU	European Union
FFF	Flexible Functional Form
FFS	Farmer Field School
GDP	Gross Domestic Product
GSO	General Statistical Office
HCMC	Ho Chi Minh City
HYV	high-yielding varieties
IFPRI	International Food Policy Research Institute
IPM	Integrated Pest Method
IRRI	International Rice Research Institute
MARD	Ministry of Agriculture and Rural Development
MDPA	Mekong Delta Poverty Analysis
MKD	Mekong Delta
OLS	Ordinary Least Square
PPD	Plant Protection Department
RNFE	Rural Non-farm Economy
RRD	Red River Delta
SA	summer-autumn

SHH	Same Household Group
UNDP	United Nations Development Programme
VHLSS	Vietnam Household Living Standards Survey
VLSS	Vietnam Living Standards Survey
VND	Vietnamese Dong
WCED	World Commission on Environment and Development
WHO	World Health Organization
WS	winter-spring

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Abstract

This study examines farm households' responses to recent changes in the economic environment in Vietnam, with a focus on the use of agrochemicals in intensive rice-based production systems and their consequences for farm profitability and farmers' health. This is done on the basis of two household surveys undertaken in the Mekong Delta, Vietnam, during a four-year period between 1997 and 2001. The two surveys had a sub-set of households in common, which provided good insights into the dynamic changes of, particularly, fertilizer and pesticide use. Qualitative information for understanding the nature and relationships between groups of farmers, production practices and the environment were complementary to quantitative estimation of profitability, quantities and price eslasticities of inputs and outputs, determinants of health risks, and farmers' health costs due to pesticide exposure and vice versa. The findings show that increase in cropping intensity has led to a dramatic increase in the use of agrochemicals per hectare per year. Rice farmers responded rationally to market signals in the transition from central planning to a market-oriented economy. The impact of a given change in any of the exogenous variables across variable input demands for labour, fertilizers and pesticides is not symmetric, and labour, fertilizers and pesticides are gross complements in rice production. This is quite consistent with *a priori* theoretical expectations. While agrochemicals contribute significantly to rice yield, the benefits from increased production decline considerably as they have a marked negative impact on farmers' health and water quality. Farmers who directly applied pesticides to their rice fields displayed signs and symptoms of pesticide-related health ailments. The study also found that reduced agrochemical use resulting from a slight increase in agrochemical prices or a low tax rate on agrochemical inputs would have little adverse impact on total production at farm level or on consumers.

1 Introduction

1.1 Background and scope

The significant contribution of agrochemicals (chemical fertilizers and pesticides) to total rice productivity growth and to keeping food costs relatively low has been recognized in most intensive rice-farming systems. In modern agriculture, continuing application of chemical fertilizers to provide plant nutrients and pesticides to reduce pest damage is essential for sustaining the increased rice yields needed to feed future populations. This is obviously important for the 50 per cent of the world's poor who are located in Asia. However, in recent years the intensive use of agrochemicals has been perceived as having negative effects on human health and causing environmental damage in many countries.[1] Pollution resulting from the application of agrochemicals is becoming a major concern not only in developed regions such as the European Union, but also in many developing countries. These contradictory outcomes – a positive contribution to total rice productivity but a negative effect on human health and the environment – create a need for the relationship between agrochemical use, crop production and environmental consequences to be carefully studied if agriculture is to become more sustainable (Wossink et al., 1998: 1). This is the main objective of the cur-rent study, which focuses on rice production in Vietnam.

1.1.1 Rice production in Vietnam

Rice is a staple food in Vietnam. Its production has played a significant role in the livelihood of people and the economy for several thousands of years. Accounting for 64 per cent of the sown crop area, it is grown by more than two-thirds of households in Vietnam. The country, which has been one of the largest rice exporters in the world since 1997, ranking second after Thailand, is aiming at total annual production of 33 million tons in order to be self-sufficient as well as provide a surplus of approximately 4 million tons for export. This is a big change from its state of near famine before 1989. The outstanding performance of the rice sector in particular, and Vietnamese agriculture in general, can be traced directly to policy reforms starting around 1980 and accelerating in the late 1980s, known as *đoi moi* (officially translated as 'renovation') (Arkadie et al., 1995).

As a result of the new institutional environment and market reforms, rice production has increased by more than double the growth of the population since 1989. Yet, there are growing concerns over the future because the productivity and sustainability of rice production systems have been declining in most rice-growing regions (Hossain, 1997). Although rice yields have continued to increase in Vietnam, the country has experienced a gradual decline in rice yield growth over the last 15 years. Meanwhile, use of agrochemicals, particularly fertilizers, has increased dramatically since 1980, from 62 kg of NPK nutrients per hectare in 1978/79 to 269 kg per hectare in 1998/99. This is the second-highest fertilizer consumption among Asian developing countries (FADINAP, 2000).

1.1.2 Economic aspects of agrochemical use

As in other Asian countries with intensive rice farming and high output levels, rice production in Vietnam is characterized by heavy dependence on agrochemicals. The increased use of these inputs followed a campaign to raise production per hectare and adoption of high-yielding varieties (HYVs), which were first introduced into Vietnam in the late 1960s (Xuan, 1995: 21-30). The effectiveness of chemical fertilizers in replenishing nutrient losses and raising crop productivity in intensive rice-farming systems, along with pesticides to reduce damage from pests, is well known. However, efficient input use is crucial for sustainable agriculture. From a microeconomic perspective, agrochemicals should be applied to the level at which the value of the marginal product equals its price, and environmental externalities generated by agrochemicals are taken into account. According to Pingali et al. (1997: 234-41) use of fertilizers can be expected to rise when there is no technology to improve nutrient use efficiency at the farm level. Similarly, a higher level of pesticide application is unavoidable in the absence of improvements in pesticide management. Site-specific nutrient management and integrated pest management (IPM) have been recommended recently in Asian rice-growing countries to reduce the cost of production. Improving input efficiencies at current yield levels is a possible option to reduce unit production cost to farmers. Thus, efficiency gains from input use are expected to be compatible with the need for sustainable resource use. Against this background, understanding how agrochemicals are used in relation to yield attainment given the current technology, and whether agrochemicals are applied in an economically efficient way is essential for the rice sector in the coming years.

1.1.3 Environmental problems due to agrochemical use

Rice production (and in general, food security) issues should not be examined without considering their environmental consequences. After many years of concentration and intensification of rice production relying on HYVs and agrochemicals in order to achieve food self-sufficiency, there is now a growing awareness in Vietnam of possible spillover effects of agrochemicals on the environment and human health (Dung and Dung, 1999). The increased use of fertilizers would have higher environmental consequences in terms of gaseous emissions into the atmosphere and the risk of water pollution. FAO (2001: 2-9) estimates that plants in general absorb only about 50 per cent of the nitrogen fertilizer applied in agricultural fields. The other 50 per cent is discharged into the environment via runoff, leaching, erosion or gaseous emissions. Fertilizer losses to water cause eutrophication in surface water, and groundwater is mainly polluted by nitrates (Ongley, 1996; Carpenter et al., 1998). Acute and chronic problems with eyes, skin, the respiratory tract and kidneys due to prolonged exposure to pesticides have been found among rice farmers in the Philippines (Antle and Pingali, 1994), and in China (Huang et al., 2001). These negative effects on health pose a significant cost to rice farmers and society in general. Although agricultural production is a very old human activity which has strongly influenced the natural environment and is one of the leading contributors to water contamination and ill-health in rural areas, little systematic research has been done into these issues in Vietnam. This study aims to addressing these issues more detail.

Environmental costs associated with inappropriate use of chemical fertilizers and pesticides have not been measured and explicitly included in prevailing pricing systems. Therefore, current economic analysis may overestimate the profitability of rice production and thereby farm households' income, and may not keep up with the public concern over the trade-off between agricultural production and potential health hazards and environmental consequences. This makes it difficult for policymakers to design and analyse the effects of alternative environmental policies on farmers' private costs and costs in relation to the environment. Thus, a thorough analysis of the sustainability of rice production would have to include not only valuations of private and social costs, but also an examination of the impact of changes in policy instruments on production, farmers' income and the environment (Faeth, 1996). In other words, quantification of potential economic and environmental trade-offs is an important input in the debate on this issue.

1.1.4 Methodological issues

Rice farms in Vietnam are mainly small-scale units operated by individual households. This implies that farm households take market prices of outputs and inputs as given, and that neoclassical production theory, especially its dual form (that is, the cost/profit function) is a convenient framework for explaining their economic behaviour. In addition, farmers are assumed to be concerned with private costs and benefits from their production, and are not expected to take into account longer-term impacts of spillover effects from their farms on human health and the environment. Under these circumstances, for the analysis of externalities, it is appropriate to model short-run behaviour of farmers in terms of profit maximization, given the technological, economic, and resource constraints. In the long run, when all production inputs (fixed and variable inputs) are variable, households' decisions may also have important consequences for the generation of externalities (Antle and Capalbo, 1995).

There are some advantages to using a simple static, risk-neutral model for this study. First, households' short-term decisions on the use of agrochemicals and other inputs are directly related to externalities induced by agrochemicals on human health and the environment. The production information and estimates derived from the model are practical for the purpose of simulation of this behaviour. Second, if the market is used for transaction and prices are exogenous, production and consumption decisions of farm households can be analysed separately. Sadoulet and De Janvry (1995: 140-75) argue that when failures of output and input markets are not important, and the price band is small, a separable model can be employed without significantly misrepresenting farm household behaviour. In the Mekong Delta, 75 per cent of rice farmers sell as much as 70 per cent of their rice production to the market (Minot and Goletti, 2000: 23-4, Tables 13 and 15). Farm households can buy rice for consumption when needed, with little variation in market price. Third, though risk aversion is likely in peasant farm households, the theory of the profit-maximizing peasant is still dominant in the analysis of peasant production (Ellis, 1993: 65-81). In addition, the profit maximization hypothesis does not require the existence of profit in a realized sum of money; rather, a situation in which farm households could attain a higher income measured in either physical or monetary terms. In Vietnam, most pesticides and fertilizers are imported and they are costly to farm households. Moreover, farm households' response to the most recent reforms in food production has not been quantified (Khiem and Pingali, 1995: 275-90). For these reasons, this study employs a static, risk-neutral model, which combines economic performance with externalities from the use of agrochemicals, for the analysis of rice production and economic decisions made by farm households.

1.2 Objectives of the study

This study focuses on the economic and environmental dimensions of agrochemical use in intensive rice production in the Mekong Delta of Vietnam. It argues that chemical fertilizers and pesticides have been used in an unsustainable manner and that if the current level of agrochemical use is maintained, the rice production system will be unsustainable. Sustainable use of agrochemicals requires that rice yield and farm income from rice do not decline when the use level decreases, and ideally there should be no harmful impacts on farmers' health and the environment. This study will correlate the socioeconomic aspects of rice production, the environment and farmers' income, which are important factors in sustainable use of agrochemicals. The overall objective of the study is to identify and then quantify, through econometric investigation, qualitative and quantitative analysis, the usage and consequences of chemical fertilizers and pesticides on farm productivity, profitability and the environment, and the impact of policy instruments on production and farmers' income. Specifically, the study has the following four objectives and research questions associated with each objective:

(i) To investigate the economic performance of rice production in the Mekong Delta, Vietnam, with a focus on the contribution of agrochemicals to rice yield and profitability.

   What is the use pattern and how intensively have agrochemicals been used in rice production in the Mekong Delta, as shown by surveys during the 1996/1997 and 2000/2001 dry seasons?

(ii) To examine the current use of chemical fertilizers and pesticides in intensive rice production, and farm households' responsiveness to market prices of rice and agrochemicals.

   Are farmers applying agrochemicals in an economically efficient way to achieve maximization of profits from rice production, given the relative market prices and production technology?

(iii) To identify and attempt to appraise as far as possible the potential spillover effects of agrochemicals on farmers' health and water quality at farm level.

   To what extent does the use of agrochemicals affect farmers' health and water quality?

(iv) To simulate the effects of changes in market prices due to policy instruments that could be employed in the short and medium term by the government to control the use of agrochemicals, by simulating their possible impact on the demand for agrochemicals, rice yield, farm income from rice, and the environment.

   What are the potential effects of price changes under alternative policy scenarios on the use of agrochemicals, productivity, farm household income and farmers' health?

1.3 Significance of the study

The perspective adopted by this study is relevant to the current debates on economic and environmental issues surrounding agrochemical use in Vietnamese agriculture. It is significant for several reasons. First, Vietnam is in transition to a market economy and economic policy reforms, especially market liberalization, have played an important role in expanding rice production. As a result, Vietnam has attained food self-sufficiency after emerging from a state of near-famine and has become the second-largest rice exporter in the world. Second, the performance of the Vietnamese rice sector affects the social and economic wellbeing of rural communities, as more than two-thirds of the rural households are engaged in growing rice and rice accounts for three-quarters of the caloric intake of households. Third, the use of agrochemicals at farm level is examined in terms of both, private profitability of farmers and the possible negative effects on the environment. Thus, the analysis is relevant to policy-making. Finally, the study contributes a new perspective to analysis of Vietnam, in that it takes into account the relationship between technical, economic and environmental aspects and policy in one integrated analysis, something that has not been done in the literature so far.

1.4 Outline of the study

This section provides a short introduction to the subsequent chapters of the study. Chapters 2, 3 and 4 describe the context of rice production and agrochemical use at national and Mekong Delta levels, and the analytical framework that will be used.

Chapter 2 first constructs an analytical framework on the basis of concepts employed in the thesis: sustainable agriculture, agricultural intensification, the linkage between economy and environment, productivity and economic profitability of production, and the concept of externality and its relevance in the context of agricultural production. It then discusses the microeconomic model of agricultural production that will be employed in empirical analysis in Chapter 6, before presenting an introduction to the economic theory underlying environmental policies. Finally, the chapter discusses methods for evaluating the negative effects of agrochemicals on human health and water quality.

Chapter 3 begins by providing an overview of the development of rice production in Vietnam since *đoi moi* (‘renovation’) with a focus on the two main rice-growing areas. Despite the slowing rice-yield growth, total rice production has increased dramatically during the last 15 years in Vietnam. The first section of the chapter examines the level of rice intensification, factors affecting the growth in rice production, and especially the high dependence of rice production on agrochemicals. The second section deals with the biophysical conditions in the Mekong Delta that strongly affect rice production, especially how soil fertility is influenced by the water regime of the Mekong Delta and its effects on land use and rice farming in the region. The final part of the chapter provides data on the basic socioeconomic conditions and standard of living of people in the region.

Chapter 4 discusses the policies, markets and regulations relating to agrochemicals in Vietnam. The reform policies have significantly influenced growth in rice production through persistent changes in the markets for rice and inputs, and especially through economic incentives to farm households. The chapter analyses these policy changes with regard to agrochemicals. The focus is on the development of agrochemical markets, market prices of agrochemicals and their impact on production, as well as other policies on research and technology development such as the national Integrated Pest Management (IPM) programme.

Chapter 5 focuses on farmers' cultivation practices and agrochemical use in rice production. The first section chapter introduces the survey sites in the Mekong Delta. It describes the characteristics of the surveyed farm households and their rice production, farming practices and management of agrochemicals. The second section examines how agrochemicals are used on farms: types and quantities of agrochemicals, the relationship between chemical fertilizers and pesticides, and the effects of agrochemical use on rice yields. The chapter then goes on to perform analyses on the basis of data from the survey. Farm households' use of agrochemicals is examined, comparing IPM farmers and non-IPM farmers among all households, the 'same households group' (SHH group), and across the two surveys. As part of the Integrated Pest Management programme, IPM farmers employ alternative pest-control methods to reduce reliance on pesticides. Significant differences in the quantities and patterns of agrochemical use are observed between IPM farmers and non-IPM farmers.

Chapter 6 analyses and discusses the economic consequences of agrochemical use by farm households in terms of economic profitability and income from rice, and farm households' responses to economic incentives. The chapter first uses the farm budgeting approach to calculate costs and benefits of rice production to farm households, and other indicators, namely returns to pesticides and to fertilizers and the cost of rice production. Then, an empirical estimation is performed of the system of a normalized translog profit function model and variable input share equations, to derive elasticities of variable input demands and rice output. Current use of agrochemicals is compared with the estimations of optimal quantities of fertilizers and pesticides for profit maximization.

Again, substantial differences in economic performance are found between IPM farmers and non-IPM farmers.

Chapter 7 analyses the consequences of agrochemical use in rice production on farmers' health and water quality. Both types and quantities of pesticides used and farmers' health status influence the probability of health risks due to exposure to pesticides. The chapter presents quantitative analyses of the effects of pesticides on the health of farmers directly exposed to them. Health risk and health cost models are used for this purpose. In addition, the chapter analyses agrochemical residuals in surface and ground water in the Mekong Delta.

Chapter 8 investigates the effects of price changes on the use of agrochemicals, productivity, farmers' health and farm income. The empirical results from Chapter 6 and 7 are used to simulate the impact of price changes under alternative scenarios on the demand for fertilizers and pesticides, rice supply, farmers' health and farm households' income from rice. Three policy scenarios are designed and examined. The final section of the chapter pinpoints the policy implications of the analysis.

The final chapter of the thesis summarizes the results of the study, drawing conclusions with regard to the effects of agrochemicals on economic aspects of rice production, farmers' income, human health and the environment in the study sites in the Mekong Delta. The policy relevance of the study findings is also outlined. Finally, the chapter presents the limitations of the study and suggests areas for further research.

Notes

[1] Antle and Capalbo, 1994; Carpenter et al., 1998; Cropper, 1994; Greenland, 1997; Huang et al., 2001; Oskam et al., 1992; Pagiola, 1995; Pingali et al., 1994; Rola and Pingali, 1993.

2

Theoretical Framework and Methodology

2.1 Introduction

This chapter presents concepts and approaches for measuring and analysing the effects of agrochemicals on profitability of rice production and on the environment. It starts by presenting some of the basic concepts and then reviews the relevant literature concerning the use and consequences of agrochemicals in rice production. The theoretical concepts discussed in this chapter will be the main constituents of the analytical framework of the study. The chapter then outlines the methodology applied to analyse the economic and environmental consequences of agrochemical use in rice production in the Mekong Delta, Vietnam. The final part introduces the survey sites and the methods used to collect data for the study.

2.2 Basic concepts

2.2.1 Chemical fertilizers and pesticides

Green Revolution technology has dramatically increased food and fibre production in developing countries, especially in rice-growing countries like Vietnam that have adopted high-yielding varieties. Since cultivating these intensively requires the application of large quantities of chemical fertilizer and pesticides, the increasing amount of land devoted to them has led to rapid growth in the consumption of agrochemicals. In Vietnam, agrochemicals have been used increasingly over the last 15 years and have played an important role in rice production. They offer the most attractive low-cost method of increasing output per unit of land and give rice farmers a high economic return on their labour and investment. Agrochemicals encompass all kinds of chemicals used in the agricultural sector. In this study, however, the term agrochemicals (or agricultural chemicals) refers only to chemical fertilizers and pesticides used in rice production.

Fertilizers are substances, either natural or manufactured, containing at least 5 per cent of one or more of the three primary nutrients (N, P_2O_5, and K_2O) that are essential for the normal growth and development of plants (FAO, 2000: 13-16). Fertilizers manufactured industrially are called chemical fertilizers, or mineral, artificial, synthetic fertilizers. For the sake of simplicity, the term chemical fertilizers, or fertilizers in short, is mainly used in this study to differentiate between natural nutrient substances such as manure, phosphate rock or sulphur, and manufactured fertilizers applied in rice fields, such as urea or ammonium sulphate. In rice production, fertilizers are used to provide sufficient nutrients for attaining economically viable yields, to compensate for nutrients lost by the removal of rice grains or by leaching or gaseous loss, and to maintain good soil conditions for subsequent cropping, especially in soil where many rice crops are cultivated a year. Thus, most of the intensive rice areas in Vietnam are dependent on chemical fertilizers for nutrients.

Pesticides are designed as biocides help to protect the crop yield from damage caused by pests. Agricultural pests are unwanted organisms such as insects, weeds, rats and birds that feed on agricultural produce in places such as fields and storage areas. Rice pests and diseases, especially brown plant hoppers, stem borers, sheath light and blast, are among the major constraints on rice production in the Mekong Delta (Takahito, et al., 1998: 272-5). Faced with high potential production loss, rice farmers apply pesticides in the fields and storage areas. The term pesticides includes a variety of different chemicals, such as insecticides, fungicides, herbicides, nematoticides, and rodenticides, used primarily in agriculture for controlling pest. However, only pesticides applied during the rice production process are considered in this study.

2.2.2 Intensive rice production

Agricultural production is one of the oldest productive activities of human beings. Traditionally, people relied on biophysical conditions, local varieties and resources, and their knowledge and experience to produce food and fibres for their own needs and consumption. Such farming, referred to as traditional or extensive agriculture, is more dependent on internal inputs than modern agriculture. It has limited productivity and generates few external impacts (Conway and Pretty, 1991: 1-16). Some traditional agriculture comprises efficiently managed systems which have hit a yield ceiling and need modernization (Pretty, 1995: 27-57). Pretty (1995) also identifies a 'forgotten' type of traditional agriculture comprising low-external input systems and located in marginal lands such as drylands, swamps, near-deserts, mountain slopes and hillsides. Farming systems in these areas are complex and diverse; agricultural production and rural livelihoods are often dependent on natural resources. However, production in these areas receives less support from scientists and research institutions and suffers from poor infrastructure and inadequate access to markets. Consequently, productivity is low there, with cereal yields typically less than 1 ton per hectare. The floating-rice system in the Mekong Delta, which is described in Chapter 3, is an example of this traditional agriculture, its rice yield averaging 1.5 ton per hectare. This system almost disappeared in the late 1990s.

With the dramatic population increase in developing countries and growing worldwide need for food over the past 50 years, agricultural production has been increased through technological breakthroughs. Modern agriculture is characterized by higher productivity and heavy dependence on external inputs, especially seeds, pesticides, chemical fertilizers, irrigation water, and tractors and other machinery. The process of agricultural modernization in industrialized countries has not only resulted in systems characterized by high external inputs and high outputs, but has also drastically reduced the number of organic farmers. Modern farming systems have most of the following attributes (Pretty, 1995): good access to roads and input and output markets, better irrigation systems and machinery, good soil, modern plant varieties and chemical inputs. Following the Green Revolution in developing countries, high-external input systems are found mostly in irrigated plains and deltas. Farmers tend to practise intensive mono-cropping systems using modern high-yield plant varieties as well as expensive external inputs, including chemical fertilizers, pesticides, machinery and water irrigation. The intensification of rice farming in the Mekong Delta is an example of agricultural modernization in Vietnam.

Many terms, such as *sustainable*, *alternative*, *ecological*, *biological*, *intensive*, and *regenerating* agriculture, are used to describe alternatives to modern farming. Groups and institutions use the term that is most in accord with their different interests and they often present diverse aspects of modern agriculture in terms of resource use and environmental conservation.

This study analyses the economic and environmental consequences of agrochemical use in the context of high-input intensive agriculture. Intensive rice cultivation is the outcome of the movement from traditional systems relying on internal resources towards multi-harvest cultivation systems where plots of land are continuously cultivated with heavy use of external inputs, namely HYV seeds, chemical fertilizers and pesticides. However, not all rice farmers in the Mekong Delta have adopted high-external input technology. Intensive rice cultivation not only increases yields, quality and profitability, it also leads to increasing environmental problems which could threaten future productivity and the health and wellbeing of farmers (Dung and Dung, 1999). Therefore, sustainable development of rice cultivation in the Mekong Delta is uncertain.

2.2.3 Sustainable development

The concept of sustainability has been used to provide a perspective and focus on development. The process through which it became important in national and international agendas, culminating in the World Summit on Sustainable Development in Johannesburg in 2002, is described below. The concept and discussion in this part are based mostly on the relatively new concept of 'sustainability' in the report 'Our Common Future', and partly on Opschoor (2002: 79-99). There are three main aspects to sustainability: ecological, social and economic. Economic sustainability focuses on the maintenance of a set of factors of production large enough to ensure that there will be no future negative changes in income or welfare per capita for several decades; environmental sustainability implies maintenance of the life-supporting environment essential for production and the continued existence of humanity or life in general. Social sustainability refers to the maintenance of societal conditions and institutions that are favourable to meeting human needs and aspirations of future generations as well as current ones. These aspects are elucidated further below.

Evolution of notion of sustainability

For several decades after the Second World War, it was assumed that economic growth would facilitate development in a much broader sense (Opschoor, 1996). However, economic development entails more than economic growth, and development *per se* is a concept far broader than economic development.

> The critique of economic growth as a single pathway to increase welfare focused on social features such as income inequality, asymmetries in the provision of socially desirable and necessary goods and services such as education, health care, and social services, etc. Based on analysis along these lines, the United Nations Development Program (UNDP) speaks of 'human development' when (a) the range of social, economic, and political choice is expanding, and (b) a decent standard of living is assured in terms of education, and health, and in terms of freedom, democracy, and human security, etc. (Opschoor, 2002: 80).

Environmental degradation is one of the exemplifications of the fact that economic growth is not necessarily the same as development. It is manifested in adversely changing levels of environmental quality (especially pollution) resulting from economic activity, depletion of natural resources, and dysfunctional ecosystems. Thus, there are declines (potential and actual ones) in economic welfare, especially the possibilities for development open to future generations. These concerns have given rise to the concept of 'sustainable development': development that meets the needs of the present without imprinting the ability of future generations to meet their own needs and fulfil their aspirations (Opschoor, 2002, WCED, 1987).

The concept of sustainability is rooted in eighteenth century continental Europe, when it was used in relation to forestry practices: the sustainable harvesting of forest resources (Opschoor, 2002). The notion remained dormant for a long time until the late 1970s, when the *World Conservation Strategy* (ICUN-UNEP-WWF, 1980) explicitly claimed that for development to be sustainable it should take into account social and ecological factors as well as economic ones, in both short-term as well as long-term perspectives.

The next stage in the evolution of the concept was reached with the publication of the so-called Brundtland Report of the World Commission on Environment and Development, *Our Common Future* (WCED, 1987), which proposed a more tangible definition:

> Sustainable development is a process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are all compatible and enhance both current and future potential to meet human needs and aspirations (WCED, 1987: 46).

In this definition, needs is another word for welfare objectives, and judgements on what should be welfare levels now and in the future are also in the field of moral questions. This report to the UN General Assembly triggered the UN Conference on Environment and Development, held in Rio de Janeiro in 1992, and eventually the Johannesburg 2002 World Summit on Sustainable Development, which was to review the progress made since Rio and to identify the subsequent steps needed to implement the Conference's resolutions.

Conceptual development of sustainability

Since the Brundtland Report, the notion of sustainability has increasingly and explicitly come to mean: 'a criterion of choice between different patterns and levels of development expressing the capacity to maintain or uphold them over time, based on the potential of inherent or underlying social, economic, as well as ecological processes' (Opschoor, 2002: 81). This will be explored below in some detail in order to capture the potential significance of sustainability for decision-making about development.

The most important innovation in the notion is a concern over the future impacts of events set in motion in the present. It looks at intertemporal aspects of possible patterns of development, and goes much further than the standard economic calculus in that it explicitly attempts to bring in intergenerational considerations. In looking at intertemporal and intergenerational issues, sustainable development only allows for non-negative changes in resource endowment, which is a potentially powerful stance on intergenerational equity. However, the conceptual development around 'sustainability' has a number of features that regrettably diminish its clarity.

In many current discussions on sustainability, what is to be sustained and for how long are often mentioned, though not with precision. For example, in many cases the period over which change is to be non-negative is implicitly 40-60 years at least, 'which is already a daunting challenge to politicians and economic actors' (Opschoor, 2002: 82). The scope of sustainability has also extended beyond the domain of natural resource utilization and management to encapsulate other environmental concerns (for example with regard to pollution and waste) and ecological conditions and processes in general.

Anthropocentric viewpoints on sustainability, such as that of the Brundtland Report, are founded on economic concepts, focusing on moral adjustments about the wellbeing of people and placing mankind at the centre of analysis. The economic concept of sustainability may also be broadly interpreted to mean that the standard of living or economic welfare of future generations will not be less than that of the present generations. Welfare is the result of development of a whole range of different types of resources, including natural ones. Discussions about these resources with regard to their availability distinguish three types of capital: human capital (in terms of qualities and quantities of labour, skill and knowledge), physical (or 'product') capital, and natural capital, which are substitutes for each other to a significant degree. Because of this substitutability', a distinction is made between 'weak' and 'strong' conditions for sustainability in the environmental economic literature. In a situation of weak sustainability, there are no limits to the possibility of substituting man-made capital (physical and human capital) for natural capital and substitution as a way of sustaining the income of future generations. That means future welfare levels may remain constant or rise even while the natural capital stock decreases – as long as this decline is compensated for by increases in physical or human capital. In other words, weak sustainability (or economic sustainability) exists when the overall or aggregate level of stocks is (at least) preserved (Opschoor, 2002; Tisdell, 1999b: 26-7). In contrast, strong sustainability (or ecological sustainability) as argued by Barbier (1999: 64-5), Pearce and Warford (1999) and Tisdell (1993) is possible when substitution between the capital stocks is strictly limited or not allowed, and kept at least constant over time, and natural resources impose an absolute constraint on development paths. In this light, it is important to keep in mind that a strict application of the Brundtland definition of sustainable development 'only calls for concern over sustainability in its weak form' (Opschoor, 2002: 84).

Furthermore, 'sustainability is – often indirectly – linked to a number of non-socioeconomic and non-ecological aspects'. The Rio Principles of sustainable development link environmental concerns with the right to development and establish a human right to 'a healthy and productive life in harmony with nature'. 'This rights-aspect theoretically matches well with the intergenerational obligations that shine through in the Brundtland definition of sustainability' (Opschoor, 2002: 84). Box 2.1 presents some of these principles of sustainable development. Finally, the consequences of globalization have recently been examined in terms of risks and opportunities for sustainability. However, that analysis is beyond the scope of this study.

2.2.4 Sustainability of intensive rice cultivation

Rice cultivation as a dominant economic activity in the Mekong Delta is greatly dependent on natural capital (that is, living organisms, biophysical processes and conditions in which rice is grown). Bad weather, soil erosion or severe pest/disease infection can affect harvests. This also applies to most other agricultural production activities. The substitution of natural capital with man-made capital, such as chemical fertilizers for natural nutrients, or pesticides for natural enemies/predators in the rice fields, provides high yields, but at a cost to the ecosystem and the environment. Thus, man-made capital cannot be easily substituted for natural capital in agriculture (Tisdell, 1999c: 38-40).

There have been many efforts to explain and define sustainable agriculture development, with each definition emphasizing different values, priorities and goals. However, they all emphasize, more or less, the three dimensions mentioned earlier: economic, environmental and social. No well-defined comprehensive concept seems to have been proposed so far and the meaning of sustainability depends on whether its definition is based upon social, economic or environmental sustainability or a combination of all three (for example, sustainable community, sustainable forestry, sustainable agriculture, sustainable land use, and sustainable nutrient management).

In this study, sustainable agriculture refers to rice-based production systems that attempt to provide long-term continuous yields and economic viability while being social acceptable and avoiding environmental degradation. This requires combining the three common perspectives of sustainability to assess the performance of rice production in the Mekong Delta. Yield is an important indicator of any production system, reflecting the rate and constancy of its production and affecting profitability. Farmers would like rice yields and production to increase over time or at least remain constant. In evaluating the production performance of farm households, however, it is worth noting that not all farmers seek high yields, but 'most farmers in small farms place higher value on risk minimization than maximizing production' (Altieri, 1987: 61-3).

From an economic point of view, agricultural techniques are unlikely to be adopted by farmers unless they are economically viable. The profit-

Box 2.1
Rio Principles of Sustainable Development

… The Rio Declaration established human beings as the centre of concern for sustainable development, with - as said - a right to healthy and productive life in harmony with nature (principle 1) and endowed with the right to development (principle 3 explicitly extends this right to both present and future generations). It reiterates that concerns over environment and development are interrelated and demand an integrated approach. States have the right to exploit their own natural resources and the duty to do so without causing damage to the environment of other states (principle 3). Poverty eradication (on which all people and states must cooperate) is an essential precondition for sustainable development (principle 5). The special needs for developing countries (principle 6) and the different shares in causing environmental degradation of developing and developed nations make for "common but differentiated" responsibilities of these categories of states (principle 7). States must end non-suitable patterns of production and consumption and facilitate appropriate demographic policies (principle 8). A "precautionary approach" is to be applied: in cases of risks of serious or irreversible damage to the environment, cost-effective interventions will not be blocked by a lack of full scientific certainty (principle 15). These and other Rio Principles (there are 27 principles altogether) are now finding their way into international legislation and agreements.

Source: Opschoor, 2002: 85

ability of rice production depends not only on physical factors (that is, yield and production) but also on market-related factors (that is, price levels of inputs and outputs, trends in prices and access to markets). Many economic studies of rice production in developing countries show that farmers try to maximize profits and adjust their input use in response to price signals in the market (Ali and Flinn, 1989; Lau and Yotopoulos, 1972). However, economic profits for farmers, while being necessary for rice production to be sustained, do not mean that the economic returns to society are positive. Some private costs are passed on to others due to production externalities (for example, health costs due to exposure to pesticides, and water contamination). Externalities are an important source of environmental degradation, as will be demonstrated in the next section. Since output (for example, yields) and farmers' incomes are heavily dependent on natural resources, they can fall sharply when these resources decline, leading to social consequences. Society may not accept intensive rice cultivation if it does not provide farm families with higher incomes or narrow the income gap among farmers. Hence, social acceptability and avoidance of environmental degradation should be analysed thoroughly when accessing the sustainability of intensive rice cultivation, instead of focusing simply on economic viability and yields.

2.3 Environmental effects of agrochemicals used in rice production

It is obvious that agrochemicals play a major role in agriculture globally. Agrochemicals provide nutrients to crops (through application of fertilizers), and reduce pests and disease (through the use of pesticides) and thus have contributed significantly to increasing crop yields and farm profitability. The transition from traditional rice varieties to high-yielding varieties has also contributed to raising productivity and profitability in most Asian rice-growing countries (for example, see Pingali et al., 1997). Rice farmers who use fertilizers to improve yields, especially of high-yielding varieties, can compensate for nutrients lost as a result of leaching and maintain soil fertility for subsequent cropping seasons (Wichmann, 2004: 2-10). The use of pesticides has helped to maintain/improve yields by eliminating or reducing competition from weeds and attacks by disease and rice pest. From a microeconomic perspective, a farmer's economic returns increase with use of agrochemicals until a level where the marginal benefit of application equals the marginal cost of application. On the national level, higher rice yields obtained through the use of agrochemicals have improved food security for growing populations and enabled marginal and forest land to be set aside, with large potential ecological gains (Wichmann, 2004: 22-6). However, when agrochemicals are applied improperly, they can generate external effects on human health and the environment. While external effects, or externalities, may also be positive, in this case they are negative.

2.3.1 Externalities of agricultural production

According to Baumol and Oates (1988: 17) an externality is present 'whenever some individual (say A's) utility or production relationships include real (that is, non-monetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare'. On the basis of this definition, externalities are not only technological (that is, affecting the production technology of other economic actors), but they can also operate through spillover effects on the utility of individuals. The externality concept is a broad one; on the environmental level it covers all forms of pollution, ranging from industrial and municipal sources in both urban and rural areas to consumption activities (Randall, 1972). However, the following discussion focuses only on the externalities agricultural production.

Externalities are usually engendered from pollution generation functions, which are also called non-point emission functions, associated with the production of an agricultural commodity (Zilberman et al., 1993). These functions represent the physical relationship between inputs used in agricultural production, such as agrochemicals and the level of their emissions to the environment. Let $E_i = h_i(Q,X,Z,R,S,T)$ be the pollution generation function related to a farm's production of a homogenous output (for example, rice). The emission E_i of externality by farm i is thus denoted as a function of its common inputs (for example, labour, seed, water) (X), environmental inputs (such as soil quality, and weather) (R), output (Q), environmental conditions (R, S) and the state of technology (T). However, only some inputs used in the production process generate emissions. For example, nitrogen fertilizers and pesticides often result in detrimental environmental externalities. Further specification of production technology, regular inputs, could be portioned in two groups, namely, X_1 and X_2. Inputs in group X_2 are denoted as 'polluting' inputs (that is, generating externalities). The level of emissions relates to the use of polluting inputs only, that is, $E_i = h_i(X_2) = h_i(Q,X_1,X_2,Z,R,S,T)$. Then, total emissions in the environment will be the sum of emissions at farm level. In practice, however, the individual emissions are difficult to identify and measure. A situation like this is referred to in the literature as non-point source (NPS) pollution. In agriculture, NPS pollution relates mostly to emissions by small sources such as farmers or farm households and includes nutrient contamination and pesticide pollution.

At a low level, these emissions could be assimilated, absorbed or metabolized through chemical, physical or biological processes in the environment. If the total emissions keep increasing and exceed this environmental buffering capacity, then changes and damage to the environment and individuals (both producers and consumers) will occur (Turner and Opschoor, 1994: 7). Such damage is known as social damage.

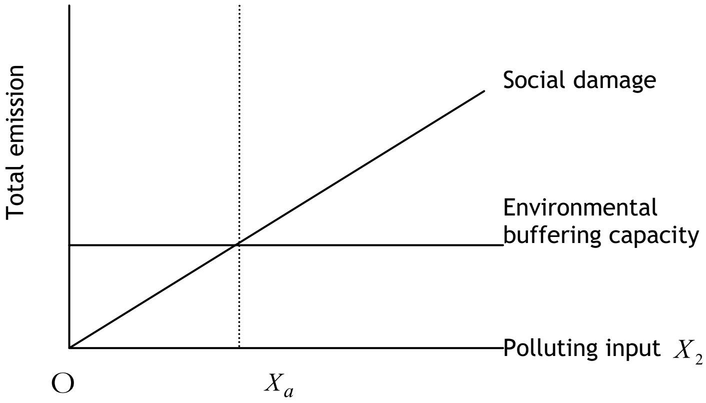
Pollution can cause two types of damage. The first and most observable is the detrimental effect on production processes of other firms, thereby reducing their productivity. The second is deterioration of environmental quality, including ambient air quality, natural habitat, biodiversity, and human health.

Individuals are affected by the total of emissions in the environment when undeletable externalities are considered (Baumol and Oates, 1988: 21). In a situation in which the level of externalities facing individuals and farms is similar, consumption by one individual does not affect consumption by other individuals. In an unregulated situation, none of the damage caused by emissions is paid for by the generating firm (or farm in this case) and therefore implies a cost to society (Turner et al., 1994: 75-7). For example, the use of pesticides on farms causes emissions, which eventually reach and contaminate surface water and groundwater. The resulting polluted water could reduce fish or shrimp production in the ponds of other producers, and increase the cost of purification of water treatment plants. Such costs to the society are not reflected in the private profits of farms. Figure 3.1 shows a simple case in which marginal social damage increases with the level of polluting inputs (for example, agrochemicals) used in rice production. As the level of emission exceeds the environmental buffering capacity,[1] damage is imposed on society.

2.3.2 Effects of pesticides on environment

Pesticides can have adverse effects on human health and the environment, both private and social (Antle and Pingali, 1994; Crissman et al., 1994; Cropper and Freeman, 1991). Direct exposure to pesticides can reduce farm productivity through the effects on farmers' health. Recent studies in the Philippines, Vietnam and China have found that both visible acute health impairment and invisible chronic health diseases in rice farmers are positively and significantly related to the extent of their exposure to pesticides (Huang et al., 2001). Acute (or short-term) effects generally occur immediately after improper application of pesticides, and are well documented (See the sources cited in this section). Eye and skin irritation, headaches, nausea, dizziness, shortage of breath and diarrhoea are examples of acute effects of pesticides. These symptoms are 'visible indicators often used by researchers as evidence of the effect of pesticides use on farmers' health and can be obtained by interviewing farmers (Huang et al., 2001: 35). The estimates of multiple abnormality models (focusing on skin irritation, headaches, eye irritation) show that doses and number of applications of herbicides and fungicides have a significant impact on farmers' health (Dung and Dung, 1999).

Figure 2.1
Social damage from polluting inputs used in production process



Source: Turner et al., 1994

Chronic effects, on the other hand, may develop over a long period of time after initial or long-term exposure to pesticides. Evidence of chronic effects, such as on kidneys, liver and the nervous system, was also found among rice farmers exposed to pesticides for a long period. Thus, the costs of recovering health after pesticide exposure may completely offset the gains from reduction in rice yield losses (Pingali and Roger, 1995; Rola and Pingali, 1993). In these studies, health costs were only minimally estimated for farmers who were directly exposed to pesticides. When applied on fields, a large proportion of pesticides are disseminated into the soil, water and air and only around 1-15 per cent of the application reaches the target pest population (Pimentel and Levitan, 1986; Varca, 2003). Therefore, the health of children and women on the farm, and people living nearby or even far away, is also at risk. However, there has been no research into the aggregate health impacts of pesticide application nor are any data available on farm workers' exposure to pesticides globally (Freeman III and Shipman, 2000). In addition to its negative effects on human health, the application of pesticides has the potential to cause a wide range of damage to the environment. Some types of pesticides degrade slowly in soil and water and may persist and accumulate in aquatic organisms and ecosystems. Moreover, when pesticides are applied in rice fields, it is not only pests that are killed but also predator or beneficial organisms. All this leads to changes in the biodiversity of production systems and aquatic ecosystems, with possibly long-term negative consequences.

2.3.3 Effects of fertilizers on environment

Like pesticides, fertilizers are among the primary agricultural non-point pollutants damaging the environment; their negative effects include eutrophication of surface water, nitrate accumulation in groundwater, and unwanted enrichment of the atmosphere with ammonia and nitrous oxide (N_2O) (Carpenter et al., 1998; FAO, 2000; Dietz and Heijnes, 1995: 15-35). Nitrogen and phosphorus losses from the soil into surface water (for example, streams, lakes and estuaries) at high rates causes excessive growth of algae and aquatic plants, the phenomenon known as eutrophication. The decomposition of these algae and plants produces unpleasant odours and reduces the oxygen supply available in surface water, which has a negative effect on the health of fish and other forms of aquatic life.

Excessive nitrogen can also reduce the quality of drinking water (in terms of taste, odour and nitrate concentration). Nitrogen in nitrate form (NO_3-N) easily leaches below the root zone into ground water or runs off into surface water. Drinking water drawn from these contaminated sources is potentially dangerous to human health, especially that of newborn infants. In the digestive tract of the human body, 'nitrate is converted to nitrite, which reduces the oxygen-carrying capacity of the blood, resulting in brain damage or even death' (US-EPA, 2003: 11). In the Mekong Delta, many people still draw drinking water from rivers and canals without any nitrate filtration. Nitrate in samples of surface water exceeds the limit of 10mg/L nitrate-nitrogen set by the Vietnamese government for water used for human consumption (see Chapter 7). However, no data are available on deaths and health problems related to nationwide or even local nitrate contamination. A third category of environmental problems is volatilization of ammonia (NH_3) from two chemical fertilizers, urea and ammonium sulphate, which lose about 5-10 per cent applied N as a result of mistakes in fertilizer use or crop management (Varca, 2003). The emission of N_2O gas into the air contributes to destruction of the ozone layer and acidification. However, acidification from ammonia emission is more concentrated in areas with large clusters of intensive livestock farms (Dietz and Heijnes, 1995: 18).

2.4 Conceptual and analytical framework

The concept of sustainability of intensive rice cultivation discussed above provides the background for the analysis in this study. Figure 3.2 is a schematic representation of the main relationships between the use of agrochemicals, productivity, profitability, environmental problems, and agricultural and environmental policy in rice production. Only relationships relevant to the objectives and key research questions of this study are displayed. The effects to be considered in the analysis are shown by arrows.

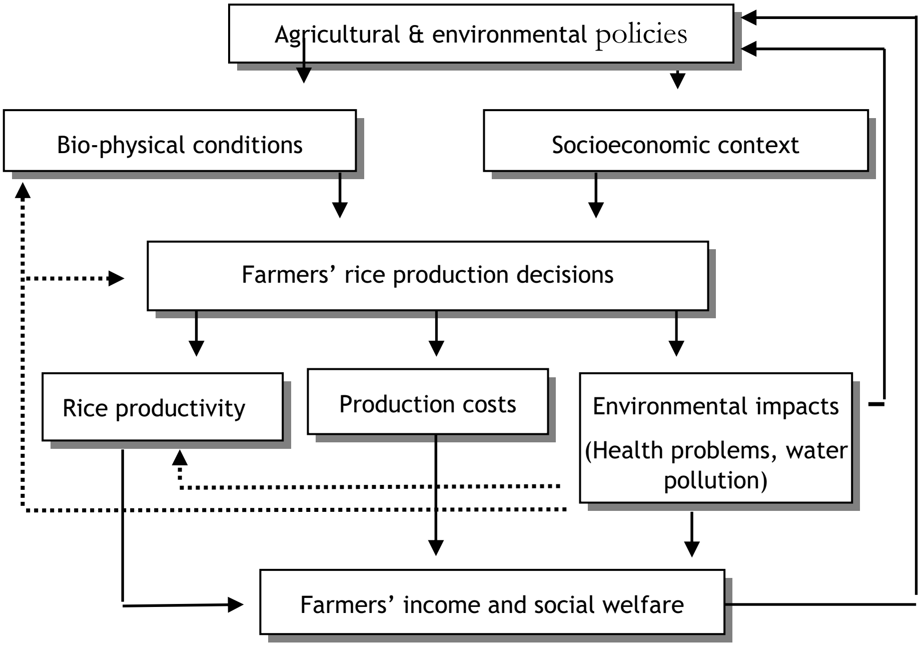
Farm household decisions about the use of agrochemicals in rice production are influenced by factors which can be categorized into two groups: biophysical conditions and socioeconomic context. Biophysical conditions refer to nature-oriented factors and processes that influence rice production and harvesting, such as precipitation, temperature, soil fertility, water and nutrient regimes, nitrogen uptake and rice growth, pest population, population of other organisms (for example, beneficial insects and bacteria) and accumulation and leaching of pollutants. These factors determine the rice yield and externalities arising from the use of agrochemicals. The socioeconomic context refers to human-influenced factors and mechanisms, such as prices of inputs and outputs, market and institutional arrangements, property rights, and production technology. These influence the decisions of farm households about application of agrochemicals and other inputs at different levels to obtain the desirable rice yield.

On the basis of prevailing biophysical conditions and the socioeconomic context, farm households take decisions about the type and level of agrochemical use, timing of fertilizer and pesticide application and the use of labour. Because of higher rice yield and a rise in the number of crops grown per year, farmers need to replenish soil nutrients frequently.

The rice yield is considerably influenced by the quantity of nutrients supplied, usually in the form of chemical fertilizers, the method and timing of fertilizer application, and response of the rice crop to the fertilizers. Under-supply of nutrients may lower the yield while over-supply would result in higher production costs and increased damage to the environment. Pest problems during the growing season and pest management practices also affect the yield. Inappropriate use of pesticides leads to higher quantities being applied, high production costs, water pollution and increased health costs to farmers. Farm labour productivity and overall farm productivity are affected when health problems arise. Communal health is also impaired through contamination of surface and underground drinking water sources by pesticide and fertilizer residuals. On the other hand, insufficient application of agrochemicals can result in lower yields, and, hence, income losses.

Figure 2.2

Linkage between production, farm household income, environment and policy



Notes: Direct analysis: ⟶ ; Feedback: ┈┈▶

The existence of health and environmental problems generated by the use of agrochemicals, along with reduced social welfare, makes reform of current agricultural and environmental policies imperative. Such reform should aim to establish a new interrelation between agrochemical use by farm households, production, profitability and the environment.

2.5 Research methodology

2.5.1 Level of analysis

It is advisable to start analysis of economic and environmental consequences of agrochemicals and other inputs used in agricultural production at the farm level. This is because it is at the level of the individual farm that actual decisions are made about cropping patterns, production and input intensities and so forth. Since the Green Revolution, agriculture has been more dependent on external inputs, namely, pesticides, fertilizers, irrigation water and energy. 'Sustainable agriculture strives for integrated use of a wide range of these input management technologies by regenerating internal resources more effectively, minimizing the external inputs use, and greater using of local knowledge' (Pretty, 1995: 19-24). All these inputs, Pretty suggests, are integrated at the individual farm level in a strategy specific to the biological and socioeconomic conditions there. Each farmer weighs the trade off between short-run private benefits and long-run environmental conservation. However, environmental degradation often imposes spillover or externality costs on other people and economic activities, and if the externality costs are significant, the level of environmental degradation that may be considered acceptable to farmers may be unacceptable at higher hierarchical, namely regional, national, and international, levels.

The main focus of the analysis is therefore on the farm household level. A number of conceptual considerations justify this focus in the Vietnamese context.

(a) In the transition from central planning to a market economy, rice farm households have emerged as autonomous economic units.
(b) Rice production in Vietnam is mainly undertaken by individual rural farm households.
(c) Farmers make the main decisions regarding allocation and use of resources, and marketing of products.

(d) Negative effects of agrochemical usage in rice production originate at the farm level.

(e) Policy instruments to reduce agricultural externalities (for example, water quality) will only be successful if they are implemented at the farm level (Ongley, 1996).

2.5.2 Economic analysis of agrochemical use

Inputs such as labour and land can be analysed within the framework of a neoclassical production function, or a profit/cost function (Lau, 1978). The technical and economic aspects of agrochemicals can also be analysed simultaneously. Other techniques, namely, partial budgeting and programming approaches (linear programming, dynamic programming and multiple-goal programming) are also applicable (Sadoulet and De Janvry, 1995). This subsection presents the approaches that will be used to analyse the economic aspects of agrochemical use.

Budgeting approach

Budgeting is the traditional approach in agricultural production analysis. It enables a farmer to compare the costs and returns of alternative production plans. Several basic budget techniques are available to help farmers in the decision-making process (Sankhayan, 1988). Each is specific in its application, but all use the same principles. The main budgets are the whole-farm budget, enterprise budget, partial budget and cash flow budget. The whole-farm budget sets the direction the farm business will take and helps farmers achieve long-term goals. The enterprise budget is a physical and financial plan for a specific crop enterprise. It estimates costs and returns for a specified period of time using a specified set of production practices. The partial budget helps farmers to evaluate the economic effects of minor adjustments in some portion of the production and to evaluate changes in the use of resources that are not fixed. Finally, the cash flow budget helps to establish the cash needs of the business over a specified planning period, usually a year.

The enterprise budget can be employed to evaluate how changes in any given production system, for instance, changes in fertilizers or pesticides, affect farm income. Its advantage is that it is uncomplicated and easy to understand. The approach is most appropriate for showing the production costs and benefits in a specific type of enterprise (for example, rice farms). The budget comprises basic items such as yield, purchased inputs, family and hired labour, other variable or fixed costs, and revenue, family income, and returns to inputs. The items in the budget can be varied, depending on what aspect of the production results the farmer want to highlight. The weak point of the approach is that it cannot predict changes in output prices due to production improvement at regional or national level. However, such changes, after being predicted by other techniques, can be incorporated in the enterprise budget. In spite of this limitation, its simplicity and practicality make the enterprise budget a popular approach with researchers, planners and farmers for most analysis at the farm level, especially for comparing changes in benefits and costs of agricultural techniques within an enterprise, such as nutrient or pest management practices (Sankhayan, 1988: 4). This approach is, therefore, used to anlayse profitability of rice production in this study (see Chapter 6).

Programming approach

The programming approach, which identifies the optimum mix of farm enterprises and production techniques or management, does not suffer from the shortcomings of the farm budget approach. Its major advantage is that it can take into account several activities or components of the production system at the same time. Linear programming is frequently used to assess the effects of policy changes on total cost/ income of farmers as well as to simulate the economic decision-making process at farm level. Examples of this approach in the literature include Horner (1975), Jacobs and Timmons (1974) and Oskam et al. (1992). However, Oskam et al. (1992) note that because uncertainty and risk elements are ignored in the programming approach, it will either underestimate the use of pesticides or overestimates the profit at farm level. Moreover, Taylor and Howitt (1993) argue that, unlike in the econometric approach, the behaviour assumed in programming models, that is, instantaneous adaptation, is not based on actual behaviour (for example, profit maximization, flexible change in technology); rather, the models assume normative optimizing behaviours being imposed on a detailed structure of constraints. This approach is not employed in this study.

Neoclassical production analysis approach

The use of agrochemicals, whether it is at the farm or higher hierarchical levels, may be analysed within the framework of a production function.

The production function is a purely technical relationship that represents a certain quantity of output obtained for each combination of inputs. The inputs or factors of production used by farmers may be classified as fixed and variable. An input is denoted as fixed when its quantity does not vary with respect to quantity of production for a given period of time. In agriculture, inputs such as land, capital and education are usually regarded as fixed inputs for a short period, since they may not change as output changes. In contrast, variable inputs are ones that farmers can control or whose level of use is altered to affect production. This implies that farmers have sufficient time to adjust the amount of inputs being used. Fertilizers and pesticides are examples of such inputs. Depending on the level of pest infection or crop nutrient deficiency in a given period, farmers may use more or less pesticide or fertilizer than the recommended level. However, whether inputs are treated as variable or fixed depends on the time period under consideration. Economists often define the long run as a time horizon of sufficient length such that all inputs to the production function can be treated as variable, and the short run as a period of time sufficient for only some inputs to be variable. Factors other than variable and fixed inputs, such as physical attributes of the resources used in production (for example, soil and water quality) also affect production functions. The attributes of biological resources (living organisms such as pests), and the state of the technology (for example, traditional variety of rice versus high-yielding variety) may also be included in the function.

In a technical sense, output refers to total biomass taken out of the production system, including that in harvested products (for example, rice grains), and crop residues (for example, rice straw). However, production data on output often mention only the useful (or economic) biomass harvested. In economic analysis, output is usually expressed in physical terms (for example, tons of rice) or monetary terms (value of rice harvested) without necessarily specifying the quantities of inputs used. In production function analysis, crop yield or land-time productivity is often used to measure physical output (that is, the rate of output can be produced over a specific time period, usually the crop season per unit of land on which the crop is grown.

The general form of the production function is commonly postulated as:

(1) $$Q = f(X, Z, R, S, T)$$

where Q is the output per unit of time (or yield); X is a vector of variable inputs measuring labour, fertilizer, water, pesticide, and seeds. Z is a vector of fixed inputs measuring land, structures, machinery and tools, infrastructure, and extension service. R is a vector representing physical attributes of the resources used in production such as soil and water quality; S is a vector capturing attributes of biological resources (for example, living organisms such as pests, beneficial insects); and T represents the state of the technology (for example, integrated pest management versus traditional pest management).

The production function described above is void of economic content, and mostly used by a number of agricultural scientists to establish the yield and input relationships. It was not until the first development of a theory of production by Cobb and Douglas' in 1928 that it became popular in economics, and agricultural economists were at the forefront of innovations in applied production economics (Chambers, 1988). Chambers notes that, since 1928, prices of inputs and outputs have been introduced in the production function to study the economic behaviour of firms/farms in the neoclassical approach. The output supply function and factor demand functions, derived from the production function, are used to investigate the firms' economic behaviour. However, a number of problems arise in analysis of firms' behaviour from a neoclassical perspective. First, some of the explanatory variables may be so highly correlated as to cause the complication of multi-collinearity. Second, many variables such as fertilizers and labour are jointly determined with output by farmers; hence, the right-hand side of the production function includes both the independent and the dependent variables, which is an element of misspecification (Sankhayan, 1988). Third, derivations of factor demand and output supply functions are not generally possible, especially when the functional forms are complicated. Fourth, since the properties of the supply and demand functions must be derived from the properties of the production function, deriving comparative static results is difficult (Antle and Capalbo, 1988).

Profit function approach

The profit function is an alternative approach for analysing production economics. It can help to analyse the supply and factor demand sides of the rice sector economy; to explain net farm crop income of farmers, and to determine how rice farmers will respond to changes in product and factor prices, regular technology and access to certain factors the lack of which constrains production (for example, infrastructure or environmental factors). The profit function approach is also one of the tools to measure production efficiency (engineering approach, average production functions for a subset of farms, and frontier production functions). It captures differences in technical and price efficiencies between pre-specified categories of farms (for example,, small versus large farms) (Chambers, 1988; Lau, 1978; Lau and Yotopoulos, 1972; McFadden, 1978; Yotopoulos and Nugent, 1976: 87-104).

Two components should be looked at when determining the response of firms (or farms). The first is the technological relationship between a number of input combinations and the resulting level of output; this is typically represented by a production function similar to the one presented above. The second is the firms' behaviour in choosing inputs, given the levels of market prices of output and inputs, and quantities of fixed inputs (Sadoulet and Janvry, 1995: 61-7). According to Binswanger (1974) these two components could be investigated by using the profit or the cost function, which provides the maximum profit or minimum cost that the firms could get given the technology and biological conditions.

According to Lau and Yotopoulos (1972) the formulation of the profit function is based on three assumptions:

(i) firms are profit maximizing;
(ii) firms are price takers in both output and variable inputs markets;
(iii) the production function is concave in the variable inputs (that is, there are decreasing returns to scale in the variable inputs taken altogether, among other things).

The firm is assumed to choose the combination of variable inputs and outputs such that the profit subject to the technology constraint is maximized according to:

$$(2) \qquad \pi(p, W, Z, R, S, T) = \underset{(X,Q)}{Max}\,(p.Q - W.X)$$

Under the restriction $Q = f(X, Z, R, S, T)$

where $\pi(p,W,Z,R,S,T)$ represents the short-run profit; p is the price of output and W is a vector of variable input prices. Thus, for a given technology (T) and a given endowment of R and S, the profit function expresses the maximum profit of a firm as a function of the prices of variable inputs and output, and the quantities of the fixed factors of production. For a function to be admissible as a profit function, the following conditions have to be fulfilled: it has to be decreasing and convex in the prices of the variable inputs, increasing in the price of output, and homogenous of degree one in all prices (Chambers, 1988; Oskam et al., 1992).

There is a dual relationship between the production function and profit function, following Shephard's Lemma (Antle and Capalbo, 1995; Lau and Yotopoulos, 1972). The remarkable property of the profit function is that its derivation with respect to output price is equal to the supply function of that product; and its derivation with respect to the price of an input is the demand function of that input. That is:

(3) The output supply function

$$\frac{\partial \pi}{\partial p}(p,W,Z,R,S,T) = Q^*$$

$$-\frac{\partial \pi}{\partial w_i}(p,W,Z,R,S,T) = X_i{}^*$$

(4) The demand function for input *i*

The supply and demand functions satisfy the following properties: (output supply and factor demand functions are homogeneous to degree zero in all prices, and symmetry is of the second-order derivatives of the profit function (Sadoulet and Janvry, 1995: 61-7).

At this point, the advantage of the profit function is quite clear. First, by starting from a profit function, the Shephard's Lemma makes it possible to derive the supply and the factor demand functions from profit maximization of a firm in a competitive market. Second, the supply and factor demand functions obtained may be explicitly written as functions of variables that are normally considered to be determined independently of the firm's behaviour. There are also econometric advantages to the dual approach because variables typically regarded as exogenous (that is, product and variable input prices, fixed inputs, agro-climatic and social variables) appear on the right-hand side of the equations and the endogenous variables appear only on the left-hand side. By estimating these functions directly, the problem of simultaneous equation bias can be avoided (Lau, 1978; Yotopoulos and Lau, 1973).

Incorporating externality into the profit function

The focus of the production analysis so far has been mainly on a firm producing a single product for a known price and without taking into account what we refer to as externality. This section shows how the externality information and environmental policy instruments can be included in the profit production model. It is to a large extent based on Howitt and Taylor (1993), Lansink and Peerling (1997) and Zilberman and Marra (1993). In order to capture externalities generated from the use of polluting inputs (chemical fertilizers and pesticides) in the production process, the above classical model can be modified to include a non-point emission function (E_i), as presented above. The vector of variable input (X) is then derived from two subsets of inputs X_1 and X_2 with associated prices W_1 and W_2, respectively. Vector X_2 represents inputs from which pollution is generated, whereas vector X_1 stands for 'non-polluting' inputs (that is, labour, seed and others).

The aggregated non-point emission function is denoted by:

(5) $E = h(X_2) = h(Q, X_1, X_2, Z, R, S, T)$

where E is the flow of pollution from X_2. Pollution as denoted in (5) is assumed to be a function of output, inputs, environmental conditions (R, S) and the state of technology (T). The pollution generation function exhibits 'a non-decreasing marginal product with respect to input levels' (Lansink and Peerling, 1997: 233-4).

Substituting the optimal solutions (3) and (4) into (5), the amount of pollution generated in an unregulated situation is obtained (Howitt and Taylor, 1993):

(6) $E \equiv h[Q^*(p, W_1, W_2, Z, R, S, T), X_1^*(p, W_1, W_2, Z, R, S, T), X_2^*(p, W_1, W_2, Z, R, S, T)]$

or $E^* = h(p, W_1, W_2, Z, R, S, T)$

Now suppose that property rights are defined in such a way that there is a (negative) price for pollution generated by the firm, or that the government imposes a tax/charge t_0 in response to production of externality (pollution). The profit function (2) then becomes:

$$\pi(p,t_0,W_1,W_2,Z,R,S,T)=\underset{(X1,X2,Q)}{Max}(p.Q-W_1.X_1-W_2.X_2-E.t_0) \tag{7}$$

The first-order condition for profit maximization with respect to input $i \in X_2$ is:

$$\frac{\partial Q}{\partial X_{2i}}-W_{2i}-t_0\frac{\partial h(X_{2i})}{\partial X_{2i}}=0 \tag{8}$$

Solving (8) yields the demand function for input $i \in X_2$ after the tax/charge has been implemented:

$$X_{2i}^*=X_{2i}^*(p,t_0,W_1,W_2,Z,R,S,T) \tag{9}$$

Rearranging the terms in equation (8) gives (10):

$$\frac{\partial Q}{\partial X_{2i}}=W_{2i}+t_0\frac{\partial h(X_{2i})}{\partial X_{2i}} \tag{10}$$

Equation (10) states that due to the tax/charge imposed for the externality, the value of the marginal product of X_{2i} is now equal to its corresponding price plus the value of the marginal pollution it produces (that is, the second term in RHS of equation 10). In other words, imposing a tax/charge for pollution is conceptually similar to increasing input prices (X_{2i}), which results in decreased use of that input. Under the tax/charge policy, the optimal quantity of X_{2i}^* after the tax/charge is lower than before the tax/charge.

To summarize, the profit function approach can be employed to study the economic behaviour of firms (farmers) under the assumption of profit maximization. Information on the output supply and factor demands can be derived from the economic production model developed on the basis of the profit function. Information on externalities and effects of taxes/charges on externalities and profit (for example, on crop income) can also be included in a dual profit function. Therefore, the above theoretical model is appropriate for examining the economic issues in this study: the responses of farmers to market prices of inputs and rice prices, substitutions between inputs, optimal quantities of fertilizers and pesticides for profit maximization, and profitability of rice production. The model specification details and derivations of economic parameters are presented in Chapter 6.

2.5.3 Valuation of damage to health and environment

Valuation of impacts of agrochemicals on human health

As mentioned in subsections 2.2.2 and 2.2.3, exposure to agrochemicals causes acute as well as chronic damage to the health of those who are involved in production- and non-production-related activities. Pingali and Roger (1995) provide a general scheme for modelling the effects of agrochemical exposure on human health. The measurement of these effects requires specific data sets and knowledge of the interaction between agrochemicals and processes within the human body. While there are many studies on occupational exposure (that is, of farmers who directly spray pesticides) and its acute health effects in developing countries, the valuation of the chronic health effects of exposure to agrochemicals is relatively poorly understood. This is due to uncertainty about the effects themselves. Because of cost, time and data constraints, the impacts of agrochemicals on human health that are analysed in this study are limited to the occupational health problems of rice farmers who directly apply pesticides. The analysis begins with a statistical description of the pesticide-related health effects reported by farmers during the surveys. The effects were mostly acute pesticide poisoning symptoms and chronic conditions that could be related to pesticide exposure. The questionnaires included questions designed to check the relationship between pesticide application and health problems, focusing particularly on health problems arising immediately after pesticide application. After confirmation that symptoms of poisoning are prevalent among farmers who apply pesticides, a ‘health risk’ model was constructed to understand the factors accounting for such symptoms. In the final stage, the author examined determinants of health costs incurred by farmers as a result of exposure to pesticides (see Chapter 7).

Empirical estimation of health risk model

Following Dung and Dung (1999) and Pingali et al. (1994), the health risk was modelled to relate a set of medical risk indicators econometrically to a set of farmer characteristics and to estimate probabilities of health risk due to pesticide exposure. The overall mathematical expression can be presented as:

$$\text{Ln Odds } \left(\frac{P_i}{1+P_i}\right) \text{ (Specific, multiple health impairments)}$$

$$= \alpha + \beta_1 \text{ (Pesticide exposure)} + \beta_2 \text{ (Farmers' characteristics)}$$

where: P_i is the probability of having a specific health impairment and $1-P_i$ is the probability of not having a specific health impairment. To know the probability of a farmer in the survey area suffering from a specific health impairment, the following formula was employed:

$$P_i = Exp.(\alpha_i + \beta_i)/1 + Exp.(\alpha_i + \beta_i)$$

The dependent variable was considered as a discrete dependent variable, and the symptoms and epidemiological data were collected to construct this variable. The independent variables in the model comprised the following: farmer's age and education level, a proxy variable for health and nutrition status, smoking and drinking habit variables, and variables representing doses of pesticides applied. Since the dependent variable in this equation was a discrete variable, ordinary least squares (OLS) may produce biased and inconsistent parameter estimates (Maddala, 1988: 481-9). Therefore, the author used an alternative method for estimating the parameters: a logit model.

Estimation of health costs due to exposure to pesticides

The 'cost-of-illness' (COI) approach was adopted in this study to value the benefit of reducing pesticide-related morbidity. This approach has been applied to value the cost of short-term health effects due to exposure to pesticides in developing countries (see, for example, Huang et al. (2000) for China; Maumbe and Swinton (2003) for Zimbabwe; Rola and Pingali (1993) for the Philippines). The approach focuses on health costs that can be directly measured: costs of recuperation (such as medicines, doctor and/or hospital visits, and meals), opportunity costs of foregone work days and restricted-activity days, and other related out-of-pocket expenses. All costs were added together to provide the total expenses for an illness borne by the farmers themselves.

Cropper (1994) notes that the cost-of-illness approach is only a starting point although it could provide a lower-bound estimate of the true health cost. This is because the approach excludes non-market losses associated with sickness, such as cost of the pain, inconvenience of being ill, values for foregone leisure time and activities occurring outside the farm household. This kind of information requires studies asking how much a farmer would be 'willing to pay' to avoid an adverse health outcome from agrochemicals, which can, in theory, be obtained by the contingent valuation (CVM) method (Cropper and Freeman, 1991; Freeman, 1993). Therefore, the mean values of reduced mobility in the COI approach are typically lower than those in the CVM approach. However, the CVM approach is subject to many biases (for example, the hypothetical, strategic and information bias) (Turner et al., 1994).

Health costs incurred by farmers as a result of pesticide exposure are considered to be a function of total pesticide dose, pesticide exposure (the number of times the farmer has actual skin contact with pesticides), pesticide hazard categories, and other personal characteristics. Based on the environmental economics literature on health production function, the following log-linear regression model was assumed in the estimation:

$$\text{Ln HC} = f(\text{FC}, \text{LnDOSE}, \text{Ln EXPO}, \text{OTHER})$$

in which HC represents farmers' health costs; FC is farmers' characteristics, DOSE is doses of pesticide applied, EXPO is characteristics of pesticide exposure. In this study, the total cost (in VND) incurred by farmers due to pesticide-induced illness was calculated on the basis of the following kinds of costs: opportunity costs of forgone work days (assumed to be equal to wage multiplied by the number of days off) and restricted-activity days; costs of recuperation (meals, medicines, doctors and/or hospital care), which were obtained through direct interviews with farmers who applied pesticides; and costs of protecting equipment. The estimated health cost for the population was weighted by the percentage of farmers going to a clinic. Finally, the average medical treatment cost was added to the estimated heath cost for the ones who did not go to a clinic, to obtain the final estimated health cost incurred by farmers as a result of exposure to pesticides. The specification and estimation details of the health cost model are presented in Chapter 7.

2.5.4 Policy instruments for reducing pesticide use

Improvement of the state of the environment requires modification of the behaviour of producers (that is, farmers) who generate these externalities. According to Randall (1972: 175-8), theoretically, to modify the behaviour of an economic unit it is necessary to modify the incentives presented to that unit so that the preferred behaviour becomes more appealing (that is, more profitable and/or more pleasant). In the Mekong Delta case, a social optimum would be achieved if there were mechanisms to induce polluters to internalize social costs caused by them. Two broad approaches can help to solve the pollution problem: market solutions without governmental intervention, and policy instruments for governmental intervention.

Resolution of pollution problems without intervention

Ronald Coase proposes a solution for internalization of social costs without government intervention. The Coase theorem represents a school of economic thought relating to the resolution of pollution problems that emphasizes the importance of property rights and bargaining between polluters and sufferers (Turner and Opschoor, 1994; Zilberman et al., 1993). Following the Coasian approach, if property rights are properly defined, with both producers and sufferers obtaining full information and no transaction cost, the social optimum could be achieved through market bargaining without any direct intervention by the government. If this mechanism could be trusted to operate adequately in a real-world situation, then there would be no need for government intervention (Turner and Opschoor, 1994: 1-38). All that society needs to do is establish a liability rule for damage associated with the externality (Randall, 1972). However, a number of problems prevent bargaining from taking place. For example, costly negotiation for compensation, weak enforcement of contracts, existence of imperfect competition and threat-making behaviour can prevent bargaining from occurring (Turner et al., 1994: 143-56). Particularly, in the case of environmental goods, transaction costs are likely to be high since many parties are involved and the exclusion of non-payers is difficult (Tietenberg, 1996). Moreover, since some social damage is not observable and measurable, the negotiation under the Coasian approach is restricted. In such cases, government intervention via direct regulation or economic incentives might provide a better alternative for achieving the social optimum with regard to pollution.

Environmental policy instruments

When externalities are present in a market economy, there are, theoretically, several ways in which environmental polices can be used to intervene and correct pollution problems: regulatory instruments, economic instruments and voluntary incentives (Barde, 1995: 201-27). Such instruments may also provide different incentives to producers (farmers) and other economic agents to change their behaviour in environmentally desirable ways.

Regulatory instruments, also known as the command-and-control or administrative approach, are the traditional form of environmental policy. The command-and-control approach forces farmers to reduce or eliminate the use of certain chemicals or to adopt specific pollution-reducing technologies. Direct regulation has until now been the most commonly used approach to tackle the problems of nitrogen and pesticides (Feather and Cropper, 1995; Reus et al., 1994). The approach consists mainly of imposing standards or quotas regarding emissions, licensing, monitoring, banning of products, or restricting use of certain inputs. Farmers are required to meet designated standards as to the level, form and management practices relating to fertilizers and pesticides. The regulatory instrument is appropriate in some specific conditions; for instance, tough licensing procedures and strict pesticide application controls are called for to reduce the use of pesticides when combined with other instruments (Nutzinger, 1994: 175-93). Although this approach may appear to be a simple solution for preventing hazards and irreversible effects on the environment, the administrative cost may be high due to weak enforcement, legal procedures and limited staff capacity (Barde, 1995: 201-27). Moreover, the total cost of achieving a given level of emissions is also higher than with the tax solution (Turner et al., 1994: 166-89).

Economic instruments, also known as market-based instruments, aim to induce a change in the decision making and behaviour of economic agents in such a way that alternatives are chosen that lead to a more environmentally desirable situation than would exist otherwise (Turner and

Opschoor, 1994: 1-38). In the language of welfare economics, these instruments aim at internalizing the cost of negative externalities of production and/or consumption upon the environment. One way to internalize these social costs is to make polluters pay a tax for pollution. Such taxes, originally proposed by an alternative school of economic thought associated with Pigou, are based on the estimated damage caused by the pollution generated. Such taxes would raise the marginal social cost of pollution and polluters would be forced to move to a socially optimal level of production and pollution (Baumol and Oates, 1988: 14-35). However, the Pigouvian fee, defined as a tax (or effluent charge) per unit of emissions equal to marginal social damage, is not easy to implement. In most cases it is impossible to tax the pollution exactly because of inadequate information on marginal damage. This is because there is little or no agreed data on the social cost of pollution, or its distribution, so policymakers fix the tax rate at levels where they expect environmental targets to be achieved (Baumol and Oates, 1988: 159-76; Turner et al., 1994: 166-89). Therefore, 'proxy solutions', such as emission charges, marketable permits and standards, have been proposed by Baumol and Oates (1988: 159-89). The emission/effluent charges would not necessarily present the optimal solution to the externality though they would ensure that abatement levels or environmental targets are met at the least cost. Since the target level (standard) is not the optimal level of pollution in the Pigouvian sense, the effluent charges/taxes are often referred to as the second-best solution for externality problems.

According to the European Environmental Agency, the main economic reason for using taxes as an environmental policy instrument is to incorporate the social costs of pollution into the prices of goods and services. An effluent charge or tax is, to some extent, to be considered as payment for each unit of pollutant discharged into the environment or for each unit of environmental damage (Barde, 1995: 209-18).[2] When an effluent charge is imposed, polluters will respond by reducing emissions to the level where their marginal pollution abatement cost equal the unit rate of the effluent charge.[3] Similarly, the optimal solution to pollution problems can be achieved if the government issues a quantity of emission permits just sufficient to reduce total emissions to the so-called socially optimal level of pollution and trading between polluters is allowed in the market within the set total. Such quantity control instruments are known as tradable permits. Theoretically, tradable permits have the same advantage as taxes/charges in the Baumol and Oates theorem context. By giving polluters a chance to trade their emission permits and with such transactions benefiting both trading partners, the total cost of pollution abatement will be minimized (Barde, 1995: 218-20; Dietz and Heijnes, 1995: 10-11; Turner and Opschoor, 1994: 1-38). However, the marketable permit system requires creation of a functioning market. This results in high administrative costs for transaction monitoring and additional enforcement cost to ensure that emissions do not exceed the set level.

A third category of environmental policy instruments often used to control non-point source pollution is voluntary incentives, which could be referred to as persuasive instruments. Voluntary incentives usually consist of promoting less-polluting technology, providing information, extension and education services, and training to improve the farmers' perceptions of environmental issues as well as providing incentives to adopt less-polluting technologies (Feather and Cropper, 1995). Better management practices with regard to polluting inputs (such as nitrogen, phosphorus and pesticides), and farm activities (such as ploughing, harvesting, and manure application) are often recommended to reduce non-point source pollution. For example, integrated pest management practices, the split application of nitrogen, the mineral balance approach, and conservation tillage help to reduce the emissions of nutrient and pesticide to the environment significantly (Follett, 1995; Kegley et al., 1999; Vitousek et al., 1997).

The above discussion has to some extent covered the basic instruments that can be used to internalize social costs caused by pollution in order to achieve specific environmental targets. As we have seen, an optimum solution to internalize social costs of pollution cannot be found until the marginal social damage cost can be measured with certainty. The proposed instruments could only help to achieve a second-best solution. The selection of environmental instruments for a specific pollution problem is, however, guided by a number of criteria, of which environmental effectiveness is the most important. An instrument is said to be effective if it motivates polluters to reduce pollution to the desirable level and improve environmental quality. In fact, the effectiveness of an instrument is usually determined by the extent to which polluters react to its introduction. For some specific environmental purposes, one instrument may be more effective than another. For example, a ban on an extremely hazardous pesticide is more effective than a quota. Economic efficiency is the second criterion that most policymakers consider in choosing an instrument. This refers to cost efficiency in both the short run and the long run. The most cost-efficient instruments may be found by comparing the marginal abatement costs facing firms (for example, with regard to abatement costs, imposing effluent charges/taxes is more efficient than setting standards).

Flexibility is a key condition for achieving environmental effectiveness and economic efficiency (Barde, 1995: 215-27). Flexibility refers to the extent to which an instrument can be adjusted in response to exogenous changes in technology or other types of economic activities. It also implies that the polluters are flexible in choosing abatement technologies and adoption strategies. The proposed instruments also have to take into account the relative difficulty of measurement of emissions or damage. In addition, the ability to enforce polluters to comply with environmental requirements is also important. Other criteria such as political acceptability affecting the selection of an instrument, administrative practicability, and distributional effects of an instrument also have to be considered when choosing among environmental instruments. Details on these criteria can be found in Barde (1995: 215-27); Turner et al., (1994: 159-61); and Turner and Opschoor (1994: 35).

Application of effluent charge/tax to non-point source pollution

As shown in the preceding subsection, there are many possible ways in which a government can intervene to correct pollution problems in agriculture. However, the characteristics of agricultural non-point source pollution create a number of problems in applying environmental instruments. This subsection illustrates the complication of designing policies to control non-point source pollution by discussing the practical aspects of applying emission taxes and polluting input taxes to control pollution associated with inorganic fertilizers and pesticides.

Many studies suggest that a tax/charge on nutrient surplus (for example, nitrogen and phosphorus), a nutrient emission tax, would reduce the chance of incentive distortions (see Dietz and Heijnes, 1995: 15-33; Lankoski, 1996; Lansink and Peerlings, 1997: 231-47; Zeijts, 1999). The basic idea behind this approach is that the tax should only be imposed on the nitrogen surplus/emission from the farms via the nutrient balance. It is exactly the effluent/emission tax discussed above. The nutrient surplus is defined as the difference between the import of nitrogen and the export of nitrogen from the system (Olesen, 1996). A tax on the emission of nutrient to the environment can, in principle, be tailored to capture the marginal environmental damage by operating with varying tax rates from one location to another. According to Lanskoski (1996), the information on mineral balance and nutrient surplus is not only useful for imposing a tax on nutrient surplus unit, but can also be used for granting a subsidy per reduced nutrient surplus, creating a deposit-refund system, and examining the effectiveness of production input use on the farm.

However, the major disadvantage of a surplus tax is that it is difficult to implement, as in the Netherlands since 1998, because it requires nutrient accounting for each farm. More specifically, it requires farmers to keep records of nutrient balance on their farms, and the need to determine the nutrient surplus for each of the millions of farms would be very expensive for the government to take action. Various studies have attempted to quantify the emissions of fertilizers to surface water and groundwater. Horner (1975) shows the resultant NO_3-N content of drainage water determined by the amount of nitrogen applied and by soil types. Nitrate (NO_3) leaching for specific soils has been modelled as a function of nitrogen, soil type and water (Helfand and House, 1995). Lankoski (1996) and Olesen (1996) use the mineral balance at farm level to estimate nitrogen leaching to the environment. Wendland and Kunkel (1996) model nitrogen leaching in Germany with the help of the geographic information system (GIS).

Since neither the source nor the size of individual emissions can be easily observed by an environmental regulator, more attention is being paid to the development of policy schemes appropriate for non-point source pollution. One of the policy schemes is based on observable polluting inputs (Zeijts, 1999). Taxing or charging on a polluting input (such as a pesticide) used in the production process is like raising the input price. Farmers will then reduce the use of the input and may look for less-polluting substitutes. This kind of tax has been studied and applied in many European countries (Brouwer, 1999). Its advantage is that it does not need to be monitored and can be implemented using administrative structures. Most of the cases in the studies deal with pesticides and nitrogen fertilizer, but the instrument could easily be extended to the application of other fertilizers (for example, phosphorus).

However, implementing effluent taxes/charges on inputs requires a number of practical issues to be taken into account. First, the effectiveness of an input tax is highly dependent upon the price elasticities of demand for inputs (Lankoski, 1996). The extent of the change in input use depends on how sensitive the demand for the polluting input is to price change. These sensitivities tend to be very small for nitrogen and pesticides. For instance, a 100 per cent nitrogen tax rate would have to be imposed in order to reduce nitrogen application by 20 per cent (Nutzinger, 1994). Simulation results in Antle and Pingali (1994) also show that a uniform tax of 300 per cent could reduce the quantity of insecticide and herbicide used by 80 per cent. Second, the tax on polluting inputs should capture the difference in efficiency of agrochemical use on different farms and crops and other characteristics such as soil types. It has to differentiate between the amount of agrochemicals being utilized on farms and that being lost to the environment. For example, taxes on an input such as nitrogen fertilizer require differentiation between the amount of nutrient being utilized on the farm and the amount lost to the environment (Dietz and Heijnes, 1995: 25-8; Lankoski, 1996). Similarly, quantitative prediction of pesticide loss through leaching and runoff is often difficult and requires complex models that incorporate soil types, crops, pesticide characteristics and climatological conditions (Rao et al., 1998). Therefore, a tax on pesticides also requires careful consideration. For example, a uniform tax should not be imposed for all pesticides (for example, insecticides, fungicides and herbicides) since the adverse environmental effects of these pesticides are different (Antle and Pingali, 1994: 426-9; Gren, 1994a,b,c; Nutzinger: 184-5). Antle and Pingali (1994) demonstrate that to reduce the adverse health effects of exposure to pesticide, an insecticide tax could reduce the use of insecticide by almost as much as a uniform tax on pesticides as a whole and is therefore almost as effective as a uniform tax.

This study investigates the effects on productivity, farmers' income and health improvement resulting from a tax to restrict use of pesticides and fertilizers, along with other policy scenarios. To do so, the study employs a simulation model using estimated parameters from the system of profit function and input demand functions, health cost function and market prices of output and inputs. A detailed explanation and simulation procedure are presented in Chapter 8.

2.5.5 Methods, techniques and sources of data collection

This study uses both qualitative and quantitative research methods to address the various research questions. Qualitative methods are often used for the purpose of understanding the nature and relationships between actors, actions and the environment, that is, farmers' production activities and the dynamic relationship between farmers and factors influencing their decisions. However, while understanding the nature or meaning of actions is essential, for a development-oriented analysis findings cannot be understood adequately without the use of quantitative parameters. For example, the supply and input demand elasticity parameters for rice help us to understand and forecast farm households' behaviour. The empirical analyses therefore focus on:

- the normalized translog profit function to derive production information and price elasticity of input demands and rice supply;
- the health-risk logit model to relate a set of medical indicators to a set of farmer' characteristics and to estimate probabilities of health risk due to pesticide exposures; and
- dose-response function to estimate health cost of farmers due to pesticide exposures.

However, it should be noted that some aspects of agricultural sustainability are difficult to quantify, and therefore, qualitative values and information have to be used. Both quantitative and qualitative data need to be collected for this analysis. The study uses primary data from surveys and secondary data from various sources. The target region is the Mekong Delta (MKD), which is the biggest rice-growing region in Vietnam and is considered to be the 'rice basket' of the country and the main source of rice for export. The principal data source for analysis is the information collected through two surveys of farm households in the MKD during the 1996/1997 and 2000/2001 dry seasons. Methods of data collection included discussions with key informants and structured interviews. A workshop was held to discuss and receive possible options for controlling agrochemicals. Furthermore, the author participated in relevant workshops to distribute views and economic options regarding agrochemical pollution and to collect documentary materials. Data from the 1996/1997 field survey serve as the base line for analysis.

Criteria for selecting the sample

Farmers were selected according to the following criteria:

(i) provinces, districts, and villages where rice production is dominant and there are different levels of intensification;
(ii) a relatively wide geographical distribution of the study sites (that is, they should not be very close to each other);
(iii) location away from cities and district centres (since agricultural land in urban areas may be allocated to other uses in coming years and may not be representative of numerous rural villages in the MKD); and
(iv) farmers being involved directly in rice production, especially in applying agrochemicals for higher rice output.

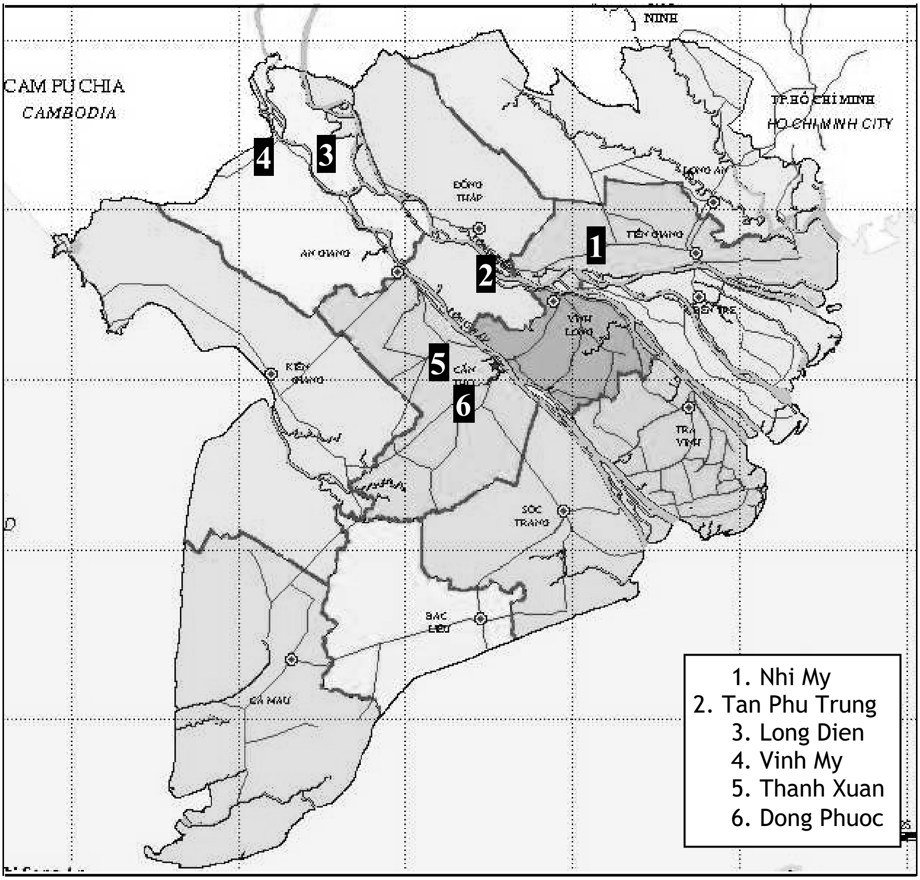
Stratified purposive sampling was employed to ensure that the smaller groups of farmers matching the sampling criteria were adequately represented in the survey sample. This technique is appropriate for sampling a geographically dispersed population (Burton, 2000: 307-19). Though stratified random sampling offers increased probability of accuracy and reduces sampling error (Babbie, 2001: 197-213; Burns, 2000: 90; Henry, 1998: 117-26), it was not feasible within the cost and time constraints, and the lack of complete lists of elements of the population selected for study. The same sampling method was applied in the two surveys to collect farm-level data.

At the provincial level, on the basis of the above criteria, the following four provinces were chosen from the set of 12 in the Mekong Delta region:[4] Tien Giang, Can Tho, An Giang and Dong Thap.

- Tien Giang has highly intensive rice production. Geographically it is located southwest of Ho Chi Minh city and north of the Tien and Hau Rivers (which constitute sub-branches of the Mekong River)
- Can Tho is in the central part of the Mekong Delta region and is located along the southern part of the Hau River.
- An Giang is an area of high rice productivity and is located near the Cambodian border and south of the Tien and Hau Rivers.
- Dong Thap has low rice productivity and is cut through by the Tien and bordered by the Hau River. As a result, one part of Dong Thap is to the north of the Tien River.

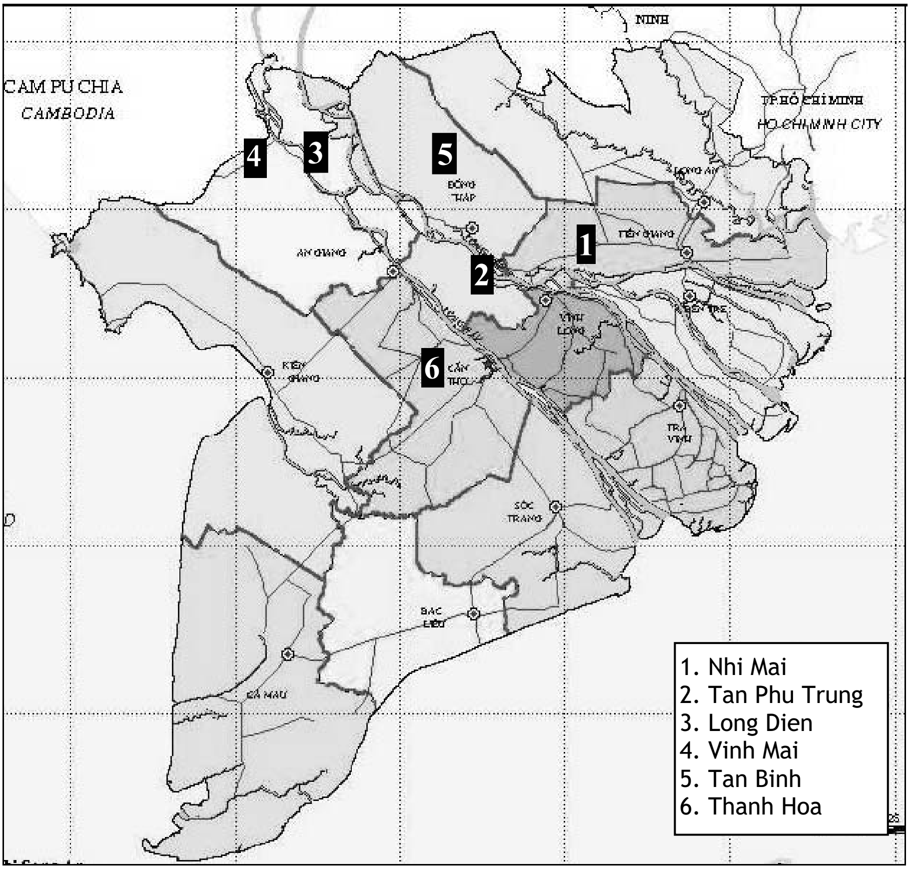
In Can Tho and An Giang provinces, two villages located in different districts were surveyed per province. In Tien Giang and Dong Thap provinces, one village was surveyed per province. Thus, a total of six villages in six districts of four provinces were selected for the surveys. The criteria for selecting the villages were the same as for provinces and districts. The survey used prior information about characteristics of rice production in the MKD (as cited below) for selecting villages. Figures 2.3 and 2.4 show the sites of the two surveys.

Figure 2.3
1996/97 survey sites



Prior to the survey, the author had discussions with experts from Farming Systems Research and Development Institute, Can Tho University, and agricultural officials at district level to make sure the selected communes would be suitable. The author also discussed the study objectives with the local People's Committees in the selected villages and requested guidance on choosing the farm households to interview. The criteria for the level of rice intensification within a commune were guided by a combination of different factors: farm size (land holdings that are greater than the average size for the commune are considered large), the knowledge of the local authorities and commune organizations (women's union, agricultural officials and youth union).

Figure 2.4
2000/01 survey sites



A total of 30 farm households were interviewed in each of the six villages, making a total sample of 180 in the MKD. At village level, different levels of intensive rice cultivation and farm sizes were used as general criteria to classify farmers into smaller groups. The knowledge of local authorities and commune organizations (women's union, agricultural officials and youth union) was an important input at this stage. Then, the lists of all households in hamlets of the village were categorized as having 'small/medium/big farm sizes' and 'low/medium/high' application of agrochemicals. Following these 'draft judgement' lists, the interval random method was used to select the households until 30 had been selected in each village. Burns (2000: 95-104) argues that as long as the sample size is greater than 30, the distribution of sample means tends to be normal. The local authorities provided guidance to help the survey team contact the farmers and interview them at their houses in different hamlets, following the sample lists. Though the sample size was not large, it enables in-depth investigation of the research objective and a partial generalization of the impact of agrochemical use.

1996/1997 field survey

The survey began in January 1996 and was completed in April 1997, interviewing a sample of individual farmers from six subdistricts (villages) in four provinces of the Mekong Delta, including Tien Giang (Nhi My in Cai Lay district), Dong Thap (Tan Phu Trung in Chau Thanh district.), An Giang (Vinh My in Chau Doc district, and Long Dien B in Cho Moi district), and Can Tho (Thanh Xuan and Dong Phuoc in Chau Thanh district). Site selection was based on the above-listed criteria and recommendations from the Rice Research Department of Mekong Delta Farming Systems Research and Development Institute, Can Tho University (Prof. Vo Tong Xuan, Director of the Institute, Mr. Nguyen Ngoc De, Head of Department, Mr. Tran Van Sau, Deputy Head of Department). The survey was part of the author's research projects on 'Economic and Health Consequences of Pesticide Use in Paddy Production in the Mekong Delta, Vietnam' and 'Agrochemicals, Productivity and Health in Vietnam'. The projects were carried out with the help of a grant and academic support from the Economy and Environment Programme for Southeast Asia (EEPSEA), managed the by the Environmental Economics Unit (EEU) of HCMC University of Economics (UEH).[5]

A total of 180 farmers (30 in each site) were interviewed, in cooperation with officials of the local Extension Services, Plant Protection Subdepartments, People's Committees and the local chapter of the Farmers' Association. These local organizations helped to arrange meetings with farm households. The survey team comprised four Masters students from the Vietnam-Netherlands MA programme on Development Economics at UEH, one medical doctor focusing on health issues relating to pesticides, and the author. At the village level, the author focused on key informants and special cases such as heavy or light use of agrochemicals, positive and negative results in rice production, and interviewed at least seven to eight farm households in each village. The questionnaires were designed to elicit the following information:

- Farm inputs and prices: Land (area cultivated, irrigated or not), agrochemicals used (fertilizers, pesticides), labour (for different farming activities), seed, farm size and productive assets (machinery, equipment);
- Farmers' and family characteristics and other variables affecting health: age, sex, drinking and smoking habits, education, nutritional status, training in agricultural development programmes (for example, agricultural extension, integrated pest management);
- Pesticide exposure: kinds and quantity of pesticides used (in grams of active ingredient per hectare), numbers of hours of pesticide application during a season, preventive measures against pesticide poisoning and cost, pesticide control practices, protection equipment, historical records of farmers' use of pesticides (when they first started using pesticides, trend in rates and types of pesticides used over time);
- Symptoms due to prolonged exposure to pesticides (eye, skin, respiratory tract and gastrointestinal effects, polyneuropathy, and so forth), medical history and expenditures incurred in treating illness, particularly focused on health impacts caused by pesticide use, farmers' awareness of change in health due to greater use or prolonged pesticide use (for example, skin rashes, weak lungs);
- Farm output and prices, income from farm and RNFE (rural nonfarm economy) income sources.

2000/2001 field survey

A supplementary field survey was conducted from October 2000 to the end of January 2001 to collect additional production information and data on environmental aspects of agrochemical use from a sample of 180 individual farmers in irrigated rice production systems. The survey was part of the research project supported by MDE/SAIL. The study sites comprised six villages in four provinces: Tien Giang (Nhi My in Cai Lay district), Dong Thap (Tan Phu Trung in Chau Thanh district and Tan Binh in Thanh Binh district), An Giang (Vinh My in Chau Doc district and Long Dien B in Cho Moi district) and Can Tho (Thanh Hoa in Phung Hiep district). Of the six villages, four had been surveyed in 1997, which saved time and cost while making comparison with the previous survey possible. The survey was also conducted in cooperation with officials of the local Extension Services, Plant Protection Subdepartments, People's Committees, the local chapter of the Farmers' Association and the Rice Research Department of Can Tho University. Of the households interviewed, 98 were the same as those in 1997. Only 86 households had complete data, and in the analysis these 86 households are denoted as 'same household group' (SHH group) within the total sample.

The production data in the 1996/97 and 2000/2001 surveys concentrated on the winter-spring season, although information on other seasons was also recorded. There are two reasons for this. First, the growing calendar is almost similar for all households, and the climate is favourable to the rice crop and much alike over the years so that the influence of agrochemicals on yields could be examined. Second, the winter-spring season provides the highest rice yield, higher profits to farm households, and a huge amount of rice surplus for export. This helps to provide better understanding of the influence of market prices of inputs and outputs on farm household decisions about agrochemical use.

Secondary data

Secondary data for the study was obtained from published documents and consisted of, for example, statistics on agrochemical residuals in water, price policy on agrochemicals and output, statistics on land, documents on the environment and various agricultural policies. These were collected from different research/academic institutions within and outside the Mekong Delta, relevant companies and at the national government level. Most of the data come from the General Statistical Office , Ministry of Agriculture and Rural Development, Ministry of Science, Technology and Environment, Plant Protection Department, Extension Services Department, Mekong Delta Farming Systems Research and Development Institute, Cuu Long Delta Rice Research Institute, and agrochemical companies and retailers. Data on safe use of pesticides are from a survey conducted by the Southern Division of the Plant Protection Department in November 1999, which contained information on farmers' perceptions, beliefs and practices in rice pest management in a highly productive system.

Expert opinion

A workshop entitled 'Policies to Control Pollution Caused by Agrochemicals Used in Rice Production in the MKD' was held at the UEH on 25 November 2000 in collaboration with the Plant Protection Department and Department of Agricultural Extension, Ministry of Agricultural and Rural Development. The purpose was to outline the current use of agrochemicals (organic fertilizers and pesticides) and their problems in rice production in the MKD, to present and discuss measures to control pollution caused by agrochemicals, to familiarize researchers in other disciplines with economic approaches to controlling agricultural pollution, and to obtain opinions from researchers and authorities. The workshop was attended by about 50 participants from the Plant Protection Department, Department of Agricultural Extension, Southern Institute of Agricultural Science, UEH, Can Tho University, HCMC Agriculture and Forestry University, provincial subdepartments of the Plant Protection Department and Department of Agricultural Extension, the provincial Department of Science, Technology and Environment, Vietnam-Netherlands MA programme on Development Economics, agrochemical companies and public media. Some of the participants attended out of individual interest.

2.6 Concluding remarks

This chapter has presented the basic concepts used in this thesis, the conceptual framework for the analysis of agrochemical use and its economic and environmental consequences, and the methodology for achieving the study's objectives. Agrochemicals are used intensively in rice-growing countries that have adopted Green Revolution technology. While the benefits of agrochemical use in agriculture are clear, their emissions into the soil, water and air have had severe negative effects on human health and the environment. A profit function approach was determined to be appropriate for investigating the profitability of rice production and responses of rice farmers to market price changes. The cost of illness approach (COI) will be employed to examine the effects of agrochemicals on human heath. Finally, a simulation model using the estimated parameters will be used to investigate impacts of tax policy on productivity, profitability and farmers' health. All analyses focus on intensive rice production in the MKD, Vietnam, and are based on survey data from direct interviews with rice farmers during the 1996/97 and 2000/01 dry seasons.

The next chapter will provide details about rice production in Vietnam and then describe the biophysical and socioeconomic environment in which Mekong Delta rice farmers cultivate and harvest their crop.

Notes

[1] The ability of the natural environment to assimilate (degrade) waste is commonly referred to as 'environmental buffering capacity' or 'assimilative capacity' (Hussen, 2000: 90-5).

[2] The terms tax and charge are used interchangeably here. Theoretically, a charge is different from a tax. A charge is earmarked and usually associated with return flows of some kind of goods or services, whereas a tax is not (Barde, 1995: 126)

[3] Marginal pollution abatement cost is the cost of removing one additional unit of pollutant (for example, a dose unit of pesticide). The MAC curve of the firm increases with abatement of pollutants.

[4] Since January 2004, Can Tho province has been divided into Can Tho City and Hau Giang province. There are 12 provinces and one city in the Mekong Delta region since 2004.

[5] The author was responsible for designing the questionnaire, which was modified later with Dr Agnes Rola of the University of the Philippines (a resource person for the Economy and Environment Programme for Southeast Asia) and others during workshops in Vietnam and Singapore. The questionnaire was tested before the fieldwork. In 1995, the author joined the Economy and Environment Program for Southeast Asia (EEPSEA) and became coordinator of EEU-EEPSEA.

3 Rice Production in Vietnam

3.1 Introduction

Vietnam is one of the poor and densely populated rice-growing countries in Asia. Rice has long been its major food crop, benefiting from the warm and humid climate. Rice production increased rapidly after the introduction of the *đoi moi* policy in the mid-1980s. While accounting for only 5.3 per cent of global rice production, Vietnam was the second major exporter in the world in 1999, supplying 4.6 million tons to the international market. Thailand, the leading exporter, supplied 6.8 million tons of rice (FAOSTAT, 2001). This outstanding achievement has been accompanied by higher dependence on agrochemicals, with chemical fertilizers being applied in increasing amounts to replenish soil nutrients and pesticides being used as the main instrument for pest control. This chapter presents the development of rice production in Vietnam, the biophysical conditions under which rice is grown and the socioeconomic conditions in the Mekong Delta (MKD). Section 3.2 provides an overview and analysis of the development of rice production in Vietnam. Section 3.3 sets out the main characteristics of the biophysical environment in the Mekong Delta. Finally, some basic information on the economy and farmers' livelihood is given to provide a foundation for interpretation of the research findings in later chapters.

3.2 Characteristics of rice production in Vietnam

Rice has been, is, and will continue to be the most important crop in Vietnam for the foreseeable future. Traditionally, it has been not only the main food staple but also the most dominant crop in most areas, providing a minimum income for poor farmers and some degree of food self-sufficiency. With limited agricultural land and an increasing population, the only way Vietnam can remain a supplier to the international rice market is by intensifying cultivation in irrigated rice-growing areas of the country. Table 3.1 shows the allocation pattern of agricultural land in Vietnam. By the end of 2000, paddies accounted for almost half (45.7 per cent) of the agricultural land. The share of other annual and perennial crop lands was 17.8 per cent and 23.3 per cent, respectively. Within the land allotted to rice cultivation, more than half was devoted to two crops annually. Most of the land, especially garden land, was allocated to individual farming households as a result of policy reforms in 1981, which will be discussed in Chapter 4. It is common in rural Vietnam for each farming household to set aside a small plot of land for a home garden. Pasture land is mainly for communal use. Around 30 per cent of agricultural land is allocated to agricultural organizations/companies for growing perennial crops such as rubber, coconut, tea, coffee, cotton and sugarcane. The main food crops cultivated in Vietnam are paddy rice, maize, sweet potatoes, cassava and potatoes; of the land allocated to food crops, 91.3 per cent was used for paddy rice in 2000 (GSO, 2002b)

3.2.1 'Rice baskets' of Vietnam

Situated between the Tropic of Cancer and 80° N latitude, Vietnam is entirely within the tropical monsoon climate zone. While the warmth and humidity allow the cultivation and good growth of tropical crops in Vietnam, rice is the most prominent in all agro-ecological regions, covering 4,267,800 hectares of the agricultural land (see Table 3.1). The share of agricultural land devoted to rice has declined by about 7.5 per cent since 1995, when it was 53.2 per cent. This indicates greater diversification in crop production during the transition process. For agricultural purposes, the country is divided into eight agro-ecological zones: Red River Delta, Northeast, Northwest, Northern Central Coast, Southern Central Coast, Central Highlands, Southeast, and Mekong Delta. The percentage of agricultural land devoted to rice cultivation is different from that of other regions. The Red River Delta in the north and Mekong Delta in the south are the two rice baskets of the country, producing 70 per cent of the rice while accounting for 40 per cent of the agricultural land (see Table 3.2). The remaining 30 per cent of the rice is produced in other regions, and mainly for local consumption. Because of the biophysical conditions, various industrial crops are grown in these regions rather than rice. For instance, rubber is grown in the Southeast, coffee and tea in the Central Highlands, coconuts in the Southern Central Coast.

Table 3.1
Allocation pattern of agricultural land in Vietnam, December 2000

Type of land use	**Land Area ('000 ha)**	**% of agricult. land area (%)**	**% allocated to Individual households**	**Communal Land (%)**	**Allocated to organizations/ companies (%)**
Total paddy land	*4,267.8*	*45.7*	*94.4*	*3.4*	*2.2*
3-crop paddy rice	465.9	5.0	98.3	1.5	0.3
2-crop paddy rice	2,681.3	28.7	94.9	3.1	2.0
1-crop paddy rice	1,069.2	11.4	91.6	4.6	3.8
Rice nursery land	51.4	0.6	93.2	6.0	0.8
Burnt-over paddy upland	199.9	2.1	93.9	4.1	2.1
Other annual crop lands	1,661.7	17.8	85.9	6.2	7.9
Garden land	628.5	6.7	98.1	0.7	1.3
Perennial crop land	2,181.9	23.3	68.7	1.4	30.0
Pasture	37.6	0.4	1.3	76.1	22.6
Water surface	367.8	3.9	69.0	12.6	18.4
Total agricultural land	9,345.3	100.0	85.7	3.9	10.4

Source: MARD (2002).

The Northeast and Northwest regions are mountainous uplands with cool weather, and are among the poorest regions. Upland rice is grown on terraced slopes and irrigated rice in the narrow mountain valleys. It is interesting to note that, while rice accounts for only 16 per cent of the agricultural land and 18 per cent of the annual crop land in the Northwest, the region's rice cultivation intensity is the highest in the country. The region's average rice yield is the lowest in Vietnam. Maize is more important, perhaps because ethnic minorities account for a large proportion of the population. In the North Central Coast, rice is cultivated on narrow plains along river valleys in the coastal districts. Approximately, 73 per cent of the annual land is used for rice cultivation and the average rice yield of about 4.06 tonnes in 2000 ranks second in the northern regions; that is, Red River Delta, Northeast, Northwest and North Central Coast (see Table 3.2).

Table 3.2
Selected indicators of rice production in Vietnam by region, December 2000

Region	**Agricultural land (ha)**	**Annual crop land (ha)**	**Paddy land (ha)**	**Sown paddy area (ha)**	**Rice intensity**	**Paddy yield (tonnes/ha)**
Red River Delta	857,515	723,240	667,278	1,212.6	1.82	5.43
Northeast	897,668	629,647	369,912	550.3	1.49	3.75
Northwest	407,373	349,641	63,451	136.8	2.16	2.95
North Central Coast	725,428	543,009	395,840	695.0	1.76	4.06
South Central Coast	545,560	415,028	206,800	422.5	2.04	3.98
Central Highlands	1,233,699	507,852	126,492	176.8	1.40	3.32
Southeast	1,707,769	734,831	355,414	526.5	1.48	3.19
Mekong Delta	2,970,334	2,226,270	2,082,662	3,945.8	1.89	4.23
Nationwide	*9,345,346*	*6,129,518*	*4,267,849*	*7,666.3*	*1.80*	*4.24*

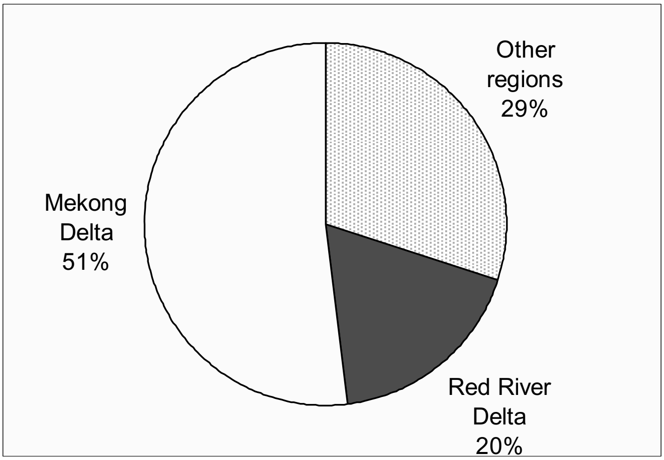
Source: GSO (2002b).

The Southern Central Coast is the second major rice production region in the south. Given that only a small proportion of agricultural land (38 per cent) is suitable for rice cultivation, rice is grown for two seasons a year in small plains along the river valleys. Fishery is more important to the inhabitants of this region. In the Central Highlands only 10 per cent of the agricultural land is given to rice production, the rest being mostly used for coffee, tea and rubber plantation. The Southeast region, which the main economic region of the country,[1] is the most urbanized and developed. The average GDP per capita was VND 7.843 million in 1999 (at 1994 prices), which was twice the national average and far higher than in other regions. The Southeast does not specialize in rice production and there is diversification into perennial and cash crops such as tobacco, soybean and vegetables. The most important crops are rubber and cashew nut, and part of the agricultural land is reserved for fruit trees and coffee.

The Red River Delta is the second-largest rice-growing region in the country after the Mekong Delta. Its good soil fertility and irrigation systems provide highly suitable conditions for rice production. Most soils are alluvial deposits from the Red River and Thai Binh River. The Red River Delta has the highest population density in the country and is one of the most densely populated agricultural regions in the world, with more than 1,000 inhabitants per km2 in some parts. Rice farming has been the main livelihood of the inhabitants for thousands of years. Due to the high population pressure and lack of agricultural land, most farmers cultivate crops intensively on very small farms (averaging 0.25 hectares). Two to three annual crops per year, of which two are rice, are common and agrochemicals are used widely (Dung et al., 1999). Around 78 per cent of the agricultural land was used for rice production in 2000, with a rice cropping intensity of 1.78. The region is much affected by monsoons: northeastern monsoons in winter, from October to March; and southeastern monsoons in summer, during the remaining months. Rice is mainly grown in two seasons: the winter-spring season from October to April and summer season from May to September. In some areas, a third crop (maize, sweet potato or vegetables) is grown from the end of October to January (Hien and Thi, 2001). The Red River Delta accounted for 20 per cent of national rice production in 2001 (see Figure 3.1) and had a surplus, which was mainly shipped to its neighbouring northern provinces. Its average rice yield of 5.43 tonnes per hectare in 2000 was the highest in the country.

The Mekong Delta[2,] located in southwestern Vietnam, is the richest agricultural production zone in the country, and is known as 'the rice bowl of the country'. It accounts for 51 per cent of the total rice production in Vietnam although it has an area of only 39,653 km2, 12 per cent of the country' total area (GSO, 2002b). Rice is the dominant crop and is grown in all 13 provinces of the delta; cropping intensity ranges from one rice crop a year to more than three. Seventy per cent of the total agricultural area in the Mekong Delta was under rice cultivation in 2000. The Mekong Delta contributes significantly to national export earnings, especially through exports of rice and fishery products. In 2000, it provided 16.7 million tonnes of paddy rice, amounting to nearly 1,022 kg of rice per capita, of which approximately 3 million tonnes was for export. In addition, about 500 thousand tonnes of rice were shipped to the north to meet local demand. Though rice I cultivated on a larger scale in the Mekong Delta than in the Red River Delta, and with a higher degree of cropping intensity (see Table 3.2), farm sizes are still small, averaging 1.26 hectares.

Figure 3.1
Contribution of Red River Delta and Mekong Delta to national rice production in 2000 (%)



Source: GSO (2002b).

3.2.2 Intensification of rice production

Benefiting from the new institutional environment since the mid-1980s, the rice sector has made considerable strides in the last decade. Real agricultural GDP grew by approximately 7 per cent annually from 1996 to the year 2000 (GSO, 2002b) with rice leading the growth. Both production and yield have risen consistently during the last 15 years. From 1986 to the year 2000, rice production doubled from about 16 million tonnes to over 32 million tonnes, and yield increased from 2.81 tonnes to 4.18

tonnes per hectare. However, the growth in rice yield has not been smooth and, as will be seen later in this chapter, it has stagnated. The growth in rice production has resulted from substantial intensification of agricultural techniques and an increase in cropping intensity (that is, rice-sown area). The intensification in rice production has made Vietnam self-sufficient in food again and has created a substantial surplus for export since 1989. Intensification in rice production has taken several forms.

Wide adoption of high-yielding varieties

Intensification of rice production has mainly been achieved through large-scale adoption of high-yielding varieties (HYVs). These grow faster than local traditional varieties and are unaffected by soil problems such as acidity (Khush et al., 1995). HYVs were introduced to Vietnamese farmers in the south of the country in the late 1960s. In the Mekong Delta, the development of rice production and technology is attributed to the rice research programme at Can Tho University, which started as early as 1971. The programme covered many respects of rice cultivation, from introduction to screening and selection, adaptive trials, and development of cultural practices as well as recommendations on fertilizer and pesticide use.[3]

Xuan (1995) observes that farmers in southern Vietnam have been growing IR8 and IR5 rice varieties since the 1968/69 crop year. These two HYVs from the International Rice Research Institute (IRRI) were the first to be introduced to the Mekong Delta where they are known as *Than Nong 8* and *Than Nong 9*. *Than Nong* (TN) means God of Agriculture in the Vietnamese language. Due to good results, the area sown with *Than Nong* varieties increased rapidly from 23,373 ha in the first year to nearly one-third of the total rice area in 1973/1974. The IR8 variety was also widely propagated in 1969 in the north of Vietnam, where it was named *Nong Nghiep 8* (Agriculture 8), and it soon covered 50 per cent of the total rice area there. The release of IR8 and varieties with high resistance to brown plant hoppers biotype 1 (for example, TN73-1, TN73-2 and IR 30) were the highlights of this programme by 1975. Today, a total of 63 breeding lines from IRRI have been released in Vietnam, and they cover 70 per cent of the irrigated rice-growing area in the Mekong Delta (Lampe, 1995).

Box 3.1
Development of high yielding varieties in southern Vietnam

- The cooperation between IRRI and South Vietnam started in the late 1960s.
- The first varieties introduced to Vietnam were IR5 and IR8 in 1968-69 under a cooperative programme of the United States Agency for International Development and the Government of the former South Vietnam.
- From 1971, the rice research programme at Can Tho University, in collaboration with IRRI, started screening and selecting IRRI rice varieties, conducting adaptive trials, developing improved cultural practices and making recommendation for rice production.
- The first outbreak of brown plant hoppers occurred in Vietnam in 1974-75. In 1974, two rice varieties, TN73-1 and TN73-2 (formerly IR1529-6-80 and IR1561-22-8), were selected and released in the south to replace IR8 and IR5, which were being affected by brown plant hoppers. Other varieties resistant to brown plant hoppers, such as IR26 and IR30, were also distributed by Can Tho University. More than 400 breeding lines were introduced and evaluated nationally between 1972 and 1975.
- From 1975 to 1978, most areas in the Mekong Delta under HYVs were under heavy attack by brown plant hoppers, and many new lines were tested and released.
- Cuu Long Delta Rice Research Institute was established in 1977 to work on rice and rice-based systems in the Mekong Delta. The institute has a successful seed multiplication and distribution programme and produces about 500-750 tones of seed annually.
- During the 1980s rice research focused on the new varieties resistant to brown plant hoppers. IR36 became the most widely planted variety in Vietnam in the early 1980s.
- Dr Vo Tong Xuan introduced 300 breeding lines from IRRI to Vietnam in 1977, and a further 254 were introduced in 1991.
- From 1990, the research on HYVs concentrated on varieties providing high yield, brown plant hopper resistance, shorter growth duration, capacity to adapt to unfavourable conditions (for example, low temperature, acidity and salinity) and better quality.

Source: Xuan, 1995; Khush et al., 1995

In 1985, the country's rice development programme was sponsored by AusAID and other donors, who provided funds for collaboration with IRRI in all fields of rice research, training and extension services.

The significance of this collaboration programme with IRRI was manifested in the rapid spread of new improved varieties of rice throughout Vietnam. Today, high-yielding varieties are dominant in both irrigated and rain-fed rice systems throughout the country. Especially, in the Mekong Delta, many HYVs are providing high yields in acid sulphate soils (for example, TN108 and IR68) and saline soils (for example, IR42) of the rain-fed rice system. Box 3.1 summarizes some main developments in the adoption of HYVs in southern Vietnam.

Increase in cropping intensity

The second way in which the rice sector was modernized was through increase in cropping intensity. Cropping intensity has increased in all regions of the country, especially in the MKD, and contributed 38.4 per cent to the growth of rice production during the 1985-95 period (see Table 3.3). The growth in intensity was driven by increased cultivation during the dry season, especially in the Mekong Delta, made possible by the growing availability of water through irrigation. This implies that increased cropping intensity has led to intensive rice farming in areas most suitable to it and thereby leaving some land formerly devoted to rice to other crops. The increased use of HYVs has caused a decrease in the traditional rice acreage. As seen in Table 3.3, total rice area actually fell slightly from 1986 to 1995. That is to say, cultivated area contributed negatively to total production growth. Recently, farmers have been growing HYVs of short growth duration, around 85 to 100 days, in the winter-spring, summer-autumn and autumn-winter seasons.

In flooded areas of the MKD, where double rice cropping is practised, the building of dikes around a small geographical area (for example, a district or some villages) has helped farmers to increase cropping intensity. The dikes prevent rice fields from flooding before the summer-autumn rice is harvested. In the Mekong Delta, cropping intensity amounted to 1.65 in 1995 and 1.89 in 2000, which is higher than the average for the country (see Tables 3.2 and 3.3).

Table 3.3 shows the contribution of land area, cropping intensity and yield to the growth in rice production between 1985 and 1998. At the national level, increases in yields were the main factor, contributing around 50 per cent to the growth in rice production. Cropping intensity was second, responsible for 37.3 per cent of production growth. In the MKD, however, cropping intensity was the leading contributor (nearly

50 per cent) to production growth. Minot and Goletti (2000, Table 10) calculate that 65.7 per cent of the national rice production during the 1985-95 period was attributable to the MKD. All this indicates that yield improvement and increase in cropping intensity vary across regions of the country.

Table 3.3
Sources of growth in rice production, Vietnam and Mekong Delta, 1985-98

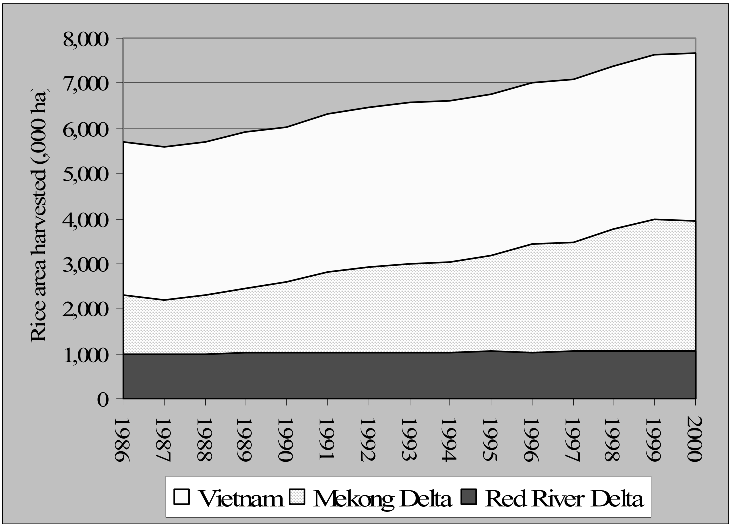
	Year			% change		% Contribution	
	1985	**1995**	**1998**	**85/95**	**85/98**	**85/95**	**85/98**
Vietnam							
Rice area ('000 hectares)	4,297	4,204	4,213	-2.2	-1.9	-3.8	-2.3
Cropping intensity	1.32	1.61	1.75	22.0	31.3	38.4	37.3
Yield (tonnes/ha/crop)	2.78	3.69	3.96	32.7	42.4	57.2	50.6
Interaction	-	-	-	4.7	11.9	8.3	14.2
Production ('000 tonnes)	15,874	24,964	29,146	57.3	83.7	100.0	100.0
Mekong Delta							
Rice area ('000 hectares)	1,974	1,936	2,062	-1.96	0.5	-2.3	3.6
Cropping intensity	1,14	1,65	1.82	44.5	59.8	51.0	48.6
Yield (tonnes/ha/crop)	3,05	4,02	4.07	31.8	33.4	37.0	27.1
Interaction	-	-	-	12.7	-	14.3	20.7
Production ('000 tonnes)	6,860	12,832	15,318	87.0	123.3	100.0	100.0

Note: Growth in rice production in the Mekong Delta calculated with Minot and Goletti method.

Source: Minot and Goletti (2000: 18, Table 9) for growth in national rice production.

Figure 3.2 shows the rice area harvested in Vietnam from 1986 to 2000. There is very small variation in the area harvested in the Red River Delta (RRD), which is around 1 million ha per year (see Figure 3.2). As only two rice crops can be grown per year there because of biological conditions, farmers grow other crops such as corn, vegetables or beans in the third growing season. The rice area expansion is also limited in the RRD due to competition for land created by urban and industrial development. In addition, as farmers allocated more land to vegetables and other crops to meet urban demand, there was little room for increasing rice cropping intensity (Minot and Goletti, 2000: 18-19). In contrast, some farmers in the Mekong Delta grow rice in the third season, increasing their annual harvest. In 2000, Mekong Delta rice farmers, with 2.083 million hectares of rice area, harvested a quantity equivalent to what would have been produced as a single crop on 3.946 million ha, which works out to a cropping intensity of 1.89. This means rice land is being used nearly twice a year for the region as a whole. In the RRD, cropping intensity in the rice area was around 1.82 in 2000. Thus, rice is cultivated intensively in the MKD as well as RRD.

Figure 3.2
Rice area harvested in Red River Delta, Mekong Delta and all Vietnam, 1986-2000



Source: GSO (1997-2002).

In 2000, Vietnam harvested a total of 7.666 million ha of rice area, which was 660 thousand ha more than in 1996. Rice production in 2000 was 32.529 million tonnes (GSO, 2002b) or double the amount in 1986, enabling Vietnam to remain the world's second-largest exporter of rice. However, natural calamities, namely flood, typhoons and drought, often restrict rice production and thereby rice yield. The northern part of the country is battered by tropical storms 6 to 10 times a year. In the MKD, annual flooding damages the summer-autumn crop in the rainy season.

High dependence on agrochemicals

The rice harvest also increased because of greater use of chemical fertilizers and pesticides per hectare. Green Revolution technology is generally considered to include chemical control for pests, fertilizers for plant nutrients, and high-yielding varieties (Greenland, 1997: 17) and the spread of HYVs in Vietnam was accompanied by greater dependence on agrochemicals. Increasing use of chemical fertilizers is also due to the falling urea/paddy price ratio (Minot and Goletti 2000: 15). Table 3.4 gives the fertilizer consumption per hectare between 1978/79 and 1998/99.

Table 3.4

Fertilizer consumption per hectare of arable and permanently cropped land in selected countries (kg/ha), 1978/79 – 1998/99

	Year				
Countries	***1978/79***	***1983/84***	***1988/89***	***1993/94***	***1998/99***
South-East Asia					
Indonesia	29	58	76	77	89
Malaysia	77	110	117	136	185
Myanmar	9	16	11	9	17
Philippines	34	37	51	57	63
Thailand	16	25	38	71	82
Viet Nam	52	57	92	126	269
Other Countries					
Bangladesh	39	61	82	115	141
China	108	159	195	190	259
India	30	46	65	73	99
Republic of Korea	392	331	411	474	458
Pakistan	44	59	80	100	112

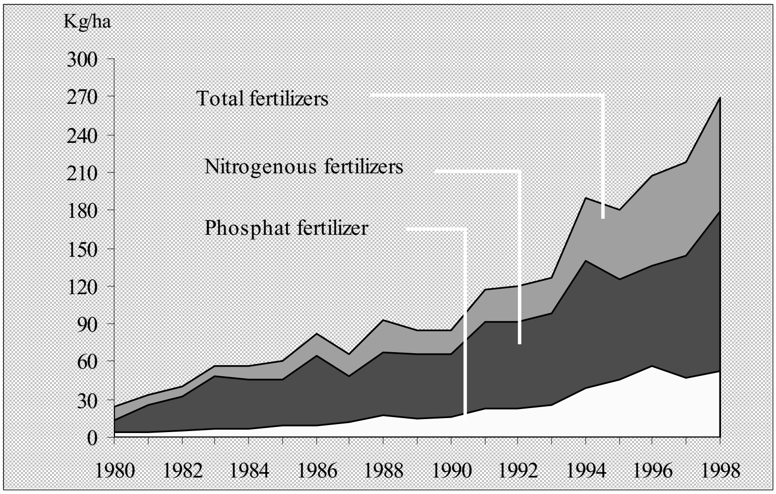
Source: FADINAP (July 2000).

The total amount of fertilizer used per hectare per year has approximately tripled from 92kg of NPK in 1988 to 269 kg in 1998. This is partly because of higher cropping intensity, at least in rice production, wide use of HYVs and increased purchasing power of farm households. Another contributing factor is that farmers have been able to make their own decisions about the amount of fertilizer to use since 1988 as collectives or cooperatives have lost their influence over them (see Chapter 4). The total amount of fertilizer applied per hectare per year in Vietnam in 1998/1999 was more than three times that in Thailand.

The increase in fertilizer use, however, is biased towards nitrogenous fertilizers, which accounted for 67 per cent of fertilizer applied in 1999 (see Figure 3.3). Though NPK nutrient requirements are not the same for all crops, this disproportionate increase implies that the application of phosphate and potassium has not kept up with the removal of those nutrients by the crops, and the efficiency of nitrogenous fertilizers may decline. Rice production, with the average use of NPK fertilizer at 170-200 kg per ha per season, accounted for at least 70-80 per cent of total fertilizer consumption in 1998 (MARD, 1998).

Figure 3.3

Fertilizer consumption Per unit of arable and permanent crops, 1980/99



Source: FADINAP (2001).

Table 3.5 displays the amounts of NPK nutrients used by rice farmers in Red River Delta and Mekong Delta per season.[4] An IFPRI survey in 1995/96 showed that the average use of chemical fertilizer was higher in the Red River Delta than in the Mekong Delta, for all seasons (IFPRI, 1996: 114). Organic fertilizers are also used more in the Red River Delta than in the Mekong Delta. In the north, rice farmers applied about 10 tonnes of farmyard manure per hectare per year towards the end of the 1990s, while no organic fertilizers, with the exception of burned rice straw, were used in the Mekong Delta (Dung et al., 1999). Surveys by the National Institute for Soils and Fertilizers have also shown that farmers in the north applied from 6 to 13 tons of farmyard manure per hectare per crop in different soil types (Hien and Thi, 2001: Table 13).

Table 3.5
Average NPK nutrients applied per hectare per rice season in Red River Delta and Mekong Delta

Location	N	P2O5	K2O	Total	Source
Red River Delta	116.8	56.8	58.2	231.8	Hien & Thi, 2001
Mekong Delta	109.4	48.9	32.6	190.9	Tan, 1999

Pesticide consumption per hectare also increased between 1991 and 1999 (see Table 3.6). The average annual quantity of active ingredient per hectare rose from 0.3 kg in 1985 to 1.01 kg in 1997. In the composition of pesticides, there has been an increase in the proportion of fungicides and herbicides, and a reduction of insecticide use. The reduction in the amount of insecticides is due to the integrated pest management programme implemented in Vietnam since 1992 (Hoe, 2000). The consumption of pesticides whose use is restricted was also significantly reduced over the past decade, from 7,500-8000 tonnes per year to around 1,000 tonnes per year.[5] Pesticides are used by most rice farmers as the main instrument for pest control. Vietnamese rice farmers account for 70 per cent of the insecticides, 82 per cent of the fungicides and 89 per cent of the herbicides used in Vietnam annually (Anh, 2000).

Table 3.6
Pesticide use in Vietnam, 1991-99

	Year								
	1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*
Pesticides ('000 M.T.)	20.3	23.1	24.8	20.4	25.6	32.7	30.4	42.7	33.7
Insecticides	16.9	18.0	18.0	15.2	16.5	17.4	15.4	19.4	-
Fungicides - bacteria & seed treat	2.6	2.5	3.6	3.3	3.4	9.0	7.1	9.6	-
Herbicides	0.8	3.7	3.7	2.8	4.9	7.7	7.6	13.7	-
Pesticide used per hectare (kg a.i./ha)	0.67	0.77	0.82	0.68	0.85	1.08	1.01	-	-
Restricted pesticides ('000 M.T.)	7.5 - 8.0	7.5 - 8.0	7.5 - 8.0	3.0	3.0	3.0	2.5	1.5	1.0

Source: Plant Protection Department, Vietnam.

3.2.3 Declining growth in rice yield

By raising rice production and yields, Vietnam has been able to overcome the food crisis and create a surplus for exports. Continued and stepped-up agricultural growth to meet internal demand while remaining important in international export markets will require even more intensification. However, the overall picture of rising average yields and production in Vietnam has tended to camouflage evidence of stagnating or even declining growth in yields. Table 3.7 shows that the growth in rice yield during 1995/2000 was less than half that during 1980/85.

The slowdown in yield growth is also visible in most Southeast Asian countries despite some recovery in the 1995/2000 period in some countries like the Philippines and Myanmar. The situation is even worse in Thailand, where rice yield growth has been negative. Vietnam and Thailand are the two biggest rice exporters in the world and so the consequence of this decreasing growth in yield and production may raise world prices and affect the demand of rice consumption in other countries. Since Vietnam's fertilizer application rates in 1998/99 (see Table 3.4 above) were higher than, or nearly the same as, the amounts applied in most other rice-growing countries, the potential for rice yield improvements in Vietnam seems to be threatened without development of new HYVs.[6]

Table 3.7
Annual rice yield and production growth in Vietnam and selected countries, 1980-85 – 1995-00 (%)

Countries	Yield growth				Production growth			
	1980/ 85	***1985/ 90***	***1990/ 95***	***1995/ 00***	***1980/ 85***	***1985/ 90***	***1990/ 95***	***1995/ 00***
Indonesia	3.9	1.8	0.2	0.4	6.3	3.1	2.0	0.5
Myanmar	2.1	-0.9	0.3	2.4	1.5	-0.5	5.7	2.3
Philippines	3.4	3.0	-1.2	2.9	3.0	2.5	1.3	3.7
Thailand	1.8	-1.0	4.7	-0.7	3.3	-3.0	5.6	1.3
Vietnam	6.8	2.9	3.1	2.7	7.3	4.2	6.0	5.6

Source: Calculations based on data from FAOSTAT (2001).

The rice yield growth in Vietnam has been fluctuating over time, especially in the Red River Delta, because of changes in natural conditions (for example, drought, rainfall and flooding). In 1991 and 1994 the yield fell so low that there was almost 15 per cent negative growth in comparison with previous years. Increases in 1992 and 1993 brought growth rates to 35 per cent and 17.25 per cent, respectively. Rice yields in the Mekong Delta have also fluctuated over time, but less so than in the Red River Delta (see Table 3.8).

Table 3.8 shows that yield growth has been higher in the Red River Delta than in the Mekong Delta since 1995. This may be due to the effects of farmyard manure and phosphorus fertilizers in the Red River Delta, differences in rice varieties, and a higher rate of fertilizer use. Chinese rice hybrids were planted on about 40,000 ha in the Red River Delta in 1993, yielding an average of 7 tonnes per hectare per crop, while in the Mekong Delta farmers did not grow such varieties. Because of the good yield, the national government planned to increase the area planted with hybrid rice in northern Vietnam to 500,000 ha by the year 2000 (Luat et al., 1995). In the Mekong Delta, the negative or near-zero growth in rice yield from 1995 to 1999 (except in 1998) indicates that further improvement is difficult with the current HYVs in the already-intensive rice monoculture system.

Table 3.8
Rice yield growth in Red River Delta, Mekong Delta and all Vietnam, 1986-2000 (%)

Year	Country Vietnam	Red River Delta	Mekong Delta
1986	1.08	-4.35	1.44
1987	-3.94	0.35	-5.48
1988	9.85	16.38	12.48
1989	8.53	7.49	10.56
1990	-1.01	-3.34	1.13
1991	-2.39	-14.41	0.36
1992	7.10	34.68	1.51
1993	4.42	17.25	-1.23
1994	2.42	-14.50	7.91
1995	3.48	10.72	0.80
1996	2.14	5.86	-0.19
1997	2.86	3.40	-0.87
1998	2.11	5.56	2.37
1999	3.70	5.85	0.25
2000	3.29	2.84	4.23

Source: GSO (1987-2002).

To summarize, the intensification of rice production in Vietnam. Is characterized by wide adoption of HYVs, increase in cropping intensity and high dependence on agrochemicals. While production and rice yield growth have slowed, the total amount of fertilizers and pesticides applied per hectare per year has increased noticeably. The stagnation in and fluctuation of rice yield growth, especially in the Red River Delta, created variability in total rice production during the 1986-2000 period (see Table 3.8).

3.3 Rice environment in Mekong Delta

The Mekong Delta has a rich in agricultural resource endowment and is an important supplier of agricultural products for export. The region is perceived as being dynamic and open to diversification and commercialization. Among the rice-growing regions in the country, it is the biggest in terms of cultivated area, cropping intensity, production and export volume. In technical terms, the growth and development of the rice crop depends mostly on the biophysical conditions, such as water, soil quality, temperature, and pest population, in which it is grown. The region's climatic conditions, soil and water regimes offer many advantages for rice production. This section provides an overview of the biophysical conditions and rice farming systems in the Mekong Delta as an essential background for understanding the biophysical basis of sustainability of rice farming, in particular regarding the use of agrochemicals.

Biophysical conditions

Biophysical factors and their characteristics play a vital role in forming the highly productive production systems in the Mekong Delta. Among these factors, soil and water conditions present both potential for and constraints to expansion of agricultural land and production.

Soil characteristics

The Mekong Delta is an alluvial flood plain, formed of coarse as well as fine sand deposited by the mighty Mekong River that has its origin in the Tibetan highland plateau 2,800 miles away. From its source, the river makes its way through China, Myanmar, Laos, Thailand, Cambodia and South Vietnam before flowing into the South China Sea. The Vietnamese name of the Mekong, Cuu Long, means Nine Dragons. It symbolizes the nine mouths that terminate the flow of this great river as it is absorbed by the sea. The process of soil deposition occurred over centuries, and eventually formed different soil types in the Mekong Delta. According to the Mekong Delta Master Plan study (NEDECO, 1993) there are seven main soil groups:

- Alluvial soil accounts for approximately 30 per cent of the total area of the delta (1.2 million ha) and constitute one-third of the alluvial soil area in the country. The soil is made up of fine particles and is fertile, usually retaining sufficient nutrients to be productive.

- Acid sulphate soil makes up 40 per cent of the total delta area. They have a weak physical structure and contain high levels of potentially toxic elements as well as high concentrations of acid that is harmful to rice growth. The pH values range from 2.26 to 3.54, posing a great constraint to rice cultivation.
- Saline soil is found along the coast of the China Sea and the Gulf of Thailand and they comprise 17 per cent of the total delta area. A high content of sodium chloride and the effect of salinity intrusion through rivers and canals in the dry season restrict the use of saline soils in rice production.
- The other four types are grey and mountainous peat soils suitable for upland crops, and soils not suitable for agriculture.

Large areas of acid sulphate soil, which has little agricultural possibility, limit the potential for expanding agricultural land. Of the above soils, alluvial soil is the best for rice production due to its physical, chemical and biological features, including water movement and ability to retain water. In the Mekong Delta, intensive rice production and high yields are often observed in alluvial soil. In both saline soil and moderately and slightly acid sulphate soil, farmers grow either traditional rice or HYVs tolerant to salinity and acidity only once during the rainy season.

Climate and hydrology

Water is one of the most critical factors influencing rice productivity. Rice originated as a wetland crop and it remains more sensitive to water deficiency than most other crops. These features are discussed at length in Greenland (1997: 141-7). The supply of agricultural water in the Mekong Delta comes from rainfall and irrigation. Rainfall distribution is uneven, varying geographically and seasonally. Seasonal distribution of rainfall is influenced by the prevailing climate. The Mekong Delta is entirely within the tropical monsoon zone. The temperature is rather stable around the year, ranging from 24.50°C to 270 °C, favourable for most paddy rice varieties. The average annual precipitation is about 1,600 mm and is distributed quite differently between the two monsoon seasons: northeast winter monsoon and southwest summer monsoon.

The southwest summer monsoon, which is referred to as the rainy season, is from May to October and accounts for about 90 to 94 per cent of the total annual rainfall. The dry season is for six months, from November to April, with a precipitation of only 100-200 mm. Both the timing as well as uneven distribution of rainfall between the two seasons have great influence on rice yield and production. Heavy rain during the rainy season causes flooding in the rice fields and affects the development and quality of rice grain. Conversely, little rain in the dry season improves the grain quality but creates a need for irrigation water. This explains why the rice yield is lower in the summer-autumn (rainy) season than in the winter-spring (dry) season, even though the varieties planted are similar.

The Mekong River is a major source of water supply during the dry season, but the river also causes serious flood damage to poorly drained areas every year. The water regime in the Mekong Delta is influenced by the flow of the Mekong River, the diurnal tidal movement of the South China Sea, and the semi-diurnal tidal movement of the Gulf of Thailand. Once the rains have started, the Mekong River gathers water from hilly and mountainous areas of upstream countries (China, Myanmar, Laos, Thailand and Cambodia) as well as from the high precipitation and overflows both banks. The flood waters inundate the land to a depth of 0.3 to 3 metres.[7] Rice fields are filled with flooded water for two to four months, depending on local conditions. In contrast, in the dry season, the flow of the Mekong River is too low, varying between 2,000 and 6000 m^3 per second. The precipitation is less than the evapotranspiration and the soil moisture is almost depleted. This results in salinity intrusion (NEDECO, 1993). During the dry season, the salinity intrusion particularly affects the Ca Mau peninsula as well as the partly coastal areas of the delta; hence, rice cultivation is impossible in this season.

Rice-based production systems in the MKD

The formation and development of rice production systems in the MKD delta is determined by biophysical conditions and socioeconomic and cultural factors. The terms 'production system' and 'farming system' are used alternatively in this study to describe agricultural activities performed by farmers in the MKD. According to Altieri (1987: 43), a system is characterized by the skills and structures of production activities in conjunction with the biophysical, socioeconomic and cultural conditions of the region. Thus, each region has a unique set of farming systems. Farming systems can be recognized through their field constructions, crop and animal components, the structure of the farm economy, the form of residential settlement, and so on (Son, 1998). This section briefly describes current rice-based production systems in the Mekong Delta.

Floating rice system

Rice cultivation in the Mekong Delta can be traced back to the Nguyen dynasty (1705-1858).[8] Floating rice-cropping was first developed during this period and further expanded under the French colonial regime (1858-1945) through canal excavation. In those days, floating rice was grown in the Long Xuyen quadrangle and in the Plain of Reeds. This cropping pattern is practised less and less due to an unattractive level of productivity and development of other farming systems. Floating or tidal rice is the only food crop that can be grown during the rainy season in unbundled fields on the flood plain or tide-affected flood areas. It is still grown in a small area under heavy flood conditions in An Giang province (Sanh et al., 1998). Rice is sown or transplanted before the floodwaters rise; it flowers about the time of maximum water depth and is harvested between December and January. This traditional rice-cropping pattern is known to need very low inputs. Fertilizers are seldom used and productivity is mainly determined by the water regime and soil conditions. Yields are usually low, ranging about 1.0 to 2.5 tonnes/ha.

Rain-fed rice system

The rain-fed rice system is yet another old cultivation method in the Delta, covering a wide area where annual precipitation makes the rice production possible. Traditional rice is grown in fields lacking sufficient water control systems, with floods and drought being potential problems. Productivity in this system is dependent to a significant degree on rice varieties used, given the soil and precipitation. Yields of local rice varieties adaptive to local soil conditions (for example, acid sulphate or saline soils) are low, about 2 to 2.5 tonnes/crop/ha. However, some local rice varieties (for example, *Nang Thom*, *Nang Huong* and *Tai Nguyen*) are grown in alluvial soil and have a higher yield, ranging from 3.0 to 5.0 tonnes/crop/ha. High-yielding varieties with a long growth period (for example, IR8 and IR 42) are also grown in the rainfed system, providing yields of 4.0 to 5.5 tons/crop/ha. Local varieties do not respond as well to higher fertilizer application as do HYVs, so farmers apply low level of fertilizer in this system. Traditionally, farmers grow only one crop a year, from May to August, and harvest it between December and January. Improvement of infield canal systems, farming practices and crop establishment now enable farmers to add an extra crop: rice, mung bean, corn, soybean or vegetables.

Irrigated rice system

The introduction of high-yielding varieties with a short gestation and growth period began in the late 1970s. As irrigation became available, farmers abandoned their traditional farming systems in favour of intensive rice systems and started using more agrochemicals. Data on land use in the Mekong Delta shows the trend in rice production intensification, decline of a single rice crop system and rapid increase in double and triple rice crops, which rose by almost 100 per cent between 1985 and 1995, from around 573,000 ha in 1985 to 1.1 million ha (see Table 3.9).

Intensive rice farming is found in nearly all areas along the Mekong River where irrigation water is available. Irrigated rice is grown in puddle fields with assured irrigation for one or more crops a year, especially in the dry season. In general, these areas are free of serious flood or soil problems. Farmers follow a highly diversified system and grow from two to three crops per year or even seven crops over a period of two years. However, rice intensification is dominant and agrochemicals are applied at a high rate while labour input is kept low (Son, 1998). The yields from irrigated rice production are quite high, with an average of more than 5.0 tonnes/crop/ha. Rice grown in the winter-spring season provides the highest yield due to favourable weather, with an average of 6 tonnes per hectare.

Rice-livestock farming systems

These systems are found in all agro-ecological zones in the MKD. By-products from rice production such as rice bran and straw are used for livestock production. According to Sanh et al. (1998), about 82 per cent of the farmers raise pigs and 15 per cent raise chickens. Duck raising is also practised in the rice fields. Baby ducks can feed on snails and insects in the rice fields at the tilling stage; then, after the harvest, ducks can feed on seeds and grains that have fallen to the ground. The MKD had 20 per cent of the country's poultry in 2000 (GSO, 2002b). Weeds, grass, rice straw, corn culms, sugarcane tops and other byproducts are used to feed cows and buffaloes. Livestock production helps farming households to make full use of family labour and agricultural byproducts and is an important source of income.

Table 3.9
Land use in Mekong Delta ('000 ha)

Types of land use	Year				
	1985 (a)	*1990 (a)*	*1995 (a)*	*1998 (b)*	*2000*
Agricultural land	2,441.9	2,462.3	2,612.2	2,918.9	2,970.3
I. Annual crops	2,130.9	1,971.1	2,106.0	2,228.2	2,226.3
1. Rice & upland crops	1,973.8	1,826.8	1,936.0	2,067.2	-
Triple crops	4.2	10.2	239.0	-	-
Of which rice	1.1	6.6	139.3		
Double crops	6,14.5	926.1	1,056.5	-	-
Of which rice	572.1	926.1	961.7		
Single crop	1,355.0	890.5	640.5	-	-
2. Upland crops & cash crops	156.0	144.3	170.0	160.9	-
II. Perennial crops	272.8	347.8	326.0	332.5	397.3
III. Pasture & Meadows	-	1.3	1.0	0.14	0.18
IV. Land for Aquaculture	32.2	145.4	180.2	208.2	229.3
V. Other Agricult. Land	-	-	-	149.7	117.3
Forestry land	339.5	348.7	285.6	297.7	337.7
Land for special use	277.9	359.0	-	205.1	223.5
Other land	906.4	757.8	623.4	543.2	-
Unused land	595.0	459.5	434.4	227.6	338.4
Total area	*3,965.8*	*3,957.2*	*3,955.5*	*3,965.3*	*3,971.2*

Note: Total area excludes islands.
Sources: (a) NIAPP (National Institute of Agricultural Planning & projection);
(b) SUB-NIAPP.

Rice-shrimp farming systems

These systems have been practised for more than 50 years in coastal areas of Soc Trang (Sanh et al., 1998), Tra Vinh, Ben Tre, and Bac Lieu and Ca Mau provinces. Many farmers have changed from monoculture systems to rice-shrimp systems or shrimp systems. Thanh (2002) conducted a survey in four coastal provinces and found that 50 per cent of the farmers practised the rice-shrimp system. The adoption of the system increased the use of labour and capital, productivity of land, labour and fertilizers. The most significant feature is that insecticides were rarely applied by 95 per cent of the farmers. Thus, the system helps reduce the use of pesticides. Both rice and shrimp products improve the income of farming households. However, water pollution and salinity continue to be a great concern in rice-shrimp systems (Thanh, 2002).

Other production systems

Besides the dominant rice production systems, many other types of cultivation are also practised in the Mekong Delta. The land area given to fruit trees such as coconut, durian, orange, pineapple, mango and banana has increased gradually. In the year 2000, the area planted with fruit trees in the MKD was 206,300 ha, a 17 per cent increase from 1996 (GSO, 2002b). Coconut palms, found in all MKD provinces, accounted for 78 per cent of the total national coconut area and 75 per cent of production in Vietnam in 2000 (GSO, 2002b). Mango, banana and pineapple also occupy a large area (see Table 3.10). In spite of the rapid expansion of fruit trees, services such as storage, manufacture and marketing are underdeveloped. Furthermore, some fruit varieties, especially citrus trees (orange, mandarin orange and lemon) are threatened by various diseases and are of low quality. Thus, more improvements in both technical and economic factors are needed.

Various annual and industrial crops such as soybean, mung bean, sesame, corn, vegetables, sugarcane, and so on are planted in rotation with rice. Aquaculture production systems have expanded considerably. Fish and shrimp are raised widely in ponds, rice fields and rivers. Fish farms in the MKD account for 71.3 per cent of the country total; of them, about 1,265 farms are 5 hectares and play a leading role in commercial aquatic production (GSO, 2003a). The 2001 rural, agricultural and fishery census found that shrimp farming households in the MKD account for 82.5 per cent of the total shrimp farming households in the country.

In conclusion, the Mekong Delta faces three major problems relating to water and land resources: the acid sulphate soil problem, saline intrusion and severe flooding. The climate of the delta varies between the dry and wet seasons. Both saline intrusion and lack of precipitation are features of the dry season. Prolonged and uncontrolled floods occur in the rainy season. The high level of acidity in sulphate acid soils and sodium chloride in saline soils limit the rice yield and expansion of the rice area during the dry season. In irrigated areas, which include almost alluvial soils and part of moderately and slightly acid sulphate soils, rice is cultivated with double or triple cropping systems, depending on the level of flood control and drainage /irrigation. The development of rice farming systems is mostly influenced by soil and water conditions. Rice is grown in all the 12 provinces of the MKD, in different soil types, providing variation in rice yield. Rice productivity in acid sulphate soil and saline soil is lower than in other soils. Therefore, NEDECO suggests that a proportion of the land reclaimed for rice cultivation be converted to inland-forest, which is more profitable and sustainable. The expansion of rice cultivation in the dry season may only reach 500,000 ha due to lack of water (NEDECO, 1993).

Table: 3.10
Area covered by other crops/trees in Red River Delta and Mekong Delta, 2000 (ha)

Regions	Fruit trees	Citrus trees	Mango	Coconut	Banana	Pine-apple
RRD	58,300 (0.28)	6,018 (0.17)	174 (0.00)	385 (0.00)	17,889 (0.57)	2,064 (0.09)
MKD	206,300 (0.38)	34,783 (0.51)	46,782 (0.46)	125,544 (0.78)	31,277 (0.32)	22,787 (0.62)
Vietnam	*544,700*	*68,614*	*102,126*	*161,345*	*98,366*	*36,541*

Note: Figures in parentheses are region's other-crop/tree area as a percentage of the total national other-crop/tree area.
Source: GSO (2002b).

3.4 Farmers and their livelihood in MKD

The Mekong Delta is one of the two most populated areas in Vietnam, with a total population of 16.7 million people at the end of 2002, of whom 81.1 per cent live in the rural areas. Of the population, 17.2 per cent are poor, which is not among the highest percentage. Northern Uplands has 22.2 per cent and North Central Coast has 0.4 per cent (GSO 2002a). However, the MKD's large population means that the absolute number of poor is relatively high. This section outlines the standard of living of farmers and socioeconomic conditions of rural households in the Mekong Delta as a prelude to providing a more detailed socioeconomic context for the chapters that follow.

3.4.1 Economic structure, the poor and poverty

Agriculture dominates the economy of the MKD. In 2001, 72.8 per cent of rural households were engaged in agricultural activities, of which 88.3 per cent were devoted fully to agriculture and 11.7 per cent were engaged in non-agriculture activities (GSO, 2003a). Though there has been a tendency for labour to move from agriculture to manufacturing and services sector to earn a higher income, most rural households (81.0 per cent) derive their main income from the primary sector (agriculture, forestry and fishery). Within the agricultural sector, the total output value of households mainly comes from crop cultivation (81.3 per cent), of which 81.8 per cent are annual crops. The findings of a poverty analysis by AusAID suggest that the poverty rate by province in the MKD has a positive correlation with the provincial share of population reliant on agriculture and the share of agriculture in total provincial GDP. In other words, the more the dependency on agriculture, the higher the poverty rate (AusAID, 2003).

The vast majority of the poor in Vietnam lived in rural areas in 2002.[9] Most rural households are poor. This is also true in the MKD, where the rural poor comprise 96 per cent of the region's total poor. During the 1992-98 period, the MKD experienced slower poverty reduction and income growth than the rest of the country. However, GSO (2002a) indicates that between 1998 and 2002, the MKD managed to reduce poverty from 37 per cent to 23 per cent, while other regions experienced a slower pace of poverty reduction. Some of the explanations for the reduced poverty in the MKD were government policies, non-agricultural job expansion, low inflation, improved infrastructure, price stability and improved terms of trade for agricultural products.

In 2002, over 77 per cent (lower than the national average of 84 per cent) of the poor people in the Mekong Delta were employed in agriculture, forestry or fishery, whereas just 9 per cent were employed in the industrial sector and nearly 13 per cent in services. In addition, households working in the primary sector have the highest poverty incidence, 27.8 per cent (see Table 3.11). A large proportion of rural poor households are engaged solely in paddy cultivation (AusAID, 2003).

Table 3.11
Poverty among labour force, 15 years and older, who have had a job in the past 12 months, by main sectoral occupation (%)

Occupation	**Poverty incidence**		**Share of total poverty**		**Share of population**	
	Vietnam	***MKD***	***Vietnam***	***MKD***	***Vietnam***	***MKD***
Agriculture, forestry, fisheries	38.9	27.8	84	77.6	58.7	62.4
Construction	15.3	13.2	8.5	8.7	17.0	12.9
Services	9.9	13.4	6.4	12.8	18.6	20.3
Other	4.9	3.7	1.1	0.9	5.7	4.4
Total	27.6	22.0	100.0	100.0	100.0	100.0

Source: GSO (2002a)

Table 3.12
Landlessness in rural areas, 2002 (%)

Year and Quintile	**Vietnam**	**North Mountain**	**RRD**	**N. Central Coast**	**S. Central Coast**	**Central Highlands**	**Southeast**	**MKD**
1993	8.2	2.0	3.2	3.8	10.7	3.9	21.3	16.9
1998	9.2	0.5	3.3	8.0	2.0	2.6	23.5	21.3
2002	18.9	4.8	13.9	12.2	19.6	4.3	43.0	28.9
Poorest	11.0	1.0	7.0	8.0	9.0	3.0	31.0	39.0
Near poorest	14.0	2.0	5.0	8.0	18.0	3.0	40.0	30.0
Middle	17.0	6.0	11.0	13.0	15.0	5.0	35.0	26.0
Near richest	23.0	12.0	15.0	22.0	27.0	7.0	41.0	25.0
Richest	38.0	25.0	43.0	25.0	45.0	11.0	59.0	28.0

Source: Vietnam Human Development Report 2004, p. 39.

Landlessness in the Mekong Delta has increased from 16.9 per cent in 1993 to 28.9 per cent in 2002 (see Table 3.12). This is one of the most urgent issues that need to be tackled and it is the main obstacle to poverty reduction (AusAID, 2003). However, the severity of landlessness varied among geographical regions and poor quintiles. Cross-regional comparison reveals that the Mekong Delta region ranked second in terms of the percentage of rural landless in 2002.

There are many reasons why farmers sold their land and became landless. In the areas near towns or cities, farmers sold their low-productivity land for expansion of industrial and other infrastructure development to get a relatively large amount of money. In the rural areas, farmers with few skills and low returns from production sold their land to richer farmers to cover debts resulting from many poor seasons. Farmer who mortgaged and sold their land did not often understand the seriousness of their action and became landless farmers, earning their living as hired workers. Thus, landlessness is more prevalent in the poorest and almost poorest quintiles, accounting for about 39 per cent and 30 per cent of the two groups, respectively.

3.4.2 Characteristics of rural households

Educational levels

Education is an issue of concern in the Mekong Delta, where people aged 15 years and above in the labour force are the least educated in comparison with other regions: 45.9 per cent have not finished primary education, compared with the national percentage of about 27.5 per cent (GSO, 2002a). The proportion of the labour force with vocational, colleges/university and higher education is also the lowest in comparison with other regions. Despite a large network of schools at the village and hamlet levels, the dropout rate is very high.

There are several reasons for this. In 82.6 per cent of the villages surveyed, household income problems and the high cost of education are the main reasons for students dropping out of primary schools. At the high school level in 46.0 per cent of the villages surveyed, it is the failure of parents to recognize the importance of education that restricts school intake and leads to students dropping out. This phenomenon has been prevalent in the Mekong Delta for many years. Parents with low education often underestimate the importance of and returns from education. An insufficient level of basic education constrains farm workers from acquiring new skills and technologies for improving productivity, and limits opportunities for higher income from non-farm activities. Thus, poverty is mostly found among those with a lower education level and non-vocational training. Farmers are the main labour force in the rural areas, and to overcome the serious problem of low education, appropriate training has been made available to them since 1992 to help them become better farms managers (see Chapter 4).

Ownership of durable assets

The distribution of durable assets (for example, refrigerators, motorcycles, water pumps, computers, television sets and telephones) among rural households is highly unequal. The average value of such assets in 60.0 per cent of agricultural households having these goods is the lowest of all regions. The total value of durable assets in the rural areas nationally in 2002 was VND 4.796 million, which was approximately one-third the value of durable assets owned by industrial and commercial households. In view of the MKD being the biggest rice-growing region in the country, it is astonishing to find that the proportion of households owning rice-milling and threshing machines is far below that in other main rice growing regions (Red River Delta and the South Central Coast).

In terms of housing, about 54.0 per cent of the households in the MKD live in temporary structures constructed of leaves and bamboo or other simple materials, which often require repairs and have to be replaced every year. This figure is about twice that of the Central Highland region (28.2 per cent), which has the second-highest figure in the south. It is also more than double the national figure (24.6 per cent). The problem is more severe among the poor (70.0 per cent) and households headed by people with a low level of education (48.5 per cent) (GSO, 2002a).

Income sources and expenditure

GSO (2002a) found that in the year 2000 the Mekong Delta had the third-highest mean per capita income and expenditure in the country, behind the Southeast and Red River Delta. Per capita monthly income in the Mekong Delta was about VND 371.3 thousand (at current prices), which was similar to that in the Red River Delta. The main source of income was agriculture (27.1 per cent) followed by wages (25.0 per cent). The income of the richest was 6.81 times that of the poorest. During the 1998-2002 period, growth in per capita expenditure was faster in rural areas (26.0 per cent) than in urban ones (7.0 per cent), whereas nationally it was 13.0 per cent. The increase in real expenditure per capita in rural areas may explain the reduction of poverty in the Mekong Delta (UNDP, 2004). Approximately 61 per cent of the average monthly income per capita was spent on food, foodstuffs, cooking fuel, drink and tobacco, with foodstuffs having the biggest share (32.2 per cent). Among foodstuffs, 14.4 per cent was spent on fishery products. As mentioned earlier, parents with low education in rural areas in the Mekong Delta do not see the value of sending their children to school; hence, the expenditure on education was only about 4.3 per cent of the monthly income per capita, the second-lowest among all the regions.

3.4.3 Infrastructure and environment

Infrastructure

The transportation infrastructure serving farms is not very developed in the Mekong Delta. Agricultural products and other goods are transported mainly through a network of canals and rivers. Road transportation is poorly developed. About 78.2 per cent of villages and hamlets have roads passable by car to village centres. Around 36.9 per cent of these roads are mostly constructed of sand and small stones. Findings AusAID (2003) observes that areas with better access roads have lower transportation costs and higher profits from market sales of agricultural products and inputs, and that provinces with more developed road infrastructure have lower poverty rates.

Irrigation infrastructure plays an important role in expanding the rice growing area and increasing the productivity of agricultural land in the dry season. The total irrigated area in the Mekong Delta in 2000 was 3,203,587 hectares, representing about a 7 per cent increase from 1996. Small irrigated systems enabling self-flowing irrigation account for 24.0 per cent of the total irrigated rice area in the dry season and they help to reduce the cost of production significantly.

In 38.4 per cent of the villages surveyed, water for drinking and cooking in the dry periods comes mainly from ponds, canals and rivers. Only 0.17 per cent of villages have access to purified drinking water. Although the proportion of households having access to clean water (not including dug wells and surface water) is now higher than in the country as a whole (54.6 per cent compared with 48.5 per cent), the situation varies considerably according to the living standard quintiles. While about 40.0 per cent of the people in the lowest two quintiles have access to clean water, the figure for the highest income quintile is over 70 per cent. Poor access to clean water causes big health problems for rural people (GSO, 2002a).

Environmental and health problems

Natural environmental problems such as soil conditions and annual flooding were outlined in the previous section. We shall now focus on water pollution and salinity in the Mekong Delta, which are mostly created by human activities. Water source pollution is quite severe and mostly visible. Many local people prefer to live along canal banks for easy access to surface water and waterway transportation. Human waste is directly discharged into the canals, especially during flooding, due to lack of appropriate toilets. Pesticides and chemical fertilizers, which easily drift along the water flows from paddy fields almost throughout the year, have made water pollution an even more serious problem. However, the level of pollution and environmental damage has not been quantified formally.

Because of poor hygiene and environmental conditions, the incidence of waterborne diseases is also very high in the region. According to GSO (2002a), 21.3 per cent of the population had access to hospitals and health care centres in 2000, which was higher that the national average. The average annual expenditure for inpatient care was VND 1.451 thousand, the second-highest among the regions. The average annual per capita cost of medical and health care was VND 83.4 thousand, also the second-highest among the regions. This cost represented about 22 per cent of the average annual income per capita. It is important to note that the total expenditure on health problems should include not only this high cost of health care, but also loss of work time for patients and their caretakers, and the willingness- to-pay value to avoid illness.

3.4.4 Progress towards achieving national development goals

The above discussion has provided a general picture of socioeconomic conditions in the Mekong Delta. Although the percentage of poor people in the Mekong Delta is relatively low, ranking sixth among the regions, its large population means that the number of poor people is high. According to GSO (2002a), the Mekong Delta has made significant strides in economic development and poverty reduction. However, most of the goals of the Comprehensive Poverty Reduction and Growth Strategy for 2001-10s have not been achieved yet. The strategy sets out a priority direction for 2001-05 in seven sectors, which are summarized in Table 3.13.

Table 3.13
Progress of Mekong Delta towards achieving national development goals

Indicator	National goals	Status
Poverty rates	Reduce poverty rate according to international standard by two-fifths; and according to national targeted poverty reduction programme's poverty line by three-fifths (2001-2005)	Only 4 provinces have achieved goal, 4 are close and 4 will have difficulty meeting target
Electricity access	Expand national transmission grid to 900 poor village centres by 2005	Close to CPRGS goal for communes, but still far from universal access by households
Road access	80% of poor villages with car-accessible roads leading to village centres	Still low for region as a whole due to high reliance on waterway transport, especially in provinces further to south
Urban unemployment	Reduce urban unemployment rate to about 5.5% in 2004	Close to goal of 5.4% for all provinces in region
Rural underemployment	Increase rural working time utilization of people of working age to about 80% by 2005	No province has achieved goal, but all are above 70%.
Primary enrolment	Increase primary school net enrolment to 97% by 2005	6 provinces have primary enrolment exceeding 90%. One exceeds goal of 97%.
Lower secondary enrolment	Increase lower secondary school net enrolment to 80% by 2005	No province has achieved 80% enrolment
Literacy for women aged <40	Eliminate illiteracy for 95% of illiterate women aged under 40rn by 2005	Half the provinces have achieved goal
Infant mortality rate	Reduce infant mortality rate to 30% by 2005	According to 1999 Census, only 3 provinces achieved goal.
Child malnutrition	Reduce malnutrition of children under 5 to 25% by 2005	One province has achieved the goal, 3 are close.
Birth rates	Maintain reduction in the birth rate	4 provinces have achieved target fertility rates.

(Continued)

Indicator	National goals	Status
Contraceptive prevalence rate	N/A	Use of modern contraceptives is low overall, although unwanted pregnancy is less of a problem than in other regions
Assisted delivery	N/A	Over 90% of women have assisted delivery in half the provinces; this is higher than national figure
VTV and VOV	More than 90% of households should receive Vietnamese TV programmes and Voice of Vietnam radio.	No province has achieved TV and radio goals
Clean water	Give 80% of urban and 60% of rural population access to clean and safe water by 2005	10 provinces achieved urban goal and 7 rural goal
Sanitation	N/A	In 2 provinces, more than 20% of households have proper sanitation.
Temporary housing	No slums and temporary houses in urban areas by 2010	In all provinces, over 20% of urban households live in temporary structures.

Sources: National goals are from 'Comprehensive Poverty Reduction and Growth Strategy for 2001-2010' (Hanoi, 2002); status of progress is from UNDP 2004.

3.5 Concluding remarks

This chapter has provided basic information on the development of rice production in Vietnam. The intensification of rice production has been characterized by wide adoption of HYVs, increase in cropping intensity and high dependence on agrochemicals. While production and rice yield growth have slowed, total amounts of fertilizers and pesticides applied per hectare per year have noticeably increased.

The Mekong Delta, known as 'the rice bowl of the country', is the biggest rice-growing region in terms of cultivated area, cropping intensity, production, and rice export volume. Though the region is considered to be rich in agricultural resources, it faces three major problems relating to water and land resources: acid sulphate soil, saline intrusion and severe flooding. In irrigated areas, rice is cultivated with double or triple cropping systems, depending on the level of flood control and drainage/irrigation conditions. While the agricultural production systems are characterized as rice-based production systems, perennial and fruit tree systems have also been developed and occupy a significant proportion of the total planted area in the country. Fishery farms in the MKD account for 71.3 per cent of total fishery farms in the country and play a leading role in aquatic commercial production. In addition, shrimp farming is also carried out in provinces along the coast, accounting for more than 80.0 per cent of total shrimp farming households in the country.

The main source of household income is agricultural production, in which income from rice production is the most important, especially for the poor. Though there have been significant achievement in poverty reduction between 1998 and 2000, the absolute number of poor people is still high in the Mekong Delta. The poverty incidence is further aggravated by the low level of education of the labour force. Insufficient basic education is among the factors constraining farm workers from acquiring new skills and technologies for improving productivity, and restricting opportunities for higher income from non-farm activities. Thus, poverty is mostly found among those with lower basic education and non-vocational training. Increasing landlessness is one of the most urgent issues that need to be tackled and is the main obstacle to poverty reduction in the Mekong Delta. Landlessness is more prevalent among the poorest and almost poorest quintiles

Water pollution and salinity are perceived by households as major environment problems caused by human activities. The practice of discharging human waste directly into canals, and loss of pesticides and chemical fertilizers from numerous paddy fields into canals has polluted water sources heavily. No formal research has been conducted to quantify the level of pollution and environment damage. Poor hygiene conditions have caused a big health problem. About 22 per cent of average monthly income per capita was spent on medical and health care in the year 2000.

In general, indicators for development and social and poverty reduction objectives for the 2001-2005 periods were not achieved in the Mekong Delta by the end of 2005.

Notes

[1] The Decision of the Prime Minister no. 44/1998 of 23 February 1998 made most of the Southeast provinces – Ho Chi Minh city, Dong Nai, Binh Duong and Baria-Vung Tau – the main economic region in the south. In June 2003 Tay Ninh, Binh Phuoc and Long An were added to the list.

[2] The Mekong Delta covers an area of 5.9 million ha, of which about 4 million ha are in Vietnam. In this study, the term Mekong Delta refers only to the part that is in the territory of Vietnam.

[3] The programme was in collaboration with the International Rice Research Institute and supported by the United States Agency for International Development (Xuan, 1995).

[4] It should be noted that the fertilizer use figures in Table 3.5 cover only one season. With the annual cropping intensity being about 1.8, the average amount of fertilizers applied per hectare per year can be calculated by taking the figures in Table 3.2 and multiplying them by 1.8.

[5] Pesticides whose use is restricted (but not banned) are those considered to be very toxic to human health and the environment. Vietnam also severely limits the registration of businesses involved with those pesticides. Decision no. 53/2003/QD-BNN of MARD, dated 2 April 2003, lists 33 pesticide products whose use is restricted.

[6] HYVs are fertilizer-responsive; that is, increased fertilizer application is needed to obtain the highest potential yield from them. However, high fertilizer application may not be the economic optimum level for profit maximization. Fertilizer use in Vietnamese rice production has exceeded the optimal quantity for profit maximization (Dung et al., 1999).

[7] The 2000 floods were considered the biggest in the past 75 years in the Mekong Delta. At the peak, the land was flooded to a water depth of 4.9 to 5.0 m (Dang, 2001).

[8] Though rice may have been cultivated for thousands of years, no data are available for the period before the Vietnamese settlement of the Mekong Delta at the beginning of the eighteenth century (See Brocheux, 1995).

[9] The general poverty line and the food poverty line in 2002 were VND 1,906,950 and VND 1,372,774 per capita per year, respectively.

4

Agrochemical Policies, Markets and Regulation in Vietnam

4.1 Introduction

Chapter 3 demonstrated that a significant increase in Vietnamese rice output has been accompanied by a rise in the use of agrochemicals. An understanding of the factors underlying the increased use of agrochemicals is important in order to predict the effects of policy reform on profitability of rice production and the economic and environmental consequences of agrochemical use. The Vietnamese government introduced economic policy reforms in 1981 and has accelerated the reform process since 1986 with the aim of achieving a transition from a centrally-planned economy to a market economy. The result has been gradual but persistent changes in rice and input markets, and particularly in economic incentives to farm households. This chapter provides an overview of the market-oriented reforms and the regulations covering the use of agrochemicals from 1976, one year after reunification.

4.2 Land policy

Land allocation and incentives to exploit and conserve agricultural land were modified and changed in Vietnam during the recent process of decollectivization as part of the transition to a market economy, which occurred in the 1980s and 1990s.[1] The land policy reforms have greatly influenced farmers' behaviour and agricultural production.

4.2.1 Collective regime (1976-80)

Before the reform, land and other means of production were owned, managed and allocated by agricultural cooperatives, which had been founded in 1958 in the northern part of Vietnam. Individual ownership of resources and individual decision-making were replaced by collective ownership and management of production. From 1956, following the Chinese model, production in northern Vietnam was collectivized in three distinct phases: mutual work teams (1956-58) in which land remained privately owned but production tools were shared among members; low-rank cooperatives (1958-60) in which all means of production were still preserved; and advanced production cooperatives (1960-72) in which means of production were owned collectively (Beresford, 1985; Pingali and Xuan, 1992; Spoor, 1985). In the mutual work team system, farmers were encouraged to become seasonal or permanent members of specified teams and participate in collective production activities through them. In 'low-level' cooperatives, production activities were carried out by specified teams (for example, for land preparation, crop establishment or plant protection) based on the general plan of the cooperative. Output was distributed to farm households according to the proportion of production inputs (including labour) contributed to the cooperative. Each member received payment in accordance with his or her working days in specified teams. In advanced (or 'high-level') production cooperatives, farmers worked under a unified management. Farm households had neither incentives nor rights to access land individually, except for a small proportion of land provided as subsidiary plots and home gardens. Payment to farm households was based on the quantity and quality of work performed, through a work-point system under which farmers were allocated points for fulfilling task norms. To support the collectivization process, the State made vast investments in agricultural infrastructure, especially irrigation networks. However, the output of cooperatives kept declining, to the point where around 70 per cent of farmers' income was derived from subsidiary land plots and home gardens covering no more than 5 per cent of arable land. (Beresford, 1985).

Collectivization in the southern provinces of Vietnam was different from that in the north, since southern Vietnam had a market economy with private farms until 1975. Most small farmers (peasants) were provided with agricultural land to cultivate as part of the 'land to tiller' programme of the former Saigon administration. Middle-scale peasant farmers played a central role in production in rural areas. Widespread adoption of technical equipment and modern rice technology considerably expanded rice production, especially in the Mekong Delta (MKD). After the reunification of Vietnam in 1975, significant efforts were made to organize farmers in the south into agricultural cooperatives based on the northern model, without adequate attention to specific conditions prevailing there. Farmers were organized into production groups and land was further redistributed. Land allocation per head was based on differences in land quality and access to irrigation water. Since land could be reallocated to other households under the management of the collectives, there was no long-term security of tenure on 'assigned land' for individual households, and farm households lacked incentives to invest in order to sustain the productivity of the land. Farm households in the south, particularly in the MKD, resisted this forcible collectivization. According to Pingali and Xuan (1992), in spite of the collectivization policy, farm households continued to be the basis agriculture in the south, especially in the MKD, and collective efforts were made only to obtain inputs and access marketing channels.

Insecurity of land tenure, elimination of private ownership of production equipment (for example, tractors and threshing machines) and limited supply of fertilizers and pesticides led to declining production in all regions, particularly in the MKD. By 1980 output per capita had fallen to between 270 and 290 kg (Pingali and Xuan, 1992).

4.2.2 Land in output contract system (1981-85)

Faced with deepening agricultural stagnation, resistance to collectivization in the south, worsening erosion of farmer incentives in northern cooperatives, and growing suffering among farmers, the Government promulgated agricultural policy reforms. Researchers generally agree that the economic reforms started after the Sixth Plenum of the Communist Party Central Committee in September 1979. They involved changes in the system of individual incentives in the household economy, recognized the objective existence of a multisectoral economy and lessened the control exercised through highly centralized and directive planning (Andreff, 1993; Beresford, 1985). The most important early reform was the introduction of the household output contract system (Directive 100CT of January 1981). Farm households and other small production units were allowed to sign production contracts with cooperatives to produce a certain level of output in return for access to land and agricultural inputs. Households allocated inputs, managed field activities and had to sell the contracted output to the State at a fixed price, but the remaining output belonged to them and they could dispose of it freely.

Land was still under the management of cooperatives or collective farms, but the revenue earned from 'above-contract' output provided an incentive for farmers to increase rice yields. As a result, for the first time food production grew faster than population, with annual rice production increasing by 2.8 per cent on the average during 1982-87 (Pingali and Xuan, 1992).

4.2.3 Market liberalization and the land law

Another concrete manifestation of a new land policy was Resolution no. 10 of 1988 (April 5, 1988), decentralizing responsibility for agricultural management from collectives to farm households. The resolution was the first tentative movement towards private property rights. Collectivized land was allocated to farm households in a long-term usufructuary arrangement. Thus, cooperatives could distribute the land-use right to farm households for 10 to 20 years on the basis of a renewable lease. The resolution recognized farm households as autonomous economic units competing with others. Farm households in general, and rice-producing farm households in particular, were allowed to take the main decisions regarding allocation and use of resources, production and marketing of their products, given the prices of rice and inputs. Rice production continued to grow at an average rate of 6.0 per cent annually during 1990-95 (see Table 3.5 in Chapter 3). In 1989, the country entered the world market with export of 1.4 million tonnes of milled rice.

More recently, the land law of 1993 provided greater stability of tenure, making land-use rights marketable and decreasing State control over land usage. The new law set out rules for allocation of long-term land-use rights, including the rights to use, transfer, lease, inherit and mortgage. It also defined several categories of land for the purpose of regulation, determination of rent and taxation. Land-use rights were granted for 15 years in urban areas and up to 50 years for agricultural land, but the State continued to own the land. Long-term security of land tenure and associated rights, along with liberalization of prices and input and output markets, stimulated farm households to invest in agricultural land. Farm households now pay land tax based on the assessed value of their land, as written into their land-use certificates. The land tax law of July 1993 defined seven land categories for annual crops and a fixed tax per hectare per year for each category. Nowadays, farm households operate in free markets as they did in the south before 1975.

4.3 Pricing and market reforms

While many adjustment policies have been implemented during the last decade, price and market liberalization have been the main aspects of economic reform in agriculture. The process of market liberalization has been more extensive in agriculture than in other sectors, and it is most evident in the rice sector.

4.3.1 Changes in pricing and market policies

The price system, market control and terms of trade were crucially influenced by the power of the central government. Before 1989, projected rice production, procurement and marketing were planned by the Central Planning Committee. Each year, the Committee drew up a plan for rice production and procurement and assigned to provincial targets. At the end of the growing season, households were required to sell the rice output to the State at 'official prices' so as to meet the targeted national procurement volume. The official prices set by the central authorities, however, were well below the 'free market prices' in the non-State sector and prices at the country's international borders. Even worse, farmers were obliged to sell their surplus production (that is, above-quota production) to the State-managed market at 'directed prices' (Que, 1998: 47-77). Thus, in general the market for rice was fully organized and managed by the State. Rice, and other agricultural products, could only be traded in the locality they were produced, usually within a district.

With Resolution No. 10 in 1988, however, these policies were reformed. To end the dual price system where the State sector paid much less for products than buyers in the non-State sector, the market became the determining force of the prices of rice as well as inputs such as water, fuel and machinery. Farm households were allowed to sell their products freely in the market. The participation of the private sector expanded in many aspects. Private traders were allowed to buy rice and other agricultural products directly from farmers and market them freely. By the end of 1988, a network of private traders and a well-established private market for fertilizers and pesticides existed in the Mekong Delta (Pingali and Xuan, 1992). Compulsory government purchase of agricultural products also ended. Because private traders, the government and other actors have to buy rice at market prices, the price of rice has become more competitive (Ordinance no. 169, November 14, 1988).

The effects of reform on prices of rice and inputs were investigated and are discussed in detail in IFPRI (1996). IFPRI found that the prices of fertilizers and rice relative to the general price level critically affected profitability in the rice sector. While the relative price of fertilizers declined and thus benefited rice farmers, reduction in the farm-gate price of rice squeezed the profits of rice farmers. Observing that rice production increased significantly even under these negative price incentives during the 1989-1995 period, the study concluded that non-price factors played an important role in increasing output in the rice sector. Land-use rights to farmers and adoption of new production technology were identified as being among the positive factors.

4.3.2 Reform of rice export policy

Market and price liberalization increased total rice production significantly, as explained in Chapter 3. In 1989, for the first time, the country had a rice surplus for export amounting to 1.4 tonnes. By the year 2000 Vietnam was exporting approximately 3.5 million tonnes, representing a 16 per cent share of the world market (see Table 4.1). The variation coefficient of the quantity exported was 45 per cent and that of the value of rice exported was 51 per cent. This variability can be attributed to the instability of the world rice market (IFPRI, 1996; Minot and Goletti, 2000) and to a lesser extent Vietnam's policy on rice export. With most rice surplus coming from the Mekong Delta and partly from the Red River Delta, other regions had a food deficit. Vietnam's policy has been to ensure domestic food security as the first priority and export the remaining surplus. With this as the basis, several changes in export policy have occurred since 1989. These include ending the government's monopoly over rice export and internal rice trade, and relaxation of export taxes.

For more than ten years (1989-2001), the Government controlled the volume of rice exports through a binding export quota and other restrictions. Each year, based on estimates of domestic supply and consumption, the Ministry of Agriculture and Rural Development, State Planning Committee and Ministry of Trade jointly set and distributed rice export quotas. The quotas were allocated only to State-owned enterprises: VINAFOOD I in the north, VINAFOOD II in the south and a number of provincial ones. At first, several of these enterprises competed for export contracts with foreign buyers, but then the government decided that the competition was excessive and unfair. Several State-owned enterprises were offering much lower prices than those in Bangkok and then were unable to fulfil the contracts they signed. The government, therefore, reduced the number of State-owned enterprises allowed to export rice. In 1992, the number of rice exporters was reduced to 40, mostly from the south, and in 1999 there was a further reduction to 15 (IFPRI, 1996).

Table 4.1
Vietnam's rice exports, 1989-2000

Year	Quantity		Value	
	Amount ('000 tonnes)	*Annual growth (%)*	*Amount (USD million)*	*Annual growth (%)*
1989	1,372	n.a.	310.2	n.a.
1990	1,478	7.7	275.4	-11.2
1991	1,016	-31.0	229.9	-16.5
1992	1,953	92.0	405.1	76.2
1993	1,649	-15.6	335.7	-17.1
1994	1,962	19.0	420.9	25.4
1995	2,025	3.2	538.8	28.0
1996	3,047	50.5	868.4	61.2
1997	3,682	20.8	891.3	2.6
1998	3,793	3.0	1,006.0	12.9
1999	4,550	20.0	1,035.0	2.9
2000	3,477	-23.6	668.0	-35.5

Note: n.a, = not available.
Source: <http:\\www.saigonnet.vn>.

Reform of the rice export policy started in 1997, with governments of provinces that had a rice surplus being authorized to allocate export quotas. In 1998, the revised Trade Law allowed both State-owned and non-State-owned enterprises that had a licence to trade in food or agricultural commodities to engage in rice export. Even foreign traders, though not yet allowed to export rice themselves, could act as agents for provincial food companies in trade and service negotiations. Finally, in 2001, Decree no. 46/2001/QD-TTg on Vietnam's Export-Import Management

Mechanism for 2001-2005 abolished rice export quotas as well as fertilizer import quotas.

Before 1988, State-owned enterprises operated on a much larger scale than private traders and played an important role in wholesale trade, especially in long-distance trade in domestic markets (Minot and Goletti, 2000). As mentioned earlier, governmental authorities and local officials imposed various restrictions on the movement of rice among regions. The result was price differences and rising transportation costs. These restrictions on the domestic rice trade were abolished on December 23, 1988, when Ordinance no. 193 was issued. Private trades were allowed to buy food grains from farmers and to process or transport them. They were also authorized to engage in business activities involving food for domestic consumption. Minot and Goletti (2000) observe that, after the ending of export quotas and removal of restrictions on internal trade, the average consumer price rose by about 20 per cent, rice consumption fell by 4 per cent and rice production expanded almost 7 per cent in the short run. Internal market liberalization resulted in lower rice prices and production in the north but the converse in the south. The combined effect of the ending of export quotas and internal restrictions was an increase in household and total income.

4.4 Fertilizer market

4.4.1 From monopoly to free market

Vietnamese rice farmers use inorganic fertilizers more intensively than those in other Asian countries. Domestic production of chemical fertilizers is well below the demand, so the country depends heavily on imports. In the year 2000, domestic demand for fertilizers was 2.267 million tonnes, of which 2.06 million tonnes, or 90 per cent, was imported (see Table 4.2). Until 1991, most of the fertilizers were imported from Russia and partly from Eastern European countries under CMEA (Council of Mutual Economic Assistance) trade agreements. Imports from Western countries were limited to small quantities, which is why there are few statistics on the import of fertilizers during that period. The situation changed when the CMEA was disbanded in 1991. The prices of fertilizers imported under the trade agreements did not change for a specific period, usually five years. However, the composition of the fertilizers (that is, urea and ammonium sulphate fertilizers) and their time of arrival in Vietnamese ports depended on the suppliers. The dissolution of the CMEA disrupted the supply chain, creating a mismatch between domestic demand and the imports. Fertilizers failed to arrive when they were needed for certain production seasons, whereas at other times they were supplied in abundance (MARD, 1998).

Table 4.2

Vietnam's fertilizer consumption and imports, 1992-2001
('000 tonnes)

	Year									
	1992	***1993***	***1994***	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***	***2001***
Fertilizer consumption										
Nitrogen	541.3	565	874.9	813.7	995.3	922.9	1186.1	1224.2	1328.0	1063.2
Phosphate	183.5	165.3	241.6	322	380.2	386.8	399.8	456.4	506.0	506.0
Potash	41.6	23.8	68.4	88.0	109.0	162.0	271.0	377.0	433.0	337.3
Urea	448.8	508.8	754.2	674.8	818.3	725.8	925.8	892.4	1071.0	836.0
Total	*766.4*	*754.1*	*1184.9*	*1223.7*	*1484.5*	*1471.7*	*1856.9*	*2057.6*	*2267.0*	*1906.5*
Fertilizer imports										
Nitrogen	484.3	504.7	806.8	734.1	900.8	805.5	1076.3	993.2	1293	1020.2
Phosphate	84.9	50.8	97.2	159.0	201.4	192.6	160.9	165.9	314.0	294.6
Potash	41.6	23.8	68.4	88.0	109.0	162.0	271.0	377.0	452.9	337.3
Urea	410.8	462.8	709.7	623.8	762.6	666	896.4	869.4	1036.0	790.0
Total	*610.8*	*579.3*	*972.4*	*981.1*	*1211.2*	*1160.1*	*1508.2*	*1436.1*	*2059.9*	*1652.1*

Source: <www.fertilizer.org/IFA/statistics/ifadata>, accessed 4 April 2004.

Before the pricing and market policy reform (1989), the State trading corporations, such as Minexport, Agrexport and Generalimex, were responsible for receiving and distributing around 90 per cent of imported fertilizers. They dispensed the fertilizers within the agricultural system, from provincial to district level, and from district to cooperative level. Fertilizers were distributed according to the relevant plans, verified by the People's Committees at local level. Then, based on how much was available, the cooperatives decided how much fertilizer to apply on the fields and redistribute to farm households. While fertilizer quantities were variable, the prices were determined by the State Pricing Committee and they were not likely to be affected by demand and supply. The prices were subsidized by the State for political purposes, especially to promote food self-sufficiency. Thus, before 1989 there really was no market for fertilizers, only an administratively-run system.

From 1989 onwards, following the land reform and with the recognition of the role of the farm household economy, the system to import and distribute fertilizer was increasingly seen as being inappropriate for meeting domestic demand. In 1989 and 1990, only 60-70 per cent of the fertilizers continued to be imported under the CMEA trade agreements, the remaining 30-40 per cent being imported from non-socialist countries. However, the political changes in Russia and Eastern Europe and the lack of foreign currency to import fertilizers from other countries led to a reduction in total fertilizer consumption in 1989/90. There was also a change in the pricing system in 1989 and 1990. Fertilizers imported from countries other than Russia and Eastern Europe were allowed to be sold in markets at prices determined by the local companies importing them. Meanwhile, fertilizers imported under the CMEA trade agreements were partly distributed at a predetermined price, and the remaining quantity was allowed to be sold in the market. Box 4.1 presents a summary of rice and fertilizer market-related reforms.

Fertilizers imported under the CMEA trade agreements have disappeared since 1991. As part of the early reform, both central and local State companies trading in agricultural products were allowed to import and market fertilizers. However, because of their inexperience in the world fertilizer market, lack of foreign currency and import imbalances among agricultural regions, the Vietnamese government maintained an important role in fertilizer markets. For example, the government used rationing of foreign currency to the benefit of some of the companies owned by the Ministry of Agriculture and Rural Development and only allowed State companies to import fertilizers. Even though the quantities imported were controlled through quotas, fertilizers were sold freely in the domestic market and prices were not controlled. Thus, the market for fertilizers was not actually run on the basis of a market mechanism, but continued to be substantially regulated. Table 4.3 shows how many State companies at central and provincial levels imported and traded in fertilizers in the market between 1991 and 1998.

Domestic prices of fertilizers varied seasonally and geographically according to the performance of trading and distribution agencies, at both

Box 4.1
Milestones in reform of rice and fertilizer markets

1988: Contracts introduced in agriculture; dual price system ended.

1989: Central government monopoly over foreign trade removed.

1990: Vietnam Central Food Corporation established; Only state-owned enterprises (SOEs), including provincial, allowed to export rice.

1991: Export duty on rice reduced from 10 per cent to 1 per cent; imported inputs used to produce exports exempted from duty; Agriculture Bank of Vietnam allowed to lend to households.

1992: Number of SOEs allowed to export rice reduced to 40, mostly concentrated in the south.

1993: Further land-use rights given to individuals.

1994: Rice export quotas imposed: 70 per cent of quotas allocated to selected SOEs exporters and rest to SOEs recognized by Rice Business Association; allocation on basis of total rice output by province; restrictions imposed on import of fertilizers through quotas and licenses to selected enterprises only.

1995: High world prices and active rice trade. Controls on domestic trade to meet deficits in north resulted in illegal rice flows to China.

1996: Export tax on rice reduced from 2 per cent to 1 per cent.

1997: Rice quotas allocated by provincial governments; license system for rice trade and transport in domestic market ended; wholesale taxes on food removed.

1998: Private sector rice exports allowed; foreign investors allowed to export unlicensed goods; rice exempted from export tax; further imports curbed in June after exceeding expected rate of 2.5 tonnes in May; domestic price rose to very high levels.

1999: Right to export and import extended further: Conditions for rice export by private companies relaxed, foreign investors allowed to buy rice for export directly from farmers.

2000: Rice restructuring policies released: to stabilize annual paddy rice output at 33 million tonnes, focus on quality and varieties of rice; VAT on rice purchases for export reduced from 5 per cent to 3 per cent; directives for restructuring and consuming agricultural products issued (Resolution 09/2000 of the Government).

2001: Quotas on rice exports and fertilizer imports cancelled; rice export and fertilizer import totally liberalized (regime of appointed rice exporters and fertilizer importers removed); temporary support measures for rice producers and exporters.

Source: Adapted from UNEP (2006: 22, Table 2)

Table 4.3

Number of Vietnamese companies importing fertilizers, 1991-98

Year	Number of companies	Sources
1991	23	MARD (1998)
1992	38	MARD (1998)
1995	26	Directive no.04/TTLB/NN-TM, 10 Feb. 1995. Regulation of import & distribution of fertilizers
1996	70	MARD (1998)
1997	27	Decision no.141/TTg, 8 March 1995. Regulation of rice export and fertilizer import
1998	35	Decision no.12/TTg, 23 January1995. Regulation of rice export and fertilizer import

provincial and national levels. Some companies, after requesting an import quota from the government, then re-sold their quotas to other import-export companies. Some sold imported fertilizers at a loss to raise liquid assets for another business or because they were unable to pay storage costs and interest on loans. One of the reasons for such behaviour was that the companies that obtained quotas did not have enough capital to fulfil their commitments. Another reason was that some import companies lacked experience and marketing information concerning the international fertilizer market. As a result, they bought fertilizers at higher prices than other companies and then had to dispose of them at a loss. Between 1992 and 1995, more than 10 State companies importing fertilizers were operating at a loss and had to ask for government help with their bank debts (MARD, 1998).

From 1996, to correct a situation termed 'sot lanh' (cold shock) – oversupply and low prices – and 'sot nong' (hot shock) – undersupply and high prices – the government again adjusted its policy on the importation of fertilizers. MARD and the National Chamber of Commerce were given responsibility for estimating domestic demand and controlling import quotas for chemical fertilizers. The quotas were adjusted following mid-year reviews of local supply and demand. Some private companies were allowed to import fertilizers provided they fulfilled certain criteria.[2] More restrictions, such as timing of import and prohibition of quota transfers, were imposed. However, the importation of fertilizers to meet domestic demand was still subject to variation, depending on the performance of companies. The Ministry of Agriculture and Rural Development's Department of Agricultural Extension Services was responsible for making recommendations for fertilizer use, including promoting technology transfer to farmers. However, while the department gave many technical recommendations on fertilizer use, it rarely gave farmers market information.

While fertilizers are mostly imported by State companies, the distribution is done by private traders. The old system of input distribution ended in 1991. In the south, most of the imported fertilizers are sold to private traders at the port, who then transport them to the provinces and sell them to retailers at district and village levels. Obviously, the monopoly of State companies adds to the cost on the fertilizers at the beginning of the marketing channel.

To sum up, until recently the fertilizer market was biased by government intervention in the allocation of import quotas for trading agencies. While the policy was modified year by year, the import situation did not change much. Importation was mostly carried out by State trading agencies, quotas were granted on application by trading agencies, and risks were absorbed by the State since most loans are provided by the State. After ten years of restrictions, fertilizer importation was finally freed in May 2001, following Decree no. 46/2001/QD-TTg on Vietnam's Export-Import Management Mechanism for 2001-2005. The Decree eliminated both rice export quotas and the fertilizer import quotas. In addition, the direct nomination of importers and exporters was also brought to an end. In other words, the markets for rice and fertilizers have been fully free since May 2001.

4.4.2 Market price of fertilizers

Table 4.4 displays the price trend for urea fertilizers and paddy rice in the Mekong Delta between 1990 and the year 2000. From 1996 to 1999, domestic prices of urea fertilizers decreased while those for rice increased. Thus, farm households could use more urea fertilizers and earn more from rice production. However, in 2000 the price of urea went up due to a rise in the world market price while the price of rice fell, reducing farm households' profits. As Table 4.4 shows, the relative price ratio of urea versus rice in the year 2000 was 1.53, similar to the 1996 relative ratio (1.59). The fluctuations in fertilizer prices were due to changes in market regulation. The response of farmers to rice price changes relative to agrochemicals is examined in Chapter 6.

Table 4.4
Prices of urea fertilizers and paddy rice in Can Tho city, December 1990-2000

Year	Rice prices (VND/kg)	Urea prices (VND/kg)	Price ratio of urea/rice
1990	866	1,497	1.73
1991	1,185	2,466	2.08
1992	1,050	2,100	2.00
1993	1,180	1,653	1.40
1994	1,360	2,236	1.64
1995	1,893	2,759	1.46
1996	1,603	2,548	1.59
1997	1,780	1,948	1.09
1998	1,793	1,935	1.08
1999	1,889	1,797	0.95
2000	1,492	2,282	1.53

Note: Urea prices are for Indonesian urea fertilizers (46% N) at Can Tho market (due to data available). All prices are retail prices in the market.

Source: Southern Information and Valuation Center (2002)

Farm households use not only urea, but also phosphorus and potassium fertilizers. The fertilizer price paid at the farm gate depends on the village retail price and the transportation costs involved. Thus, examination of the farm-gate prices of all fertilizers is of interest. Production decisions of farm households are affected by relative price changes. For example, in deciding how much fertilizer should be applied, farm households would consider the expected rice yield and prices of rice and fertilizers. The expected economic returns to fertilizer use normally increase when the relative prices of fertilizers to rice fall, as happened in 1997-99. In such a situation we would expect farm households to prefer to use more fertilizers than if the relative prices had remained the same.

Table 4.5 reports the farm-gate prices of fertilizers and the price ratios of fertilizer and rice for households surveyed in 1996/97 and 2000/2001. For all households, fertilizer prices relative to rice prices are slightly lower in the 2000/01 winter-spring season. In 2000/01 a kilogram of NPK nutrients cost the same as about 4.27 kilograms of rice, while in 1996/97 it was equivalent to 4.40 kilograms of rice. Of the 76 similar households in four villages in the two surveys, there is also an increasing trend in rice prices and a decrease in fertilizer prices (prices in kg of NPK nutrients). Though the relative prices of fertilizers to rice show that farm households bought fertilizers relatively cheaper in the 2000/01 winter-spring season, they were not homogeneous across villages. For example, the relative prices of fertilizers in Tan Phu Trung are almost the same in the two surveys, but those in Nhi My village are lower in 2000/01. At the village level, many factors cause the variation in prices between households; for example, the composition of nutrients, types of fertilizers (for example, straight or compound fertilizers), terms of payment, and where they are purchased.

Table 4.5
Farm-gate prices of rice and fertilizers in survey villages
(VND per kg)

	Same households group (N=76)				**All households**
	Nhi My	***Tan Phu Trung***	***Long Dien***	***Vinh My***	
1996/97		*n=76*			*n=159*
Fertilizers	5,217.9	5,694.0	5,426.7	5,546.8	5,601.7
Rice	1,306.0	1,253.6	1,254.5	1,214.7	1,279.3
Price ratios of fertilizer/rice	4.03	4.57	4.33	4.57	4.40
2000/01		*n=76*			*n=177*
Fertilizers	5,303.1	5,741.7	5,513.4	5,418.2	5,562.1
Rice	1,383.2	1,265.0	1,325.0	1,272.1	1,313.6
Price ratios of fertilizer/rice	3.85	4.58	4,18	4.29	4.27

Source: 1996/1997 and 2000/2001 surveys.

4.5 Pesticide market

4.5.1 Development of pesticide market

As with fertilizers, until 1988 the pubic sector had a monopoly over pesticides even though there had been no policy on pesticide regulation, except for plant protection techniques (Hoe, 2000). Before 1988, only a few State companies at the national level were assigned by the government to import the quantity and types in accordance with a fixed plan of application. The supply system was the same as for fertilizers. Since agricultural production was run mostly by cooperatives through a central mechanism, the supply and distribution of pesticides was also channelled from central to provincial and district levels.[3] The distribution was according to sown areas of crops and the fixed plan. Farm households received a certain amount of pesticides according to their contract with the cooperatives. Prices and costs of production were not an issue for farmers, only for the government and cooperatives. Since the supply of pesticides and other inputs was far less than demand and they were not easy to buy in the market, especially for farm households in the Mekong Delta, conflicts and competition occurred between various groups demanding inputs (Pingali and Xuan, 1992). Thus, as for fertilizers, a market for pesticides did not exist before 1988, and only an administrative system was in place. Before 1988, annual pesticide use in the whole country was estimated at between 6,500 and 9,000 tonnes of finished products per year, including those in the WHO categories of extremely or highly hazardous ones. These included methyl parathion, monocrotophos and methamidophos as well as the highly persistent DDT and HCH, of which 7,000 tonnes were awaiting disposal in 2000 as a result of the past policy (Hoe, 2000).

The market for pesticides started to develop nationally in 1989 following the reform in markets for agricultural inputs and outputs, in which supply and demand were to be determined by market forces (Ordinance no. 170, 14 November 1988). However, in the Mekong Delta they developed somewhat earlier. Pingali and Xuan (1992) observe that some markets for fertilizers and pesticides, using price analysis and with a network of private traders, were established in four provinces in the Mekong Delta in December 1988. Pesticides were imported mostly by State companies and sold in the markets via a network of private traders.

From 1988 to 1990, the estimated amount of pesticides used per year was around 13,000-15,000 tonnes of final products (Hoe, 2000).

Since 1991, the market for pesticides has spread on a national scale. Pesticides are imported by both private and State companies and there are no import quotas. Almost all pesticides are imported in unprocessed form and then packaged domestically. Some pesticides are imported as finished products with high concentrations and in big containers and then repackaged in small boxes/bottles with suitable concentrations for application. By the end of 1999, there were about 50 private and 30 State pesticide enterprises/companies manufacturing, bottling, packing and trading in pesticides. In addition, about 50 foreign companies engage in activities relating to the pesticide business, such as liaison, supplying raw materials, and manufacturing, or full business operation. With the high demand for pesticides in the Mekong Delta, many companies, enterprises and factories were established and developed in the south.[4] The sale of pesticides has risen significantly since 1996 (see Table 4.6). In Vietnamese Dong currency, pesticide sales have more than doubled between 1996 and 2001, with insecticides accounting for the biggest share with 57 per cent of the value of sales in 2001.

Table 4.6
Pesticide sales in Vietnam, 1996-2001 (VND billion)

Year	Herbicides	Insecticides	Fungicides	others	Total
1996	110	330	70	0	510
1997	140	420	90	0	660
1998	200	500	130	0	840
1999	250	560	15	0	960
2000	270	580	170	0	1,000
2001	270	590	170	0	1,000

Source: Watkins (2003).

In June 2000, there were 26 pesticide factories operating at different scales, mostly in Ho Chi Minh city and south-eastern provinces. Prominent among them were the international companies Bayer, Novartis, Aventis, Dupont, and BASF (PPD, Southern Division, 30 June 2000). In the Mekong Delta, private traders distribute pesticides through their Delta-wide network. According to the PPD -Southern Division, as of 30 June 2000 at least 80 private and State traders classified as medium- and large-scale pesticide businesses were located in Ho Chi Minh city. Pesticide demand for rice cultivation has been rising due to the improving economy and easier supply of pesticides. International companies are still looking for expansion in the pesticide markets in Vietnam, although the demand seems to have reached its upper ceiling (Watkins, 2003).

The pesticide market in Vietnam has only been competitive since 1991. The competition takes place not only between importers, foreign companies, domestic manufacturers and distributors, but also between the members of each of these groups. The competition between companies supplying new products is usually supported by advertising. Almost every day in the Mekong Delta, especially during the crop seasons, pesticides are advertised through public television and radio stations. In addition, demonstrations of the technical efficiency of new pesticides are performed in demonstration fields scattered around the regions. Small gifts such as lighters and caps, as well as pesticide information leaflets, are provided free by the technical teams of companies during their advertising campaigns in villages. Retailers at the village level usually offer easy terms of payment. Farmers have the choice of paying at the time of purchase, or some days later, or even at the end of the growing season, particularly for those households that buy relatively large quantities regularly. The advertising in general persuades farmers to switch to new products, thus causing variation in types of pesticides used in the surveyed areas (see Chapter 5).

4.5.2 Market price of pesticides

As many different economic units entered the market, pesticides have been widely available since1991. In spite of strong competition in the market, prices do not fluctuate much. Distribution agents at provincial and district levels sell pesticides on the basis of prices recommended by supplier companies. These agents receive a commission and promotions from the companies. The commission varies from company to company, ranging from 2 to 5 per cent of the total sale value.

The farm-gate prices of pesticides varies between farm households, depending on the composition (herbicides, fungicides and pesticides), as well as distance to markets and possibly personal connections and knowledge. For example, to control weeds, farm households can use any of the herbicides in Table 4.7, and the choice could mean a difference in costs and total active ingredients applied per hectare. The relative price of pesticides to rice was higher in 2000/01 than in 1996/97 (0.36 and 0.30 respectively). However, the increase is not homogeneous among farm households. For instance, as can be seen in Table 4.8, farm households in Nhi My village paid a high price in 1996/97 but a lower relative price in comparison with those in other villages in 2000/01. This may have encouraged farm households in Nhi My village to use more pesticide (see Chapter 5). In contrast, farm households in Tan Phu Trung paid higher prices for pesticides in 2000/01, and there was hardly any change in the relative pesticide- rice price ratio in the villages of Long Dien and Vinh My.

Table 4.7
Wholesale prices of some pesticides in Mekong Delta, 1995-2001
('000 VND per unit)

Pesticides	Unit	1995	1996	1997	1998	1999	2000	2001
Insecticides								
Applaud 10WP	Litre	95	95	98	108	112	115	115
Sumi-alpha 5EC	Litre	108	108	115	118	110	110	110
Fastac 5EC	Litre	101	97	97	107	106	106	106
Hopsan 75 EC	Litre	63	65	70	75	78	78	78
Fungicides								
Bavistin 50 FL	Litre	140	143	150	160	168	168	168
Carbenda 50 SC	Litre	120	120	115	110	90	90	75
Herbicides								
OK 683 DD	Litre	30.6	32.3	38.5	38.5	43.1	43.1	43.1
Onecide 15EC	Litre	180	180	180	198	198	198	198
Sirius 10WP	Kg	940	940	980	1,070	1,070	1,070	1,090

Note: Figures are at current prices.
Source: Pesticides Company No.2, Ho Chi Minh city.

Table 4.8
Current farm-gate rice and pesticide prices for survey households (VND per gram of active ingredient)

	Same households group (N=76)				All households
	Nhi My	*Tan Phu Trung*	*Long Dien*	*Vinh My*	
1996/97		*n=76*			*n=159*
Pesticides	458.46	356.02	437.48	460.64	380.05
Rice	1,306.0	1,253.6	1,254.5	1,214.7	1,279.3
Price ratios of fertilizer/rice	0.35	0.29	0.35	0.38	0.30
2000/01		*n=76*			*n=177*
Pesticides	370.26	436.35	477.34	468.50	464.26
Rice	1,383.2	1,265.0	1,325.0	1,272.1	1,313.6
Price ratios of fertilizer/rice	0.27	0.35	0.36	0.37	0.36

Source: 1996/1997 and 2000/2001 surveys.

4.5.3 Pesticide regulation policies

By the end of 1988 liberalization of the pesticide market was accompanied by implementation of pesticide regulation policies. Recognizing the increased use of pesticides in agricultural production as well as evidence of pesticide poisoning, the government implemented a number of regulatory policies. The first regulation was Decree no. 47-CT of 20/2/1990 of the Council of Ministers regarding the management, production, trading and use of pesticides. Individuals or organizations producing, distributing or using pesticides had to follow safety requirements. As in other developing countries, pesticide management policies in Vietnam cover production, import, formulation, distribution, marketing, training, safe handling and obsolete stocks of pesticides. Box 4.2 provides an overview of the main regulatory policies for pesticides implemented in the 1990-2000 period.

The Plant Protection Department is ultimately responsible for pesticide management. Vietnam officially approved and adopted the International Code of Conduct on the Distribution and Use of Pesticides of the

Box 4.2
Recent regulations on pesticide management in Vietnam

1990: Decree no. 47-CT of 20/2/1990 of the Council of Ministers regarding the management, production, trading and use of pesticides.

1991: The Ministry of Agriculture and Food Industries (from 1997 renamed Ministry of Agricultural and Rural Development) issued a list of first 77 pesticides permitted for use in Vietnam.

1992: The Ministry of Agriculture and Food Industries issued a list of 83 permitted pesticides, 20 banned pesticides and 14 restricted pesticides.

1993: Presidential Decree no. 08L/CTN of 15/2/1993 enacting the Ordinance on Plant Protection and Quarantine.

1993: Decree no. 92-CP of 27/11/1993 setting out regulations on pesticide management.

1995: Decision no. 100/NN-BVTV/QD of 23/2/1995 of the Ministry of Agriculture and Food Industries on procedures for production, formulation, registration, exportation, importation, storage, packaging and advertisement of pesticides.

1995: Decision no. 150/NN-BVTV/QD of 10/3/1995 of the Ministry of Agriculture and Food Industries on quality assurance, control of pesticide residues and testing of new pesticides.

1998: Directive no. 29/1998/CT-Ttg of the Prime Minister's Office on strengthening of management and use of pesticides and persistent organic pollutants.

1998: Decision no. 193/1998/QD/BNN-BVTV of 02/12/1998 of the Ministry of Agriculture and Rural Development regarding quality assurance, residue control and testing of new pesticides for registration in Vietnam (replacing Decision 150/NN-BVTV-QD).

1999: Decision no. 165/1999/QD/BNN-BVTV of 13/12/1999 of the Ministry of Agriculture and Rural Development on procedures for production, formulation, registration, exportation, importation, trading, storage, disposal, labelling, packaging, seminar, advertisement and use of pesticides (replacing Decision no. 100/NN-BVTV-QD).
2000: Circular no. 75/2000/TT-BNN-KHCN of 17/7/2000 of the Ministry of Agriculture and Rural Development guiding implementation of Decision no. 178/1999/QD-Ttg of 30/8/1999 of the Prime Minister's Office regulating good labelling for domestic distribution, import and export.

Source: Huan and Anh (2000)

Food and Agriculture Organization of the UN in 1990. In 1991 the Ministry of Agriculture and Rural Development issued a first list of 77 permitted pesticides. Then, on 24 March 1992, for the first time, the Ministry promulgated regulations for pesticide registration. The list of pesticides that were permitted was modified and updated to 83, while 20 were banned. and 14 were for restricted use. Since then, any pesticides produced in Vietnam or abroad have had to be registered before being sold in the market. The Ministry will revise, update and issue a new list of pesticides, especially banned and restricted ones. Approval of new pesticide is strictly based on the results of chemical quality control and field tests, and the decision of a Consultant Committee comprising many representatives from different ministries and academia. As a result of this regulation, the number of restricted and banned pesticides has increased from 34 in 1992 to 53 in 2000, and the import of restricted pesticides reduced from 7000-8000 tonnes/year before 1994 to around 1000 tonnes in 2000. More radical steps were taken following the Ordinance on Plant Protection and Quarantine enacted in February 1993, and by Decree no. 92/CP on pesticide management in November 1993. These are the regulatory documents for plant protection chemicals with the highest legal effectiveness in the whole country (Anh, 1998).

Total pesticide use went up from 20,300 tonnes in 1991 to 33,700 tonnes in 1999, with even a peak of 42,700 tonnes in 1998, as shown in Table 3.4 (Chapter 3). Administratively, the restriction and banning of highly toxic pesticides such as carbofuran, endosulfan, methamidophos, monocrotophos, methyl parathion and phosphamidon since 1994 had been the first step towards reducing chemical hazards to human health and the environment (Huan and Anh, 2001). However, the effects of pesticides on human health and the environment lie not only in the types used, but also in how they are applied by farm households in the fields. Counterfeit pesticides and illegal sales of banned pesticides still occur in most areas. After inspection by the Plant Protection Department, about 3.5 tons of pesticides that were counterfeit, banned or not in the list of approved pesticides were seized in 1999. At present, about 336 kinds of pesticides, of which the trade names are quite popular,[5] are sold in Vietnam; of them, 27 are restricted and 26 are banned (MARD, 2000).

4.5.4 National integrated pest management programme

Regulatory policies help to control the activities of enterprises/ companies, distribution agents and retailers of imported hazardous pesticides, and the production, distribution, and storage of pesticides. However, at the farm level households make their own decisions on the use of pesticides, for example on the quantity, types and frequency of application. Farm households often use pesticides excessively and farmers do not always understand or follow safety instructions, which reduces the technical and economic efficiency of pesticides and causes an increasing number of pesticide poisoning cases (Heong et al., 1995 and 1998; Huan et al., 1999). To help farmers make better use of pesticides and improve farmers' knowledge of pest control strategies and safe use, Vietnam initiated the integrated pest management (IPM) programme in mid-1992 (see Box 4.3).

The FAO Intercountry Programme for IPM in Rice in South and Southeast Asia with its broad experience in IPM activities in several countries, together with other international donors, supported the design and implementation of a large-scale national IPM programme in Vietnam. Having learned from the experience of neighbouring countries, especially Indonesia, the programme has developed a robust model based on training and technology transfer. The objective is to empower small-scale farmers to become skilful and better-informed decision-makers. Vietnam's IPM, known as a system approach to pest management, is based on an understanding of pest ecology. It was provided with a set of principles instead of technical/mechanical instructions. The four key principles of IPM are:

(i) growing a healthy crop;
(ii) conserving natural enemies of pests in the rice field;
(iii) observing the field regularly; and
(iv) helping farmers to become experts (Vietnam IPM, 1999).

With these principles, farmers are offered a set of agro-economic and ecological concepts as tools for their decision-making. The IPM programme first started with training of trainers, who then became instructors in Farmer Field Schools, which use rice fields as the study environment to convey and demonstrate the benefits of IPM. The successes achieved with rice farmers have been so impressive that IPM Farmer

Box 4.3

Donor support to Vietnam's national IPM programme

The national IPM programme is implemented with financial support from many international donors. in the early stages, the Australian government (the major donor) supported the programme between 1992 and 1998 through the FAO Intercountry Programme for IPM in Rice in South and Southeast Asia. The Norwegian Government was the main donor in Phase IV of the programme, which is called Community IPM, from 1998 to 2002. The Netherlands-funded FAO Intercountry Programme for the Development and Application of Integrated Pest Control in Vegetable Growing in South and Southeast Asia supported additional IPM research and extension activities in vegetable crops from 1996 to 2001. Vietnam is also a member of the European Commission-funded FAO-EU Programme for IPM for Cotton in Asia, Phase I of which ran from 1999 to 2004. DANIDA funded Community IPM activities in rice production in three provinces (Thai Binh, Can Tho and Soc Trang) from 2000 to 2005. DANIDA IPM as part of Denmark's Agriculture Sector Programme Support in Vietnam, will assume major responsibility in future for further development of IPM in rice and other crops and is expected to operate in about half of Vietnam's provinces.

Besides the above main donors, local governments (provincial, district and village) and projects have been also funded by NGOs, international agencies and other donors for IPM activities nationwide. A national survey of provincial PPDs asking about funding sources for IPM training for three seasons ending May 2000 revealed that during that period, 54 per cent of all rice Farmer Field Schools and 67 per cent of all IPM follow-up activities were locally funded and funding by NGOs and other donor-funded projects supported 10 per cent of Farmer Field Schools and 3 per cent of follow-up activities.

FAO is thus no longer the major financial supporter of Vietnam's national IPM Programme. The role of FAO-IPM in Hanoi has shifted to strengthening PPD's IPM programme management capacity, strategic support for IPM technology development and training, and assistance with national programme coordination.

Source: Plant Protection Department, 'Country Report-Vietnam', Ayutthaya, Thailand, Nov. 2001

Field Schools have also been launched for vegetables, soybean, peanuts, tea, cotton, and more recently sweet potatoes.

The Plant Protection Department is responsible for coordinating and implementing Vietnam's National IPM Programme. An IPM Group has been set up within the Department to take care of daily management and coordination of the IPM programme. The Department's Vice-Director in charge of plant protection extension in southern Vietnam helps to implement selected projects. The IPM Group is supported by and collaborates with a number of international programmes: the FAO Programme for IPM in Rice (now known as the FAO Programme for Community IPM in Asia) and in Vegetables in South and Southeast Asia, the FAO-EU Programme for IPM for Cotton in Asia, and the IPM Component of MARD/DANIDA Agricultural Sector Programme Support. At the provincial level, Plant Protection Sub-departments in cities and provinces are in charge of managing and implementing the IPM programme by organizing Farmer Field Schools and follow-up activities for the school graduates.

The IPM programme comprises a broad range of training and research activities, media campaigns and forums. The components vary from village to village and season to season depending on differences in budgets, the funding available, identification of pest problems in the area, social needs, cropping patterns and production constraints. The activities include training based on the season-long Farmer Field Schools (FFS); farmer technical training; farmer training of trainers; group activities including the IPM group and gender integration in the IPM programme; forums comprising village/district planning meetings, meetings to exchange experiences and trainers' technical meetings; field activities including rice field studies and village cross-visits; media campaigns; and development of training curricula case studies.

Some 20,000 farmers were trained in 1994. The programme began by focusing on rice but quickly spread to vegetables, soybean, cotton, tea, peanut, and rice-fish culture (see Box 4.4). According to the FAO Vietnam office, 55,098 farmers have participated in nearly 2,000 FFSs for other crops. Table 4.9 shows the development of IPM training courses in Vietnam during 1994-98. In 1998, there were 10.981 million agricultural farm households in Vietnam (GSO, 2000); thus, the number of IPM farmers represents about 3 per cent of the farm households.

Since May 2000, at least one FFS is held in over 83 per cent of Viet Nam's rice growing villages nationwide, including 97 per cent of all villages in the Mekong and Red River Deltas. Nearly 20,000 FFSs for rice have been organized for more than 515,927 farmers, representing 4 per-cent of all Vietnamese farming households that have one member trained in an IPM-FFS for rice.

Box 4.4
Expansion of IPM programme to other crops

Cotton IPM activities are being carried out in collaboration with the Vietnam Cotton Company. By the end of the year 2000, two cotton IPM training of trainers (ToT) courses had been organized, and nearly 2,500 farmers had participated in cotton FFS. Additional (ToT) courses and a strong farmer-training-farmer programme were planned in support of Vietnam's goal of expanding cotton production into the Mekong Delta and additional areas of central Vietnam.

From 1998, the national IPM programme started to develop Community IPM and reach out to farmers throughout Vietnam as a result of more supports from donors. In 2000, FAO Community IPM activities began in three more provinces: Yen Bai in the northern mountainous region, Quang Ngai on the central coast, and Long An in the Mekong Delta. By the 2000 summer season, FAO had funded Community IPM activities in over 120 pilot villages in 29 districts of 19 provinces, sometimes in conjunction with local funding.

By 1997, four vegetable ToTs had been organized, training 132 trainers. Currently each province has a core group of vegetable IPM trainers capable of designing and carrying out provincial vegetable programmes. Approximately 22,000 farmers have been trained in 802 vegetable FFS supported by the national IPM programme. By early 2000, an additional 15,000 farmers had been trained in locally-funded vegetable IPM FFSs.

Source: Plant Protection Department, 'Country Report-Vietnam', Ayutthaya, Thailand, Nov. 2001.

Table 4.9
Number of IPM training courses In Vietnam, 1994-98

	1994	1995	1996	1997	1998	Total
No. of classes	435	790	1,105	2,202	1,462	5,994
No. of farmers	19,490	50,539	58,870	125,273	81,140	335,312

Source: Anh (2000: Table 6)

Since the 2000/01 winter-spring season, DANIDA-IPM has been supporting province-wide development of Community IPM in three priority provinces: Thai Binh in the Red River Delta, and Soc Trang and Can Tho in the Mekong Delta. These provinces are major rice producers and already had long-standing agricultural development partnerships with DANIDA. In Thai Binh, DANIDA-IPM is building on FAO's 1998-2000 support for Community IPM.

It is worth noting that not all farmers have applied IPM techniques in their fields after taking IPM training courses. On the other hand, those who do not have opportunity to participate in classes may nevertheless also use IPM techniques on the basis of knowledge acquired via public media, neighbouring farmers or direct contact with local agricultural technicians. The economic benefits of using IPM techniques have encouraged more adoption by farmers. Experiments in FFS fields demonstrate that IPM not only helps farmers to reduce unnecessary pesticide spraying, but also reduces seed use and application of fertilizers, particularly nitrogenous fertilizers. The impact of IPM and FFS on output, cultivation practices and economic returns have been reported in many studies, for example, Chung and Dung (1996) and Pincus (2000). An FAO Intercountry Programme evaluation of the impact of IPM Farmer Field Schools on cultivation practices found that trained farmers changed their pest control behaviour and obtained several benefits from the programme (Pincus, 2000). Chapter 5 uses survey data to discuss the IPM programme further.

One instrument successfully implemented in Vietnam was the use of multimedia to transfer technical knowledge to farmers quickly through the IRRI Rice IPM Network. The pilot programme was launched by the Ministry of Agriculture and Rural Development and carried out in two remote districts in Long An province as early as November 1994. Two activities of the programme were provision of information on pest management through multimedia, and farmers' direct participation in experiments on their fields. Farmers were invited to conduct such experiments with a simple text message: 'Early spraying for leaf-feeder control in the first 40 days after sowing is not necessary.' Farmers were required to earmark a plot of 500 m2 for the experiment, not to spray insecticides for controlling leaf feeders on that plot, and to measure and compare the final yields and cost of pesticides with those of other plots. The result was that, while yields in the experimental plot and the rest of the field were similar, insecticides costs were lower for the experimental plots. However, even though the pilot programme contributed to changing farmers' views about the use of insecticides against leaf-feeders, most farmers continue to believe that they are still problematic at the heading stage. In addition, more spays are targeted at other insects, such as stem-borers (Heong, et al., 1995; Huan et al., 1999: 557-63).

4.6 Concluding remarks

This chapter presented an overview of market-oriented reforms and regulations for the use of agrochemicals from 1976, one year after reunification. The reforms in the agricultural sector, especially in the rice sector, have created incentives for farmers to increase production. During the application of *đoi moi*, Vietnam has changed from a food-importing to a rice-exporting country.

Efforts to impose collectivization in rice production throughout the country after reunification failed. Reforms in agriculture, which started in 1981 by introducing an output contract system, privatization of the output market and decentralization of input supplies, brought about a significant boost in rice production. From May 2001, the markets for rice, fertilizers, pesticides and other agricultural outputs and inputs were fully free. Farming households now make their own decisions about rice production and marketing. Both State and private enterprises have equal rights to engage in import and export of agricultural output and inputs.

Reform of pesticide regulation policies as early as 1990 helped to control the activities of enterprises/companies, distribution agents and retailers of imported hazardous pesticides, as well as the production, distribution and storage of pesticides. These policies are expected contribute to reducing the risks posed by pesticides to human health and the environment. Since 1992, at the farm level, the national IPM programme, comprising a broad range of training and research activities, has helped farmers not only to make better use of pesticides but also to improve their knowledge of and skills in pest control and safe use. Farmers' gains from the programme are both economically and socially beneficial (for example, reduced cost of pesticides, fertilizers and seeds). As a result, the programme has continued to be implemented on a large scale and on a community basis.

Notes

[1] Agricultural land covers 22 per cent of the total area. Three-quarters of the agricultural land is under annual crops, of which rice makes up 77 per cent.

[2] In early 1988, private companies were officially allowed to participate directly in the fertilizer import business (Khiem and Pingali, 1995).

[3] In the MKD, although agriculture continued operating on a farm household basis, the households were also grouped in 'so-called' cooperatives to obtain inputs and marketing channels (Pingali and Xuan, 1992).

[4] Some factories and companies produced pesticides in the south before 1975 (for example, Saigon Pesticides Company and Binh Trieu Pesticides Factory).

[5] The common name or chemical name of pesticides refers to their active ingredients. Many pesticides marketed under different trade names have the same active ingredient. For example, fungicides known as Amine, Anco, Cantosin, Quick, and Nufa all contain the same active ingredient, 2.4 D.

5

Rice Cultivation Practices and Agrochemical Use

5.1 Introduction

The analysis in Chapters 3 and 4 showed that the development of rice production in Vietnam since *đoi moi* has been influenced by market reforms and biophysical attributes of natural resources. Rice has been grown intensively in both favourable and unfavourable environments, its cropping intensity has been increased, and its production now highly depends on agrochemicals. Given local biophysical and socioeconomic conditions, understanding farmers' decisions regarding cultivation practices and input use are crucial for enhancing the adoption of farming technologies that are environmentally sound, socially acceptable and profitable to farmers. At the farm level, the amounts of primary nutrients have often been studied since they play a vital role in rice growth. They are used in large amounts and pose a significant cost to farmers and a threat to the environment. Technically, the amount of fertilizers to be applied depends on many factors, such as rice varieties, growing seasons, crop establishment and soil and water conditions. Farmers also have to consider pest population, nutrients and crop growth status prior to pesticide application.

The purpose of this chapter is mainly to explore issues relating to farmers' farming practices, and patterns of agrochemical use, on the basis of information from the two surveys carried out in the MKD in 1996/97 and 2000/01. Although the study area is considered to be homogeneous in terms of physical, environmental and socioeconomic conditions, each village has its specific resource endowment, history of agricultural development and traditional farming practices.

The second section of this chapter outlines specific features of the study sites, focusing especially on the resource endowments of farm households (for example, land, labour force and education). In addition, it describes farmers' rice cultivation practices, such as seed selection and land preparation, which influence the use of agrochemicals. The third and fourth sections describe farmers' fertilizer and pesticide management practices, respectively, and analyse various factors affecting the use of agrochemicals. Farm households' use of agrochemicals will be analysed for all households and the same households group as well as across the two surveys to pinpoint the changes over time. Furthermore, as seen in Chapter 4, the IPM programme does more than equip farmers with better pest management skills; it also imparts knowledge about nutrients and other cultivation techniques. Therefore, the analyses are also presented for two groups of farmers, IPM and non-IPM. The fifth section summarizes the findings of the chapter.

5.2 Profile of survey area

5.2.1 Characteristics of survey sites

The study sites in the two surveys are located in the Mekong Delta (MKD) of Vietnam. The 1996/97 survey covered six villages in five districts of four provinces, and the 2000/01survey was conducted in six villages of six districts of the same provinces as in the 1996/1997 survey. The districts are located along the Mekong River, 120 kilometres to the west of Ho Chi Minh city, between the area near the border with Cambodia and the city of Can Tho. These districts vary in production environment (access to irrigation water and soil fertility) and agrochemical application per hectare.

The patterns of agrochemical use are studied by comparing all households across the two surveys. As explained earlier, the fact that 76 households in four villages are the same in the two surveys makes comparisons over time possible. These 76 households provided rather complete information and are denoted as the 'same households group'. The term 'households' refers to rice-farming households in both surveys and will be used in that sense throughout the study. The terms 'farmers' and 'rice farmers' are also used interchangeably. However, in examining the effects of pesticides on farmers' health, the farmers directly exposed to pesticides are in this case not the entire household.

5.2.2 Agricultural and rice lands

Agricultural land in Vietnamese statistics includes land for annual crops, perennial crops and aquaculture. The distribution of agricultural and rice lands in the survey sites is presented in Table 5.1. The amount of agricultural land per household is quite small for all farmers and across villages, with an average of 0.96 and 1.22 hectare for the two surveys, respectively (see Table 5.2). This is quite close to that found by GSO (2000b), which was 1.06 acres per household in the MKD. The smallest cultivated land holding in the study sites is 0.2 ha, the biggest is 3.9 ha in 1996/97 and 4.3 ha in 2000/01. The difference is due to differences in survey sites.

Table 5.1
Distribution and size of agricultural and rice land in survey villages

Villages	**Land (ha)**	**Survey year**			
		1996/97		***2000/01***	
		Mean	*Median*	*Mean*	*Median*
Nhi My*	Rice	0.47 (0.26)	0.40	0.49 (0.24)	0.40
	Agriculture	0.52 (0.30)	0.43	0.55 (0.28)	0.50
Tan Phu Trung*	Rice	1.05 (0.74)	0.78	1.20 (0.81)	1.00
	Agriculture	1.14 (0.85)	0.80	1.25 (0.80)	1.00
Long Dien*	Rice	0.94 (0.80)	0.68	0.94 (0.80)	0.73
	Agriculture	0.99 (0.85)	0.75	1.00 (0.80)	0.80
Vinh My*	Rice	1.33 (0.88)	1.00	1.36 (0.90)	1.00
	Agriculture	1.48 (0.89)	1.00	1.39 (0.87)	1.00
Thanh Xuan	Rice	0.84 (0.50)	0.70	-	-
	Agriculture	0.96 (0.62)	0.70	-	-
Dong Phuoc	Rice	0.68 (0.29)	0.63	-	-
	Agriculture	0.73 (0.38)	0.63	-	-
Thanh Hoa	Rice	-	-	1.25 (0.64)	1.20
	Agriculture	-	-	1.47 (0.78)	1.30
Tan Binh	Rice	-	-	1.46 (0.82)	1.49
	Agriculture	-	-	1.49 (0.82)	1.54

Notes: * Villages common to both surveys. Figures in parentheses are standard deviations.

It is often assumed that in the process of rural development, households with large amounts of agricultural land will have an opportunity to buy more land, and that small farmers (that is, households with small amounts of land) will lose their lands gradually as a result of incentives provided by land law (Ahram-Lodhi, 2005: 83-7). However, the analysis shows that this is not yet the case in the MKD. In the four comparable villages, there are also no big changes in agricultural landholding, although there is a slight increase in Tan Phu Trung, where more land is allocated to rice production. This shows that the possibility of increasing agricultural land is limited by the current level of availability of land for agriculture and by increases in the number of rural households. During the 1997-2001 period, farm size is small on the average but there is uneven distribution between households and between villages. In the survey, farmers in Nhi My village have the smallest farm size, which is approximately equal to half the sizes in other villages. Nhi My is one of the most intensive rice-producing villages in the MKD, with the crop being grown almost three times a year, or even seven times in two consecutive years.

Given the small land acreage, it is important to know how households allocate their land to production. Almost 94 per cent of agricultural land is devoted to rice production in all villages, and this figure remains the same throughout the years between the two surveys. Households usually use the remaining land for home gardens or small fishery ponds.[1] However, some households with rather large amounts of agricultural land use some of it for perennial crops. Most agricultural land is devoted to rice production, with increasing rice crop intensity as a tendency. Table 5.2 presents rice production characteristics of farm households in the survey sites. The range of agricultural land-holdings again indicates that there was substantial inequality in land distribution among households. As seen within the same household (SHH) group, while there was little change in the average land size, the land distribution varied. The smallest and biggest agricultural land size were 0.2 and 3.0 hectares, respectively.

5.2.3 Land quality

Farm households faced different conditions for rice cultivation, in terms of soil type, topography, and irrigation system. Soil quality is a valuable indicator for capturing these differences. Following the levying of agricultural land tax in 1993, lands for annual crops were classified into six

Table 5.2
General characteristics of farm households in survey sites

Characteristics	1996/97		2000/01	
	Mean	*Range*	*Mean*	*Range*
	All households			
Agricultural land (ha)	0.96	0.2-4.5	1.22	0.2-3.9
Rice land (ha)	0.88	0.2-4.3	1.04	0.2-3.6
Rice land/Agri. land ratio (%)	93.76	50.0-100.0	93.55	41.7-100.0
Double crops (% of HH)	70.60	-	42.10	-
Triple crops (% of HH)	29.40	-	57.90	-
Household size (persons)	5.84	1-14	5.25	2-13
Household labour (persons)	3.26	1-9	2.81	1-8
Years of rice farming (years)	23.2	3-55	22.5	2-56
	Same household group			
Agricultural land (ha)	1.00	0.2-3.0	1.01	0.2-3.0
Rice land (ha)	0.91	0.2-3.0	0.95	0.2-3.0
Rice land/Agri. land ratio (%)	93.47	56.6-100.0	93.68	41.7-100
Double crops (% of HH)	60.50	-	34.20	-
Triple crops (% of HH)	39.50	-	65.80	-
Household size (persons)	5.38	2-13	5.17	2-13
Household labour (persons)	2.97	1-7	2.79	1-7
Years of rice farming (years)	20.5	5-50	22.5	10-55

Note: HH = Households.
Source: 1996/97 and 2000/01 surveys.

categories subject to different tax rates. The basis for classification was soil type, location, topography, drainage/irrigation and weather conditions. Land in Class 1 is considered as having the best conditions for crops and is subject to the highest tax rate, while the land in class 6 is the worst. In general, rice lands in the survey sites have favourable conditions for crop cultivation. Table 5.3 shows that 48.4 per cent of households have Class 1 agricultural land and approximately 9.4 per cent of the total land of the surveyed households falls in Classes 4 and 5. There is no land in Class 6. Land owned by the SHH groups displays somewhat similar characteristics: 10.6 per cent falls in Classes 4 and 5, and 39.5 per cent is Class 1 land. Thus, most of the land farmed by the survey households is of good quality.

Table 5.3
Distribution of agricultural land among survey households, by land class (%)

	Land classes					
	1	*2*	*3*	*4*	*5*	*6*
All farmers	48.4	29.6	12.6	5.0	4.4	0.0
SHH group	39.5	34.2	15.8	5.3	5.3	0.0

Notes: SHH group = Same household group.
Source: 1996/97 and 2000/01 surveys.

5.2.4 Cropping patterns and crop intensity

Cropping patterns in the study sites generally do not vary over time or space or because of differences in local economic and social conditions. Given the availability of irrigation, rice was the only main crop grown in the study sites during the survey periods, though some other crops were grown in rotation with rice. Farmers gave various explanations for why rotation of other crops in rice field is seldom practised. Among these, the most significant were: unfavourable field conditions, fewer markets for alternative crops, availability of rice markets and availability of family labour (that is, other crops require more intensive use of family labour for irrigation and crop care than rice). Crops such as maize, soybean and vegetables are mostly grown on land unsuitable for rice. They are usually planted when the rainy season is due, and harvested three months later.

The sowing and harvesting dates of rice mostly depend on water availability, which varies among villages. The growing season lasts for about 95 to 110 days, and sowing and harvesting dates are spread around one month from place to place in the survey sites. Farmers make decisions according to the biophysical conditions in their own fields. In areas where flood water cannot be controlled from September to November, farmers practise only double cropping. The sowing dates for summer-autumn rice are around one month later than those in triple-cropping areas, which are mostly dependent on the rainy season (mostly in late May). The sowing dates for winter-spring rice are around late November to December when flood waters have receded. The water for winter-spring rice is supplied through irrigation systems. Where flood water is controlled, farmers grow a third autumn-winter crop. This asymmetry of growing schedules may be problematic in terms of pest control. When one rice field is treated with pesticides, a number of pests will move from one field to another since rice is always available in different fields. Then, the neighbouring farmers have to spray to prevent their crops from pest damage. Nevertheless, differentiation in planting schedules could help farm households lessen some pressures in production, such as peak demand for labour during planting and harvesting, huge quantities of rice becoming available in the market and thus lowering prices, and peak demands for pesticides and fertilizers within a short time.

There is a considerable increase in cropping intensity in the study area from the 1996/97 winter-spring to 2000/01 winter-spring season, partly reflecting improvement in the irrigation system. Thus, building dikes gradually along canal networks to prevent rice fields from flooding has made triple cropping possible in the MKD. However, other factors such as demand for rice and income pressures may influence farm households' decisions regarding cropping intensity. Farm households cultivate rice twice or thrice, or even 3.5 times a year. As seen in Table 5.2, triple rice crops are practised more and more from 1996/97 to 2000/01. Nearly 60 per cent of farm households grow three crops a year, which indicates that they are choosing to further intensify rice monoculture. Within the SHH group, the proportion of households cultivating three rice crops a year increases from 39.5 in the 1996/97 winter-spring season to 65.8 per cent in the 2000/01 winter-spring season (see Table 5.2). For all households, the increase is from 29.4 to 57.9 per cent.

However, intensive rice monoculture leads to serious worries about changes in production and environmental consequences. Rice productivity could decline due to changes in soil nutrients and physical characteristics, increased reliance on chemical fertilizers, increasing pest build-up and pest-related yield losses (Pingali et al., 1997). According to Greenland (1997), these consequences are not the same for every farming system, but they vary with specific agro-ecological conditions. Rice farming systems in alluvial flood plains of the river have special properties relating to soil characteristics resulting from different cultivating conditions. Nutrients and silt are partly replenished by flood and irrigation water. Hence, nutrients tend to be leached into the soil rather than out of it, and soil erosion is unlikely to occur.[2] Rice yields obtained by farm households in the survey sites are examined in Chapter 6, where the possible negative effects on land productivity will be discussed.

5.2.5 Rice seed and varieties

At the beginning of a growing season, one of the first decisions of farm households, aside from market considerations regarding inputs and output, is the choice of seeds is. As demonstrated in Chapter 3, the wide adoption of HYVs in rice-growing areas has contributed significantly to the increase in Vietnam's rice production recently. At the farm level, high yield is the expectation of most farm households. Thy thus look for varieties and seeds that will provide the highest possible yields while being suitable for the physical characteristics of their fields. In the MKD, there is a strong demand-driven process of technological renewal in rice varieties. There is substantial and constant demand from farmers for new rice varieties providing high yield, suitable for the local environment and with resistance to major pests, which has forced the development research institutions to keep breeding, testing and releasing new varieties. In the past, when traditional varieties were cultivated, most farmers saved their own seeds for the next season. With the increasing availability of new and further improved rice varieties in recent years, farmers have recognized the value attached to seeds in terms of yield, pest resistance, and shortened growth period. There are three factors that seem to account for the wide adoption of HYVs in the study sites:

(i) availability of HYVs with short growth duration and which are suitable for a particular area;
(ii) tendency of farmers to maximize annual crop production or net economic gains per unit area of land; and
(iii) relatively low yields and long growth duration of local rice varieties.

Taken together, these factors reflect both the farm households' behaviour and influences of rice research and extension services.

The seeding rate per hectare is significantly lower in the 2000/01 winter-spring season (169.4 to 190.6 kg/ha) than in the 1996/97 winter-spring season (213.3 to 218.6 kg/ha) (see Table 5.4). The lower seeding rate in the 2000/01 winter-spring season is partly due to relatively higher price of seeds when compared with the rice price, among other factors such as row-sowing technique and knowledge acquired from the IPM programme. In the 2000/01 winter-spring season, one kilogram of seed cost farmers 1.36 kg of rice, but had been only 1.30 in the 1996/97 winter-spring season.

All rice varieties used by farm households are characterized as high yielding, and with short growing periods, and resistant to the Brown Plant Hopper, a pest causing serious damage to previous HYVs. By cultivating these HYVs, farmers in well-irrigated villages can grow three crops a year and thus increase their output. In addition, due to favourable weather, rice yields in the dry season are usually high and stable over time; hence, farmers do not favour local rice varieties, with low yields and a longer growing period (around 4.5 to 5.5 months) any more.

Table 5.4
Seeding rate (kg/ha) and seed prices (VND/kg) paid by survey households

	SHH group			**All households**		
	2000/01	***1996/97***	***t-ratio***	***2000/01***	***1996/97***	***t-ratio***
Seeding rate	169.40	213.30	5.63 ***	190.60	218.60	5.56 ***
Current price	1,769.50	1,621.30	2.23 **	1,784.30	1,653.10	2.78 **
Relative price	1.36	1.30	1.80 *	1.37	1.30	1.87*

Notes: ***,**,* : significant at 1%, 5%, and 10% levels, respectively. SHH group = Same household group.

Source: 1996/97 and 2000/01 surveys.

In both surveys, the high-yielding varieties were prominently grown in the study sites. Since all village lands were considered to be suitable (favourable rainfall patterns, access to irrigation, good topography, and so on.) for modern rice varieties, it is not surprising that all surveyed farm households cultivated HYVs in both rainy and dry seasons. The traditional rice varieties are not suitable for growing two or more rice crops a year in the study sites. Hybrid rice seeds from China are not grown in the study sites. These hybrid seeds cannot be kept and planted in the next season because the advantages of the seed can no longer be sustained (Pingali et al., 1997: 208-33). Current HYVs grown in the study sites are inbred rice varieties, which can be saved and planted in subsequent seasons.

The changes in rice varieties are shown in Table 5.5. In the villages as a whole, approximately 70 per cent of farm households changed rice varieties from three to five times in four years and only about 6 per cent continued using the same varieties. From the farmers' points of view, new varieties have a number of advantages, such as higher yields, better quality meeting market requirements, higher prices, and better resistance to pests. On the other hand, when seeds are kept from previous seasons, the result is lower yield and quality, disease and insect infection, and unsuitability to field conditions. Among the factors influencing farmers' choice of seed are recommendations and release of new seed varieties by agricultural research institutions, extension centres and rice-breeding centres.

Table 5.5

Change in rice varieties used by individual households during 1996/97 - 2000/01

Numbers of varieties changed *	**All households**		**SHH group**	
	No. of HH	*%*	*No. of HH*	*%*
0	7	4.4	6	7.9
2	26	16.4	12	15.8
3	55	34.6	24	31.6
4	31	19.5	16	21.1
5	22	13.8	10	13.2
6	15	9.4	7	9.2
7	1	0.6	1	1.3
10	2	1.3	-	-
Total	N=159	100.0	N=76	100.0

Notes: * Within a four-year period. SHH group = Same household group. HH = Households.

Source: 1996/97 and 2000/01 surveys.

However, there are problems regarding seeds of new varieties. New variety seeds can be bought from a number of sources. Farmers may buy them within or outside the village. For example, a farmer who sees neighbours obtaining a higher yield from a variety different from the one in his field may buy those seeds and grow them in the next growing season. The quality of new variety seeds bought from other farmers is usually low since the seed is not pure and the origin and name of the variety are unclear. Some farmers buy seeds from farmers who specialize in multiplying certified seed released by agricultural centres. Other farmers go to different agricultural centres (that is, the official or reliable sources) to buy new seeds after discussing with experts there and receiving recommendations for appropriate use.

Though changing to new HYVs is reasonable, the use of unofficial sources for seeds is also an issue of concern. The farmers may not receive appropriate information on the cultivation of such varieties, especially basic information on fertilizer use. Hence, they might use too little or too much fertilizer. The danger of pests and disease may also be underestimated, which may lead to an outbreak of pests or rice disease in the region.

5.2.6 Farmers' education levels

Education is among the factors that constrain rice yields and the effective transfer of new technology. According to Arnon (1981: 214) education of farmers contributes to increased agricultural production in several ways:

(i) it provides farmers with basic skills which support them in making decisions regarding the benefits of new techniques;
(ii) it improves rationality so that it is easier for farmers to overcome traditional social and cultural constraints;
(iii) it improves receptivity to new opportunities and cultivating methods; and
(iv) it changes farmers' values and aspirations.

To illustrate his arguments, Arnon cites the case of Japan. Education of the rural population in Japan is considered as one of the main factors responsible for the extraordinary development of agriculture since the beginning of the twentieth century.

Under recent policy reforms in Vietnam, farmers are responsible for making most farm management decisions. Farmers lean some basic skills during their school education, of which reading, writing and arithmetic are particularly important. These skills enable farmers to make simple calculations such as fertilizer conversion to nutrients or amount of pesticide needed to spray per unit of area. In Vietnam, however, a considerable proportion of illiterate people are concentrated in the rural areas, especially in the MKD. Fifteen per cent of the population who are 10 years and older are illiterate. The percentage of rural communes with ongoing literacy programmes is also highest in the MKD (GSO, 2000b: Table 2.1).

Table 5.6 summarizes the education level of farmers in the survey sites. More than 50 per cent of the farmers have only primary education. There is almost no change in the level of education of sample farmers between 1996/97 and 2000/01. In fact, the survey team noticed that the farmers with only primary education had difficulty reading technical information in brochures or pesticide labels, and/or keeping farm records. Though alternative measures can be used to influence and train illiterate farmers to adopt new technology, it is obviously more difficult than with literate farmers. In the Mekong Delta farmers rarely go to school for further education, as observed in Chapter 3. Therefore, the education level of farmers could be considered a fixed factor of production in the short run. Whether the educational level of the main labour in farm households affects rice supply and demand for agrochemicals will be investigated in Chapter 6.

Table 5.6

Education level of main labour in farm households, 1996/97 and 2000/01(%)

Education level	**All households**		**SHH group**	
	1996/97	***2000/01***	***1996/97***	***2000/01***
Primary school & lower	55.4	57.9	52.6	53.9
Secondary school	32.2	27.0	35.5	32.9
High school & upper*	12.4	15.1	11.8	13.2

Notes: * Upper levels include college and university. SHH group = Same household group.

Source: 1996/97 and 2000/01 surveys.

5.2.7 Rice cultivation practices

Analysis of rice cultivation practices helps to explain and compare the results of agrochemical use by farm households. Cultivation practices refers to the technical activities, such as seed selection, land preparation, crop establishment, caring activities, and nutrient and pest management, undertaken in the rice fields during the growing season. These practices vary according to growing seasons, water conditions, available technology and farmers' preferences, and they affect the final yield. If the practices are very different, the use of nutrients and other inputs also varies, resulting in yield variance. This subsection describes land preparation and crop establishment practices of rice-farming households.

Land preparation

Land preparation is one of the activities for prevention of diminution of soil fertility, through improving the physical, chemical and biological processes in the soil. The techniques used in land preparation are not only a technical issue, they also represent a cost of production to farmers. In general, two land preparation techniques are popular in the study sites and which technique is used in a given season depends on field conditions. Puddled tillage and minimum tillage techniques are the ones most practised by farmers. Land is usually ploughed once a year in the summer-autumn season. In another season it is only harrowed and puddled before sowing. The puddling technique is more popular in the sort of wetlands that are used to produce rice in most countries (Arnon, 1981). In this practice, the soil is soaked with water, puddling the field, and the water is then drained off. Farmers wait about one or two days for the soil surface to become firmer and then sow the pre-germinated seeds. This technique is applied in fields with good irrigation and drainage. In the minimum tillage technique, farmers only harrow the soil and then sow the pre-germinated seeds without puddling. This helps to reduce the cost of land preparation, but more seed is needed in comparison with puddled tillage. Comparing land preparation practices in the north and the south, Yamauchi et al. (1995: 89-95) found that though direct seeding was practised less in the north, fields were well puddled before direct seeding, and the seed rate was lower than that in the MKD (80-100 kg/ha versus 100-300 kg/ha).

Crop establishment

Current crop establishment practices help farmers lower the unit cost of production.[3] Rice crops can be established by transplanting or by wet or dry direct sowing. However, crop establishment by transplanting is not practised in the study sites. In the Mekong Delta, direct sowing has been practised by farmers in both rain-fed and irrigated rice areas since the introduction of HYVs (My et al., 1995: 111-22). Direct sowing requires more seed per unit of land than the traditional transplanting method, but it provides a number of advantages. First, the use of direct sowing increases the area of rice production because the area required for the nursery bed can be converted for production. Second, a substantial part of labour and nursery costs is reduced, and finally, the grain yield of direct-seeded rice is equivalent to or even higher than that of transplanted rice, given the same variety. As the saving in labour and nursery costs outweighs the increase in seed costs, the profitability of direct seeding is higher than that of transplanting, and thus attractive to farmers (Dung, 1994).

Dry direct sowing has been practised in the study sites but is less popular than wet seeding. It is used by a few farmers for summer-autumn rice in double-cropping areas (for example, Tan Phu Trung village). Fields are prepared before the start of the rainy season. Then, non-geminated seeds are spread on dry soil prior to the rains' arrival, and they remain there until there is adequate moisture for germination. The time of sowing is determined by farmers' experience with the local weather (that is, knowledge of when the rains are due). If the seeds are sown long before the rains come, a number of seeds are damaged by birds, insects (ants), heat, and so on, and the germination ratio of the seed is reduced. To obtain a uniform rice stand in the field, farmers often replant empty spaces with young seedlings after the seeds have germinated and there is a standing water layer on the land. In wet direct sowing, the seeds have to be pre-germinated before being sowed. They then start growing as soon as they contact to the soil surface.

Though the direct seeding method is now practised widely, it requires more seed and the seed is unevenly distributed over the field. Farmers in the study sites have recently started using a sowing machine to cope with this problem. In fact, very simple tools for rice sowing have been manufactured and used by farmers. Using the IRRI drum seeders as a model, they are made of plastic to reduce their weight and make operation easier in the paddy fields. Farmers with sowing tools use nearly half of the normal seed quantity per hectare while the cost of the tools was low as VND 100,000 in the 2000/01 winter-spring. So, with the normal seed rate of about 190 kg/ha and a seed price of VND 1,784 per kg (see Table 5.4), these sowing tools are worth the investment. The benefit of using these tools is enhanced by increased efficiency in fertilizing a rice crop planted in rows and decreased pest infection (Tan et al., 2000).

5.3 Nutrient management and use of fertilizers

5.3.1 Nutrient management

Nutrients in the correct amounts are essential for good yields, so nutrient management to replace those used up by plants is very important. If the supply of nutrients in the soil is appropriate, the rice crop will be more likely to grow well. This is especially salient in the case of current varieties, which use a high amount of nutrients. Nutrients in the soil come from many sources, such as rainfall, irrigation and flood water, sediment, nitrogen fixation, manure and crop residuals, but chemical fertilizers are an important source when the amount of nutrients used up from the soil is higher than the natural replenishment (Greenland, 1997; FAO, 2000). Among the essential nutrients for rice crops, he primary ones are nitrogen (N), phosphorus (in the form of P2O5) and potassium (in the form of K2O) and they are used in larger amounts than the others. These nutrients are manufactured and mixed in different concentrations and forms of fertilizers to be used in the fields. The farmers decide the timing, quantity and method of application for optimum crop use efficiency.

Most farmers in the study sites supply primary nutrients to rice fields by top-dressing (that is, applying fertilizers on the soil surface when the rice crop is growing in the field). This is an appropriate method since the farmers practise direct seeding for crop establishment and there is little space between the plants. Some farmers sow seeds in rows, in which case they fertilize the rice crop along the rows. Farm households usually apply fertilizer three times: one basal and two top-dressing applications. When more nutrients are needed during the flowering stage, farmers use liquid fertilizer, usually nitrogenous nutrients, to spray on the rice leaves.

In addition to chemical fertilizers, farmers also apply natural fertilizer in the form of ash made by burning rice straw.[4] In the application of all fertilizers, the amount and timing of nutrient uptake are important elements for optimum efficiency.

5.3.2 Types of chemical fertilizers used

Numerous chemical fertilizers containing the three main nutrients are used by farm households. Urea is the most prominent straight fertilizer used to supply nitrogenous nutrients to the rice crop.[5] Almost 90 per cent of farm households use urea in rice production. KCl fertilizer is another straight fertilizer, usually used during the third fertilizer application to supply potassium to the rice crop. The rest of the fertilizers are multi-nutrient, containing different concentrations of nutrients. DAP (Diammonium phosphate) and NPK fertilizers are the most popular ones in this category. However, different mixtures of N, P and K in NPK fertilizers may puzzle farm households when they are calculating the appropriate amounts of nutrients that should be applied. About 120 commercial types of NPK fertilizer in different concentration mixtures are permitted for use in Vietnam.[6] The most popular fertilizers used in the study sites are urea, KCl, DAP and NPK (16-16-8, 20-20-15, 15-15-20, 15-20-15, 20-10-10, 20-20-10). The prices of commercial fertilizers vary according to the nutrient mixture and concentration. Therefore, the total amounts of various commercial fertilizers used do not serve the purpose of making comparisons of fertilizer use. All types of commercial fertilizers applied by farm households are therefore converted into N, P, K nutrients.

5.3.3 Quantity of chemical fertilizers used in rice production

The amount and balance of nutrients supplied in the form of fertilizers should ideally be equal to those removed from a specific rice field, measured through soil or plant analysis. In practice, most small rice farmers cannot perform such analysis due to lack of knowledge, technical assistance and the small size of their rice fields which makes investment in such assistance or knowledge uneconomic. Farmers often receive recommendations from agricultural officials or sources such as retailers, neighbours, extension workers, experiment centres, and particularly the suppliers of rice seeds, and then make adjustments for their fields. Farmers buy rice seeds from various supply sources; hence they are recommended different dosage rates of fertilizer. Recommendations given by experimental or research centres and even in demonstration fields are generally uniform on a provincial or regional basis. However, there is wide variation in fertilizer quantities used by rice farmers, deviating considerably from the general recommendation. As a result, rice yield and technical efficiency of fertilizer use were lower on the farms than at research stations (Tan et al., 1999). In addition, though HYVs are characterized as having higher response to fertilizers than traditional rice varieties, nutrient requirements and their yields are not necessary the same for HYVs. In general, higher yields require higher nutrients to be replenished, if other things remain constant. Consequently, when a farmer uses a new variety advertised as giving higher yield than the previous one, he is likely to apply more fertilizer initially.

The amount of fertilizer (converted into N, P, K nutrients) used per hectare per season in the study sites is presented in Table 5.7. On average, farmers applied 178.46 and 171.60 kg of NPK in the 1996/97 and 2000/01 dry seasons, respectively. Though the amount of fertilizer applied per hectare is lower for the 2000/01 winter-spring rice season, the difference in the average amount of fertilizers applied across a four-year period (between 1996/97 and 2000/01) is not statistically significant. The largest amount applied was of nitrogenous fertilizers (99.48 kg/ha), with phosphorus fertilizers ranking second (43.01 kg/ha) and potassium fertilizers third (29.10 kg/ha) in the 2000/01 winter-spring season. A similar pattern of fertilizer application was found in 1996/97 winter-spring season.

However, with regard to the combination of N, P, K nutrients, three was a clear change in nutrient balance practice in the study sites. Technically speaking, the balance of N, P, K nutrients in rice production is necessary for optimum efficiency of fertilizer use; without phosphorus and potassium application, nitrogen efficiency declined (FAO, 2000: 12). Farmers have tended to increase the amount of potassium, but have reduced the use of nitrogenous and phosphorus fertilizers. All these changes are significantly different between the two surveys. Farmers increased potassium fertilizer rates from 18.29 kg K/ha/crop in 1996/97 to 29.10 kg K/ha/crop in 2000/01, implying a movement to a more balanced fertilizer use as a factor for increasing N efficiency.

Within the SHH group, there is a substantial and significant reduction in fertilizers used per crop per hectare over a four-year period (1996/97 – 2000/01). The mean value of the fertilizer use rate was 18.72 kg of nutrients lower in the 2000/01 dry season in compared with that of 1996/97, of which 15.97 kg was due to reduction in nitrogenous fertilizers (Table 5.7). Farm households increased potassium and adjusted the rate of applied N and P downwards accordingly. The t-tests show that the changes of NPK nutrient ratios in fertilizer application are significantly different at 1 per cent level. The new balance of NPK nutrients and reduction in NPK quantity could provide better yield and a cost saving, thus more profits (see Chapter 6).

Table 5.7

Change in fertilizer use per crop per ha in rice production

Input quantity	Unit	2000/01	1996/97	Mean difference	t-ratio
		All households			
Fertilizer	Kg of N, P,K	171.6	178.5	6.86	1.48 NS
Nitrogen	Kg of N	99.48	111.73	12.25	4.55 ***
Phosphorus	Kg of P_2O_5	43.01	48.45	5.43	2.31 **
Potassium	Kg of K_2O	29.10	18.29	10.80	5.97 ***
		SHH group			
Fertilizer	Kg of N, P,K	165.02	183.80	18.72	2.70 ***
Nitrogen	Kg of N	96.30	112.27	15.97	4.14 ***
Phosphorus	Kg of P_2O_5	40.83	54.82	13.99	3.92 ***
Potassium	Kg of K_2O	27.91	16.70	11.21	4.28 ***

Note: SHH group = Same household group.
Source: 1996/97 and 2000/01 surveys.

The average use of fertilizers in the survey sites is slightly lower than that reported in some other studies. A three-year study of fertilizer application in rice production in five provinces during 1997-2000 (Tan et al., 2000) found that farmers on average used 109 kg, 49 kg and 32 kg of N, P, K nutrients respectively per crop per hectare. The difference is most likely due to variation in study sites, farmer selection[7] and crop season.

Amongst the factors determining the fertilizer use rates of their rice fields, farmers are likely to take into account soil replenishment from silt[8] and yield expectations. Over a year, fertilizer use rates are not much different between growing seasons, while yields are. The summer-autumn rice (second season) was fertilized at the same rate as winter-spring rice (first season). In the autumn-winter rice season (third season), fertilizers were applied at higher rates than during the other two seasons. The surveyed farmers only increased fertilizers a little for the third season, by about 5-7 per cent in comparison with that for the winter-spring rice. Farmers said they had increased fertilizer in the third season because a large amount of soil nutrients had been used up in the previous seasons. However, because rice yields in this season are low, most farmers do not increase fertilizer use much. Higher fertilizer use rates in the autumn-winter rice seasons have been recorded in various studies in the

Mekong Delta, while yields were the lowest (Dung et al., 1999; Sau, 1997; Tan et al., 1999 and 2000). Normally, the autumn-winter crop is poorer than the winter-spring crop due to poor photosynthesis (Sau, 1997), so farmers would be expected to apply more nitrogenous fertilizers in the autumn-winter despite low yield potential and numerous pest problems (Tan et al., 1999). As a consequence, the partial productivity of nitrogenous fertilizers in the autumn-winter season is low, approximately equal to half of the winter-spring season (Tan et al., 1999).

IPM farmers and fertilizer application

IPM farmers were trained not only in pest control, but also how to keep the rice plants healthy through better nutrient management. They were therefore expected to take more rational decisions about the amount used and timing of fertilizer application. Tables 5.8 and 5.9 show that IPM farmers, in the SHH group and all households, had a lower application rate than non-IPM farmers in both surveys.

The picture is clearer in the SHH group. Within a season, the amounts of fertilizers applied per crop per hectare of IPM farmers were lower by 12.32 kg (in 1996/97) and 7.90 kg (in 2000/01) than those of non-IPM farmers (see Table 5.8). Following the t-tests results, however, the mean differences were not statistically significant. This indicates that the mean differences in NPK fertilizer application rates of IPM and non-IPM farmers within a season were due to random effects. When a comparison is made across both surveys, it is interesting to see that the reduction in N and P fertilizers of IPM farmers in the 2000/01 winter-spring season is significantly different at 10 per cent, and 5 per cent, respectively. However, IPM farmers adjusted the amount of K fertilizers upwards in the 2000/01 winter-spring season by 8.41 kg/crop/hectare, which is significantly different at 5 per cent level. Nevertheless, the average mean difference of NPK fertilizer rates was not significant. Significant differences in the amount of N, P, K nutrients applied were also found in the non-IPM farmer group between the two surveys. The reductions in N, P, fertilizer rates in the 2000/01 winter-spring season were 16.41 kg and 14.79 kg, and significantly different at 1 per cent and 5 per cent respectively, in comparison with those in the 1996/97 winter-spring season. Non-IPM farmers increased K fertilizer by 13.67 kg per crop per hectare in the 2000/01 winter-spring season. The increase was significantly different at 1 per cent level. This suggests that farmers who do not have IPM training have alternative sources of fertilizer use information, and balance the nutrients as well as IPM farmers.

Table 5.8
Changes in fertilizer use by non-IPM and IPM farmers per crop per ha, SHH group

Input quantity	Unit	Non-IPM farmers	IPM farmers	Mean difference	t-ratio
		2000/01 winter-spring season			
Fertilizer	Kg of NPK	170.65	162.75	7.90	0.71 ^{NS}
Nitrogen	Kg of N	100.59	94.55	6.04	0.96 ^{NS}
Phosphorus	Kg of P_2O_5	41.45	40.58	0.86	0.17 ^{NS}
Potassium	Kg of K_2O	28.89	27.52	1.37	0.34 ^{NS}
		1996/97 winter-spring season			
Fertilizer	Kg of NPK	188.50	176.10	12.32	1.26 ^{NS}
Nitrogen	Kg of N	117.00	104.60	12.40	2.39 **
Phosphorus	Kg of P_2O_5	56.24	52.50	3.74	0.65 ^{NS}
Potassium	Kg of K_2O	15.21	19.10	3.89	1.01 ^{NS}

Source: 1996/97 and 2000/01 surveys.

The fertilizer application rate of IPM farmers in all farm households are similar to those of the SHH group. IPM farmers significantly reduced both the average fertilizer use rate (at 5 per cent level), and individual N and P nutrient rates (at 1 per cent level) in the 2000/01 winter-spring season (Table 5.9). The increase in K fertilizers of IPM farmers in the 2000/01 season (8.29 kg) was significant at 1 per cent level, while the reduction of the average fertilizer application rate of non-IPM farmers was small (1.23 kg NPK) and not significantly different across the two surveys. While the reduction in N fertilizers was significant at 5 per cent level, the reduction in P fertilizers was not. The most noticeable aspect is that non-IPM farmers significantly increased the amount of K fertilizer by 11.79 kg from the 1996/97 winter-spring season. Within a season, differences in fertilizer application rates of IPM and non-IPM farmers were not statistically significant. In short, IPM and non-IPM farmers reduced the amount of N and P fertilizers and adjusted K fertilizers upwards in the 2000/01 winter-spring season in comparisons with the 1996/97 winter-spring season.

Table 5.9
Changes in fertilizers use by non-IPM and IPM farmers per crop per ha, all households

Input quantity	Unit	Non-IPM Farmers	IPM Farmers	Mean difference	t-ratio
		2000/01 winter-spring season			
Fertilizer	Kg of NPK	173.80	170.62	3.18	0.45 ^{NS}
Nitrogen	Kg of N	101.43	98.67	2.76	0.68 ^{NS}
Phosphorus	Kg of P_2O_5	43.78	42.69	1.09	0.36 ^{NS}
Potassium	Kg of K_2O	28.76	29.24	0.48	0.17 ^{NS}
		1996/97 winter-spring season			
Fertilizer	Kg of NPK	175.07	185.41	10.34	1.45 ^{NS}
Nitrogen	Kg of N	111.45	112.31	0.86	0.21 ^{NS}
Phosphorus	Kg of P_2O_5	46.65	52.14	5.49	1.36 ^{NS}
Potassium	Kg of K_2O	16.97	21.00	4.03	1.50 ^{NS}

Source: 1996/97 and 2000/01 surveys.

Overall consumption of fertilizers per hectare per year

Recent studies of rice production in the Mekong Delta have found that the average amounts of fertilizers applied per crop were almost similar across the three seasons (summer-autumn, autumn-winter and winter-spring,) although there were slight adjustments of the NPK nutrient ratios (see Nhan et al., 2002; Sau, 1997; and Tan et al., 1999). Nhan et al. (2002) report that farmers applied 178.66 kg of NPK per hectare in winter-spring, which is very close to the fertilizer application rate in the 2000/01 winter-spring season in this study. In other seasons farmers used the same fertilizers rate (summer-winter) or a slightly higher one of 184 kg NPK in spring-summer.

From the pattern of fertilizer use between seasons in a year, the total fertilizer used in rice production per hectare per year is estimated using the cropping intensity and the winter-spring fertilizer rates. Table 5.10 shows that despite the fertilizer use rate per crop per hectare in 2000/01 being lower than in 1996/97, the total amount of fertilizers applied per hectare per year still increased during a four-year period. Farm households growing three rice crops a year had higher rates of fertilizer application in the 2000/01 winter-spring season than in the 1996/97 winter-spring season. Fertilizer consumption per hectare per year was thus very high compared with the average fertilizer consumption per hectare of arable land for Vietnam (as observed in Chapter 3). Total increase in fertilizer use was due to increased cropping intensity, from 2.23 to 2.57 for all households and from 2.33 to 2.70 for the SHH group (see Table 5.10). Triple rice crops required an increased fertilizer use rate, as confirmed by comparison between the two surveys, indicating that the more rice production is intensified, the higher the amount of fertilizers applied per hectare per year.

Table 5.10

Estimated quantity of fertilizers used in rice production per ha/ year (kg of nutrients)

Categories	Cropping intensity	Double crop	Triple crop
		1997/97 survey	
All households	2.23	344.47	554.70
SHH group	2.33	359.13	541.85
		2000/01 survey	
All households	2.57	321.34	556.00
SHH group	2.70	337.35	555.88

Note: SHH group = Same household group.

Source: 1996/97 and 2000/01 surveys.

Thus, fertilizer use by farm households in the study area can be summarized as follows. Chemical fertilizer is the main source of nutrient supply to the rice crop. The only organic fertilizer applied is rice straw. Nitrogenous fertilizers account for the largest proportion of fertilizer used. All farm households practise split application of fertilizers, which enhances their technical efficiency. Though the amount of fertilizers applied in 2000/01 by IPM farmers were lower than in 1996/97 and lower than those of non-IPM farmers, the difference is not statistically significant. The quantity of fertilizers applied is similar among the three growing seasons within a year, and is about 555 kg of N, P, K nutrients per hectare per year when rice is grown three times a year. Intensity through multiple cropping is increasing rapidly, which outweighs the positive effects of the diminishing use of fertilizers per crop per hectare.

5.4 Pest management practices and use of pesticides

5.4.1 Integrated pest management in study sites

Pest management in rice fields is inseparable from sound farm management. It comprises farmers' activities to protect the crop from, or to control, all harmful organisms from seedling till harvesting. In traditional rice systems farmers developed a number of practices that kept pest damage low without the use of pesticides. This has changed. Farmers growing HYVs in the study sites use a range of pest management practices, from natural controls basically relying on cultural, physical or mechanical techniques to the use of biological control agents and chemical pesticides. Simple natural techniques such as selecting uniform seed grains and sun-drying before sowing, preparing the rice field well before seed establishment, and burning straw after harvesting the winter-spring rice are practised by almost all farmers surveyed. The use of HYVs resistant to main rice pests (for example, Brown Plant Hoppers) was a need expressed by all farmers. However, chemical pesticides were the main technique for control pests.

To address concerns regarding pesticide use at the farm level, a more knowledge-intensive technique of pest management known as integrated pest management (IPM) has been introduced and expanded among farmers since 1992, as explained in Chapter 4. Following the four key principles of the national IPM programme, farmers were provided with knowledge on rice pests and skills in managing rice production systems. They were informed of the benefits of using pest predators and other beneficial insects to controlling rice pests, and were given better understanding of the environment in which pests thrive and the interaction between rice crops and pests. IPM can be best described as a key component of integrated farming practices that are based on farmers' knowledge and use of pest control measures and skills, taking into account the dynamics of pest population, rice yield, profits, safety, and risks to the environment. For the analysis of pest management practices and the consequences of agrochemical use in the study area, the farmers are categorized into two groups: IPM farmers and non-IPM farmers for examining in rice production.

IPM was introduced to farmers in some of the study villages very soon after the national IPM programme started in Vietnam (Dung, 1994). The proportion of farmers adopting IPM has increased over time. By 2001, 70.4 per cent of farmers were practise IPM, which is more than double the percentage in 1996/97 (see Table 5.11). In the SHH group, too, there is also an increase in the number of farmers applying IPM techniques. Most of these have attended an IPM training courses at the village or district level. There are several reasons why IPM is not attractive to the remaining 35 per cent of farmers. Some simply do not have the opportunity to participate in training courses, IPM clubs or IPM demonstration fields. Some farmers, after taking these courses, are still not convinced and have a 'wait and see' attitude. Others do not pay much attention to the IPM information and activities since they believe in what they 'know', through perception and experience, about controlling pests. Some farmers argue that rice pests could move from other fields that are treated with pesticides to their fields. Therefore, sooner or later, they, too, will have to spray pesticides to kill pests, so it is not worth spending time on learning IPM techniques. These farmers seem to have the misconception that IPM is nothing more than appropriate use of pesticides, something they can learn in practice.

The IPM programme in the study area is not biased towards large farm households (that is, those having a large agricultural area). In the 1996/97 winter-spring season the percentage of farmers in households with a small agricultural area (less than 1 hectare) who practised IPM was higher than that of large households (Table 5.12). However, during the four years between the two surveys the number of farmers owning more than 1 hectare of agricultural land practising IPM increased. If the adoption of IPM provides higher profits, then the IPM development policy in rural areas can be expected to offer similar benefits to both small and large land owners.

5.4.2 Use of pesticides in rice production

Pesticides of various kinds have been used on a large scale since the introduction of HYVs to the Mekong Delta. Surveyed farmers typically apply insecticides, fungicides and herbicides during the course of the

Table 5.11
Adoption of integrated pest management in study sites (numbers and percentage of farmers)

	All households		SHH group	
	2000/01	***1996/97***	***2000/01***	***1996/97***
Non-IPM farmers	47 (29.6)	119 (67.2)	22 (28.9)	47 (61.8)
IPM farmers	112 (70.4)	58 (32.8)	54 (71.1)	29 (38.2)

Note: Figures in parentheses are percentages.
Source: 1996/97 and 2000/01 surveys.

Table 5.12
Distribution of IPM farmers according to agricultural land size (numbers and percentage of farmers)

Land size (ha)	2000/01		1996/97	
	IPM farmers	*Non-IPM farmers*	*IPM farmers*	*Non-IPM farmers*
0.00-0.50	27 (24.1)	5 (10.6)	17 (29.3)	36 (30.3)
0.51-1.00	31 (27.7)	19 (40.4)	26 (44.8)	50 (42.0)
1.01-1.50	21 (18.8)	9 (19.1)	4 (6.9)	18 (15.1)
1.51-2.00	18 (16.1)	6 (12.8)	2 (3.4)	5 (4.2)
>2.00 ha	15 (13.4)	8 (17.0)	9 (15.5)	10 (8.4)
Total	*112 (100.0)*	*47 (100.0)*	*58 (100.0)*	*119 (100.0)*

Note: Figures in parentheses are percentages.65
Source: 1996/97 and 2000/01 surveys.

growing season. In both 1996/97 and 2000/01 surveys, all farmers reported using pesticides to control rice pests, including several products that have been restricted in use because of their toxicity. The World health Organization (WHO) classifies pesticides into four categories based on the toxicity of the chemical compound and on their formulaion: extremely hazardous (Ia) and highly hazardous (Ib); moderately hazardous (II); slightly hazardous (III); and unlikely to present acute hazard in normal use (IV). In the 2000/01 winter-spring season, farmers in the study area used relatively more category I and II pesticides than they did in the 1996/97 winter-spring season. This subsection analyses pesticide use in the area in detail through their types, quantities and frequency of application.

Types of pesticides

The type of pesticide is an important element in studies on the use of pesticides. It provides basic information for quantifying the actual active ingredient of chemical compounds and for determining potential effects on the environment and human health. The wide range of pesticides to control rice pests available in the market is one of the main factors influencing farmers' decisions on what type should be used. As a result, a large range of pesticides have been applied in the rice fields. Of the 891 types allowed in the Vietnamese market in the year 2000, those selling under 75 trade names were used by rice farmers in the 1996/97 winter-spring season and those selling under 96 trade names were used in the 2000/01 winter-spring season (see Appendix A, Tables A.1 to A.6). [9]

It is interesting that none of the pesticides used in the 2000/01 winter-spring season is on the list of banned pesticides. This is evidence of the success of Vietnam's pesticide regulation policies. However, some farmers said they knew other farmers in the village who did use banned pesticides, but they dared not report them to the authorities.

Herbicides are among the vital components of rice production in the MKD. Rising wages, increasing crop intensity and the availability of herbicides tend to lower the profitability of hand-weeding and bias farmers towards the increased use of herbicides. However, during the growing season farmers still often weed by hand two or three times after applying herbicides at the beginning of the season. A recent study found that the loss in rice yield due to weeds in the MKD was around 10-45 per cent of total production, especially when rice was direct sown (Chin, 2000). Weed growth and weed-related yield losses in the rice fields are influenced significantly by land preparation, crop establishment, crop and water management and seed selection (Chin, 2000; Greenland, 1977). Given the current dominance of direct seeding in rice farming, herbicides are crucial for eradication o weeds at the very early stage of crop growth. A few surveyed farmers (less than 5 per cent) did not use herbicides to control weeds at the beginning of the growing season because their fields were flooded some months before and weeds were destroyed. Herbicides sold under 15 trade names were used in 1996/97 and two more trade names were added to make a total of 17 in 2000/01 (Appendix A, Tables A.1 and A.2). Herbicides were used either pre-emergence or post-emergence of the weeds, or a combination of the two. Of the 17 herbicides, 2-4-D, Butachlor, Fenoxaprop-P-Ethyl, and Bispyribac- Sodium were used by most farmers. Only one herbicide, namely Gramoxome, is in category II. Gramoxome, with only 5 ml of active ingredients, can cause death when ingested. Although restricted, it was still in use, and indeed there were cases of acute poisoning symptoms among rice farmers. However, not more than 2 per cent of rice farmers used this herbicide in 1996/97 and no use was found in the 2000/01 survey. The rest of the herbicides were in categories III and IV, which the WHO defines as slightly hazardous and unlikely to present an acute hazard in normal use.

In contrast to herbicides, most insecticides used were in categories I and II, which are classified as extremely and moderately hazardous, respectively (see Appendix A, Tables A.3 and A.4). Heong et al. (1995) found that 17 per cent of insecticides used in Vietnam and 20 per cent in the Philippines were in category Ia, and most of these sprays contained methyl parathion. There was significant decrease in the use of restricted pesticides in categories I and II in the study sites, in comparison with the early 1990s and between the two surveys (see Table 5.13). This reduction can also be explained by the pesticide regulation policies and expansion of the IPM programme. Pesticides, especially insecticides, pose extreme hazards to human health and the environment, and have been banned or restricted in Vietnamese agriculture since 1992. For instance, the proportion of users and the amount of methyl parathion applied in the 1996 dry season were far less than in the 1992/93 dry season (Dung and Dung, 1999).

Methyl parathion was banned in February 2000, yet about 3 per cent of the surveyed farmers continued to use it. This may partly be due to leftover stocks after the ban and the relatively low price and wide-spectrum toxicity of the pesticide. There might also be some weakness in enforcing the ban and controlling the use of hazardous chemicals; or farmers' perception that no other pesticide could be substituted for methyl parathion. During the 2000/01 survey, 90 per cent of farmers knew about the banned insecticides and none of the banned insecticides were being used, with the exception of methyl parathion. The diversification of insecticides in the market is one of the reasons for this change

Table 5.13

Trend in use of banned/restricted insecticides in Mekong Delta

Pesticides	**WHO cate-gory**	**1996/97 winter-spring season**		**2000/01 winter-spring season**	
		% farmers	Gm a.i./ ha	% farmers	Gm a.i. /ha
Methyl parathion	Ia	4.5	180.0	2.0	165
Metaphos	Ia	-	-	-	-
Azodrin	Ib	5.6	317.5	-	-
Monitor	Ib	17.4	424	-	-
Thiodan	II	2.8	29.8	-	-
Furadan	Ib	2.8	350.0	3.0	300

Note: a.i. = active ingredients.
Source: 996/97 and 2000/01 surveys.

In addition to the change in the use of banned/restricted insecticides, there is a noticeable change in the number of insecticide types marketed in terms of both trade names and chemical compounds (common names). As Tables A.3 and A.4 in Appendix A show, insecticides sold under 40 trade names were used in the 2000/01 winter-spring season, while only 30 were applied in the 1996/97 winter-spring season. This can be viewed as an indication of the 'diversification' of pesticide products in the market.

Another group of pesticides that farmers applied to control rice disease was fungicides. As with insecticides, there was an increase in the number of fungicide types used by rice farmers, from 28 in 1996/97 to 41 in 2000/01 (see Tables A.5 and A.6 in Appendix A). The most popular fungicides were Propiconazole, Benomyl, Validamycine, and Iprodione. In the two surveys, most fungicides used were in WHO categories III and IV. Two of the fungicides used in 2000/01, namely Benomyl and Carbendazim, were produced and marketed under different trade names.

Quantity of pesticides used

Table 5.14 summarizes pesticide use in terms of the 'active ingredients' (a.i.). Despite the widespread use of pesticides, the consumption per crop per hectare declined during the four-year period in all study villages. Farmers tended to use lower quantities of insecticides, fungicides as well as herbicides. Taking all three types of pesticides together, the average pesticide quantity used per hectare per crop fell. All households reduced use by approximately 240 grams a.i. per hectare per crop, from 990.85 grams a.i. in the 1996/97 winter-spring season to 750.93 grams a.i. in the 2000/01 winter-spring season. In the SHH group, pesticide quantity was reduced by about 325.46 grams a.i. per hectare per crop. In other words, per crop per hectare consumption of pesticides fell by approximately 25 per cent for all survey farm households and 32 per cent for the SHH group.

Of the pesticides, herbicide use per hectare per crop was reduced most in 2000/01. The large reduction in herbicides, however, does not necessary mean that farmers were practising a new weeding technique. Rice fields have fewer weed problems in the dry season than in other seasons. The change in types of herbicides partly led to a change in quantity of herbicides (in gram a.i.). For instance, in 2000/01, 30 per cent of farm households in the SHH group reported using the herbicide Nominee 10SC, which had not been applied in 1996/97. Nominee 10SC is applied at the rate of 400 ml, or 4 grams a.i., per crop per hectare. In 1996/97 around 20 per cent of the SHH group used the herbicide Sofit 300 EC, which was applied by only 6 per cent of farm households in 2000/01. The rate of application for this herbicide is 1000 ml, or 300 grams a.i., per crop per hectare. While the cost and function of these two herbicides are similar (VND 190,000 to 210,000/ha in 2000/01 at current prices), they are obviously different when the quantity is measured in terms of active ingredients.

The reduction in insecticides can also be explained by insecticide reduction interventions and IPM to farmers in the MKD. As mentioned in Chapter 4 (subsection 4.5.4), between 1992 and 1997, farmer field schools were launched in the MKD and farmers were encouraged to participate in experiments to determine whether early season spraying is necessary to protect crops against leaf-feeders. The overall result of such interventions was that farmers' insecticide use, early season spraying and perceptions regarding pest management changed markedly over the five-year period (Huan et al., 1999). The reduction in insecticide use, accomplished without loss of rice yield, attracted more and more farmers in the MKD (Chi, 1999; Heong et al., 1995; Pincus, 2000). Farmers in the study sites may further change their pesticide spraying behaviour as a result of IPM training, advice from agricultural officials and media campaigns. On average, the SHH group and all farm households reduced use by about 96 and 90 grams a.i. of insecticide per hectare per crop in 2000/01 and 1996/97, respectively.

Table 5.14
Changes in pesticide use per crop per ha (grams of a.i.)

Input quantity	2000/01	1996/97	Mean difference	t-ratio
		All households		
Total pesticides	750.93	990.85	239.93	6.18 ***
Herbicide	189.26	313.64	124.38	4.80 ***
Fungicide	273.76	299.34	25.58	0.94 NS
Insecticide	287.92	377.88	89.96	2.61 ***
Categories I & II	293.70	431.53	137.84	4.52 ***
Categories III & IV	457.23	559.32	102.09	2.99 ***
		SHH group		
Total pesticides	697.35	1,022.81	325.56	6.60 ***
Herbicide	188.22	286.43	98.20	2.90 ***
Fungicide	248.79	380.11	131.32	3.36 ***
Insecticide	260.34	356.23	95.89	2.02 **
Categories I & II	316.67	442.83	126.15	2.94 ***
Categories III & IV	380.68	579.82	199.14	4.49 ***

Source: 1996/97 and 2000/01 surveys.

The consumption of fungicides as a means to prevent disease was also reduced as the case of insecticides and herbicides. Farmers in the SHH-group on average applied 248.79 grams a.i. of fungicides per hectare per crop in the 2000/01 WS season, which is 131.32 grams a.i. lower than that applied in the 1996/97 WS season (Table 5.14). Although there were no disease pressures during the surveys, all farmers applied fungicides so as to prevent rice crops from the risk of plant disease.

Integrated pest management and quantity of pesticides

One important question remains to be answered: are there differences in pesticide use between IPM farmers and those who do not apply IPM techniques? Fortunately, the information from the two surveys can help to provide at least a partial answer to this. The average doses of pesticides used by IPM and non-IPM farmers in the two surveys are presented in Table 5.15 (for all households) and Table 5.16 (for the SHH group). Significantly, the pesticide doses used by IPM farmers were lower than those applied by non-IPM farmers in both surveyed seasons.

Table 5.15
Changes in pesticide use per crop per ha by non-IPM and IPM farmers, all households (grams of a.i.)

Input quantity	Non-IPM farmers	IPM farmers	Mean difference	t-ratio
	2000/01 winter-spring season			
Pesticide	756.64	748.53	8.12	0.16 NS
Herbicide	192.78	187.78	5.00	0.18 NS
Fungicide	219.17	296.66	77.49	2.05 **
Insecticide	344.69	264.10	80.59	1.68 *
Category I & II	287.64	296.24	8.60	0.22 NS
Category III & IV	469.01	452.29	16.72	0.34 NS
	1996/97 winter-spring season			
Pesticide	1,035.69	898.86	163.83	1.95 **
Herbicide	336.42	266.91	69.51	1.53 NS
Fungicide	275.99	347.25	71.26	1.60 *
Insecticide	423.29	284.71	138.58	2.50 **
Category I & II	453.17	387.14	66.03	1.27 NS
Category III & IV	582.57	511.62	70.95	1.29 NS

Source: 1996/97 and 2000/01 surveys.

In the SHH group for both surveys, IPM farmers used lower pesticide dose than those applied by non-IPM farmers, and the differences were statistically significant. (see Table 5.16). For all households, the difference was not statistically significant between the two groups in the 2000/01 winter-spring season, but in 1996/97 it was (Table 5.15). The insignificant difference in pesticide dose applied per hectare per crop of IPM and non-IPM farmers in 2000/01 winter-spring season is due to a larger variation in survey data.

Table 5.16
Changes in pesticide use per crop per ha by non-IPM and IPM farmers, SHH group (grams of a.i.)

Input quantity	Non-IPM farmers	IPM farmers	Mean difference	t-ratio
		2000/01 winter-spring season		
Pesticide	802.15	654.66	147.49	2.16 ***
Herbicide	244.50	165.30	79.20	1.68 *
Fungicide	189.17	273.08	83.91	1.69 *
Insecticide	368.48	216.28	152.19	2.22 **
Category I & II	356.22	300.56	55.66	0.92 NS
Category III & IV	445.93	354.09	91.84	1.37 NS
		1996/97 winter-spring season		
Pesticide	1,163.16	795.35	367.81	5.07 ***
Herbicide	307.40	252.43	54.97	0.95 NS
Fungicide	401.91	344.76	57.15	0.94 NS
Insecticide	453.69	198.28	255.41	3.83 ***
Category I & II	516.36	323.66	192.70	2.97 ***
Category III & IV	646.69	471.45	175.24	2.76 ***

Source: 1996/97 and 2000/01 surveys.

There is increased use of fungicides relative to the use of insecticides and herbicides, though the absolute amount fell. IPM farmers applied more fungicides than non-IPM farmers in the 2000 survey. Pincus (2000), who investigated the impacts of IPM Farmer Field Schools on farmers' cultivation practices, obtained similar results. He found that in the southern provinces of Vietnam, there was evidence of a significant rise in fungicide use, even among IPM farmers, and aggressive marketing tactics of pesticide companies were the key influencing-factor.

Overall consumption of pesticides per hectare per year

Up to this point, the analysis has focused only on the types, frequency of application and doses of pesticides applied per crop per hectare. Since the surveyed farmers showed an increasing trend in cropping intensity, total pesticide used per hectare per year is estimated using cropping intensity and pesticide doses applied in winter-spring seasons. Data analysis earlier in this chapter indicated that the quantity of pesticide per hectare per crop, measured in active ingredients, declined in the 2000/01 winter-spring season. The change in pesticide types was among the important reasons for this reduction. However, the increase in cropping intensity lessens reduces the positive effects of diminishing use of pesticides per crop per hectare, as was observed in Chapter 3.

Table 5.17 shows that, for farm households growing three rice crops a year, the total pesticide doses used per hectare per year were higher in the 2000/01 winter-spring season than in the 1996/97 winter-spring season, by about 8.6 per cent for the SHH group and 4 per cent for all households. Although the total pesticide doses applied per hectare per year were lower in the 2000/01 winter-spring season in double-cropping, there was an increase in cropping intensity during the four-year period between surveys, with a shift from double to triple crops a year. This increases concern about intensification of rice cultivation in the future. These findings apparently support the assumption that crop intensification is followed by heavy dependence on pesticides and chemical fertilizers. The quantity of pesticides used represents only one aspect of production. The main issue is whether the current use brings the highest profits to farm households, since in economic term pesticides and other inputs should be used at the point where the value of marginal product equals price. Another issue is whether there are health effects due to pesticide exposure and whether these effects reduce the value of marginal product. The answers to these questions are given in subsequent chapters.

Table 5.17

Estimated pesticide use in rice production per hectare/ year (grams a.i.)

Categories	**Cropping intensity**	**Double crop**	**Triple crop**
	1996/97 survey		
All farms	2.23	2,066.73	2,288.63
SHH group	2.33	2,288.49	2,221.67
	2000/01 survey		
All farms	2.57	1,420.23	2,380.06
SHH group	2.70	1,272.93	2,413.18

Note: SHH group = Same household group.
Source: 1996/97 and 2000/01 surveys.

5.5 Concluding remarks

This chapter has profiled the study sites and analysed patterns of agrochemical use as given by respondents in the 1996/97 and 2000/01 surveys. Rice monoculture, increasing cropping intensity and higher level of agrochemical inputs have had various effects on profitability (which will be discussed in Chapter 6), and on environment and health (which will be discussed in Chapter 7). The main features and findings of this chapter are:

Rice is the dominant crop in the area and the intensiveness of its cultivation is increasing in the study sites.

Most of the farm households' land (94 per cent) is devoted to rice production. Rice is cultivated two or three times, or even 3.5 times a year, depending mostly on factors such as technical issues, market demand and prices, or income pressure. There is an increasing trend in cropping intensity in the study area from the 1996/97 winter-spring season to the 2000/01 winter-spring season. This is an indication of intensified rice cultivation in the MKD. The fact that nearly 60 per cent of farm households practise triple-cropping a year causes serious worry about changes in production and the environmental consequences of rice monoculture. Moreover, the surveyed farmers obtained seeds of high-yielding varieties from different supply sources, increasing the risks in terms of fertilizer cost, efficiency, yield variability and pest problems.

Fertilizer use per hectare per year has increased due to intensified cultivation.

All surveyed households relied heavily on chemical fertilizers to replenish soil nutrients, of which nitrogen (N), phosphorus (in the form of P2O5) and potassium (in the form of K2O) were three main nutrients. The only organic fertilizer used is ash from burning rice straw. Farmers have a tendency to reduce fertilizer use per crop per hectare and there is movement towards more balanced fertilizer use during the four-year period between the two surveys. Farm households increased potassium and reduced the rate of applied nitrogen accordingly. All these changes are significantly different between the two surveys. However, despite the fact that the fertilizer use rate per crop per hectare in 2000/01 was lower than in 1996/97, the total amount of fertilizers applied per hectare per year increased during the four-year period due to increase in cropping intensity.

Pesticide dose per hectare per year also increased due to intensified cultivation.

Pesticides of various kinds have been used on a large scale since the introduction of HYVs to the Mekong Delta in general, and the study sites in particular. Farmers typically applied herbicides once, insecticides once or twice, and fungicides twice during the course of the growing season. Farmers in general decreased their frequency of insecticide application but increased the frequency of fungicide spraying. This resulted in a higher frequency of pesticides application in the 2000/01 winter-spring season as compared with the 1996/97 winter-spring season. Substantial use of many different types of hazardous pesticides has had an impact on farmers' health (which will be discussed in Chapter 7).

In spite of widespread use of pesticides, the consumption of pesticides in rice production per crop per hectare declined during the four-year period in all the villages studied. Farmers significantly reduced quantities of insecticide, fungicide and herbicide. Nevertheless, the increase in cropping intensity lessens the positive effects of diminishing use of pesticides per crop per hectare. More pesticide doses were applied to triple crops.

IPM adoption helps farmers reduce agrochemical use significantly

Integrated pest management (IPM) was practised and expanded among farmers during the four-year period. The percentage of farmers in the study area who use the IPM techniques to control pest problems mounted to around 70 per cent in the 2000/01 winter-spring season. The IPM programme has had positive effects on farmers' pest control practices in terms of their knowledge and their perception of pesticide efficiency and safety, as well in terms of fertilizer rate reduction. Pesticide doses and fertilizers applied per crop per hectare by IPM farmers in the two surveys were significantly lower than those applied by non-IPM farmers. Significantly, none of the pesticides used in the 2000/01 winter-spring season is on the list of banned pesticides. This is evidence of the success of pesticide regulation policies in Vietnam.

Notes

[1] The homestead areas are separated from agricultural land and not included in the surveys.

[2] This is because rice fields are level and so flood waters deposit their silt before receding.

[3] Crop establishment is a technical term used to describe how the rice crop is planted in the field.

[4] The use of the huge amount of rice straw available on farms after the harvest is an aspect of nutrient management. However, returning the rice straw directly to the soil, while contributing to the soil nutrient content, also increase the release of methane, which is a much more powerful greenhouse gas than carbon dioxide (Greenland, 1997: 188). In the study sites, rice straw is often burnt after the winter-spring season and the ash is incorporated into the soil. This technique helps to recycle the nutrients in straw, prevents weed growth and improves crop establishment in wet sowing (Yamauchi et al., 1995).

[5] Fertilizers that contain only one nutrient are known as straight fertilizers. Those containing two or three nutrients are called multi-nutrient fertilizers (FAO, 2000: 15).

[6] The Decision of the Ministry of Agriculture and Rural Development issued on 14 October 1997 lists a total of 397 types of fertilizers approved for use in Vietnamese agriculture.

[7] The farmers in the Tan et al. survey included those who participated in the current research project, but they were not randomly selected.

[8] On the average, there are 120-180 grams of alluvial particles per m^3 of flood water (Thai, 1995), and fields usually retain sufficient nutrients to be productive (Greenland, 1997).

[9] The trade name is the name under which the pesticide is sold in the market. Many pesticides have the same chemical active ingredient but are marketed under different names or brands.

6

Economics of Agrochemical Use in Rice Production

6.1 Introduction

Chapter 5 analysed the agrochemical use patterns of farm households in the survey sites over a four-year period, in the context of recent advances in fertilizer and pesticide application technology. This chapter carries out a comparative economic analysis to investigate the profitability of rice production. Then, on the basis of neoclassical economic theory, it will undertake an empirical study of the demand for fertilizers and pesticides. To achieve higher profits from rice production and efficiency of input use, farmers need to operate at the economic optimum rather than the technical optimum. Thus, this chapter will explore whether or not farm households are efficient at their current level of fertilizer and pesticide application when input and output prices are taken into account. The next section presents the main indicators of farm households' production performance, such as rice yields, unit cost of production and rates of return to fertilizers, pesticides and labour. The chapter then goes on to develop the empirical model for deriving the demand for fertilizers, pesticides and labour, as well as the rice supply, simultaneously through a model of a translog profit function and variable input share equations. The final section presents and discusses the estimation results, focusing on aspects such as price elasticities of demand for fertilizers, pesticides and labour, and output elasticities.

6.2 Production performance of farm households

The concept of sustainable development of rice production implies a continued productivity level through certain farming practices over a period of time. Rice yields,[1] a standard measurement of productivity, are the result of the interactions between HYVs and bio-physical conditions, socioeconomic characteristics and farmers' decisions on matters such as agrochemical use and cultivation practices in the study sites (see Figure 2.1, Chapter 2).

6.2.1 Improvement in rice yields

During the winter-spring rice seasons of 1996/97 and 2000/01, there was no pest infestation of any importance and weather conditions were extraordinary, with not much rain, abundant sunshine and adequate irrigation water. According to farmers, such conditions always improve the harvest. However, rice yields also depend on human-controlled inputs such as labour, nutrient supply, and pest control measures. Chapter 5 showed that the quantities of agrochemicals used per crop per ha were lower in the 2000/01 winter-spring season than in the 1996/97 winter-spring season. An overall decline in the consumption of pesticides supports the argument that increased pesticide prices would reduce the quantity used, while the reduction in fertilizer application rates may be due to the effects of management practices.

However, did the reduced use of agrochemicals result in productivity loss? Table 6.1 displays the results of paired t-tests for rice yields per hectare harvested in the 1996/97 and 2000/01 winter-spring seasons. At the sample mean, farmers achieved rice yields of 6,037 kg and 6,204 kg per hectare in the 1996/97 and 2000/01 winter-spring seasons, respectively, or a 2.7 per cent yield increase. The rice yield in the 2000/01 winter-spring season was significantly higher than the yield average in the 1996/97 winter-spring season at 5 per cent statistical level. In the same households (SHH) group, the trend of rice yields was similar while the per hectare consumption per crop of agrochemicals declined.

As can be seen in Table 6.1, rice yields are higher in the 2000/01 winter-spring season (6,280 kg of rice per hectare) than in the 1996/97 winter-spring season (6,141 kg of rice per hectare) by or 2.2 per cent. The increase in rice yields can be explained largely by farmers' production practices. Within a four-year period, rice yields increased while the use of agrochemical inputs fell, implying an increase in the partial productivity of fertilizer nutrients and pesticides. In other words, farm households used agrochemicals with better technical efficiency in 2000/01, a result of adopting knowledge-intensive nutrient and pesticide management techniques.

Table 6.1
Rice yields in 2000/01 and 1996/97 winter-spring seasons (kg/ha/harvest)

	All households		Same households group	
	1996/97	***2000/01***	***1996/97***	***2000/01***
Rice yields	6,037	6,204	6,141	6,280
Standard deviation	(759.14)	(817.21)	(528.06)	(677.15)
Std error difference	86.01		87.3	
t-test of mean difference	1.93*		1.59*	

Source: 1996/97 and 2000/01 surveys.

Variability in yields is also important to farmers since rice yields, together with market price, determine the return from rice production. The standard deviation of the mean yield is a useful measure for determining yield variability (Pincus, 2000). Technically speaking, variability in yields should be determined by examining the variation among fields that are cultivated with the same rice variety. That way, only one source of yield variation in the sample is examined, other things being equal. However, due to the lack of data on rice varieties, the analysis here is mainly focused on yield variability of all farm households.

A comparative analysis of yield variability for the two periods (1996/97 and 2000/01 winter-spring seasons) leads to the conclusion that the 1996/97 winter-spring season was less risky. As shown in Table 6.1, the lower standard deviations of the mean yield in the 1996/97 winter-spring season (759 kg as compared with 817 kg per hectare) indicates an increase in yield variability, or a higher production risk, in 2000/01.[2] Within the SHH group, while also getting higher yields, farmers faced higher yield variability in the 2000/01 winter-spring season. The higher yield variability could be mainly due to variation in the use of various new HYVs when there is no yield loss of importance due to pests. As noted in Chapter 5, the use of unofficial sources for obtaining seed is an issue of concern. Farmers may not be given appropriate information on the cultivation of such varieties; they particularly lack basic information on fertilizer use, so pest problems may exist. This increases the farmers' production risk.

Rice yields can also vary according to local conditions. An analysis of rice yields harvested in the villages common to the two surveys showed that the yields are different between villages (see Table 6.2). Farmers in Nhi My attained the highest yield, Long Dien ranked second, Tan Phu Trung came third and Vinh My had the lowest yield. This variability is probably caused by local differences in soil fertility, water conditions, pest infestation and farmers' practices. Though higher yields were obtained in the 2000/01 winter-spring season in all four villages, the standard deviations of the yield means were also higher in comparison with those of 1996/97. Again, increased production risk is attached to achieving a higher yield. This issue is important to small farmers since they may get into debt and suffer other hardships that result from a poor harvest.

Table 6.2
Rice yield variability in survey villages between 1996/97 and 2000/01(kg/ha/crop)

	Same households group (N=76)			
	Nhi My	***Tan Phu Trung***	***Long Dien***	***Vinh My***
		1996/97 WS season		
Mean	*6,489*	*5,961*	*6,312*	*5,784*
Std. of the mean	(381.36)	(448.71)	(429.16)	(553.04)
		2000/01 WS season		
Mean	*6,663*	*6,206*	*6,404*	*5,836*
Std. of the mean	(537.52)	(670.27)	(509.58)	(733.01)

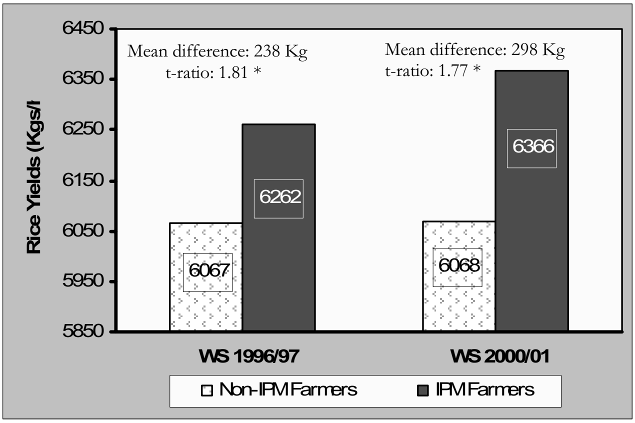
Source: 1996/97 and 2000/01 surveys.

6.2.2 Higher rice yields for IPM farmers

As can be seen from Figures 6.1 and 6.2, the adoption of IPM seems to have brought about higher yield for IPM farmers in both seasons. It is clear that the yields of IPM farmers in the SHH group (Figure 6.1) , with an average of 238Kg and 298 kg per crop per hectare for 1996/97 and 2000/01 respectively, are significantly higher than those of non-IPM farmers.

Figure 6.1

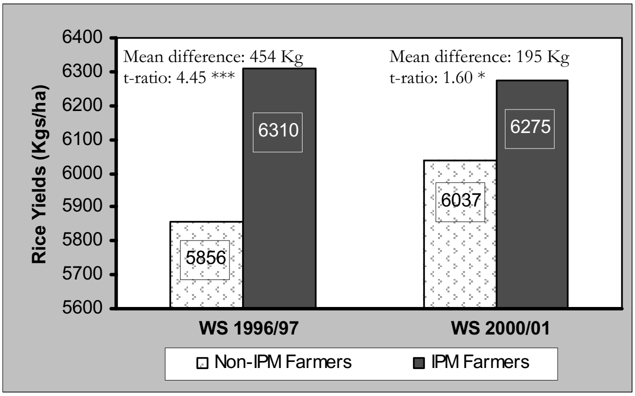
Rice yields in 1996/97 and 2000/01 WS seasons (SHH group)



Source: 1996/97 and 2000/01 surveys.

Figure 6.2

Rice yields in 1996/97 and 2000/01 WS seasons (All Households)



Source: 1996/97 and 2000/01 surveys.

For all farm households (Figure 6.2) the yield difference between the two groups of farmers was 195 kg per crop per hectare in the 2000/01 winter-spring season. As mentioned in Chapter 5, the cultivation practices of IPM farmers were not considerably different from those of non-IPM farmers, except in pest management. In addition, the yield differences between two groups are narrowing, as they are in other aspects of cultivation as well (for example, in fertilizer and pesticide use). Day-to-day management of rice fields and efforts to apply the four principles of the IPM programme were perhaps the main factors that helped IPM farmers to obtain higher yields. The impact of IPM training and application not only helped farmers to use pesticides and fertilizers better, but it also raised rice yields and brought economic and social gains (Pincus, 2000).

6.2.3 Impact of agrochemicals on rice yields

It is necessary to understand the factors that determine the level of productivity in rice cultivation, and especially the effects of agrochemicals on rice yields. The relationship between rice yields and agrochemicals is examined through Pearson correlation coefficients (Table 6.3) and production elasticities. Both pesticides and fertilizers contributed positively to rice yields in the two survey periods. However, the correlation between fertilizers and yield was generally higher than that of pesticides. The non-significant correlation between pesticides and yield in the 1996/97 dry season was perhaps due to large variation in rice yields and quantities of pesticide used by farmers. The low Pearson correlation coefficients of yield and agrochemicals imply that there other factors are influencing rice yields (for example, rice varieties, water, weather and labour). The correlation between fertilizers and pesticides is positive, meaning that more fertilizers will be accompanied by a higher amount of pesticides. However, high fertilizer doses are not often assumed to contribute much to higher yields, since at an excessive level, especially with nitrogenous fertilizer, there will be more pest problems.

Table 6.4 presents the relationship between agrochemicals and the rice yields of the sample households. Farmers are likely to increase quantities of fertilizers and pesticides to obtain a higher yield range in both survey years. Table 6.4 shows that the highest yield (> 7,000 tonnes/ha/harvest) is obtained at applications of around 183 kg and 199 kg of NPK nutrients/ha/crop in 2000/01 and 1996/97 respectively.

However, it seems that at a lower yield range (from 6,000 to <7,000) no increase in the amount of agrochemicals is needed to achieve a marginal yield increase of 500 kg per ha per harvest. Higher rice yields are

Table 6.3

Pearson correlation between fertilizers, pesticides and rice yields (all households)

Agrochemicals	Pesticides	Rice yields
	1996/97 WS season	
Fertilizers	0.15**	0.24***
Pesticides	-	0.11 NS
	2000/01 WS season	
Fertilizers	0.13**	0.22***
Pesticides	-	0.18**

Notes: *, **, *** correlation is significant at 1%, 5%, and 10% levels, respectively; NS = not significant

Table 6.4

Average amount of agrochemicals used to achieve various rice yield ranges

Indicators	Rice yield ranges (kg/ha/harvest)				
	< 5,500	*5,500-5,999*	*6,000-6,499*	*6,500-6,999*	*> 7,000*
			1996/97 WS season		
% of households	23.7	20.3	25.4	18.1	12.4
NPK fertilizers*	165.2	169.5	184.0	183.8	199.2
Pesticides **	936.59	964.09	956.60	1154.98	969.60
			2000/01 WS season		
% of households	17.0	22.0	18.9	22.0	20.1
NPK fertilizers	155.3	172.4	168.8	175.2	183.0
Pesticides	646.49	759.27	779.60	769.42	848.43

Notes: * NPK fertilizers in kg of NPK nutrients/ha/crop; ** Pesticides in grams of a.i./ha/crop.

also observed at higher doses of pesticides, but they do not increase proportionally with the in rice yield increments. This suggests that a decline in agrochemical use did not result in loss of productivity over the four-year period. Thus, higher yields were achieved at lower quantities of agrochemicals applied per hectare per crop in the 2000/01 winter-spring season in comparison with the 1996/97 winter-spring season. In other words, there was a clear shift to higher output/ha/harvest in the study sites.

The influence of agrochemicals on rice yield can also be examined through production elasticities. These are derived indirectly from parameters estimated from a model of the normalized translog profit function and input share equations (as will be elaborated in section 6.4) by using a set of relations between the production and the normalized profit function (Lau, 1978). Production elasticities of fertilizers and pesticides in 2000/2001 were 0.15 and 0.09 respectively. That is, rice yield will increase by 1.5 per cent when fertilizer use rises by 10 per cent, with other inputs remaining constant. By the same token, a 10 per cent rise in total quantity of pesticides used will contribute a micro-increase of 0.9 per cent in yield. Rice production elasticities of fertilizers and pesticides used in the 1996/97 winter-spring season in the MKD, estimated using the Cobb-Douglas production function, were 0.086 and 0.035 respectively (Dung and Dung, 1999: 18).

6.3 Profitability of rice production

The production analysis in the previous section shows that a decline in agrochemical use did not result in loss of rice productivity over the four-year period. However, profitability of rice production depends not only on rice yields but also on the current relative prices of rice, agrochemicals and other inputs. This section analyses the costs and profitability of rice production in the winter-spring seasons of 1996/97 and 2000/01 for all sample households and the SHH group. For comparison between the two periods, prices and costs are computed using 1996 real (constant) prices.[3] In addition, the expenditures on and returns from rice production of IPM and non-IPM farmers are calculated and compared.

Table 6.5 provides an overview and economic analysis of the input and output data for 1996/97 and 2000/01 winter-spring rice production. It contains core costs and returns directly related to rice farming by households. Production costs include hired labour, seed, fertilizers, pesticides, and other costs comprising irrigation fees, land preparation and land tax. Only the opportunity cost of family labour imputed at market wage rate is included in the analysis.

6.3.1 Costs of rice production

Costs of rice production for all households

The costs/expenditures of rice production are divided into four main categories: agrochemicals, labour, seeds, and other purchased inputs. Fertilizers and pesticides account for 28.3 per cent and 30.6 per cent in the total cost of winter-spring rice production in 2000/01 and 1996/97, respectively. Expenditures on pest control account for only a minor portion in the total cost. The share of pesticides fell from 8.2 per cent in the 1996/97 winter-spring season to 7.4 per cent in 2000/01. Due to reduction in the rate of application, farm households on the average save 2.3 per cent of expenditure on agrochemicals, of which the saving in fertilizers is around 1.5 per cent. However, average expenditures on fertilizers and pesticides (in 1996 real prices) are not statistically different between the two periods.

Labour costs comprised real wages paid to hired labour and opportunity costs of family labour imputed using the average prevailing market wage rates. About 34-35 per cent of total cost was spent on labour, on average VND 4,460- 4,800 million. As Table 6.5 shows, farm households spent a little more on family labour than on hired labour. During the two surveys, the author noticed that small farmers tended to deploy more family labour for most of the fieldwork. In contrast, richer farmers with relatively big farms often hired more labour, especially for spraying pesticide. The labour cost was significantly higher in 2000/01 due to increase in the market wage and use of more hired labour.

Seed costs accounted for about 7-8 per cent of the total cost in the two winter-spring rice seasons of 1996/97 and 2000/01. The seed cost was lower in 2000/01 because of a large reduction in seed quantity used, which was a consequence of row seedling methods or direct benefit of knowledge derived from Farmer Field Schools. Expenditures on other purchased inputs including land preparation costs were significantly higher in the 2000/01 winter-spring rice season. All together, the real cost of production was VND 341,228 higher in the 2000/01 winter-spring season than in 1996/97. The cost difference is statistically significant at 1 per cent level. This eventually raised the unit cost of rice to VND 782 per kg, which is VND 35 higher than in the 1996/97 winter-spring season.

Table 6.5

Costs of rice production in MKD, in 1996 real prices (VND per ha per crop)

Items	2000/01	1996/97	Mean difference	t-ratio
		All households		
Total Cost	4,801,555	4,460,327	341,228	4.38***
Fertilizers	998,776	992,706	6,070	0.24
Pesticides	352,702	376,269	23,567	-1.08
Labour	1,701,605	1,500,473	201,132	3.94***
Hired labour	766,014	628,941	137,073	4.60***
Seed	355,768	363,997	8,229	- 0.6
Other costs	1,392,705	1,226,881	165,823	5.45***
Cost/kg of paddy	782	747	35	2.42***
		Same households group		
Total Cost	4,480,377	4,714,725	234,348	- 2.37**
Fertilizers	948,712	997,548	48,836	- 1.31
Pesticides	299,725	441,292	141,567	- 5.4***
Labour	1,528,853	1,585,036	56,183	- 0.92
Hire labour	688,595	593,841	94,754	2.62**
Seed	312,014	347,793	35,779	- 2.18**
Other costs	1,391,073	1,343,055	48,018	1.01
Cost/kg of paddy	718	774	56	- 3.04***

Notes: Total cost = Costs of pesticide, fertilizer, seed + costs of labour + other purchased costs.

Source: Calculated from 1996/97 and 2000/01 survey data.

Cost of rice production for SHH group

The overall picture of expenditure on rice production of the SHH group is somewhat different. Table 6.5 shows that both the total costs and unit costs of rice were statistically lower in the 2000/01 winter-spring season than in the 1996/97 winter-spring season, which is the opposite of the situation for all surveyed farms. However, farmers also reduced production costs by cutting the cost of agrochemicals, especially pesticides, which is similar to the trend for all sample households. The reduction in pesticide is statistically significant at 1 per cent level. Fertilizer and pesticide costs account for 27.8 per cent and 30.4 per cent of the total cost of winter-spring rice production in 2000/01 and 1996/97, respectively. Farmers within the SHH group also cut the cost of seed by reducing the amount of seed used. This saved farm households about VND 35,779 in seed costs. With higher rice yields and lower production costs, farmers within the SHH group achieved the cheaper cost of VND 718 per kg of rice in the 2000/01 winter-spring season.

6.3.2 Returns from rice production

Rice is the main output that can be traded in the market for money during the surveyed periods. Farmers' gross return from rice production was estimated by multiplying rice output by farm-gate prices of paddy rice (unhusked rice). In the study sites, about 60 per cent of farmers sold part of their dried paddy rice to middlemen at the farm gate immediately after the harvest, due to lack of storage facilities. The rice prices at the farm gate are not uniform for farm households; they depend on the power of the traders, rice quality and supply of rice in the rural market. Farmers who cannot store the harvest, need cash for daily expenditures or sell a small quantity, generally receive lower prices from traders.

Table 6.6 presents the returns from rice production for all households and the SSH group in the two survey seasons. Gross returns from rice production for all households are, on average, VND 8,570,236 per ha and VND 7,715,445 per ha. A higher gross return was obtained in the 2000/01 winter-spring season and was significantly different at 1 per cent level from the return received in the 1996/97 winter-spring season.

A measure of profits from rice production is given by the benefit indicator or 'operating surplus', which equals gross return of production minus total cost. The benefits in the cultivation of rice crops for all households are estimated at VND 3,255,119 per ha per crop and VND 3,768,681 per ha per crop for 2000/01 and 1996/97 winter-spring seasons respectively.

Family income from rice cultivation, or the returns to family input, are estimated at VND 4,704,271 per ha per crop in the 2000/01 winter-spring season and VND 4,126,651 per ha per crop in the 1996/97 winter-spring season. Family income from rice farming thus increased by about 14 per cent in the 2000/01 winter-spring season, but more in the SHH group. The main factor behind this increase was greater scope for employment of family labour in production.

Table 6.6
Returns from rice production in MKD, in 1996 constant prices (VND/ ha/ crop)

Items	2000/01	1996/97	Mean difference	t-ratio
		All households		
Gross return	8,570,236	7,715,445	854,790	6.50***
Benefit	3,768,681	3,255,119	513,562	3.93***
Family income	4,704,271	4,126,651	577,620	4.51***
Return rate to fertilizer	5.30	4.48	0.82	4.39***
Return rate to pesticide	19.47	15.62	3.84	1.46^{NS}
Return rate to labour	3.73	3.31	0.42	3.12***
		Same households group		
Gross return	8,681,317	7,726,267	995,050	5.23***
Benefit	4,200,940	3,011,542	1,189,398	6.17***
Family income	5,041,198	4,002,737	1,038,461	5.55***
Return rate to fertilizer	6.00	4.19	1.81	6.42***
Return rate to pesticide	18.16	11.13	7.03	4.35***
Return rate to labour	4.27	2.97	1.30	6.70***

Notes: Gross return = Yield in kg x price per kg.
Benefit = Gross return - total cost.
Family income = Gross return – all costs except family labour.
Return rate to pesticide = (Gross return - all costs other than pesticides)/total pesticide cost.
Return rate to fertilizer = (Gross return - all costs other than fertilizers)/total fertilizer cost.
Return rate to labour = (Gross return-all costs other than labour)/total labour cost.

Source: Calculated from 1996/97 and 2000/01 survey data.

The investment in fertilizer, labour, and especially pesticide, brought higher rates of return in the 2000/01 winter-spring season as compared with the 1996/97 winter-spring season. Though accounting only for a small share of total production cost, the return rate to pesticide was the highest among the inputs analysed. This may be one of the factors influencing farmers' pesticide spraying. The return rate to pesticide for all households was not significantly different between the two surveys, perhaps due to large variation in pesticide costs. Better management of fertilizer application and pesticide spraying might improve the efficiency of agrochemicals use considerably, and therefore increase the rates of return to these inputs.

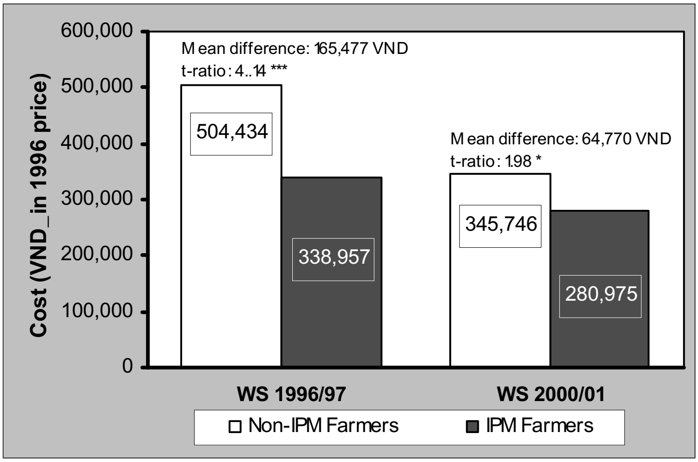
The same analysis of costs and benefits in the two survey seasons was made for the SSH group. The economic indicators presented in Table 6.6 show that farmers in the SHH group achieved better economic returns in the 2000/01 winter-spring season. Gross return and benefit from rice increased by 12 per cent and 39 per cent, respectively, over the four-year period. The increase in gross return and benefit was partly due to reduction in production costs and increased yield. Thus, average family income from rice in 2000/01 increased by 26 per cent compared with 1996/97, implying that purchasing power of the income improved. Rate of return to pesticide investment provided the highest rate of return: 18.16, compared with 6.0 for fertilizer and 4.27 for labour.

6.3.3 Profits of IPM and non-IPM rice farmers

Experience in many IPM programmes internationally indicates that IPM farmers are likely to obtain an increased gross return as a result of higher yields and decreased pest management costs (Fliert, 1993: 209). Recent evaluation studies of the IPM programme in Vietnam confirm this (For details, see Chung and Dung, 1996; Pincus, 2000). In order to determine the economic effects of IPM implementation in the study sites, the analysis below focuses on management costs and family income from rice farming, using data from the SHH group.

The real pesticide costs (in 1996 constant prices) of IPM and non-IPM farmers over the two seasons are displayed in Figure 6.3. Money for pest control is mainly spent on pesticides, including insecticides, fungicides and herbicides. Expenditure on pesticides declined over the four-year period. Both IPM and non-IPM farmers spent less on pesticides in the 2000/01 winter-spring season than they did in the 1996/97 winter-spring season. One of the reasons for this is reduction in pesticide dose applied per crop.

Figure 6.3
Pest control costs in 1996/97 and 2000/01 winter-spring seasons (SHH group)

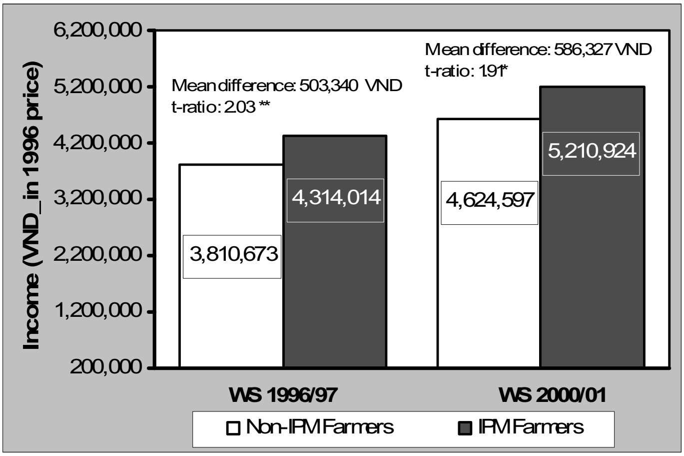


Source: Calculated from 1996/97 and 2000/01 survey data.

Figure 6.3 shows that the average expenditure on pest control by non-IPM farmers is higher than that of IPM farmers over the two seasons. In both seasons, significant differences were visible between pest control expenditures by the two groups. However, the difference in pest control costs narrowed over the four-year period, from VND 185,447 per ha/crop in the 1996/97 winter-spring season to about VND 64,770 per ha/crop in the 2000/01 winter-spring season.

The average family income from rice production of IPM and non-IPM farmers is compared in Figure 6.4. Due to lower production costs and higher gross returns, both groups of farmers obtained higher incomes from rice farming in the 2000/01 winter-spring season. All the income mean differences are statistically significant. For non-IPM farmers, this income increased by about VND 813,923 per ha/crop, or by 12 per cent. The increase in family income from rice farming of IPM farmers was VND 896,910 per ha/crop, or 21 per cent. Figure 6.4 shows that IPM farmers achieved a higher increase (about 13 per cent) than non-IPM farmers in both years. This positive economic effect is part of the evidence of successful implementation of the national IPM Programme.

Figure 6.4
Family income from rice production of IPM and non-IPM farmers (SHH group)



Source: Calculated from 1996/97 and 2000/01 survey data.

In this study, IPM farmers include those being formally trained in Farmer Field Schools as well those who learn IPM techniques from neighbours or public media. The IPM technique requires farmers to spend more time observing the rice fields at a more appropriate time, not to put in more working hours. Knowledge of IPM technique is expected to help farmers to become better farm managers and thus make more effective use of their investment. Table 6.7 presents some economic returns from rice production for IPM and non-IPM farmers.

All in all, IPM implementation resulted in higher economic returns in both seasons. Within each group of farmers, benefits and returns to labour, fertilizer and pesticide significantly improved in the 2000/01 winter-spring season. Investment in pest control provided the highest rate of return. This may be due to reduction of unnecessary spraying, less-frequent spraying, and use of other control measures simultaneously. It is interesting that non-IPM farmers also received a better rate of return to pesticide (VND 14.76) in the 2000/01 winter-spring season. Non-IPM farmers may use information from pesticide dealers, public media or workshops held by pesticide companies to improve their pesticide use.

Therefore, both groups of farmers are likely to narrow the gap in their access to effective information on pesticides.

Table 6.7
Economic indicators of rice production by IPM farmers during 1996/97 – 2000/01, SSH group (VND per ha per crop, in 1996 constant prices)

Economic indicators	**2000/01**	**1996/97**	**Mean difference**	**t-ratio**
	IPM farmers			
Benefit	4,355,301	3,285,040	1,070,261	3.95***
Family income	5,210,924	4,314,014	896,910	3.40***
Return rate to labour	4.28	3.00	1.28	4.71***
Return rate to fertilizer	6.29	4.65	1.64	3.79***
Return rate to pesticide	19.54	16.30	3.24	1.61*
	Non-IPM farmers			
Benefit	3,822,054	2,842,788	979,266	3.12***
Family income	4,624,597	3,810,673	813,923	2.75***
Return rate to labour	4.25	2.95	1.30	4.04***
Return rate to fertilizer	5.26	3.90	1.36	3.41***
Return rate to pesticide	14.76	7.93	6.83	4.19***

Source: Calculated from 1996/97 and 2000/01 survey data.

6.4 Empirical model: Demand for agrochemicals and rice supply

6.4.1 Choosing a functional form

For the purpose of empirical implementation, it is necessary to specify an explicit functional form for the normalized restricted profit function described in Chapter II. If the profit function satisfies certain required conditions, it is a dual to the production function, and a well-defined production possibilities set corresponding to it can be obtained.[4] According to Chambers (1988: 158-61), the functional form chosen should not impose prior restrictions on the parameters which portray the technology of production, and the number of parameters needed depends on the number of separate effects characterizing the behaviour of economics agents to be measured. In addition, while measuring as many of the economically relevant effects as possible, the functional form should be econometrically convenient.

A number of common functional forms have been developed and applied to derive the supply and demand of agricultural commodities in the market, such as: the Cobb-Douglas, generalized Leontief, translog, and general linear functions. The log linear functional form (the Cobb-Douglas) has been employed in much of the research on production, profit and input demand functions in agriculture around the world. The attraction of this functional form lies in its relative simplicity and in that the estimated parameters can be interpreted as short-run elasticities. The long-run elasticities can then be computed in a straightforward manner (Berndt, 1991: 326). However, it also has a number of disadvantages. As a simple example, prior to estimation, one has to place restrictions on the constant of elasticities of substitution between inputs. Hence, the magnitude of different elasticities of substitution cannot be investigated, since the function forces all Allen elasticities to equal unity. The constant elasticity substitution (CES) functional form is similar to the Cobb-Douglas function (Chambers, 1988: 158-61). In agricultural reality, one would like to see that a unit of input, say a pesticide, being substituted by another input, say labour, is not likely to be the same as the substitution of labour by pesticide. One of the purposes of this study is to examine the possibility of substitution between inputs such as labour for agrochemicals; therefore, the Cobb-Douglas and the CES are unsuitable.

Since the early 1970s, a number of so-called flexible functional forms (FFF),[5] imposing no or few prior restrictions on substitution elasticities and technology (for example, constant return to scale) have been proposed and applied in empirical studies. Among these are the Generalized Leontief introduced by Diewert (1971), Generalized Cobb-Douglas, and Generalized Square-root Quadratic forms; the Transendental Logarithmic function (translog for short), initiated by Christensen, Jorgenson and Lau in 1971; and the Normalized Quadratic function, introduced by Lau

(1976). Though FFFs have been widely used in applied production analysis, they are not necessarily free from problems (see Chambers, 1988: 173-8). In the literature, researchers have compared a number of the FFFs empirically, examining their ability to closely approximate technology. For example, Berndt and Khaled (1979), Despotakis (1986), Diewert and Wales (1987) and Lansink (1997: 28) showed that estimation results (for example, parameter estimates and elasticities) were not insensitive to the functional form chosen. Therefore, the choice of a functional form should depend on its ultimate use. The translog functional form is employed in this study because it is one of the most commonly used FFFs for the profit function in applied agricultural production analysis. The translog imposes no restriction on substitution elasticities and fewer prior restrictions on the technology than linear functional forms do (Lopez, 1985; Berndt, 1991: 458).

6.4.2 Normalized restricted translog profit function

In order to derive empirical estimates of agricultural commodity supply and input demand functions, which are crucial for understanding a farmer's response to market price incentives and for development policies, this analysis focuses on the profit function of the agricultural production process. The function represents a broad array of interactions among the underlying inputs and outputs. In the two surveys, farm households grew only rice in each season (that is, there was no mixed cropping); therefore, the model represents the relationship between rice output and variable inputs and fixed inputs. The normalized restricted translog profit function, for a single output, takes the general forms (Christensen, Jorgensen, and Lau, 1973):

$$(1)\ \ln \pi^* = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln P_i^* + \tfrac{1}{2} \sum_{i=1}^{n} \sum_{h=1}^{n} \gamma_{ih} \ln P_i^* \ln P_h^* + \sum_{k=1}^{m} \beta_k \ln Z_k + \sum_{i=1}^{n} \sum_{k=1}^{m} \delta_{ik} \ln P_i^* \ln Z_k + \tfrac{1}{2} \sum_{k=1}^{m} \sum_{j=1}^{m} \psi_{kj} \ln Z_k \ln Z_j$$

where:

π^* is the restricted profit, defined as total revenue less total costs of variable inputs, normalized by the price of output P_y; P_i^* is the price of variable input X_i normalized by the output price, P_y; Z_k is the *k* th fixed inputs. $I = h = 1,2,3,\ldots,n$ and $k = j = 1,2,3,\ldots,m$; ln is the natural logarithm; and α_0, $\alpha_i\,\gamma_{ih}$, δ_{ik}, β_k, and ψ_{kj} are parameters to be estimated.

In this model, all variable inputs and profit are normalized by the price of output (Yotopoulos and Lau, 1973)). The translog function reduces to the constant-return-to-scale Cobb-Douglas function when each of the $\gamma_{ih} = 0$, $\delta_{ik} = 0$, and $\psi_{kj} = 0$ (Berndt, 1991: 470; Binswanger, 1974).

Variable input share equations

The linkages between demand for variable inputs and their corresponding market prices and fixed inputs are represented by variable input share equations based on Shephard's lemma. Differentiating the translog profit function with respect to $\ln P_i^*$ gives a system of variable input share equations (Sidhu and Baanante, 1981):

$$(2)\quad \frac{\partial \ln \pi^*}{\partial \ln P_i^*} = -\ \frac{P_i^* X_i}{\pi^*} = \alpha_i + \sum_{h=1}^{n} \gamma_{ih} \ln P_h^* + \sum_{k=1}^{m} \delta_{ik} \ln Z_k$$

Define $S_i \equiv \frac{P_i^* X_i}{\pi^*}$ as the relative profit share of the variable input *i* (that is, the share of variable expenditure for the *i* th input relative to restricted profit), and $S_q \equiv \frac{Q}{\pi^*}$ as the relative profit share of the output (for example, the ratio of total value of output relative to restricted profit). Since the S_i and S_q sum to unity, the output supply equation can be ignored, and the estimation only comprises the translog profit function (1) and the variable input share equations (2); that is, profits and variable inputs are determined simultaneously.

Variable input demand and output supply equations

From equation (2), the demand for variable input *i* th will be:

$$((3)\quad X_i = \frac{\pi}{P_i}\left(- \frac{\partial \ln \pi}{\partial \ln P_i} \right), \text{ or}$$

$$(4)\quad \ln X_i = \ln \pi - \ln P_i + \left(\frac{\partial \ln \pi}{\partial \ln P_i} \right)$$

Following the duality theory (Lau and Yotopoulos, 1972), the output supply equation can be written as:

$$(5)\quad Q = \pi + \sum_{i=1}^{n} P_i X_i \text{ , or}$$

$$(6)\quad \ln Q = \ln \pi + \ln\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_i} \right)$$

Under the assumption of profit maximization, equation (3) is the *i* th input quantity demand for maximizing profits, and equation (5) is the profit-maximizing output level.

6.4.3 Derivation of elasticities

Price elasticities of demand for inputs and output supply

Having estimated the parameters of the profit function, price elasticities of demand for inputs, and output supply could be derived since these elasticities are linear transformations of the estimated parameters of the profit function.[6] The elasticities are evaluated at the simple averages of S_i , denoted as S_i^* and at given levels of variable input prices, and quantity of fixed inputs.

Using equation (4), the own-price elasticity of demand for input X_i can be computed as:

$$(7)\quad \eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*},\ i = 1,\ldots,n$$

while the cross-price elasticities of demand for input *i* with respect to the price of *h* th input can be obtained from (4):

(8) $\eta_{ih} = -S_h^* - \frac{\gamma_{ih}}{S_i^*}$, i, h = 1,…,n but $i \neq h$

From (4), the elasticity of demand for input i with respect to the price of output can also be derived as:

(9) $\eta_{iy} = \sum_{i=1}^{n} S_i^* + 1 + \sum_{h=1}^{n} \frac{\gamma_{ih}}{S_i^*}$, i, h = 1,…, n

With respect to the k th fixed input Z_k, the elasticity of demand for input i, will be

(10) $\eta_{ik} = \sum_{i}^{n} \delta_{ik} \ln P_i + \beta_k - \frac{\delta_{ik}}{S_i^*}$

Using equation (6), the elasticities of output supply with respect to output price (ε_{qq}), the price of the i variable input (ε_{qi}), and fixed inputs (ε_{qk}) are given by:

(11) $\varepsilon_{qq} = \sum_{i=1}^{n} S_i^* + \sum_{i=1}^{n} \sum_{h=1}^{n} \gamma_{ih} / \left(1 + \sum_{h=1}^{n} S_h^* \right)$, i, h = 1,…, n

(12) $\varepsilon_{qi} = -S_i^* - \sum_{h=1}^{n} \gamma_{ih} / \left(1 + \sum_{h=1}^{n} S_h^* \right)$, i, h = 1,…, n

(13) $\varepsilon_{qk} = \sum_{i=1}^{n} \delta_{ik} \ln P_i + \beta_k - \sum_{i=1}^{n} \delta_{ik} / \left(1 + \sum_{i=1}^{n} S_h^* \right)$

Production elasticities

On the basis of parameters estimated from the normalized translog profit function, production elasticities of fertilizers and pesticides can be calculated by using a set of relations between the production and the normalized profit function (Lau, 1978: 146-156; Thijssen, 1992).

(14) $\frac{\partial \ln q}{\partial \ln x_i} = -\frac{\theta}{1-\theta}$

where $\theta = \dfrac{\partial \ln \pi^*}{\partial \ln P_i^*} = \alpha_i + \sum_{h=1}^{n} \gamma_{ih} \ln P_h^* + \sum_{k=1}^{m} \delta_{ik} \ln Z_k$

6.4.4 Model estimation and statistical inference

To estimate the model, a disturbance term is appended to each of the profit and input demand equations since it is assumed that farmers will not always succeed in allocating the levels of inputs and output that will lead to profit maximization, capturing measurement errors and omitted variables, and so on. Parameters to calculate output supply and demand elasticities with respect to all prices and fixed inputs are provided by estimating a system of equations (2). In addition, these parameters could also be obtained by direct estimation of the profit function by OLS (1). However, as the input demand share equations have cross-equation symmetry constraints, and disturbances across input demand share equations may be contemporaneously correlated, the profit and input demand share equations should be estimated jointly (Berndt, 1991: 462; Lau and Yotopoulos, 1972). A maximum likelihood estimator is employed to estimate of parameters of a systems of the profit and input demand share equations, with cross-equation symmetry constraints imposed. The symmetry constraints among input demand share equations require that

$\gamma_{ih} = \gamma_{hi}$, where i, $h = 1,\ldots,n$, but . $i \neq h$

For statistical inference on the validity of parameters estimated and restrictions imposed in the system of equations, there are three common test statistics that could be used interchangeably: the Wald, Lagrange multiplier (LM) and likelihood ratio (LR) tests procedures. However, none of the tests is more powerful than the others, though the tests are subject to the inequality relationship: Wald > LR >LM (Berndt, 1991: 465-9). In this study, the Wald and the likelihood ratio (LR) test statistic are used since it is easy to implement from the standard output of the value of the sample maximized log-likelihood functions from the software programme (LIMDEP). In addition, the *t*-statistics for each of the coefficients estimated are actually square roots of the Wald test for testing whether the coefficient equals zero. The Wald, and LR test statistic is distributed asymptotically as a chi-square random variable, with degrees of freedom equal to the difference between the number of free parameters estimated in the constrained and unconstrained models.

This completes the presentation of the concept of the normalized restricted translog profit function, and basic derivations of elasticities, as well as estimation procedure. All these concepts and equations form a basis for empirical implementation of the model with the survey data presented in the next section.

6.5 Empirical estimation of model

The assumptions employed in the model are:

(a) management decisions on agrochemicals and other inputs used can be described as static profit maximization in the short-run,
(b) farm households are price takers, and
(c) the production function is concave in the variable inputs.

The model helps to provide understanding of the short-run behaviour of farmers in making output and input decisions in each production period, given the available technology, endowment of fixed factors of production, and economic constraints (Antle and Capalbo, 1995) The profit function in translog form expressing the maximizing profit of a farm household as a function of the prices of inputs and outputs and the fixed factor of production is specified in actual variables as in equation (17) below. To understand the relative economic efficiency of IPM farmers and non-IPM farmers, and capture the difference in soil fertility, two dummy variables are added in the model.

(15) The normalized translog profit function:

$$\begin{aligned}
\ln\pi^* =& \alpha_o + \alpha_W \ln P_W^* + \alpha_F \ln P_F^* + \alpha_P \ln P_P^* + \tfrac{1}{2}\gamma_{WW}(\ln P_W)^2 + \tfrac{1}{2}\gamma_{FF}(\ln P_F)^2 + \\
&\tfrac{1}{2}\gamma_{PP}(\ln P_P^*)^2 + \gamma_{WF}\ln P_W^* \ln P_F^* + \gamma_{WP}\ln P_W^* \ln P_F^* + \gamma_{FP}\ln P_F^* \ln P_P^* + \beta_L \ln Z_L + \beta_E \ln Z_E \\
&+ \tfrac{1}{2}\psi_{LL}(\ln Z_L)^2 + \tfrac{1}{2}\psi_{EE}(\ln Z_E)^2 + \psi_{LE}\ln Z_L . \ln Z_E + \delta_{WL}\ln P_W^* \ln Z_L + \delta_{WE}\ln P_W^* \ln Z_E + \\
&\delta_{FL}\ln P_F^* \ln Z_L + \delta_{FE}\ln P_F^* \ln Z_E + \delta_{PL}\ln P_P^* \ln Z_L + \delta_{PE}\ln P_P^* \ln Z_E + \lambda_1 IPM + \lambda_2 SOIL
\end{aligned}$$

There are three variable inputs and two fixed inputs specified in the profit function. Their definitions and notations, along with other variables, are as follows:

π^* Restricted profit from rice production per farm, defined as total revenue less total variable costs of labour, chemical fertilizers and pesticides normalized by output price P_y. This profit is known as the Unit-Output-Price (UOP) profit. The

	UOP profit function is characterized as increasing in the price of output, decreasing and convex in the normalized prices of variable inputs and increasing in quantities of fixed inputs (Yotopoulos and Lau, 1973)
P_W^*	Wage rate per day normalized by output price P_y. The wage rate is derived by dividing the total labour expenditure in rice production by the quantity of labour, including both family and hired labour. It is expected to have negative effects on profit, demand for inputs and output supply.
P_F^*	Price of NPK fertilizer nutrient per kilogram normalized by output price P_y. It is expected to have negative effects on profit, demand for inputs and output supply
P_P^*	Price of pesticides per gram of active ingredient normalized by output price P_y. This variable expected to have negative effects on profit, demand for inputs and output supply.
Z_L	Land input measured in acres of rice grown. It is expected to have positive effects on profit, inputs demand and output supply.
Z_E	The education level of main family labour (over 15 years of age). Primary school = 1, Secondary school = 2; and High school and Upper =3. It is expected to have positive effects on profit, demand for inputs and output supply.
IPM	Dummy variable taking the value of 1 for farms practising IPM, and 0 otherwise. The sign for this variable is expected to be positive for IPM farmers
SOIL	Dummy variable represented for land classes from 1 to 5, which captures difference in soil fertility. Land class 1 is the most fertile and provides the highest rice yield. The sign for this variable is expected to be negative to profit.

$\alpha, \beta, \gamma, \delta, \psi, \lambda$ are parameters to be estimated, and the subscripts W, F, P, L, E denoted for inputs in the production: labour, fertilizers, pesticides, land, and education, respectively.

From (2), the three variable input share equations (S_i) of labour, fertilizers and pesticides are obtained by differentiating the normalized restricted translog profit function (17) as follows:

Labour share equation (16)

$$S_W \equiv -\frac{P_W^* X_W}{\pi^*} = \alpha_W + \gamma_{WW} \ln P_W^* + \gamma_{WF} \ln P_F^* + \gamma_{WP} \ln P_P^* + \delta_{WL} \ln Z_L + \delta_{WE} \ln Z_E$$

Fertilizer share equation (17)

$$S_F \equiv -\frac{P_F^* X_F}{\pi^*} = \alpha_F + \gamma_{FW} \ln P_W^* + \gamma_{FF} \ln P_F^* + \gamma_{FP} \ln P_P^* + \delta_{FL} \ln Z_L + \delta_{FE} \ln Z_E$$

Pesticide share equation (18)

$$S_P \equiv -\frac{P_P^* X_P}{\pi^*} = \alpha_P + \gamma_{PW} \ln P_W^* + \gamma_{PF} \ln P_F^* + \gamma_{PP} \ln P_P^* + \delta_{PL} \ln Z_L + \delta_{PE} \ln Z_E$$

Where X_W, X_F, X_P are denoted for quantities of variable inputs used in rice production, respectively. The measurement units of these variables are man-days for labour, kilogram of nutrients for fertilizers, and grams of active ingredient for pesticides. The system of equations (15), (16), (17), and (18) will be jointly estimated by a maximum likelihood estimator (MLE). Symmetry constraints across and within equations are imposed in the system. In the absence of symmetry restrictions, there are 41 parameters to be estimated, 23 in the profit function and six in each of three input share equations. When cross-equation symmetry constraints $\gamma_{WF} = \gamma_{FW}, \gamma_{WP} = \gamma_{PW}, \gamma_{PF} = \gamma_{FP}$ are imposed, the number of parameter drops to 38. For profit maximization, parameters of the input share equations have to be equal to the corresponding parameters of the profit function, maintaining the symmetry constraints (Lau and Yotopoulos, 1972; Sidhu and Baanante, 1981). This results in a total of 18 restrictions to be imposed in the system, and the number of free parameters to be estimated being reduced from 38 to 23.

Two sets of estimations were performed separately for the 1996/97 winter-spring and 2000/01 winter-spring seasons, which are named 1996/97 model (N=177) and 2000/01 model (N=159). However, prior to estimating the system of equations separately for each rice season, a pool data is used in a 'pre-test' model to test whether the assumption of profit maximization holds and profits in the two seasons are the same. A dummy variable, namely *YEAR,* takes the value of 1 for 2000/01, and 0 for 1996/97. This is equivalent to testing the null hypothesis that the *YEAR* coefficient is not statistically different from zero. The system of parameters estimated is then used to derive (a) the price elasticities of input demand and rice supply to price changes, (b) production elasticities of fertilizers and pesticides, and (c) elasticities of input substitution.

6.6 Estimation results

6.6.1 Statistical tests of models

Formal tests of the model for the two rice seasons are presented in Table 6.8. The first hypothesis test concerns the empirical validity of symmetry restrictions across input share equations in the model. Given symmetry, the second is for testing the profit maximization assumption. The LR test statistic shows the validity of the symmetry and parametric constraints through imposition of 18 restrictions on the system of equations.

In the pre-test model using pool data from the two surveys (N=336), the symmetry condition necessary for the derivation of input and output supply equations from the profit function is satisfied. However, the null hypothesis of profit maximization is rejected. The result of this test implies that farmers are not equating the marginal values of variable inputs to specific market prices at the farm gate. The estimated coefficient of the *YEAR* dummy is 0.043 and significantly different from zero at 1% level. This implies that rice production in the 2000/01 winter-spring season provided higher profit for farm households than in the 1996/97 winter-spring season. The empirical result is also consistent with the analysis earlier in this chapter. To see whether profit is relatively equal across years within the SHH group, another pre-test model was also run by using pool data of 152 same households in the two seasons. The test result is that the computed χ^2 (18 d.f.) of the LR test for profit maximization is 65.98, and the critical χ^2 at 1 per cent level of significance equals 34.81. Thus, the null hypothesis is rejected at the 1% level of significance.

Test results of the 1996/97 model are similar to those of the pre-test model. The LR tests show that while the symmetry condition is satisfied, the null hypothesis of profit maximization is rejected. Farmers might over-use or under-use inputs as comparison to the optimal input levels for profit maximization. Over-use of agrochemicals has been reported by recent studies in the MKD. Dung and Dung (1999: 18) found that farmers in the MKD over-used pesticides by 274.4 grams a.i. per hectare in the 1996/97 winter-spring rice season. In another study, Dung et al. (1999) observed that on the average farmers in the MKD overused

27 kg of N nutrient per hectare per season. Ha (1999: 467-75) found that 50-90 per cents of farmers over-used pesticides, either spraying for prevention or to control pests. The over-use of fertilizers and pesticides is not only uneconomical but also places an additional burden on the environment. It is noticeable that the optimal quantities estimated in these studies are in terms of the specific prices of fertilizers and pesticides, and environmental costs are not taken into account. Any change in prices of these factors will lead to a change in the optimal amounts.

Table 6.8

Statistical tests of models[7]

Hypothesis test	Pre-test model	1996/97 model	2000/01 model
Symmetry	χ^2 (3 d.f.) = 4.90	χ^2 (3 d.f.) = - 0.68	χ^2 (3 d.f.) = 6.64
Profit maximization	χ^2 (18 d.f.) = 54.43	χ^2 (18 d.f.) = 43.12	χ^2 (18 d.f.) = 34.16

Notes: Using Lagrange multiplier (LR) test.
Critical χ^2 (3 d.f.) at 1% level = 11.35; Critical χ^2 (18 d.f.) at 1% level = 34.81

The null hypotheses of symmetry and profit maximization are not rejected in the 2000/01 model. The computed χ^2(18 d.f.) of the LR test for profit maximization is 34.16, and the critical χ^2at 1% level of significance equals 34.81. Thus, the null hypothesis cannot be rejected at the 1% level of significance. This implies that, among other things, farm households maximize profits by equating the marginal values of variable inputs to normalized prices of variable inputs. That is fertilizers, pesticides and labour were used at their economically optimal levels in the 2000/01 winter-spring season. The testing result of the 2000/01 model thus empirically supports the assumption of profit maximization.

In conclusion, of the three models being tested for the assumption of profit maximization, the pre-test model using pool data of all households (N=336) and the SHH group (N=152), and the 1996/97 model (N=177) are rejected at 1% level of significance. The rejection of profit maximization may be explained by self-consumption of rice and the use of own labour by farm households. In such a case, production and consumption/labour decisions cannot be separated (de Janvry et al., 1991). However, the growing importance of the market may have influenced farmers' movement from self-subsistence towards profit maximization in the 2000/01 season. Therefore, further empirical analysis and other derivations of interest in this chapter will now be focused on the 2000/01 model (N=159).

6.6.2 Additional statistical tests for 2000/01 model

After testing the assumption of profit maximization, there are three more testable conditions for the 2000/01 model. The estimated parameters have to satisfy certain restrictions that ensure they are consistent with the underlying theory. The convexity and monotonicity in prices are not imposed in the model since they are involved in non-linear constraints and not easily imposed on the parameters of the share equations. They can be checked ex-post using the estimated parameters of the share equations. It is known that the translog profit function is not well-behaved globally, that is the convexity and monotonicity condition in price assumptions will not necessarily hold at all price levels of input and output. At the point of approximation, the monotonicity condition can be checked to see whether the α_i in the share equations are negative (Antle and Capalbo, 1988). In the model, the monotonicity condition is satisfied at the point of approximation, since the share equations are all negative. The result implies that the profit function is decreasing and convex in the normalized price of variable inputs. The convexity condition of the profit function can be checked further by examining the cross-price elasticities reporting in the next section.

The final statistical test is conducted to test for the Cobb-Douglas hypothesis. It is known that the translog profit function will reduce to the constant-return-to-scale Cobb-Douglas profit function if coefficients of all second-order terms (cross-products) in (15) equal zero. The Wald and LR tests were employed to test the validity of 30 restrictions imposed in the system of equations, that is all γ_{ij} and δ_{ik} equal zero. The computed χ^2 (30 d.f.) of Wald and LR tests are 187.36 and 159.15, respectively, and the critical χ^2 at 0.01 level of significance equal 50.90. Thus, the null hypothesis is rejected. This implies, given the survey data of the 2000/01 winter-spring season in the MKD, that the Cobb-

Douglas functional form may not be more suitable than the translog form specified in this study. Descriptions of variables used in the 2000/01 model are presented in Table B.1, Appendix B.

6.6.3 Parameters estimated from 2000/01 model

The parameters of the system of equations for the 2000/01 model with symmetry and profit maximization constraints, estimated by MLE are given in Tables 6.9 - 6.12. Table 6.9 shows that 16 and 11 of the total 41 coefficients in the profit and share equations, respectively, are statistically significant at 5% level or higher. The large number of significant cross-product terms indicates the high degree of interdependence between inputs and output in production.

Negative cross-product coefficients imply a complementarity in variable inputs and a negative impact on profits. The significant coefficients of the two fixed factors, land and education, indicates that the level of education and farm size have positive influence in providing higher profit from rice production.

Statistical significance at 1% level of the dummy variable *IPM* (λ_1) means that farmers who apply the IPM technique do achieve higher profit than the non-IPM farmers. This finding is consistent with the analysis of profitability presented in section 2 of this chapter. Higher profitability in rice production of IPM farmers is perhaps due to more effective use of inputs, as discussed in the previous section.

The *SOIL* coefficient represented for soil fertility in rice production in the study sites is statistically significant at 1% level, implying a lower profit to farm households that cultivate rice on less-fertile soils.

The parameters estimated from the system of equations, however, are interesting not in themselves, but for the derivation of elasticities, since there are complex interactions between variables and the effects of each variable input price on profit are not clear-cut. Final conclusions can be drawn meaningfully from the elasticities to be discussed in the next section.

Table 6.9
Parameter estimates of the system of normalized translog profit and variable input share equations, MKD 2000/01 survey

Variables	Parameters	Estimated	Standard error	t-ratio
Intercept	α_0	5.112	0.274	18.62***
$\ln P_W$	α_W	0.661	0.132	4.98***
$\ln P_F$	α_F	0.166	0.069	2.40**
$\ln P_P$	α_P	0.210	0.038	5.48***
$\ln P_W \ln P_W$	γ_{WW}	-0.319	0.041	-7.64***
$\ln P_F \ln P_F$	γ_{FF}	-0.158	0.029	-5.55***
$\ln P_P \ln P_P$	γ_{PP}	-0.045	0.004	-10.86***
$\ln P_W \ln P_F$	γ_{WF}	-0.049	0.021	-2.23**
$\ln P_W \ln P_P$	γ_{WP}	-0.004	0.010	-0.32^{NS}
$\ln P_F \ln P_P$	γ_{FP}	0.001	0.006	0.16^{NS}
$\ln Z_L$	β_L	0.680	0.077	8.83***
$\ln Z_E$	β_E	0.193	0.095	2.03**
$\ln Z_L \ln Z_L$	ψ_{LL}	-0.085	0.068	-1.25^{NS}
$\ln Z_E \ln Z_E$	ψ_{EE}	0.006	0.140	0.041^{NS}
$\ln Z_L \ln Z_E$	ψ_{LE}	-0.036	0.025	-1.41^{NS}
$\ln P_W \ln Z_L$	δ_{WL}	0.042	0.019	2.25**
$\ln P_W \ln Z_E$	δ_{WE}	-0.012	0.007	-1.71*
$\ln P_F \ln Z_L$	δ_{FL}	0.006	0.010	0.64^{NS}
$\ln P_F \ln Z_E$	δ_{FE}	0.001	0.003	0.33^{NS}
$\ln P_P \ln Z_L$	δ_{PL}	-0.007	0.004	-1.70*
$\ln P_P \ln Z_E$	δ_{PE}	-0.005	0.002	-2.50***
IPM	λ_1	0.033	0.017	1.91**
SOIL	λ_2	-0.053	0.007	-7.25***

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.

Source: Estimated from system of translog profit and variable input demand functions (equations 15, 16, 17 and 18).

Table 6.10

Parameter estimates of labour-share equation, MKD 2000/01 survey

Variables	Parameters	Estimated	Standard error	t-ratio
Intercept	α_W	0.661	0.132	4.98***
$\ln P_W$	γ_{WW}	-0.319	0.041	-7.64***
$\ln P_F$	γ_{WF}	-0.049	0.021	-2.23**
$\ln P_P$	γ_{WP}	-0.004	0.010	-0.32^{NS}
$\ln Z_L$	δ_{WL}	0.042	0.019	2.25**
$\ln Z_E$	δ_{WE}	-0.012	0.007	-1.71*

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.
Source: Estimated from system of translog profit and variable input share equation 16).

Table 6.11

Parameter estimates of fertilizer-share equation, MKD 2000/01 survey

Variables	Parameters	Estimated	Standard error	t-ratio
Intercept	α_F	0.166	0.069	2.40**
$\ln P_W$	γ_{FW}	-0.049	0.021	-2.23**
$\ln P_F$	γ_{FF}	-0.158	0.029	-5.55***
$\ln P_P$	γ_{FP}	0.001	0.006	0.16^{NS}
$\ln Z_L$	δ_{FL}	0.006	0.010	0.64^{NS}
$\ln Z_E$	δ_{FE}	0.001	0.003	0.33^{NS}

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.
Source: Estimated from system of translog profit and variable input share equation 17).

Table 6.12

Parameter estimates of pesticide-share equation, MKD 2000/01 survey

Variables	Parameters	Estimated	Standard Error	t-ratio
Intercept	α_P	0.210	0.038	5.48***
$\ln P_W$	γ_{PW}	-0.004	0.010	-0.32^{NS}
$\ln P_F$	γ_{PF}	0.001	0.006	0.16^{NS}
$\ln P_P$	γ_{PP}	-0.045	0.004	-10.86***
$\ln Z_L$	δ_{PL}	-0.007	0.004	-1.70*
$\ln Z_E$	δ_{PE}	-0.005	0.002	-2.50***

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.

Source: Estimated from system of translog profit and variable input share equation 18).

6.6.4 Estimated elasticities of output supply and variable input demand

Elasticities of output supply and variable input demand with respect to (w.r.t.) market prices and fixed inputs are presented in Table 6.13. All these elasticities are evaluated from the parameter estimates, the values of the dependent variables at the sample means, and the simple averages of the relative share of input expenditures to profit (see equations 16, 17 and 18). The standard errors are presented in brackets under the elasticity estimates. The effects of changes in prices and levels of fixed factors on output supply and input demand are theoretically correct, and most elasticities are found to be statistically significant at the critical 1% level. Detailed discussions and estimation results of elasticities are presented in the following section.

Output supply elasticities

The elasticities of output supply w.r.t. rice price, prices of variable inputs, and levels of fixed inputs, derived from (11), (12) and (13), have expected positive signs. The elasticity of output supply w.r.t. its own price (ε_{qq}) is 0.23, and significantly different from zero. The inelasticity of own-output supply reveals that with current rice varieties, farmers are not able to increase significant output supply as there is a rise in the

Table 6.13
Price elasticities of output supply and variable input demand for rice production, Mekong Delta 2000/01 survey

Supply / Demand	Rice price	Wage	Fertilizer Price	Pesticide Price	Land	Education
Output	0.227	-0.086	-0.059	-0.039	1.021	0.146
	(0.035)	(0.030)	(0.019)	(0.008)	(0.063)	(0.091)
t-ratio	6.39**	-2.79***	-3.05***	-4.67***	16.25***	1.60*
Labour	0.462	-0.361	-0.041	-0.059	0.928	0.170
	(0.148)	(0.126)	(0.066)	(0.032)	(0.084)	(0.094)
t-ratio	3.11***	-2.84***	-0.62^{NS}	-1.86*	11.05***	1.82*
Fertilizer	0.497	-0.071	-0.355	-0.070	1.022	0.131
	(0.162)	(0.115)	(0.150)	(0.031)	(0.082)	(0.093)
t-ratio	3.05***	-0.62	-2.36**	-2.26**	12.46***	1.40^{NS}
Pesticide	0.897	-0.281	-0.191	-0.425	.952	0.202
	(0.192)	(0.150)	(0.084)	(0.059)	(0.098)	(0.095)
t-ratio	4.67***	-1.86*	-2.26**	-7.16***	9.63***	2.13**

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.
Source: Estimated from parameters of translog profit function, and sample means of rice price, wage, prices of fertilizers and pesticides.

market price of rice. This implies a limitation in current rice production technology.

Rice output supply is slightly influenced negatively when there is an increase in prices of variable inputs. The elasticities of output supply w.r.t. prices of fertilizers and pesticides and wage rates are inelastic and significantly different from zero, at 0.09, 0.06 and 0.04, respectively. Increase in the wage rate and prices of fertilizers and pesticides leads to a reduction in the quantities of inputs used, and thus output supply. However, the reduction in output supply is rather small. For example, a 10 per cent increase in pesticide price will lead to a reduction of 0.4 per cent in output (Table 6.13). Output supply elasticities with respect to fixed factors of production can be considered as production elasticities provided variable inputs can be adapted freely to the optimal level (Lansink, 1997: 40). Both education and farm size (size of the area in which rice is grown) have positively influenced output supply. The largest positive effect on production is the change in farm size. Output supply is approximately doubled when there is a 100 per cent increase in farm size.

Demand and cross-demand elasticities for variable inputs

Profit maximization requires that all of the own-price elasticities of demand for variable inputs are negative. As shown in Table 6.13, the demand for labour, fertilizers and pesticides w.r.t. to their own-prices has the correct signs (that is, negative signs). All these elasticities are less than one in absolute value, implying inelastic response of input factor utilization. It is well known that an increase in input prices will cause a decrease in quantity demanded and vice versa. However, the net impact of a price on total farm expenditures depends on exactly how much quantity demand changes in response to a given price change. The own-price elasticity of demand for pesticides (η_{PP} = -0.43) is higher than those for labour and fertilizers (η_{FF} = -0.36, and η_{WW} = -0.36, respectively), implying that, for an equivalent rise in prices, farmers' response to a change in pesticide price is relatively higher than the change in wage rate and fertilizer price. Regarding the farms expenditures, there would be an increase in total costs of labour, fertilizers and pesticides as their prices increased due to inelastic demand. This is because when a price (P_i) increases, the fall in quantity (X_i) is less than proportionate to the rise in price, resulting in a higher combined value ($P_i X_i$).

All cross-price elasticities of demand for inputs η_{ih} are generally small, less than one in absolute value, and negative in signs (Table 6.13). The low cross-price elasticities of demand reflect limited price responsiveness across the inputs. In other words, changes in prices of one input have small impacts on the demand for other inputs. The effect of wage rate change on fertilizer demand is smaller than on the demand for pesticides. When the wage rate increases by 10 per cent, demand for fertilizers and pesticides is reduced by 0.7 per cent and 2.8 per cent, respectively. All negative signs of cross-price elasticities of demand reveal that labour, fertilizers and pesticides are gross complements in rice production. This means that, for any pair of inputs, when relative price of a factor increases, quantity ratio of the two inputs will decrease. The complementary relationships between labour and fertilizers, labour and pesticides, and fertilizers and pesticides are reasonable. In rice production, fertilizers and pesticides are applied by labour, hence the higher the quantity of pesticides and fertilizers applied, the more labour is required. Farmers cannot achieve a good harvest in the absence of one of the three inputs. When farm households use more fertilizers, they need more workers for fertilizer application. Then, higher fertilizer application may help the rice crop to grow better while also creating more pest problems. As a consequence, more pesticides will be demanded.

Variable input demand elasticities w.r.t. fixed factors of production, namely land and education, indicate the response to exogenous changes in these factors, holding the prices of output and variable inputs constant. The demand for labour, fertilizers and pesticides is most heavily influenced by expansion of farm size. The input demand elasticities w.r.t. farm size are approximately unity and statistically different from zero. As the rice land increases by 1 per cent, demand for labour, fertilizers and pesticides increases by 0.92, 1.02, and 0.95 per cent, respectively. The influence of more education of farm family labours on the demand for variable inputs is also quite important. It increases the demand for all, labour, fertilizers and pesticides.

A rise in the price of rice will have an expansive effect on the demand for variable inputs used in rice production. Elasticities of demand for labour, fertilizers and pesticides w.r.t. to rice price are all positive in sign, consistent with the expectation. The pesticide demand elasticity w.r.t. rice price (η_{PY}=0.89) is almost twice in absolute value than those of labour (η_{WY} = 0.46) and fertilizers (η_{FY} =0.49), indicating that when there is a rise in rice price, farmers will use more pesticides than fertilizers and labour.

Production elasticities of fertilizers and pesticides

Production elasticities of fertilizers and pesticides calculated from equation (14) are 0.15 and 0.09, and statistically significant at 1 per cent and 5 per cent levels, respectively. The positive sign of these elasticities indicates that fertilizers and pesticides contributed positively to rice yields in the 2000/01 winter-spring season. However, an increase in one of these inputs while keeping the other constant does not result in a high increase in rice production. A 10 per cent increase in fertilizer applied per crop per hectare will result in 1.5 per cent increase in rice yield. On the other hand, rice yields will increase by only 0.9 per cent for every 10 per cent increase in pesticide applied per crop per hectare. This finding makes sense because fertilizers are nutrients for the rice crop and thus predetermine the yield potential, while pesticides are only for protecting the rice crop from pests and yield loss. The low response of rice yields to changes in the application of fertilizers and pesticides suggests that increasing agrochemical inputs to HYV varieties used by farmers is not a wise investment. Since rice yields may reach the ceiling, new rice varieties providing higher yields would be worth investigating and recommending to farmers. These estimated elasticities are higher in absolute value than those performed in other studies (Table 6.14). However, none of those studies used the FFF (that is, translog) to calculate these elasticities.

Table 6.14
Production elasticities of fertilizers and pesticides in other studies

Variables	Production elasticities	Source
NPK fertilizers	0.086	Dung and Dung (1999)
Nitrogenous fertilizers	0.016	Ha (1999)
Nitrogenous fertilizers	0.070	Son (1998)
Nitrogenous fertilizers	0.078	Minh (2000)
Pesticides	0.035	Dung and Dung (1999)
Insecticides	-0.0005	Ha (1999)
Fungicides	0.0150	Ha (1999)
Herbicides	0.0001	Ha (1999)

6.7 Concluding remarks

Several economic aspects of rice production by farm households were examined in this chapter through comparative economic analysis and neoclassical economic theory, using survey data from the 1996/97 and 2000/01 winter-spring seasons in the Mekong Delta. Empirical results in this chapter show that using the translog profit function allows a considerably disaggregated analysis of farm production. The optimal demand for labour, fertilizers and pesticides is jointly estimated with the maximizing rice output supply, providing estimates of the impacts of changes in input prices, or non-price variables (fixed inputs) or combinations of the two. All this is crucial for analysing the impacts of policies to restrict agrochemical use presented in Chapter 8.

The economic effects of agrochemicals on rice production were first observed through analysis of rice yields, a standard measurement of productivity and a major component of economic return. The findings showed that farm households achieved a better rice yield over the four-year period despite an overall decline in consumption of fertilizers and pesticides. The rice yields increased by about 2.7 per cent and 2.2 per cent for all farm households and the SHH group, respectively. Rice yields increased while the use of agrochemicals per crop per hectare fell, implying an increase of partial productivity of fertilizer nutrients and pesticides. However, the yield increase is not ground for optimism since it was accompanied by higher variability in yields, which implies higher production risks to farmers. This issue is important for small farmers since they may get into debt and suffer other hardships that result from a poor harvest. The higher variability in rice yield is assumed to be mainly due to variation in uncontrolled use of new HYVs when there is no significant yield loss due to pests during the survey periods. Local conditions, namely, soil fertility, water conditions, pest infestation and farmers' practices, also influenced the yield variability.

The main findings of this chapter are:

Higher yields were obtained by IPM farmers

IPM implementation in rice production had a positive influence on rice yields. IPM farmers achieved significantly higher yields than non-IPM farmers, within a season as well as over the four-year period. The reasons for higher yields lie in the IPM aspects of crop management, such as day-to-day management of rice fields, and efforts to apply the four principles of the IPM programme. This finding corresponds with the results of the nationwide impact study conducted for the national IPM programme in 2000 (Pincus, 2000). The IPM farmers in the SHH group also achieved higher yields in the 2000/01 winter-spring season. While the average doses of fertilizer applied by IPM farmers were not significantly different from those of non-IPM farmers, the pesticide doses did show a difference.

Fertilizers and pesticides positively influenced rice yield

Both pesticides and fertilizers are among the factors that determine the level of productivity in rice cultivation. The Pearson correlation coefficient between fertilizers and rice yield was higher than that between pesticides and yields, which showed the more important effect of fertilizers on rice production. High yields were observed at higher doses of fertilizers and pesticides, but not proportionally. Production elasticities of fertilizers and pesticides for the 2000/01 winter-spring season, derived using parameters estimated from a system of the normalized translog profit function and input share equations (Section 6.4), were 0.15 and 0.09 and statistically significant at 1% and 5% levels, respectively.

There was a slight increase in costs of rice production

For all surveyed farmers, total expenditures (in constant 1996prices) of rice production were slightly higher in the 2000/02 winter-spring season than in the 1996/97 winter-spring season due to increases in labour costs and other costs. The cost difference is statistically significant at 10% level. This eventually raised the unit cost of production per kg of rice to VND 782, which is VND 35 higher than the unit cost of rice in the 1996/97 winter-spring season. The overall picture of expenditures on rice production by the SHH group is somewhat different. Total costs and unit costs of production per kg of rice in the 2000/01 winter-spring season are statistically lower than in the 1996/97 winter-spring season, which is the opposite of the situation in all surveyed farms. Farmers in the SHH group reduced production costs by cutting the amounts of agrochemicals, labour and seed, especially of pesticides. As a consequence, they produced at the cheaper cost of VND 718 per kg in the 2000/01 winter-spring season.

Profitability was higher within the four-year period

Both, all farm households and the SHH group, obtained higher gross return, benefit and household income from rice cultivation due to significantly higher yields and better rice prices. Household income from rice farming thus increased by about 14 per cent for all farms, and 26 per cent for the SHH group in the 2000/01 winter-spring season. The investment in fertilizers, labour, and especially pesticides, brought higher returns in the 2000/01 winter-spring season than in the 1996/97 winter-spring season. Better management of fertilizer application and pesticide spraying might improve the efficiency of agrochemicals considerably, and therefore increase the return to farmers. The cost-benefit ratio of rice farming in general shows that the rate of return on capital investment increased over the four-year period.

Both IPM and non-IPM households received higher income from rice

Detailed examination of the profitability of rice production for IPM and non-IPM farmers within the SHH group shows that both groups of farmers spent less money in the 20000/01 winter-spring season than in the 1996/97 winter-spring season. One of the reasons for this is reduction in pesticide doses applied per crop. However, average expenditure on pest control by non-IPM farmers was higher than that of IPM farmers. In both seasons, significant differences were visible between pest control expenditure by the two groups. Due to lower production costs and higher gross returns, both groups of farmers obtained higher income from rice farming in the 2000/01 winter-spring season (12 per cent and 21 per cent for non-IPM and IPM farmers respectively). All in all, IPM implementation resulted in higher economic returns in both seasons. Within each group of farmers, benefits, returns to labour, fertilizer and pesticide improved significantly in the 2000/01 winter-spring season. Investment in pest control provided the highest return. This may have been due to reduction in unnecessary sprays and frequency of spraying as well as simultaneous application of other control measures.

Farmers have pursued profit maximization in rice production

The assumption of profit maximization is accepted for the 2000/01 model (N=159). This implies that, among other things, farm households maximize profits by equating the marginal values of variable inputs to normalized prices of variable inputs. That is, fertilizers, pesticides and labour were used at their economically optimal levels in the 2000/01 winter-spring season. The test for the Cobb-Douglas hypothesis is also rejected at 1% level of significance. This implies, given the survey data for the 2000/01 winter-spring season, that the Cobb-Douglas functional form may not be more suitable than the translog form specified in this study.

The assumption of profit maximization in rice production by farm households is rejected at 1% level of significance for the pre-test model, using pool data of all households (N=336) and the SHH group (N=152), and the 1996/97 model (N=177). The rejection of profit maximization in these cases may be explained by self-consumption of rice and use of own labour by farm households. In such a case, production and consumption/labour decisions cannot be separated (de Janvry et al., 1991). The estimated coefficient of the *YEAR* dummy in the pre-test model using pool data of all households is 0.043 and significantly different from zero at 1 per cent level. This implies rice production in the 2000/01 winter-spring season provided higher profit for farm households than in the 1996/97 winter-spring season. The empirical result is consistent with the comparative economic analysis in this respect.

Profitability was also influenced by factors other than market prices of inputs and outputs

The test results of dummy variables *IPM* (λ_1) and *SOIL* (λ_2) are statistically significant at 0.01 level and consistent with the comparative economic analysis. This implies that farmers who apply the IPM technique do achieve higher profit than non-IPM farmers, and that farm households that cultivate rice in less-fertile soils obtain a lower profit. Profit from rice production increases positively with expansion of fixed factors of production, rice land size and education of main household labour. It could be inferred that profit from rice production would contribute little to the income of farm households with poor endowment in rice land size and education. The situation would be even more serious for households that obtain their entire income from rice production and have many dependent family members.

Rice farmers responded rationally to market price signals

Demand elasticities for labour, fertilizers and pesticides w.r.t. their own-prices have the correct signs (that is, negative signs). The impact of a given change in any of the exogenous variables across variable input demand for labour, fertilizers and pesticides is not symmetric; thus it is quite consistent with a priori theoretical expectations. For an equivalent rise in prices, farmers' response to change in pesticide price is relatively higher than the change in wage rate and fertilizer price, since the own-price elasticity of demand for pesticide is higher than those of labour and fertilizers. All negative signs of cross-price elasticities of demand reveal that labour, fertilizer and pesticide are gross complements in rice production. This means that, for any pair of inputs, when relative price of a factor increases, quantity ratio of the two inputs will decrease. An increase in rice price is not able to stimulate a significant increase in rice output. A rise in rice price will have an expansive effect on the demand for variable inputs used in rice production. The higher value of pesticide demand elasticity w.r.t. rice price indicates that when there is a rise in the rice price, farmers will use more pesticide than fertilizers and labour in rice production. The inelasticity of own-output supply indicates that with current rice varieties, farmers are not able to increase output supply significantly when there is a rise in the market price of rice. This implies a limitation in the current rice production technology of farm households.

Notes

[1] The rice yields reported in this study are the aggregate yield results across surveyed farm households regardless of rice varieties. Nevertheless, the aggregate yields can provide some useful indications of trends in intensive rice agriculture in the Mekong Delta.

[2] Production risks involve technical aspects of production such as biological conditions, technology and pest outbreaks.

[3] Real price (1996) = Current price/CPI (2000)*CPI (1996). CPI (December this year compared to December of the previous year) from 1996 to 2000: 104.5, 103.6, 109.2, 100.1, 99.4, respectively.

[4] Duality, one-to-one correspondence, between the production and profit functions is widely discussed in the literature, for example Antle and Capalbo (1988), Chambers (1988), Lau (1978).

[5] Forms that can be interpreted as a second-order Taylor series approximation to an arbitrary function or second-order differential approximation are referred to as flexible functional forms (Chambers, 1988: 164).

[6] For detailed proofs of these elasticities, see Binswanger (1974) and Sidhu and Baanante (1981).

[7] Since the study is investigating the empirical application of profit functions, only some common regularity conditions on the production and profit functions are tested.

7 Effects of Agrochemicals on Farmers' Health and Water Quality

7.1 Introduction

While Chapter 6 analysed the economic consequences of pesticide and chemical fertilizer use for production and profitability of farm households, this chapter deals with other important effects of agrochemical use on the environment. It investigates the hazards posed to human health, ecosystems and natural resources. Potentially, emissions of agrochemicals, especially pesticides, can occur in production, formulation, use and disposal. The production, formulation and disposal stages are not discussed here because they fall outside the study's direct area of interest. The chapter concentrates on effects following the use of agrochemicals at farm level. The next section discusses the effects of pesticide use on the health of farmers who come into direct contact with them. The chapter then analyses the possible negative side effects of fertilizers on the environment, specifically on water quality.

7.2 Effects of pesticides on human health

Farm households have succeeded in improving productivity and increasing their income from rice, but the intensification of rice production relying heavily on HYVs and agrochemicals has had negative effects on human health. As Chapters 5 and 6 demonstrated, pesticide use per crop per hectare decreased by 25 per cent in rice production over a four-year period while rice production was maintained or even rose. While this is a positive step, insecticides, fungicides and herbicides are not entirely used by the rice crop nor are they retained within the rice fields. Some of the agrochemicals leave the system as liquid leakages, surface runoff, spray drift and gases. The emission of pesticides through application on the fields unfortunately poses risks to both, those who apply them as well as consumers; beneficial organisms; ground water; and ecosystem integrity. These effects constitute a significant cost to society and to individual rice farmers, affecting the long-term sustainability of rice production. In this study, risk is defined as the likelihood of the occurrence of unwanted adverse effects on farmers or the environment by pesticide application.

In general, there are two possible routes through which humans and wildlife are exposed to pesticides. The first is direct exposure during or after spraying/granulate treatment via spray drift and gases. This includes exposure of terrestrial and aquatic organisms through leaching and run-off. The second route is through indirect exposure via residues in food derived from crops on which pesticides are applied directly, and drinking water prepared from contaminated ground/surface water. This study focuses on the effects of pesticide use on farmers' health. Results of the characterization of exposure to pesticides and the associated effects are combined to estimate the risk to farmers' health (through a health risk model). The analysis begins with a statistical description of farmers' direct exposure to pesticides and the pesticide-related health effects reported by survey respondents in the study areas. These effects include both acute pesticide poisoning symptoms and chronic conditions that could be related to pesticide exposure. In the second step, a conservative estimate of pesticide-related health costs is calculated (through a health cost model) to give a lower-bound estimate of the true value of reducing illness.

7.2.1 Health risks posed by pesticides

Risk of adverse health effects is a function of pesticide toxicity and exposure to pesticides during application. Pesticide toxicity refers to the capacity to cause injury or illness. Toxicity of pesticide can be either acute, causing ill effects that develop soon after exposure, or chronic, causing ill effects that develop over a long time after exposure. Chronic effects of pesticide poisoning are often irreversible, and may include reduced body weight, anaemia, kidney disorders, central nervous system disorders and cardiovascular disorders (EXTOXNET). However, the health impact of pesticide use has not been monitored so far, and no adequate statistics on it are available at either local or national level in Vietnam. A pesticide with high acute toxicity can be very hazardous to health, even when a very small amount is absorbed. Acute toxicity levels are used as a way to assess and compare how poisonous pesticides are.

The acute toxicity of a pesticide is the basis for the poison warning statements on labels. Acute toxicity may be measured as acute oral toxicity, acute dermal toxicity or acute inhalation toxicity (EXTOXNET).

Exposure is defined in this study as contact with pesticides. Exposure to pesticides can occur at any stage of pesticide handling. There are three main routes through which pesticides may enter a farmer's body: dermal absorption (via skin and eyes), inhalation (breathing), and ingestion (by mouth) (EXTOXNET). The amount of pesticide applied and the area of application are important in determining exposure. Pesticides that are applied infrequently or in small quantities to a limited area in a remote location are less likely to result in significant human exposure, and vice versa.

Frequency of pesticide application

The threat to health from exposure to pesticides may also result from frequent contact with pesticides belonging to hazardous categories. The frequency of pesticide application refers to the number of sprayings, or dissemination of pesticides, during the growing season, and it is an important indicator for understanding the level of pesticide exposure. Farmers decide how many times pesticides should be applied, depending on pest conditions, for the purpose of prevention, suppression or eradication. Eradication of pests in open rice fields is difficult to achieve since pests, like insects, fungus, and bacteria can move from one field to surrounding ones. Therefore, most pesticide applications are to keep a pest from becoming a problem, reduce the size of a pest population or keep the damage to an acceptable level.

Table 7.1 shows that the average number of pesticide applications increased from 3.71 in the 1996/97 winter-spring season to 4.06 in the 2000/01 winter-spring season, which is statistically significant at 10 per cent level. Farmers typically applied herbicides once, insecticides once, and fungicides twice. All farmers sprayed fungicides at least once to protect their rice crops from disease, whether there were symptoms of disease or not. Although the situation varies from case to case, many factors have contributed to the relative increase in fungicide use: numerous advertisements for fungicides that are broadcast daily via television and radio, relatively low prices, increased marketing by pesticide companies, and retailers' influence on farmers through promotion of and guidance on the use of fungicides.

Table 7.1
Mean values of frequency of pesticide application per crop (times per crop)

Pesticides types	1996/97 WS season	2000/01 WS season	t-test
		Non-IPM farmers (N=166)	
All pesticides	3.72 (1-9)	4.15 (1-7)	-1.83*
Categories I and II	2.70 (0-8)	1.91 (0-5)	2.75***
Categories III and IV	2.60 (1-7)	3.60 (1-7)	-3.26***
		IPM farmers (N=170)	
All pesticides	3.69 (1-8)	4.02 (1-7)	-1.69*
Categories I and II	2.16 (1-7)	1.75 (0-5)	1.82*
Categories III and IV	2.76 (1-6)	3.50 (0-6)	-2.85***
		All farmers (N=336)	
All pesticides	3.71 (1-9)	4.06 (1-7)	-2.47**
Categories I and II	2.53 (0-8)	1.80 (0-5)	4.34***
Categories III and IV	2.65 (1-7)	3.53 (0-7)	-4.76***

Note: WS = winter-spring.
Source: 1996/97 and 2000/01 surveys.

In the MKD, farmers decreased frequency of insecticide application but raised that of herbicides and fungicides out of necessity. Heong et al. (1995) found that the number of insecticide sprayings was reduced because farmers stopped early-season spraying against leaf-folders. The mean number of insecticide sprays per farmer per season decreased significantly, from 3.4 in 1992 to 1.0 in 1997 (Huan et al., 1999). A Plant Protection Department survey on the use of pesticides in rice production in the Mekong Delta (PPD, 1999) found that farmers usually sprayed herbicides once, insecticides once or twice, and fungicides twice or three times during the 1999 rainy season (autumn-winter season) (See Table C.1, Appendix C). Though the surveys for the current study and the PPD surveys were not conducted at the same time, in the same locations and during the same growing seasons, the findings on the frequency of pesticide application in rice production are similar. Thus, the results are reasonably representative of the current of pesticide application practices of rice farmers in the Mekong Delta and indicate a change in farmers' perceptions of pesticide application, especially insecticide spraying.

Another important point is that farmers often applied more than one pesticide in an application; this was especially so for fungicides. In other words, farmers were exposed to more hazardous pesticides in one application. Therefore, the total number of direct exposures to pesticides in hazardous categories is somewhat different from the number of applications of pesticides. Frequencies of exposure to pesticides in categories I and II (NA1) and III and IV (NA2) were defined as the number of times farmers had contact with a certain kind of pesticide; therefore, each farmer could be exposed to more than one type of pesticide during one application. This means that the sum of NA1 and NA2 would be at least equal to or larger than the number of applications per season. This separation was expected to reflect the impact of pesticide on farmers' health more explicitly. A 'vertical' comparison between seasons reveals a substantial change in the application different categories of pesticide. Table 7.1 shows that during a four-year period, surveyed farmers reduced the frequency of application of pesticides in categories I and II from 2.53 times to 1.80 times per crop, but raised that of pesticides in categories III and IV from 2.76 times to 3.50 times per crop. These changes are statistically significant. The change in the application frequency of different categories of pesticide is due to variations in pesticide type across the two surveys (see tables in Appendix C).

IPM farmers, through participation in Farmer Field Schools, training courses, or the use of experimental fields, have partly changed their perceptions of insecticide spraying, thereby helping to reduce the overall number of applications. Within one season, the average frequencies of total pesticide application and of pesticides in categories NA1 and NA2, by IPM farmers were lower than those by non-IPM farmers (except for the application of NA2 in the 1996/97 winter-spring season). However, the differences were not statistically significant (see Table C.2, Appendix C), except for the application frequency of pesticides in categories NA1 applied in the 1996/97 winter-spring season. Though the average number of pesticide applications per crop of IPM farmers was lower than that of non-IPM farmers, Table 7.2 shows that both groups increased the number of pesticide applications between 1996/97 and 2000/01. In the 2000/01 winter-spring season, about 46.8 per cent of all non-IPM households and 54.5 per cent of the non-IPM SHH group of farmers sprayed more than five times per season, while only around 34.8 per cent of all PM households and 33.3 per cent of the IPM SHH group of IPM sprayed that frequently. PPD (1999) also found that the number of pesticide applications by IPM farmers was lower than that by non-IPM farmers. In addition, farmers with higher education tended to reduce the number of pesticide applications, implying that those farmers had better access to IPM practices and innovation (see Table C.1, Annex C). How farmers' health is affected by this pesticide exposure will be discussed later in this chapter.

Table 7.2
Frequency of pesticide application in rice production of survey households (percentage of farm households)

Frequency (Times/crop)	**1996/97 WS season**			**2000/01 WS season**		
	Non-IPM	***IPM***	***All***	***Non-IPM***	***IPM***	***All***
			All farm households			
0-2	19.3	15.5	18.1	19.1	12.5	14.5
3-4	57.1	67.2	60.5	34.0	52.7	47.2
>=5	23.5	17.2	21.5	46.8	34.8	38.4
			SHH-group			
0-2	19.1	20.7	19.7	13.6	13.0	13.2
3-4	57.4	72.4	63.2	31.8	53.7	47.4
>=5	23.4	6.9	17.1	54.5	33.3	39.5

Note: WS = winter-spring.
Source: 1996/97 and 2000/01 surveys.

Farmers' perceptions of the effects of pesticides on their health

The perception that long-term use of pesticides can contribute to health ailments was relatively common in the survey villages. During the two surveys, most of the farmers interviewed said that their spouses, children and other family members participated in rice cultivation. Their field activities include planting, weeding, applying fertilizer, spraying pesticides and harvesting the crop. However, no farmers allowed their children (those not part of the labour force) and female members of the household to apply the pesticides directly. Some children could help by fetching pesticide bottles/boxes and sprayers, and water for those applying the pesticides. Though pesticide drifts and pesticide diluted in water in the rice fields may have indirect effects on female workers and children during weeding, for example, this study focuses only on the health problems of those applying the pesticides.

Almost all the farmers interviewed believed that pesticides could have some negative effects on their health (Table 7.3). The more-experienced farmers thought pesticides had a very strong effect on health, causing many or severe health problems, whereas farmers who had been using pesticides for a shorter time perceived the effects of pesticides as being less strong. Table 7.3 summarizes how low or high farmers in the two surveys rated the effect of pesticides on their health. In the 1996/97 survey, 18.6 per cent and 10.7 per cent said there had been very much and extremely large effect, respectively, compared with 14.1 per cent and 29.4 per cent who said it was very little or little, respectively. Of the respondents, 22.6 per cent thought pesticide application had had much effect on their health. They believed that long-term pesticide use might cause their bodies to become weaker, reduce their life span, and lead to other 'unknown' health problems. Approximately 4.5 per cent said pesticides had no influence on their health. These were predominantly young farmers who had recently begun rice cultivation and did not perceive pesticide exposure as a health hazard because they had never experienced 'clear' poisoning. In their view, acute poisoning signs such as fatigue, headaches and itching skin were normal and short-lived, and these signs normally disappeared after bathing. They also considered age to be a factor, with older farmers being more vulnerable than younger ones. In addition, they believed that the weaker the person applying pesticide was, the more likely he would be to become sick.

In the 2000/01 survey, farmers were more aware of health hazards resulting from pesticide application. Only 2.5 per cent of respondents said pesticides spraying had no effects on their health (Table 7.3). A majority of 66 per cent of the respondents considered that pesticides had much effect, very much effect or large effect, an increase from the 52 per cent four years previously. This change in farmers' perceptions seems to imply a significant improvement of knowledge as a result of the national IPM programme.

Health damage evidence from rice farmers

Farmers in the survey villages reported many visible symptoms of pesticide poisoning. Since signs or symptoms of pesticide poisoning can be confused with other health ailments (for example, influenza, food poisoning, and so on), the respondents were asked if the symptoms had appeared immediately after or within 24 hours of spraying. Therefore, the reported symptoms in this study are of actual poisoning. Researchers often use visible health impairment as evidence of the effects of pesticide use on farmers' health (Huang et al., 2001). Biochemical, blood and pathological investigation is needed to verify these and to determine if there are invisible/chronic symptoms that accumulate in the human body. Since no medical tests were conducted for this study, health impairment may be underestimated here, but it is consistently being observed among farmers.

Table 7.3
Farmers' perceptions of effects of prolonged pesticide use on their health

	1996/97 survey			2000/01 survey		
	No. of farmers	*% of farmers*		*No. of farmers*	*% of farmers*	
No effect	8	4.5	48.0	4	2.5	34.0
Very little effect	25	14.1		20	12.6	
Little effect	52	29.4		30	18.9	
Much effect	40	22.6	52.0	54	34.0	66.0
Very much effect	33	18.6		29	18.2	
Extremely large effect	19	10.7		22	13.8	
	177	100.0		159	100.0	

Source: 1996/97 and 2000/01 surveys.

In the survey villages, farmers who directly apply pesticides experienced many complaints after spraying. To identify reporting bias, all respondents were asked if they believed pesticides could cause such health ailments. Of the sample farmers, 90.7 per cent in the 1996/97 survey and 89.8 per cent in the 2000/01 survey said they were sure of the link between pesticide spraying and their symptoms, as they did not occur during or after other field activities (for example, fertilizer application) (Table 7.4). Post-spray symptoms such as blurred vision, body tremors, muscle fasciculation (eyelid twitching), skin itching and irritation, or even vomiting, were considered to be linked to pesticide exposure.

Table 7.4
Farmers' linking of symptoms to pesticide poisoning after application

Assessment scale	**1996/97 survey (n=177)**			**2000/01 survey (n=159)**		
	No. of farmers*	***% of farmers***		***No. of farmers***	***% of farmers***	
No opinion	3	2.3		4	4.6	
Perhaps	9	7.0		5	5.7	
Sure	9	7.0	90.7	14	15.9	89.8
Very sure	85	65.9		56	63.6	
Completely sure	23	17.8		9	10.2	
No. respondents with symptoms	129	100.0		88	100.00	

Note: * based on respondents who had poisoning signs/symptoms only.
Source: 1996/97 and 2000/01 surveys.

Table 7.4 shows that 72.9 per cent (129 out of 177) and 55.3 per cent (88 out of 159) farmers experienced pesticide poisoning in the 1996/97 and 2000/01 seasons, respectively. The lower percentage of farmers reporting such symptoms in the 2000/01 winter-spring season may be a result of the reduction in pesticide doses applied, better knowledge of safe use, and a shift from category I and II to category III and IV pesticides. However, it should be noted that each farmer can display more than one acute poisoning symptom at the same time. The symptoms during or shortly after applying pesticides were reported to include headaches, eye irritation, fatigue, shortness of breath, vomiting, skin irritation, coughing, diarrhoea, convulsion, and others (stomach cramps, body tremors, dry throat, chest pains, and dizziness). The signs and symptoms of pesticide poisoning reported by all farmers in the sample are presented in Table 7.5.

The most noticed symptom 'ever experienced' was headache, though non-specific and possibly associated with other conditions or hard work. Approximately, 39.5 per cent (1996/97 survey) and 39.0 per cent (2000/01 survey) of the sample farmers in the two surveys reported this symptom (Table 7.5). Headaches were not reported to be severe, but medium and requiring a short rest. Fatigue was another neurological effect of pesticide exposure, experienced by 25.4 per cent (1996/97 survey) and 25.8 per cent (2000/01 survey) of the sample farmers. Headaches, dizziness and fatigue are among symptoms of the central nervous system indicating mild pesticide poisoning common to organophosphates, organochlorines, carbamates and high doses of pyrethroids (Sodavy et al., 2000).

Table 7.5
Signs and symptoms of pesticide poisoning reported by all farmers

Signs/symptoms	**1996/97 WS season**		**2000/01 WS season**	
	No. of farmers	*% of farmers*	*No. of farmers*	*% of farmers*
Headache	70	39.5	62	39.0
Skin irritation	47	26.6	38	23.9
Fatigue	45	25.4	41	25.8
Eye irritation	31	17.5	34	21.4
Shortage of breath	20	11.3	10	6.3
Heart	19	10.7	9	5.7
Vomiting	12	6.8	4	2.5
Cough	5	2.8	1	0.6
Fever	4	2.3	2	1.3
Diarrhoea	4	2.3	1	0.6
Convulsion	4	2.3	0	0.0
Others	27	15.3	21	13.2

Source: 1996/97 and 2000/01 surveys.

Skin irritation was also experienced by more than 26.6 per cent (1996/97 survey) and 23.9 per cent (2000/01 survey) of farmers. Skin, the main route for pesticides to enter human body as a result of spraying, was more seriously harmed by pesticides in the 1996/97 survey. Most farmers reported that their hands, legs, face and eyes were often exposed to pesticides during mixing and application and through spray drift.

Many did not wear goggles during spaying. Eye irritation was reported by 17.5 per cent and 21.4 per cent, respectively, a substantial increase over four years. Shortage of breath was reported by 11.3 per cent of the sample farmers in the 1996/97 survey, but only 6.3 per cent in the 2000/01 survey. Vomiting after spraying is a verifiable sign of moderate pesticide poisoning, but only 2.5 per cent of the farmers reported this symptom in the 2000/01 survey, compared with 6.8 per cent in the 1996/97 survey. Almost all the farmers wear masks (in most cases, a simple 'cloth mask') to minimize inhalation of pesticide spray drift and vapours Thus a very low percentage of farmers experienced respiratory tract effects. Though coughing was often reported, only 2.8 per cent (1996/97) and 0.6 per cent (2000/01, one case) of farmers linked this symptom with inhalation of pesticide drift. Convulsion, a severe symptom of pesticide poisoning, was not reported in the 2000/01 survey, but four cases were reported in the 1996/97 season. Various other pesticide-related symptoms were also reported, most notably dizziness.

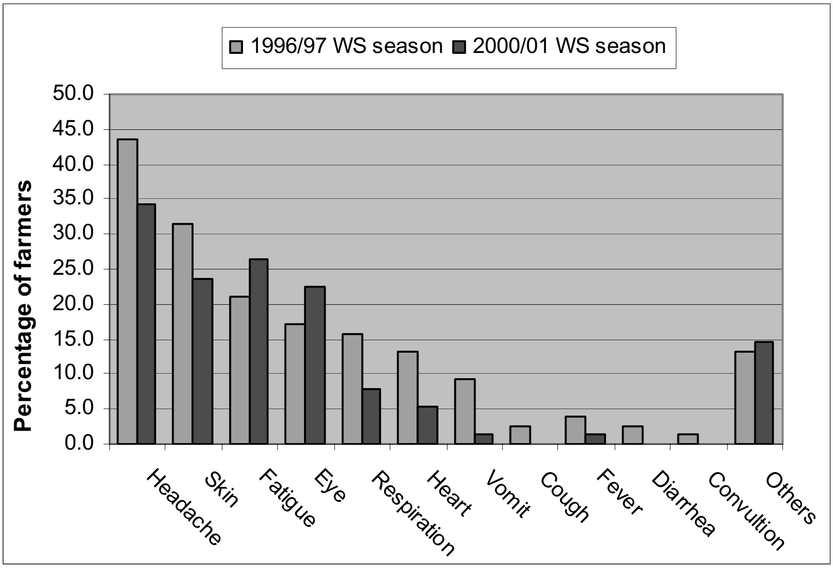
The signs and symptoms of pesticide poisoning reported by farmers in the SHH group are graphically displayed in Figure 7.1. Poisoning symptoms, namely, headache, skin irritation, fatigue and eye irritation, were reported at similar levels as those of all sample farmers, with fatigue and eye problems showing an unexplained increase in the second survey.

A World Bank study of the health effects of pesticide use in the MKD,[1] especially organophosphates and carbamates, found serious pesticide poisoning symptoms among rice-growing farmers. Medical laboratory tests showed that the prevalent rates of cardiovascular, respiratory and skin diseases were 11.2, 1.8, and 37.5 per cent, respectively, which are higher rates of poisoning symptoms than those found in this study. A medical blood test (n=67) showed that acute and chronic pesticide poisoning rates among rice-growing farmers were 41.8 per cent and 58.2 per cent, respectively. These results strengthen the probability that the visible impairments presented in this study underestimate the problem because of unseen impacts of pesticide exposure.

7.2.2 Determinants of acute pesticide poisoning symptoms

The theoretical health risk model presented in Chapter 2 was used to investigate determinants of the reported pesticide poisoning symptoms. The model was specified for empirical estimation as follows:

Figure 7.1
Signs and symptoms of pesticide poisoning reported by SHH group



$$HRISK_i = \alpha_0 + \beta_1 AGE_i + \beta_2 WTHT_i + \beta_3 SMOKE_i + \beta_4 DRINK_i + \beta_5 TOCA1_i$$
$$+ \beta_6 TOCA2_i + \beta_7 NA1_i + \beta_8 NA2_i + e_i$$

where *HRISK* denotes health impairment indicator and is equal to 1 if any health impairment occurred; and equal to 0 if no health impairment was reported. Three separate health risk models were estimated for headache, skin irritation and eye irritation. *AGE* is farmer's age (years since birth). *WTHT*, a ratio of farmer's weight (kg) to height (metres) is a proxy for health status and level (and quality) of nutrition. This variable is expected to have a negative impact on the probability of farmers having their health impairment investigated. *SMOKE* is a dummy for a smoking habit, and equal to 1 if the respondent smokes regularly and equal to 0 otherwise. *DRINK* is a dummy for an alcohol drinking habit, and equal to 1 if the respondent drinks regularly and equal to 0 otherwise. *TOCA1* denotes total dose of category I & II pesticides in grams of a.i. used per hectare per crop. *TOCA2* denotes total dose of category III & IV pesticides in grams of a.i. used per hectare per crop. *NA1* is the number of applications of category I & II pesticides per season (times). *NA2* is the number of applications of category III & IV pesticides per season (times). The *i*'s denote individual farmers. Finally, e_i is an error term.

Effects of pesticide exposure on eyes

Determinants of eye effects due to pesticide exposure are presented in Table 7.6. Of the five human senses, sight provides the most help in terms of perception. The eye is very vulnerable to physical and chemical hazards. Chronic eye effects can lead to formation of a vascular membrane over the cornea which diminishes visual capacity and eventually reduces farmers' productivity (Pingali et al., 1994). Few farmers use goggles during spraying, indicating that they generally pay little attention to the possibility of ill effects to their eyes caused by pesticides in the long run. The incidence of eye irritation increases significantly with drinking habits and exposure to herbicides and fungicides (*TOCA2*). The ratio of weight by height (*WTHT*) carries a negative sign, as expected, on eye abnormalities of farmers in both surveys. In addition, the number of contacts with pesticides in categories I & II (*NA1*) contributes significantly to an increase in eye irritation, whereas the number of contacts with categories III & IV (*NA2*) does not have a significant effect. The probability of eye abnormalities among sample farmers in 1996/97 and 2000/01 was 0.18 and 0.21, respectively. It was determined from parameters estimated from the logit function at the mean levels of all variables.

Neurological effects

In both surveys, the incidence of headaches is also significantly associated with drinking habits and physical status (Table 7.7). Farmers who drink experienced this symptom more often than non-drinking farmers after spraying. Smoking habits also significantly increased the probability of headaches in the 2000/01 survey, but not in 1996/97. Headaches are positively related to the use of pesticides in both categories, I & II (*TOCA1*) and III & IV (*TOCA2*), although the latter is insignificant in the 2000/01 survey. The results are understandable since most pesticides are neuro-toxicants, especially pesticides in categories I & II. More frequent application of pesticides also increased the probability of headache after spraying. Farmers in the two surveys have a probability, estimated at the sample mean level of all variables, of 0.40 of having headache.

Table 7.6

Estimates of eye irritation among rice farmers

Variables	1996/97 WS rice season			2000/01 WS rice season		
	Coefficient		*Wald test*	*Coefficient*		*Wald test*
Constant	-1.356	(2.917)	0.216	0.374	(2.946)	0.016
AGE	0.116	(0.057)	0.411	0.001	(0.022)	0.003
WTHT	-0.147 *	(0.083)	3.108	-0.166**	(0.082)	4.243
SMOKE	0.496	(0.565)	0.771	0.374	(0.508)	0.541
DRINK	0.969 *	(0.573)	2.859	0.402	(0.541)	0.552
*TOCA*1	0.005	(0.008)	0.391	0.003*	(0.002)	2.689
*TOCA*2	0.025***	(0.008)	8.985	0.003*	(0.001)	3.532
*NA*1	0.249 *	(0.147)	2.882	0.531*	(0.279)	3.616
*NA*2	0.118	(0.144)	0.672	0.058	(0.278)	0.044
Chi square (8 d.f.)	27.473***			36.321***		
Predicted probability	0.18			0.21		

Notes: WS = winter-spring.
Figures in parentheses are standard errors of estimates.
***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Effects of skin exposure to pesticide

Skin problems occur widely among rice farmers who are often exposed to pesticides. The logit regression estimates in Table 7.8 indicate that the incidence of skin problems can indeed be related positively and significantly to the doses of both pesticide categories, I & II (*TOCA1*) and III and IV (*TOCA2*) in the two surveys. The influence of the number of applications, *NA1* and *NA2*, on skin problems was expected to be positive, but the results are not consistent between the two surveys. The number of contacts with pesticides in categories 1 & II is significantly related to skin irritation in the 2000/01 survey. Finally, the physical health status (*WTHT*), with a negative sign as expected, is related significantly to skin effects. The incidence of skin abnormalities is not significantly related to

Table 7.7

Estimates of headache among rice farmers

Variables	**1996/97 WS rice season**			**2000/01 WS rice season**		
	Coefficient		***Wald test***	***Coefficient***		***Wald test***
Constant	-0.096	(2.252)	0.002	-0.891	(2.523)	0.125
AGE	0.053***	(0.019)	7.440	0.003	(0.018)	0.019
WTHT	-0.156**	(0.066)	5.435	-0.131*	(0.067)	3.802
SMOKE	-0.328	(0.382)	0.739	0.797 *	(0.434)	3.381
DRINK	1.020 **	(0.408)	6.227	0.789 *	(0.453)	3.024
*TOCA*1	0.025 **	(0.012)	4.340	0.004 **	(0.001)	5.310
*TOCA*2	0.002 **	(0.000)	6.073	0.001	(0.001)	0.702
*NA*1	0.105	(0.126)	0.701	0.473 *	(0.263)	3.241
*NA*2	-0.005	(0.117)	0.002	0.396 *	(0.238)	2.773
Chi square (8 d.f.)	36.707***			52.342***		
Predicted probability	0.40			0.39		

Notes: Figures in parentheses are standard errors of estimates.
***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 7.8

Estimates of skin irritation among rice farmers

Variables	**1996/97 WS rice season**			**2000/01 WS rice season**		
	Coefficient		**Wald test**	**Coefficient**		**Wald test**
Constant	-0.161	(2.618)	0.004	-0.0878	(3.044)	0.0008
AGE	-0.010	(0.021)	0.215	0.0197	(0.021)	0.817
WTHT	-0.129 *	(0.077)	2.812	-0.202**	(0.086)	5.547
SMOKE	-0.518	(0.456)	1.293	0.122	(0.497)	0.060
DRINK	1.995***	(0.593)	11.296	0.939*	(0.565)	2.769
*TOCA*1	0.001*	(0.0007)	2.939	0.003*	(0.002)	3.262
*TOCA*2	0.002**	(0.0009)	3.567	0.003**	(0.002)	4.486
*NA*1	0.111	(0.145)	0.589	0.457*	(0.280)	2.686
*NA*2	0.245 *	(0.129)	3.577	0.224	(0.276)	0.662
Chi square (8 d.f.)	39.313***			43.776***		
Predicted probability	0.27			0.24		

Notes: WS = winter-spring.
Figures in parentheses are standard errors of estimates.
***, **, and * denote significance at 1%, 5%, and 10%, respectively.

age and smoking habits. At the sample mean value of all variables, the estimated probabilities of abnormal skin problems for farmers in the 1996/97 and 2000/01 surveys are 0.27 and 0.24, respectively.

7.2.3 Health costs resulting from pesticide use

Model specification

In order to explain the principal factors affecting health costs arising from pesticide exposure among rice-growing farmers,[2] the theoretical health cost model presented in Chapter 2 is estimated, using pesticide-related health costs from the 1996/97 survey. Then, coefficients derived from this model are used to estimate the farmer's health cost for the 2000/2001 winter-spring season. Health costs related to pesticide use are commonly computed with estimates of the treatment required to restore the farmer's health. In this study, the components of health cost incurred by farmers due to pesticide-induced illness were calculated on the basis of the following cost items (in VND): opportunity costs of work days lost to illness (assumed to be equal to the average wage in the 1996/97 winter-spring season multiplied by number of days off) and restricted-activity days (assumed to be equal to one-third of the average wage); costs of recuperation (meals, medicines, doctors or hospital care), which were obtained through face-to-face interviews with farmers who come into direct contact with pesticides; and costs of protective equipment.

Due to the difficulty of estimating costs related to treatment required to restore farmers' health to normal, the health costs of farmers discussed in this chapter are for a single rice season only, and limited to treatments related to visible health impairment. The explanatory factors of health costs were linked with four broad classes of variables: those related to health, pesticide exposure, farmer characteristics, and rice farming practices. The health variables include a proxy variable of farmer's health status (farmer's weight by height); and two known voluntary health hazards, namely smoking and alcohol drinking habits. Pesticide exposure variables include total pesticide dose used per hectare per crop, and the number of applications (proxy for the number of times a farmer comes into contact with pesticides). The age of the respondent is represented as a farmer characteristic. Finally, rice farming practices are represented by the IPM technique application variable.

In keeping with the health economics literature (Antle and Pingali, 1994; Pingali et al., 1995: 110-16), the health cost function was modelled as a logarithmic form of the hypothesized determinant factors. The log-log cost function can be interpreted as first-order approximation to true cost function, and is globally well behaved (Pingali et al., 1995: 110-16).

$$LnHC_i = \alpha + \beta_1 LnAGE + \beta_2 WTHT + \beta_3 SMOKE + \beta_4 DRINK + \beta_5 LnDOSE + \beta_6 NA + \beta_7 IPM + e_i$$

where,
LnHC: health cost (in VND) in natural log form.
LnAGE: natural log form of farmer's age. This variable is expected to have a positive sign on health cost.
WTHT: a proxy for health and nutrition, measured as farmer's weight (kg) over height (metres). This variable is expected to have a negative sign, meaning the bigger the value of the estimated coefficient, the lower the health cost.
SMOKE: dummy for smoking (0 for non-smokers, and 1 for smokers)
DRINK: dummy for drinking alcohol (0 for non-drinkers & 1 for drinkers)
LnDOSE: natural log form of total dosage of all pesticides (herbicide, fungicide and insecticide) used (grams of a.i./crop/ha). This variable is expected to have a positive impact on health cost.
NA: number (frequency) of pesticide application per season (times)
IPM: dummy variable taking a value of 1 if practising IPM technique, and a value of 0 otherwise.

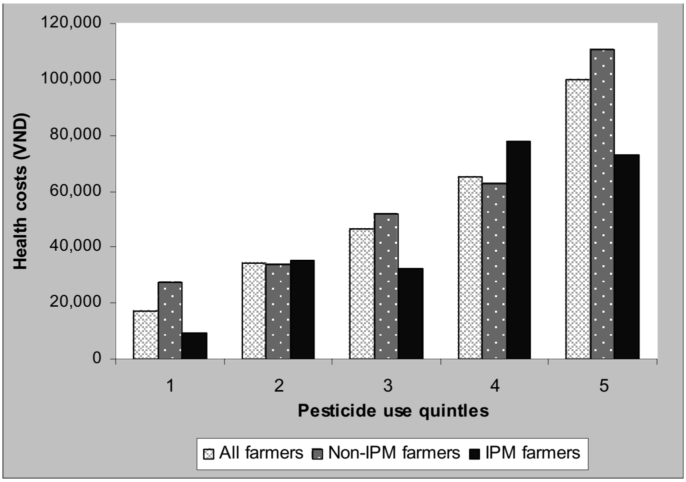
Descriptive statistics of variables with continuous values such as health cost, age, pesticide doses, and height by weight (*WTHT*) are presented in Table C.3, Appendix C. Box-plot diagrams show that these variables are normally distributed and not skewed. The ordinary least square method was employed to estimate parameters of the model.

Results of analysis

The estimated parameters for farmers' health costs are presented in Table 7.9. The results of the overall test for significance of the model (F test) and Adjusted R square are that the model was significant and that independent variables in the right- hand side (RHS) could explain 55 per cent of changes in pesticide-related health costs (the dependent variable). While all other explanatory variables are significant and consistent with expectations, the smoking dummy variable has a negative sign, contrary to theoretical expectation. This is unexpected because smoking was found to affect rice farmers' health costs significantly in a similar study done in the Philippines (Pingali et al., 1994). Though bearing an unexpected sign, the estimated coefficient is not statistically significant, indicating that smoking habits do not affect farmers' health costs as a result of pesticide exposure. Drinking habits contribute significantly to a rise in age and smoking habits. At the sample mean value of all variables, the health costs. This is cause for concern because drinking is widespread among farmers in the study sites (61.4 per cent of the respondents in the 1996/97 survey engaged in it). The coefficient of weight by height ratio is statistically significant, with a negative sign as expected. The finding indicates that the nutritional/physical status of farmers is an important factor in helping to reduce farmers' health costs. It also indicates high health costs for farmers with 'weak' physical status. The estimated coefficient of the age variable shows that the older the farmer, the higher the health costs, a relationship that was to be expected.

With regard to the impact of total quantity of pesticides used on farmers' health costs, estimates show that the health cost increases by 0.934 per cent for every 1 per cent increase in total dose. The significant impact of pesticides dose on farmers' costs is consistent with previous studies in other countries (Pingali et al., 1994; Dung and Dung, 1999; Huang et al., 2001). Figure 7.2 shows that the health cost reported by farmers increased as the sprayed pesticide dose increased. Health costs due to pesticide exposure are higher for non-IPM farmers.

Figure 7.2
Pesticide-related health cost reported by farmers in 1996/97 winter-spring season



The coefficient of frequency of application is also statistically significant, indicating that the more frequent the pesticide exposure, the higher the health cost. This finding is consistent with regression results in the health risk model presented in the previous section. The author assumed that farmers only applied a specific dose of a given pesticide (measured in grams of a.i.) during one season. The expectation was that the more frequent the pesticide use (and therefore the smaller the amount of pesticide applied each time), the lower the health costs (Huang et al., 2001). However, this assumption may be not valid since toxicity or hazards are not the same among pesticides, nor within a hazard category. Farmers in the study sites used a combination of herbicides, insecticides and fungicides, with different toxicity characteristics. Thus, when they use a bigger dose of category I and II pesticides, and more frequently, health problems, and hence health costs, are likely to increase.

Finally, application of IPM techniques has a beneficial impact on farmers' health. The negative and significant coefficient of the IPM dummy variable indicates that farmers practising IPM techniques have significantly lower health costs. IPM farmers applied smaller pesticide dose per crop per season (as explained in Chapter 5) and therefore suffered less exposure. In addition, they might better understand the health hazards of pesticides and use more precautionary measures. The pesticide health cost value was estimated at VND 54,720 per farmer/season, using sample mean values (that is, average values of the sample in the model).

The parameters estimated from the health cost regression results are also used to calculate the average and marginal farmers' health cost values per applied pesticide dose. Two scenarios with various assumption values are presented for illustration. In scenario 1, the health cost is based on estimates for a non-smoking, but drinking farmer population. It assumes an average farmer's age of 41 years, with a weight of 51 kg and height of 1.60 m (WTHT ratio of 31.87). Pesticide doses applied are simulated at levels of 750, 850, and 950 grams of a.i./ha/crop, respectively. The number of pesticide applications is four times per season. Finally, health costs are predicted for both, IPM and non-IPM farmers. In scenario 2, all assumption values are similar to those of scenario 1, except that the number of pesticide applications is five times per season. The results are summarized in Tables C.4 and C.5, Appendix C.

Table 7.9
Estimated heath cost of pesticide exposure for Mekong Delta farmers, 1996/97

Variables	**Coefficient**	**Standard error**	**t-ratio**
Constant	1.806	1.017	1.775*
LnDOSE	0.934	0.092	10.178***
NA	0.179	0.037	4.882***
LnAGE	0.774	0.164	4.728***
WTHT	-0.028	0.016	- 1.778*
SMOKE	-0.048	0.076	- 0.641
DRINK	0.109	0.064	1.695*
IPM	-0.201	0.070	- 2.865***
Predicted health cost	VND 54,720; Min: VND 18,958; Max: VND 154,517		

Notes: Adjusted R square =0.55.
Regression F value (7, 136) = 37.464.
***. ***,**, and * denote significance at 1%, 5%, and 10%, respectively.
Source: Estimated from 1996/97 survey.

A number of observations can be made from the estimated results. For IPM farmers, when pesticide doses are applied four times, and increased from 750 (average dose of the 2000/01 winter-spring season) to 850, and 950 grams of a.i. (average dose of the 1996/97 winter-spring season), health costs increase from VND 40,135 to VND 45,115 and 50,032 per farmer/per season, respectively. The marginal health cost values indicate that each additional gram of pesticide a.i. use will cause the health cost to increase by VND 49.98, 49.56 and 49.19, respectively. For non-IPM farmers, with the same doses of pesticide use and other characteristics, pesticide health cost per season, per gram a.i. of pesticide, and marginal health costs are all higher than those of IPM farmers (Table C.4, Appendix C). When frequency of application increases from four to five times per crop per season, estimated health cost values increase by about 16.4 per cent (Table C.5, Appendix C).

7.2.4 Conclusion on health effects of pesticide use

This chapter has so far provided an overview of pesticide use, exposure, farmers' perceptions and pesticide-related ailments as well as farmers' health costs. Intensified cultivation that relies heavily on HYVs and agrochemicals has caused damage to human health. This poses a significant cost to society and to rice farmers, affecting the long-term sustainability of rice production. These aspects of pesticides use and their consequences for farmers' health were analyzed and compared between all sample farmers and the SHH group as well as non-IPM and IPM farmers in the two surveys. However, none of this analysis has estimated the environmental impact of specific pesticides. For instance, the comparative analysis focused on quantifying pesticide use and health impacts to compare different pest management practices, between non-IPM and IPM farmers. Up to the time this study was conducted, no method was available to assist policymakers or farmers to make an environmentally friendly choice in using pesticides. This study is intended to fill that gap to some extent.

7.3 Effects of fertilizers on water quality

The negative effects on the environment of intensive use of chemical fertilizers associated with production growth are widely recognized and viewed with great concern. Gaseous nitrogen emissions from rice fields contribute significantly to global warming. At the same time, nitrogen in nitrate forms not taken up by crops or immobilized in soil organic matter can potentially leach out of the root zone and eventually end up in ground water. In addition, chemical fertilizers can run out of the rice fields during the growing period via the water management schemes (that is, irrigation and drainage) practised by farm households. These fertilizer losses, especially nitrogen and phosphorus, have resulted in serious degradation of aquatic ecosystems and impeded the use of water for drinking, industry, recreation and other purposes. However, the threat to water quality and aquatic ecosystems does not only come from cropping production, but also from other urban and economic activities. The environmental literature on nutrient pollution pinpoints wastewater and sewage treatment plants, industries, septic tanks, forests, animal husbandry and atmospheric deposition as being responsible for the preponderance of nutrient pollution (Carpenter et. al., 1998). This section begins with an overview of water quality issues in the MKD and then determines the extent of the potential negative effects of nitrogenous fertilizers on the environment.

7.3.1 Water quality issues in MKD

Recent environmental monitoring data on water quality in Vietnamese rivers shows that nitrate pollution in surface and ground water has become a great problem (NEA, 2002). Organic pollution measured via two indicators, biochemical oxygen demand (BOD) and ammonia-nitrogen (NH3-N) exceeds the maximum under national water quality standards several-fold. Pollution is especially present where rivers pass through urban and industrial sites, and is even worse during the dry season. According to NEA (2002), ground water remains of good quality generally, but there is evidence of pollution due to poorly maintained septic tanks, garbage dumping and industrial effluents in parts of Hanoi, HCM city and the Mekong Delta.

However, according to a report on the state of Vietnam's environment (NEA, 2002), the overall water quality in the major rivers of the Mekong Delta is within the standard classes A-B (Table C.6, Appendix C). The only indicator that exceeds he standards is BOD5, and occasionally NH4. Available data on three MKD provinces, presented in Table 7.10, show that there is class B concentration of NH3-N, and class A concentration of NO3-N. In other words, nitrate contamination in surface water was not severe in the MKD up to 2002.

Table 7.10
Nutrient levels in surface water of selected provinces in MKD

Indicator	Tien Giang	Vinh Long	Can Tho
NO_3-N	0.76	1.11	0.60
(Min – Max)	0.10 - 1.60	0.01 - 2.00	0.40 - 1.10
NH_3-N	0.08	0.34	0.22
(Min – Max)	0.01 - 0.29	0.09- 1.66	0.05 - 0.97

Sources: Data collected from Departments of Science, Technology and Environment of Tien Giang (December 1999), Vinh Long (April 2000) and Can Tho (December 1999).

7.3.2 Nitrate leaching from rice fields in MKD

Up to the end of 2000, there was no report on nitrate contamination in ground water in the MKD. The maximum permitted concentration of

NO3-N in ground water, according to Vietnamese water quality standards, was 45 mg/litre, and zero for pesticides. In April 2000 groundwater quality in 10 deep (80-100 m) wells in Vinh Long had an average concentration of NO3-N of 1.07 mg/l with a maximum of 1.5 mg/l. Although figures for NO3-N concentration in ground water are below the threshold value of the WHO drinking water standard (10 mg/l), caution should be exercised about drinking directly during the dry season when the ground water recharge is very low and there are also other contaminants in such water.

Even though the loss of nitrogen is economically and environmentally undesirable, there is little research into it in the MKD. In some rice-growing countries, many studies have reported heavy nitrate pollution of ground water with in rural areas, especially those producing vegetables, fruit trees, horticultural products, livestock, and cereals other than paddy rice (Fang at al., 2005; FFTC, 2002; Roy and Misra, 2002). Leaching of nitrogen from lowland rice fields is probably not as high as one might expect, due to the anaerobic conditions. When fields are flooded during the period of rice growth (that is, reduction condition), nitrates are not formed and their concentration in percolation is low (Zhu et al., 2000).

Direct seeding is commonly practised by all farmers in the MKD, as explained in Chapter 4. In this practice, the soil is usually soaked with standing water for several weeks during the period of rice growth, after which the water is drained at the maturation stage. Leaching is possible at the end of the season when the rice soil begins to dry (Roy and Misra, 2002). However, the farmers in the sample usually stop applying nitrogen fertilizer to the rice crop at least one month before harvesting; hence loss through leaching is expected to be minimal.

Hung et al. (1995) studied the N balance of direct-seeded lowland rice in Can Tho, using 15N urea, and found that 75.1 to 83.2 per cent of the applied nitrogen was recovered in grain and straw; and 16.8 to 24.9 per cent of 15N was retained in the soil and root, of which 13 to 20 per cent was at a soil depth of 0-5 cm and only 1.1 to 1.8 per cent at a depth of 15-30 cm. The total loss of nitrogen fertilizer applied was presumed to be due to NH3 volatilization and denitrification. Leaching was not judged to be important in this respect. Using the information from Hung et al. (1995), this study estimates that the nitrogen loss from rice fields of sample farmers in the 2000/01 winter-spring season was 16.7 to 24.8 kg of N per hectare per crop, which was equivalent to 16.8 to 25.0 per cent of total applied nitrogen fertilizer per hectare per crop.[3] Pathak et al. (2004) calculated the sum N loss from rice fields in central Thailand, using the nitrogen mass balance, and found it to be 16.7 kg per hectare per crop (or 13.6 per cent of total N input), very similar to this study's findings in the MKD.

Unfortunately, no information is available on how much of the total nitrogen loss from the rice fields leaches into ground water in the MKD. In South China, the leaching of applied N and soil N from paddy fields ranges from 6.75 to 27 kg per hectare per year (Xing and Zhu, 2000); the leaching loss is 21.3 kg to 28.2 kg of N per hectare per year for single-crop rice and double-crop rice in Pujang, respectively (Fang et al., 2004). In central Thailand, the amount of N leaching into ground water is estimated at about 3.53 kg of total N input (Pathak et al., 2004). Though the leaching of nitrate from the rice fields is obvious and depends mostly on soil and climate conditions and cultivation practices, no study has reported the concentrations of nitrate in ground water in rice-growing areas as being higher than the threshold value of the WHO drinking water standard; on the contrary, the concentration is reported to be far below that threshold.

In conclusion, while there are no statistics on nitrogen leaching into ground water in the MKD, the loss of nitrogen to the environment from the rice fields is apparent and indicates the existence of water pollution as well as loss of resources. Most of the nitrogen loss is presumed to be due to NH3 volatilization and denitrification, and not in nitrate form into ground water. To reduce water pollution, a critical review of existing cultivation practices such as cropping patterns, types of fertilizers, timings, and methods of nitrogen fertilizer application would be necessary (Pathak et al., 2004; Roy and Misra, 2002;), something which is beyond the scope of this study.

Notes

[1] The study, 'Poverty and Pesticide Use in Vietnam', was conducted in 2003 by the World Bank in collaboration with University of Economics HCMC and Centre of Occupational and Environmental Health (Vietnam Association of Occupational Health). It covered 10 communes in five provinces of the MKD; 600 rice-growing farmers were interviewed, of whom 220 were medically tested (Poverty Environment Nexus workshop report, Hanoi, April 2004.)

[2] Predicted value of health cost from this model is interpreted as a measure of the health impairment associated with pesticide use (Antle and Pingali, 1994).

[3] In the Hung et al. (1994) study, 150 kg of ^{15}N urea was applied per hectare per crop, which was equivalent to 69 kg of nitrogen. In the 2000/01 winter-spring season, 99.48 kg of N was applied per hectare per crop (see Chapter 5).

8

Effects of Price Changes on Agrochemical Use, Productivity and Farm Income

8.1 Introduction

According to the theoretical literature discussed in Chapter 2, governments can use alternative policy measures to alter farmers' behaviour with regard to externalities caused by the use of agrochemicals in agriculture. Policymakers are mostly focused on inputs or expected emissions and on the choice of a mechanism to regulate chemical agro-inputs via taxes or quantity controls. Both input quantity control and prices of rice output and inputs will affect the demand for agrochemicals, rice supply, expected profit from rice production of households and the environmental performance of agriculture in general. However, uncertainty about the effects of such instruments on input allocation by farm households, social benefit and costs, and the characteristics of agricultural non-point source pollution create a number of problems in applying them.

While taxes on quantity of emissions are more appropriate, taxes/subsidies per unit of fertilizers and pesticides have the advantage of simple administration. However, a number of practical issues have to be considered when implementing taxes on inputs; these include effects of price changes on the use of agrochemicals, rice supply, expenditures on inputs, and finally the income of farm households. When examining the effects of agro-environmental policies on crop production, we need the following information. First, we have to know how farmers will respond to such taxes on the input demand side. Second, we have to know how rice productivity and farm household income will be influenced by changes in input use. Finally, we have to consider how much the governmental cost and tax revenue will be.

This chapter investigates the effects of price changes on the use of agrochemicals under alternative policy scenarios, and their potential impacts on productivity and farm household income. The findings of this analysis provide the basis for making several policy recommendations. The next section focuses on the design of policy scenarios and assumptions. It is followed by a section describing a numerical procedure for analysis. Results of alternative policy scenarios are presented in the subsequent sections and the final section discusses the results and whether they have policy implications.

8.2 Assumptions and policy scenarios

The economic behaviour of farm households modelled and estimated in Chapter 6 is used to estimate the change in rice supply and demand for inputs. The economic model also shows the price-quantity linkages between rice supply and inputs via estimated own-price and cross-price elasticities. For example, a change in the price of rice affects not only the rice supply but also alternative uses of other inputs, namely, fertilizers, pesticides and labour. The use of output supply and factor demand, and derived elasticities to simulate the effects of price changes in supply, demand and farmer's income from production is well known and applied in many studies. This is a kind of 'partial equilibrium analysis' using partial elasticities estimated from the econometric model. (Sadoulet and de Janvry, 1995; Sidhu and Baanante, 1979 & 1981; Tsakok, 1990). All changes in the supply, demand, farmers' income from rice production, and other financial indicators (for example, government cost) are valued in monetary terms for aggregation.

The analysis is based on a set of assumptions about production, input and output markets, and policy scenarios. First, we shall consider farmers to be price takers producing rice in a competitive market. As market prices of rice and agrochemicals change due to a specific policy (for example, a tax or subsidy), farmers will adjust the amount of inputs used in their rice production. A change in any input price will impact on the demand for that input and on other complementary inputs as well (that is, labour, fertilizers and pesticides), through their own and cross-price elasticities. Similarly, a change in the market price of rice will influence the rice supply and demand for inputs. Second, since this analysis is typically an *ex ante* evaluation of resource policy, a policy scenario designed to reduce the use of agrochemicals providing the greatest expected benefit to farmers will be given preference. Third, the analysis assumes a single-price change while keeping other prices and variables unchanged. Policy scenarios are defined in terms of a percentage change in the price wedge (Sadoulet and de Janvry, 1995: 67-83). Finally, the analysis in this section is known as comparative static analysis since it does not capture the effects of changes in price policy over time.

The analysis focuses on evaluating the impact of changes in prices of rice, fertilizers and pesticides:

- One scenario for examining the effects of an increase in the market price of fertilizers ($F_{Tax,}$), defined as fertilizer tax scenario.
- One scenario for examining the effects of increase in the market price of pesticides ((P_{Tax}), defined as pesticide tax scenario.
- One scenario for examining the effects of increase in market price of rice (R_{Sub}), defined as a producer subsidy scenario. The market price of rice can be influenced in a number of ways, such as an income support programme, improvement of marketing charnels (for example, reducing the marketing margin), better post-harvest technology (for example, improving rice quality), provision of better rural development services, financial support in return for adoption of 'good agricultural practice and technology', or a price increase in the world rice market.

Table 8.1 presents and describes the nature of possible policy scenarios.

Table 8.1

Descriptions of possible policy scenarios to be examined

Policy scenarios	Nature	Symbol
Rice producer subsidy	5% increase in rice price	(P1) R_{sub}
Fertilizer price	10% increase in fertilizer price	(P2) F_{Tax}
Pesticide price	10% increase in pesticide price	(P3) P_{Tax}

The analysis assumes an increase of 10 per cent in the market price of agrochemicals and a 5 per cent change in rice prices from the baseline data (2000/2001 winter-spring rice season).

8.3 Analytical procedure

In analyzing changes in policy, our interest is to examine the impact of a change in price on rice supply and input demand. These changes are captured in own-price and cross-price elasticities derived from the model in Chapter 6. Therefore, an analytical procedure is started with these elasticities and carried out as follows:

Step 1: To understand responses of farmers under a specific policy scenario, we use own-price elasticities of demand for inputs to calculate the percentage change in the use of labour, fertilizers or pesticides. Then, using cross-price elasticity estimates we calculate the change in the other inputs. That is, for example, when a tax is imposed on pesticide there will be a change not only in pesticides, but fertilizers and labour as well.

Next, using baseline information on the average amounts of labour, pesticides and fertilizers per hectare per crop (Table 8.2), we convert these percentage changes to predict changes in quantities of fertilizers and pesticides, which are the agrochemical demand of farmers under new market prices. The values of inputs and rice output and their corresponding prices are sample mean values of the 2000/01 winter-spring season. Elasticities of demand for input and rice supply are from Table 6. 13 (Chapter 6).

Table 8.2
Parameters and economic indicators used to analyse policy alternatives

Parameters/indicators	Labour (man-days)	Fertilizer (kg)	Pesticide (grams of a.i)	Output (kg)
Mean level/ha/crop	76	172	751	6,204
Price/unit (VND)	21,166	5,600	465	1,314
Post-policy prices	-	6,160	511.5	1,379.7
Own-price elasticities	-0.361	-0.355	-0.425	0.227
Output cross-price elasticities	0.462	0.497	0.897	-
Labour cross-price elasticities	-	-0.071	-0.281	-0.086
Fertilizer cross-price elasticities	-0.041	-	-0.191	-0.059
Pesticide cross-price elasticities	-0.059	-0.070	-	-0.039

Step 2: To see how the change in input use affects rice yields, we use cross-price elasticities of output supply to calculate percentage and quantity changes in rice yield. Own-price elasticity of output supply will be used to derive change in rice output when there is an increase in rice market price.

Step 3: Calculate the sum of all changes in input demand and output supply resulting from price changes in each policy scenario.

Step 4: Given the changes in labour, fertilizers, pesticides and rice output in step 3, we calculate the change in costs of fertilizers and pesticides and in value of rice output. The cost is calculated by multiplying the quantity demanded by the post-policy prices. The demand for agrochemicals will fall when there is a rise in the market price. Then, farmers are able to save on expenditure for these inputs. When rice price increases, farmers will spend more on agrochemicals, but gain more output value as well as the initial gains through the price increase.

Step 5: To examine the effects on farm household income from rice, the benefit to farmers from rice production is calculated by subtracting the change in output value and the change in cost of inputs. For policy scenario P1 (increase in rice price), benefit to farmers is the difference between changes in input costs, and increase in output value plus the initial gains through the price increase.

Step 6: Estimate the cost (producer subsidy policy) and tax 'revenue' (producer tax policy) to the government.

Step 7: Estimate total benefit. This is the difference between cost to the government (in case of producer subsidy) and benefit to farmers plus tax amount to the government (tax scenario), with the assumption that there are no transaction and implementation costs.

8.4 Results of price change effects simulation

8.4.1 Effects on use of agrochemicals

A 10 per cent increase in price due to 'environmental taxes' on inputs will reduce chemical fertilizers and pesticides used at farm level, (scenarios P2 and P3). Given that demand for chemical fertilizer and pesticide s relatively price-inelastic in the MKD, low tax rates would not achieve significant reductions in fertilizer and pesticide use. Thus, in comparison with the baseline data, a 10 per cent tax on fertilizer input (P2) can only reduce fertilizer use by 6.11 kg of NPK/ha/crop and pesticide use by

14.34 grams of a.i./ha/crop. If a 10 per cent tax is imposed on pesticide input (P3), the reduction will be 31.918 grams of a.i./ha/crop and 1.204 kg of NPK/ha/crop. To reduce pesticides by 100 grams of a.i. /ha/crop (or 13.5 per cent compared with the baseline level), a tax rate of 31.3 per cent would be needed. Similarity, farmers would reduce their fertilizer use by 10 kg of NPK/ha/crop (or 5.82 per cent compared with the baseline level) if a 16.4 per cent tax rate were applied. The results of this simulation on the effects of price changes on agrochemical use are similar to those in other studies, which have found that high tax rates would need to be introduced to achieve significant reductions in pesticide and nitrogen fertilizer use (see Antle and Pingali, 1994; Dubgaard, 1989; Hanley, 1990; and Oskam et al., 1992).

If the government wants to raise rice production with a subsidy for farmers a policy leading to a 5 per cent increase in rice price (P1) could be introduced. Other things being equal, a 5 per cent increase in rice price (P1) results in an increase of pesticides and fertilizers per hectare per crop of 33.68 gram a.i. and 4.27 kg NPK, respectively, which is more than that caused by a 10 per cent tax on pesticides. This scenario significantly affects rice yield and increases farm income, as discussed in the next section.

Table 8.3
Changes in quantities of agrochemicals, labour and rice output under various policy alternatives

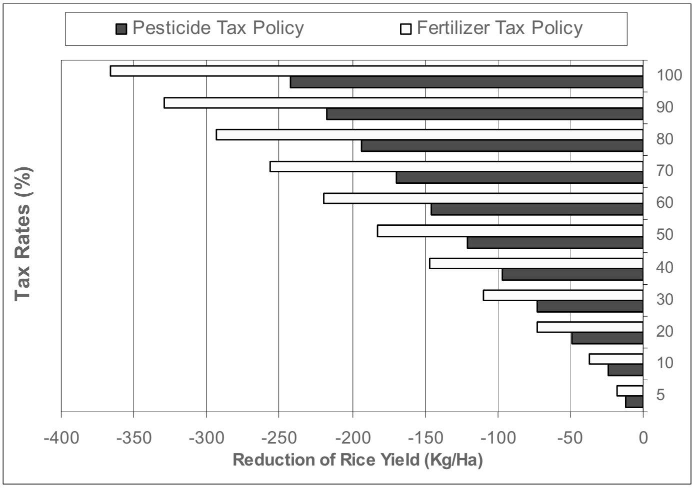
Policy scenarios	**Quantity change per hectare per crop**			
	Rice output	***Labour***	***Fertilizer***	***Pesticide***
(P1) R_{sub}	70.42	1.76	4.27	33.68
(P2) F_{Tax}	-36.60	-0.31	-6.11	-14.34
(P3) P_{Tax}	-24.20	-0.45	-1.20	-31.92

8.4.2 Effects on rice yield

Reduced pesticide and fertilizer use due to higher market prices will lower the yield per hectare per crop. Figure 8.1 shows the productivity effects of taxes on pesticides and fertilizers: the higher the increase in prices of agrochemicals, the larger the total yield lost. When the price of pesticides (or fertilizers) increases, quantity demand will decrease and lead to reduction in quantities of labour and fertilizers (or pesticides). Consequently, productivity will inevitably fall. Total productivity loss will be equal to the sum of yield loss caused by reduction of pesticides, labour and fertilizers. Farmers will, however, save on input costs.

With the same proportional change in market price, rice yield is affected more by a fertilizer tax than by a pesticide tax. A 10 per cent increase in fertilizers price causes rice yield to fall by 36.60 kg per hectare per crop, while about 24.20 kg of rice is foregone if a 10 per cent tax is imposed on pesticides. This is due to the demand elasticity of fertilizer being higher than that of pesticide, as shown in Chapter 6. In a policy scenario that leads to a 5 per cent increase in rice price, farmers will obtain a higher rice yield (70.42 kg/ha/crop).

Figure 8.1
Changes in rice output under various fertilizer and pesticide tax scenarios



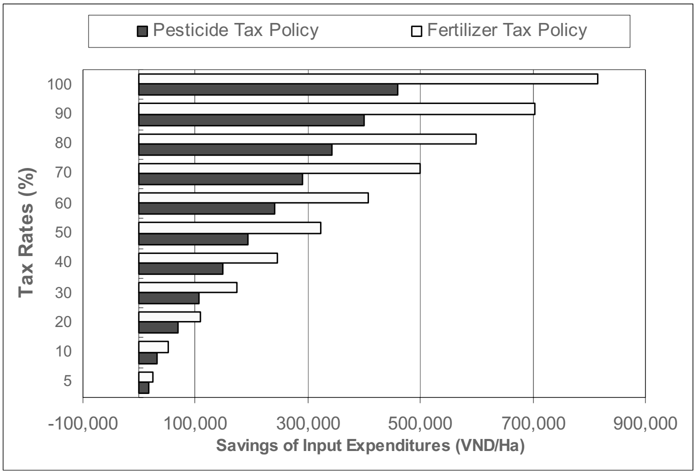
8.4.3 Effects on farmers' input expenditure

The reduced application of agrochemicals in rice production is expected to be beneficial to farmers in terms of reducing input expenditure (Table 8.4). Farmers will use lower quantities of pesticides and fertilizers if market prices of these inputs increase or if the rice price falls. Therefore, farm households will save a certain amount of expenditure on agrochemicals. Figure 8.2 shows farm households' savings on input expenditure when a 10 per cent tax is imposed on fertilizers and pesticides. As with the other effects presented above, the higher the tax rate the bigger the savings. Farm households save more on input expenditure when fertilizer is taxed than in a pesticide tax scenario.

Table 8.4
Reduction in input expenditure under three policy scenarios (VND/ha/crop)

Policy scenarios	**Input savings/cost**			**Change in total Cost**
	Labour	***Fertilizer***	***Pesticide***	
(P1) R_{sub}	37,159	23,936	15,662	76,757
(P2) F_{Tax}	-6,595	-37,613	-6,670	-50,878
(P3) P_{Tax}	-9,491	-6,742	-16,326	-32,559

Figure 8.2
Farm households' savings on input expenditure when pesticides and fertilizers are taxed



8.4.4 Effects on farm income from rice production

The effects on farm household income from rice production vary among the simulated policy scenarios. The difference between output benefit and savings/increase in input costs is used as a proxy for change in income (expected net benefits). The expected net benefits to farm households under alternative policy scenarios are presented in Table 8.5. In pesticide and fertilizer tax scenarios, output value per hectare per crop falls since there is lower rice yield. Farm households lose output amounting to VND 32,559 per ha/crop and VND 50,878 per ha/crop, respectively. This means that the total return from selling rice output of farm households will be less in comparison with the baseline figure in the 2000/01 winter-spring season. Nevertheless, the savings in fertilizers, pesticides, and labour cost outweigh the loss in output value. Therefore, a 10 per cent increase in pesticide and fertilizer prices will bring about a relatively small net benefit of VND 776 per ha/crop and VND 2,781 per ha/crop, respectively, to farm households.

Table 8.5

Benefits to farm households under various policy scenarios (VND/ha/crop)

Policy scenarios	Change in total cost	Output value change	Initial output gain	Total output benefit	Farmers' net benefit
(P1) R_{sub}	76,757	97,152	407,603	504,755	427,998
(P2) F_{Tax}	-50,878	-48,097	0	-48,097	2,781
(P3) P_{Tax}	-32,559	-31,793	0	-31,793	776

Notes: Change in total cost = costs of fertilizer + pesticide + labour.
Output value change = decrease in rice yields X market price of rice (P2 & P3); increase in rice yields X post-market price of rice (P1).
Initial output gain = baseline rice yield X % increase in rice price.
Total output benefit = output value change + initial output gain.
Farmer's net benefit = total output benefit - change in total cost.

8.4.5 Total impact under alternative policy scenarios

The final point to be considered in the simulation analysis is the total benefit likely to be obtained under various policy scenarios. As assumed in section 8.2 of this chapter, producer subsidy is used for the purpose of illustrating the changes in expected net benefits to farm households when market price of rice increases. There would be a cost burden to the government in the producer subsidy scenario. On the other hand, a certain tax amount would be collected in the producer tax scenario. Under this assumption, the total benefit in the context of this simulation is calculated as the sum of expected benefits to farm households and tax collected minus government subsidy cost.

The results are presented in Table 5.6. When a 10 per cent tax is imposed on fertilizer and pesticide inputs, total benefits are VND 96,681 per ha/crop and VND 34,203 per ha/crop, respectively. There is no cost to the government in these scenarios; on the contrary, but it gets tax revenue. Total benefit in P2, where fertilizer price increases, is greater than in P3, where pesticide price increases, since farm households get higher net benefit and the government receives more tax.

Table 8.6
Estimated total benefits under various policy scenarios (VND/ha/crop)

Policy scenarios	Farmers' net benefit (1)	Tax collected (2)	Government cost (3)	Total impact
(P1) R_{sub}	427,998	0	412,229	-15,769
(P2) F_{Tax}	2,781	92,901	0	95,681
(P3) P_{Tax}	776	33,437	0	34,203

Notes: Tax collected = post-input demand X % increase in input market price.
Government cost = post-rice yield X % increase in rice price.
Total impact =(1) + (2) - (3).

When the rice price is increased through a producer subsidy, farmers benefit more but at a cost to the government. Total impact in this scenario is estimated at VND 15,769 per ha/crop, which is lower than in the agrochemical tax policy scenarios.

8.5 Discussion of the results

Up to this point, we have gone though all possible effects of rice changes under various policy scenarios. The simulation analysis in this chapter is typically an *ex ante* evaluation of policies using economic parameters estimated in Chapters 6 and 7. Three policy scenarios constructed to examine the effects of price changes were analysed and presented in the above sections. This final section discusses a number of points of interest from the simulation analysis.

The chapter analysed the effects of market price changes on demand for agrochemicals, rice output, farm household income, and total impact under three alternative scenarios. Of course, other effects at the farm level would also occur, such as changes in pest or fertilizer management practices, crop diversification, and so on. These effects however, are beyond the scope of this study. The findings show that increase in the market prices of pesticides and fertilizers would not only affect the use of these agrochemicals and other variable inputs (labour, in this study) but also the supply of rice and farm household income from rice production. The reductions in pesticide and fertilizer use was estimated to have small effects on rice yield. Therefore, reducing agrochemicals use would have little adverse impact on total production at farm level or on consumers. The results are clearly contingent on the econometric simulation model of input demand and rice supply functions. 'With *ex ante* evaluation, there is uncertainty about the change in prices and other economic variables with and without the policy' (Taylor and Howitt, 1993).

Though the econometric simulation shows the possible effects of market price changes under alternative policy scenarios on the use of agrochemicals, the results are not sufficient for implementation of the economic instruments. The implementation and performance of economic incentive measures requires good quantitative information on external effects, a comparison with other approaches, and information on the effects of technology and other agricultural services (Oskam, 1992). In the current simulation, no alternative approach of ex ante analysis is available for comparison, and the effects of agricultural extension or technology are not included.

The simulation assumes a uniform tax charge per gram of active ingredient of pesticide; however, the adverse environmental effects of different types of pesticides (for example, insecticide, fungicide and herbicide) and their toxicity (WHO classification) are not the same and vary in proportion with the amount used. In the Mekong Delta, the IPM programme seems to be important in reducing agrochemical use. A uniform tax/subsidy rate for agrochemical inputs for both IPM and non-IPM farmers may be inappropriate. Therefore, how taxes and other economic incentive measures to restrict the use of pesticides and fertilizers influence the adoption of IPM is still an important research area. Similarly, the 'fertilizer tax' policy scenario is merely for examining the effects of the change in fertilizer price; it is not a 'real' tax scheme since a flat rate tax is assumed per kilo of NKP nutrients. A tax on NPK nutrients is inappropriate because potassium is unlikely to have harmful effects on the environment, unlike nitrogen and phosphorus. In addition, from the point of view of environmental policy, charges based on emissions of nitrogen and phosphorus into the environment are more relevant than the input itself (Dijk and Hoogeveen, 1998; Gren, 1994a). These emissions are not estimated in this study. Finally, the simulation analysis is performed only for a single rice crop, while the changes in agrochemical prices would also influence farmers' decisions on the use of agrochemicals for other crops and farm household income from those crops as well. Because of these limitations, no specific agri-environmental instrument is designed in detail and recommended to policymakers.

9 Conclusions

9.1 Introduction

This study focused on the effects on farmers' income, human health and the environment of agrochemical use in rice production in the Mekong Delta of Vietnam. Since 1989, the growth in output of rice, the main food staple, has been more than double the growth of the Vietnamese population, but there are growing concerns over future productivity and sustainability of the rice production system. This is due to the dual outcome of the application of agrochemicals – a positive contribution to total rice productivity but a negative effect on human health and the environment.

The study was designed to describe and analyse the patterns and effects of intensive use of agrochemicals in rice production at the farm level. It involved 180 individual farmers in irrigated rice production systems, who were surveyed during the 1996/97 and 2000/01 winter-spring rice-growing seasons in the Mekong Delta (MKD). The first survey was carried out with the help of a grant and academic support from the Economy and Environment Programme for Southeast Asia (EEPSEA), and the second survey was part of research supported by the MDE/SAIL project. The two surveys were managed by the Environmental Economics Unit, Ho Chi Minh City University of Economics. The study covered four research questions:

(i) What is the pattern of use and how intensively have fertilizers and pesticides been applied?
(ii) Are farmers applying agrochemicals in an economically efficient way?
(iii) To what extent are farmers' health and water quality affected?

(iv) What would be the effects of changes in the market prices of agrochemicals and rice in conditions induced by policy measures?

The study has described and analysed rice production and the environment in the MKD (Chapter 3); economic incentives and the agrochemical market (Chapter 4); agrochemical use patterns in rice production (Chapter 5); economic aspects of the use of agrochemicals (Chapter 6) environmental effects of agrochemical use (Chapter 7); and the possible effects of market price changes in alternative policy scenarios (Chapter 8). This chapter first summarizes the main findings of the study to answer these questions. It then discusses some methodology issues that emerged during the conduct of the study before making suggestions for further research.

9.2 Main findings

9.2.1 Intensive rice production and use of agrochemicals

More economic incentives to rice farm households

The Mekong Delta of Vietnam is one of Asia's most fertile rice-growing areas. The government introduced agricultural policy reforms in 1981, and they were accelerated in 1986 with the introduction of *đoi moi*, enabling the region to increase total rice production further. The reforms have caused gradual but persistent changes in markets for rice and inputs, and have fundamentally transformed economic incentives to farm households. Increased security of land tenure, along with market and price liberalization, have greatly influenced farmers' behaviour and created important incentives for farm households to increase their rice output.

Rice is the dominant crop and grown more and more intensively

Benefiting from the new institutional environment and market reforms as well as technological innovations, rice is being cultivated two or three times, or even 3.5 times a year, depending mostly on factors such as technology, market demand and prices, or income pressure. A significant increase was noticeable in the cropping intensity in the study area, from 2.23 in the 1996/97 winter-spring season to 2.57 in the 2000/01 winter-spring season. However, the fact that nearly 60 per cent of farm households practise triple rice cropping is cause for serious worry about changes in production and the environmental consequences of rice monoculture. Moreover, while rice yields have not declined during the four-year period, the production risks for farm households in terms of fertilizer cost, efficiency, yield variability and pest problems due to the predominant use of high-yielding varieties (HYVs), have increased with intensification of rice production

Overall consumption of chemical fertilizers and pesticides per hectare per year has dramatically increased

All survey households tried to attain high yields through heavy reliance on chemical fertilizers to replenish soil nutrients and on pesticides to protect the crop from pests.

The study found that the only organic fertilizer applied to the fields was ash obtained by burning rice straw. The farmers displayed a tendency to reduce fertilizer use per crop per hectare. Farm households increased the potassium nutrient and reduced the rate of applied N accordingly. All these changes were significantly different between the two surveys. However, despite the fact that the fertilizer application rate per hectare per crop in 2000/01 was lower than in 1996/97, total fertilizer applied per hectare per year rose during the four-year period due to increase in cropping intensity.

The use pattern of pesticides also changed over time in the study sites. Pesticides of various kinds (insecticides, fungicides and herbicides) have been used on a large scale since the introduction of HYVs to the MKD. Farmers in general decreased their doses and frequency of insecticide application but raised the frequency of fungicide spraying. Interestingly, none of the pesticides used in rice production in the 2000/01 winter-spring season was on the list of banned pesticides, possibly indicating the success of the pesticide regulation policies introduced in Vietnam. Though there was still widespread use of pesticides, the dose applied per hectare per crop declined during the four-year period in all the villages studied. Farmers significantly reduced quantities used of insecticide, fungicide and herbicide. Nevertheless, overall consumption of pesticides rose because more pesticide doses per hectare per year were applied in triple cropping. Thus, cropping intensity negated the positive effects of diminishing use of pesticides per hectare per crop.

IPM adoption helps farmers to reduce agrochemical use significantly

The IPM programme has had positive effects on farmers' pest control practices in terms of increasing their knowledge and changing their perceptions of pesticide efficiency and safety as well as of fertilizer rate reduction. Pesticides doses and fertilizer applied per hectare per crop by IPM farmers in the two surveys were significantly lower than those of non-IPM farmers. Yet, rice yields attained by IPM farmers were significantly higher than those harvested by non-IPM farmers. Day-to-day management of rice fields and efforts to apply the four principles of the IPM programme were perhaps the main factors helping IPM farmers to obtain higher yields (See subsection 6.1.2, Chapter 6).

9.2.2 Economics of agrochemical use

Improved profitability and higher family income from rice

Rice yield increased by about 2.7 per cent and 2.2 per cent for all farm households and the SHH group, respectively, over the four-year period. Yield increased while the use of agrochemicals per hectare per crop fell, implying an increase in partial productivity of fertilizer nutrients and pesticides, and improvement in field management of agrochemicals. However, yield increase was accompanied by higher variability in yields, which implies higher production risk to farmers. This issue is of concern to small farmers since they may get into debt and suffer other hardships that result from a bad harvest.

Improving input efficiencies at current yield levels is a possible option for reducing unit production cost to farmers. Thus, efficiency gains from input use are likely to be compatible with the need for sustainable resource use. The reduction in agrochemicals, labour and seeds applied per hectare per crop results in lower costs of production, especially the cost of pesticide. Total costs and unit costs of production (in constant 1996 prices) per kg of rice in the 2000/01 winter-spring season in the SHH group were lower than in the 1996/97 winter-spring season. This was not the case for all farm households. All farm households and the SHH group both obtained higher gross return, benefit and family income from rice cultivation due to significantly higher yields and better rice prices. Family income from rice farming thus increased by about 14 per cent for all farms, and 26 per cent for the SHH group over the four-year period.

Farmers responded rationally to market signals

From a microeconomic perspective, agrochemicals should be applied to the level at which the value of the marginal product equals its price, while environmental externalities generated by the agrochemicals are taken into account. The study found that rice farmers responded rationally to market signals in the transition from central planning to a market-oriented economy. The assumption of profit maximization is accepted for the 2000/01 winter-spring season but not for the 1996/97 winter-spring season, supporting this argument. It implies, among other things, that farm households maximized profits by equating the marginal values of variable inputs to normalized prices of variable inputs. That is, fertilizers, pesticides and labour were used at their economically optimal levels in the 2000/01 winter-spring season, while these inputs were overused in the 1996/97 winter-spring season. Increase in the prices of agrochemicals relative to the rice price was among the factors influencing the reduction and downward adjustment in fertilizer and pesticide doses applied per hectare per crop. In addition, in estimates of input demand and rice supply elasticities, all estimated elasticities have the correct signs and are inelastic (negative for input demand and positive for rice supply). The study also found that the impact of a given change in any of the exogenous variables across variable input demands for labour, fertilizers and pesticides is not symmetric, and that labour, fertilizers and pesticides are gross complements in rice production, thus quite consistent with *a priori* theoretical expectations. Although sample farmers showed profit maximization behaviour, risk aversion may still prevail among poor-resource households, an aspect of their behaviour which is not explored in this study.

9.2.3 Environmental problems resulting from agrochemical use

Exposure to pesticides had adverse effects on farmers' health

The study demonstrated that farmers who directly applied pesticides to their rice fields displayed signs and symptoms of pesticide-related health ailments. These are characteristics of 'normal observation' in Vietnamese rice production and in many other rice-growing areas in the developing world. What was remarkable in the findings of this study was the high percentage of sample farmers (about 90.7 per cent and 89.8 per cent in the 1996/97 and 2000/01 surveys respectively) who were certain of the link between agrochemicals and their symptoms since the symptoms did not occur during or after other field activities. Pesticides were applied continually during the growing season, which indicates non-stop exposure to pesticides throughout the year. Farmers affirmed that they had suffered post-spraying symptoms such as blurred vision, body tremors, muscle fasciculation (eyelid twitching), skin itching and irritation, or even vomiting, and said they were due to pesticide exposure.

These health effects pose a significant cost to society and to rice farmers themselves. Health costs to rice farmers are positively related to the total dose of pesticides applied and the frequency of application. On the other hand, adoption of IPM techniques and the nutritional/physical status of farmers are important factors helping to reduce farmers' health costs. However, the health costs discussed in this study are only for a single rice season and limited to treatment related to visible health impairment. The health costs would be higher if all costs related to treatment required to restore farmers' health to its normal state were included in the total, especially in cases of chronic poisoning.

Loss of nitrogen fertilizer from rice fields is apparent

The loss of nitrogen is economically and environmentally undesirable, and apparent in the MKD, as in many rice-growing countries. The total loss of nitrogen fertilizer applied was presumed to be due to NH3 volatilization and denitrification, and leaching was not perceived as being an important loss mechanism in MKD paddy fields. Using information from a technical study in the MKD, loss of nitrogen from rice fields of sample farmers in the 2000/01 winter-spring season was estimated to be 16.7 to 24.8 kg of N per hectare per crop, equivalent to 16.8 to 25.0 per cent of total applied nitrogen fertilizer per hectare per crop. The loss of nitrogen to the environment indicates existence of air and water pollution as well as representing loss of resources. Without the development of innovative loss-reducing techniques, this issue will be a great concern in the coming years in the MKD since the higher doses of fertilizer are applied per hectare per year due to the increase in cropping intensity.

9.2.4 Combined effects of market price changes

Vietnam is rapidly moving to a full system of market allocation of resources, in which changes in market prices of inputs and rice output directly influence farmers' production decisions. Simulation results indicate that any increase in prices of fertilizers and pesticides, for example through a tax on agrochemical inputs, will not only affect the use of these inputs and that of other variable inputs, but also the supply of rice and farm household income from rice production. Though reduction of agrochemicals use via market signals is desirable from the point of view of environmental policy, rice yields will be strongly affected only when there is a very high increase in market prices of agrochemicals. In other words, reducing agrochemical use will have little adverse impact on total production at farm level or on consumers when agrochemical prices increase slightly or at a low tax rate on agrochemical inputs.

9.3 Methodological issues

The methodology of the study comprised a variety of qualitative and quantitative research methods. Qualitative information for understanding the nature and relationships between groups of farmers, production practices and the environment were complementary to quantitative estimation of profitability, quantities and price eslasticities of inputs and outputs, determinants of health risks, and farmers' health costs due to pesticide exposures, and vice versa.

The information collected in a cross-sectional survey of rice-growing farmers enabled spatial comparisons to be made between the production performance of groups of rice farmers, while introducing temporal variation. Data from the two surveys provided a good opportunity to see changes in agrochemical use patterns and effects of fluctuating market prices or variable annual weather in both temporal and spatial aspects. Though the sample size was not large, 180 farmers in each survey, it covered six villages in four provinces where rice is the dominant crop and is cultivated at different levels of intensity. The study, however, did not include rice-growing villages located in coastal areas and rice-aquaculture farming systems, where rice is grown extensively once or twice a year with different cultivation techniques and cropping calendar, and with limited use of pesticides. The value of this study is that it is expected to be representative of intensive rice production in the MKD and can serve as baseline information for further research into the economics and environmental impact of agrochemical use in the context of economic and agricultural development.

The study examined the demand and supply sides of rice production by farm households simultaneously via the profit function approach, which is common in studies of production economics. The use of the translog profit function allowed a considerably disaggregated analysis of farm production. The model provided opportunities to explore interactions among variable and fixed factors; however, the estimation of the model would be complex with inclusion of many more variables. The estimation of price elasticities of fertilizers and pesticides would have been of more value if they had been derived from a model comprising many crops at the same time. Therefore, care is advisable when using these estimated elasticities.

The sampling method used in this study is not a fully stratified random sample method, in which all farmers have equal probability of being selected in the sample. Due to time and cost constraints, and lacking official lists of farm households in the study villages, a pre-determined quota of 30 samples was set. Though the sample allows in-depth investigation of the research objective and generalization of the impact of agrochemical use, it was not a 'standard' sample for quantitative analysis. Therefore, recommendations drawn from the findings of this study should be adopted with care. Further research on a similar topic intended for policy analysis and recommendations should rely on a full probabilistic sampling method, which would ensure that all farmers in the study villages have equal probability of being included in the sample.

Finally, though the monetary value of reduced morbidity comprises four types – medical expenses (including opportunity cost of time spent), lost wages, defensive or preventive expenditures, and disutility – the health costs in the 'cost of illness' approach do not typically include the social value of preventive/defensive expenditures (Freeman III, 1993: 343-51). In this study, the defensive expenditure was included in the estimated health cost model. The author assumed that farmers incur this cost in advance to prevent health problems due to pesticide exposure. If farmers apply higher pesticide doses, they may increase the number of applications or select better protective clothing or equipment. When they change these more often, the cost will increase. However, the protective expenditures in the data collected are minimal, mostly for face masks, long-sleeved shirts, trousers and hats, and therefore will not influence the analytical results

9.4 Suggestions for further research

The sustainability of high rice yields in such an intensive rice production system seems an interesting area for further investigation. Do farmers still attain high yields with HYVs grown consecutively in soil replenished mainly by chemical fertilizers? Is there potential for further increase in rice productivity in the MKD without higher agrochemical cost?

The effects of the IPM programme on rice production are significant in terms of farmers' awareness of pesticide hazards; reduction in agrochemical application rates of and amount of rice seed used; and yield achieved. These open up many interesting research questions: Does the IPM programme become strategic pest management at the village level? What are the 'real' benefits to society when all the programme costs are fully counted in? Given the increasing advertising of new types of pesticides in the MKD, do farmers continue to view pesticides as a measure of last resort? In addition, how do taxes and other economic incentive measures restricting the use of agrochemicals influence the adoption of IPM?

Unwanted effects of pesticides are not only suffered by farmers who are directly exposed to them while spraying. Pesticide-related health ailments may also be suffered by neighbouring farming households or labour force working in rice fields with standing water that contains different kinds of pesticides. Thus, more research is needed on the cost of 'damage' caused by pesticide use to consumers, aquaculture production, wildlife and other organisms. Similarly, quantitative evaluation is needed of the damage caused by fertilizer application to the environment.

A final issue is how to improve rice-farming household income during the transition to a market-oriented economy. Income from rice production depends not only on rice yields, but also on market prices of output and inputs. Possible farmer responses to market price changes also raise a number of issues for investigation. Do rice farmers continue to exhibit profit maximization behaviour in a competitive market? What would be the appropriate system to provide reliable market information to rice farmers? What policy measures should be introduced to help farmers obtain a higher market price for rice while reducing the effects on consumers?

All these issues arise from the findings and simulation results in this study. For sustainable development of the rice sector, they need to be carefully investigated, as the livelihood of many rice-farming households in the MKD is at stake.

Appendices

Appendix A

Table A.1

Herbicides used in Mekong Delta rice production, 2000/01 winter-spring season, classified according to WHO categories

WHO category	Trade name	Common name
II	Anco 720 DD	2.4D
II	Amine 720 EC	2.4D
II	Quick 720 EC	2.4D
III	Tiller S EC	Fenoxaprop-P-Ethyl + 2.4D + MCPA
IV	Nominee 10 SC	Bispyribac -Sodium
IV	Kocin 60 EC	Butachlor
IV	Meco 60 EC	Butachlor
IV	Clincher 10 EC	Cyhalofop_butyl
IV	Almix 20 WP	Metsulfuron methyl 10% +Chlorimuron Ethyl 10%
IV	Ronstar 2.5 EC	Oxadiazon
IV	Sofit 300 EC	Pretilachlor + Fenclorim
IV	Sirius 10 WP	Pyrazosulfuron Ethyl
IV	Facet 25 SC	Quinclorac
N/A	Sunrice 15 WDG	Ethoxysulfuron
O	Whip'S 7.5 EW	Fenoxaprop-P-Ethyl

Source: 2000/01 survey.

Table A.2
Herbicides used inMekong Delta rice production, 1996/97 winter-spring season, classified according to WHO categories

WHO category	Trade name	Common name
II	Gramoxone 20 SL	Paraquat
III	Cantanil 550 EC	Butachlor + Propanil
III	Anco 720 EC	2.4 D
III	OK 720 EC	2.4 D
III	2,4 D 720 EC	2.4 D
III	Tiller 50 EC	MCPA + Fenxaprop-P-ethyl + 2.4 D
III	Wham 80 DF	Propanil
III	Vi 2,4 D 80 WP	2.4 D
IV	Ally 20 DF	Metsulfuron Methyl
IV	Batoxim 60 EC	Butachlor
IV	Echo 60 EC	Butachlor
IV	Meco 60 EC	Butachlor
IV	Sirius 10 WP	Pyrazosulfuron Ethyl
IV	Sindax 10 WP	Metsulfuron Methyl + Bensulfuron
IV	Sofit 300 EC	Pretilachlor
IV	Ronstar 25 EC	Oxadiazon
IV	Whip's 7,5 EC	Fenxaprop-P-ethyl

Source: 1996/97 survey.

Table A.3
Insecticides used in Mekong Delta rice production, 2000/01 winter-spring season, classified according to WHO categories

WHO category	Trade name	Common name
N/A	Binhdan 95 WP	Nereistoxin (Dimehypo)
N/A	Catodan SL	Nereistoxin (Dimehypo)
N/A	Netoxin 18 SL, 95 SP	Nereistoxin (Dimehypo)
N/A	Sat trung Dan 95 WP, 18 SL	Nereistoxin (Dimehypo)
N/A	Shachong Shuang 18 SL, 90 WP	Nereistoxin (Dimehypo)
Ia	Methyl parathion 50 EC	Methyl Parathion
Ib	Furadan 3 G	Carbofuran
Ib	Monster 40 EC	Acephate
II	Carbavin 85 WP	Carbaryl
II	Cyperin 5 EC	Cypermethrin
II	Cyperan 5 EC	Cypermethrin
II	Cyper-Anpha 2.5 EC, 5 EC	Cypermethrin
II	Decis 2.5 EC	Deltamethrin
II	Sherpa 25 EC	Cypermethrin
II	Fastac 5 EC	Alpha-Cypermethrin
II	Fastocid 5 EC	Alpha-Cypermethrin
II	Vifast 5 EC	Alpha-Cypermethrin
II + Ib	Sat trung Linh 15 EC	Deltamethrin 2% + Dichlorvos 13%
II	Basudin 40 EC	Diazinon
II	Diazol 60 EC	Diazinon
II	Vibasu 40 EC, 10 G	Diazinon
II	Bian 40 EC	Dimethoate
II	Thiodan 35 EC	Endosulfan
II	Sumi-Alpha 5 EC	Esfenvalerate
II	Ofatox 400 EC, 400 WP	Fenitrothion + Trichlorfon
II	Sumithion 50 EC	Fenitrothion
II	Applaud - Bas 27 WP	BuprofeZin 7% + Fenobucarb 20%
II	Apphad - Mipc 25 SP	BuprofeZin 7% + Fenobucarb 20%
II	Bassa 50 EC	Fenobucarb
II	Hopsan 75 EC	Fenobucarb 30% + Phenthoate 45%

WHO category	Trade name	Common name
II	Super Kill 50 EC	Fenobucarb
II	Sagomycin 10 EC, 20 EC	Fenvalerate
II	Regent 5 SC, 0.3 G, 800 WG	Fipronil
II	Mipcide 20 EC	Isoprocarb
II	Karate 2.5 EC	Lambda-cyhalothrin
II	Vifen – 50 EC	Phenthoate
IV	Applaud 10WP	Buprofezin
IV	Butyl 10 WP	Buprofezin
IV	Padan 50 SP, 95 SP, 4 G, 10G	Cartap
IV	Trebon 10 EC	Etofenprox

Source: 2000/01 survey.

Table A.4

Insecticides used in Mekong Delta rice production, 1996/97 winter-spring season, classified according to WHO categories

WHO Category	Trade name	Common name
II	Thiodan 30 EC	Edosulfan
II	Basudin 50 EC	Diazinon
II	Sumithion 50 EC	Fenitrothion
Ia	Methyl Parathion 50 EC	Methyl parathion
Ib	Filitox 60 SC	Methamidophos
Ib	Monitor 50 SC	Methamidophos
Ib	Azodrin 50 EC	N/A
II	Bassa 50 EC	Fenobucarb
II	Bassan 50 EC	Fenobucarb
II	Hopsan 75 EC	Fenobucarb + Phenthoate
Ib	Furadan 3 G	Carbofuran
Ib	Oncol 20 EC, 25 WP	Benfuracarb
II	Cyper alpha 5 EC	Alpha-cypermethrin
II	Decis 2,5 EC	Deltamethrin
II	Fastac 5 EC	Alpha-cypermethrin
II	Fastocide 5 EC	Alpha-cypermethrin
II	Fenbis 25 EC	Fenvalerate + Dimethoate
II	Karate 2,5 EC	Lambda-cyhalothrin
II	Sapen alpha 5 EC	Alpha-cypermethrin
II	Sherpa 25 EC	Cypermethrin
II	Sumi alpha 5 EC	Esfenvalerate
II	Vifast 5 EC	Alpha-cypermethrin
II	Visher 25 EC	Cypermethrin
II	Deathline Bullet 4%	Metaldehide
II	Padan 4 G, 95 WP	Cartap
II	Regent 0.3 G, 800 WP	Fipronil
IV	Applaud 10 WP	Buprofezin
IV	Trebon 10 EC	Etofenprox

Source: 1996/97 survey.

Table A.5
Fungicides used in Mekong Delta rice production, 2000/01 winter-spring season, classified according to WHO categories

WHO category	Trade name	Common name
N/A	Dinasin 6.5 SC, 50 SC	MAFA
N/A	Opus 125 SC	Epoxiconazole
N/A	Sasa 20 WP	Sai Ku Zuo (MBAMT)
II	Vectra 100 SC	Bromuconazole
II	Tilt 250 EC	Propiconazole
II	Beam 75 WP	Tricyclazole
II	Trizole 20 WP	Tricyclazole
III	Fungruran OH 50 WP	Copper Hydrocide
III	Bonanza 100 SL, 100 DD	Cyproconazole
III + II	Tilt Super 300 EC	Difenoconazole + Propiconazole
III	Nustar 40 EC	Flusilazole
III	Kian 50 EC	Iprobenphos
III	Kitazin 50 EC, 17 G	Iprobenphos
III	Fuan 40 EC	Isoprothiolane
III	Fuji- One 40 EC	Isoprothiolane
IV	Bendazol 50 WP	Benomyl
IV	Benofun 50WP	Benomyl
IV	Bemyl 50WP	Benomyl
IV	Binhnomyl	Benomyl
IV	Candazole 50 WP	Benomyl
IV	Fundazol 50 WP	Benomyl
IV	Funomyl 50WP	Benomyl
IV	Mimyl 12.5 SP	Benomyl 12.5% +$ZnSO_4$ +$MgSO_4$
IV	Viben 50 WP	Benomyl
IV	Appencarb super 50FL	Carbendazim
IV	Bavisan 50 WP	Carbendazim
IV	Carban 50 SC	Carbendazim
IV	Carben 50 WP, 50 SC	Carbendazim
IV	Carbenzim 50 WP	Carbendazim
IV	Cavil 50SC, 50WP	Carbendazim
IV	Derosal 50 SC, 60 WP	Carbendazim
IV	Anvil 5 SC	Hexaconazole
IV	Rovral 50 WP, 750 WG	Iprodione
IV	Kasumin 2 L	Kasugamycin

(Continued)

WHO category	**Trade name**	**Common name**
IV + III	Kasuran 50 WP	Kasugamycin 2% + Copper Oxychloride 45%
IV	Folicur 250 EW	Tebuconazole
IV	Cantop- M 72 WP	Thiophanate-Methyl
IV	Thio-M 70 WP	Thiophanate - Methyl
IV	Validacin 3L, 5SP	Validamycin
IV	Validan 3L	Validamycin
IV	Kasai 16.2 SC	Fthalide 20% + Kasugamycin 1.2%

Source: 2000/01 survey.

Table A.6
Fungicides used in Mekong Delta rice production, 1996/97 winter-spring season, classified according to WHO categories

WHO category	Trade name	Common name
II	Beam 75 WP	Tricyclazole
II	Tilt 250 EC	Propiconazole
III	Kitazin 50 EC	Iprobenphos
III	Viben - C 50 WP	Copper Oxychloride
III	Bayfolan	Triadimenol
III	Fuji – one 40 EC	Isoprothiolane
IV	Dinasin 6,5 EC	MAFA
IV	Komix TS 9	-
IV	Vivadamy 3 EC	Validamycine
IV	Zineb 80% WP	Zineb
IV	Anvil 5 SC	Hexacodazole
IV	Appencarb super 50 FL	Carbendazim
IV	Bavistin 50 FL	Carbendazim
IV	Bemyl 50 WP	Benomyl
IV	Bendazol 50 WP	Benomyl
IV	Benlat C 50 WP	Benomyl
IV	Cadazim 50 FL	Carbendazim
IV	Carbenzim 50 WP	Carbendazim
IV	Captan 7,5 WP	Captan
IV	Copper - B WP 75%	Zineb + Bordeaux + Benomyl
IV	Derosal 50 SC, 60 WP	Carbendazim
IV	Dithane 2-78 72 WP	Mancozeb
IV	Fundazol 50 WP	Benomyl
IV	Kasai 21,2 WP	Thalide + Kasugamycin
IV	Mancozeb 80 WP	Mancozeb
IV	Mimyl 12,5 SP	Benomyl
IV	Monceren 25 WP	Pencycuron
IV	Topsin 50 WP, 70 WP	Thiophanate-Methyl
IV	Rovral 50 WP (10 G)	Iprodione
IV	Validacine 5 WP, 5 EC	Validamycine

Source: 1996/97 survey.

Appendix B

Table B.1
Description of variables in 2000/01 model

Variables	Mean	Std.	Min	Max	Skewness
Normalized wage	2.773	0.172	2.297	3.263	0.00
Normalized fertilizer price	1.442	1.129	1.093	1.747	-0.30
Normalized pesticide price	5.910	0.627	3.208	6.970	-1.30
Land	2.197	0.713	0.693	3.583	-0.10
Education	0.353	0.430	0.000	1.098	0.60
Labour share	-0.330	0.158	-1.106	-0.110	-1.50
Fertilizer share	-0.192	0.070	-0.538	-0.073	-1.40
Pesticide share	-0.068	0.047	-0.385	-0.003	-2.60

Source: Data from 2000/01 survey.

Appendix C

Table C.1

Pesticide application in rice production, rainy season, Mekong Delta 1999, classified by farmers' education and IPM practice

No. of applications	**IPM training**		**Farmers' education**			**All farmers**
	Trained	***Non-trained***	***Elementary***	***Secondary***	***Tertiary***	
	Percentage of farmers who applied/ did not apply insecticide					
0	10.6	1.8	4.4	5.1	10.3	6.3
1	50.8	30.2	30.7	46.4	44.3	40.7
2	24.6	34.9	33.3	26.1	30.9	29.8
3	10.6	14.8	14.0	13.0	10.3	12.6
4	3.4	13.0	13.2	7.2	3.1	8.0
>=5	0.0	5.4	4.4	2.1	0.0	2.6
	Percentage of farmers who applied/ did not apply fungicide					
1	6.3	3.4	2.4	7.5	4.3	5.0
2	38.0	28.1	30.9	36.0	32.8	33.5
3	41.6	46.1	44.7	43.5	43.1	43.8
4	10.9	17.4	18.7	9.3	14.7	13.8
5	3.2	3.9	3.3	3.1	4.3	3.5
6	0.0	.6	0.0	0.0	0.9	0.3
7	0.0	.6	0.0	.6	0.0	0.3
	Percentage of farmers who applied/ did not apply herbicide					
0	4.1	1.2	4.1	2.6	1.8	2.8
1	93.6	90.1	87.7	91.6	97.4	92.1
2	2.3	8.8	8.2	5.8	.9	5.1
	Percentage of farmers who applied pesticides as a whole					
2	0.5	0.6	0.0	1.2	0.0	0.5
3	18.1	2.8	4.1	16.1	12.1	11.3
4	28.1	15.7	19.5	21.1	27.6	22.5
5	26.7	23.0	24.4	24.8	25.9	25.0
6	13.1	20.8	14.6	17.4	18.1	16.8
7	9.0	18.5	21.1	9.9	9.5	13.3

(Continued)

No. of applications	IPM training		Farmers' education			All farmers
	Trained	*Non-trained*	*Elementary*	*Secondary*	*Tertiary*	
8	3.2	7.3	5.7	5.0	4.3	5.0
9	0.5	6.2	8.1	1.2	0.0	3.0
10	0.9	2.2	2.4	1.2	0.9	1.5
>10	0.0	2.9	0.0	1.8	1.7	1.4

Source: Calculated from 1999 survey of Plant Protection Department, Southern Division.

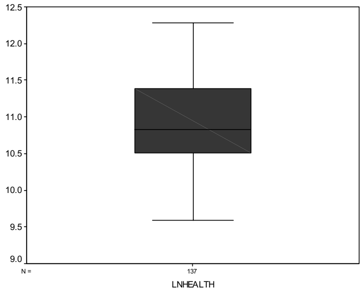
Table C.2

Mean values of frequency of pesticide application per crop by IPM and non-IPM farmers (times per crop)

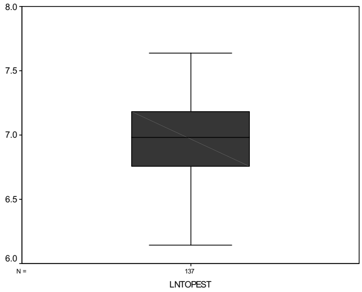
Pesticides types	Non-IPM (N=166)	IPM (N=170)	t-test
	1996/97 winter-spring season		
All pesticides	3.72 (1-9)	3.69 (1- 8)	0.17^{NS}
Categories I and II	2.70 (0-8)	2.16 (1-7)	2.08**
Categories III and IV	2.60 (1-7)	2.76 (1-6)	-0.57^{NS}
	2000/01 WS season		
All pesticides	4.15 (1-7)	4.02 (1-7)	0.56^{NS}
Categories I and II	1.91 (0-5)	1.75 (0-5)	0.50^{NS}
Categories III and IV	3.60 (1-7)	3.50 (0- 6)	0.35^{NS}

Source: 1996/97 and 2000/01 surveys.

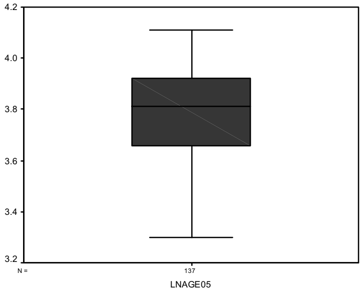
Table C.3
Description of variables used in health cost model



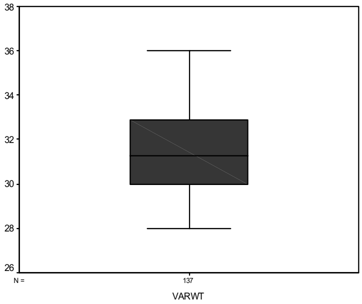
LNHEALTH	Statistic	Std. Error
Mean	10.931	0.006
Median	10.829	
Std. Deviation	0.668	
Minimum	9.59	
Maximum	12.28	
Skewness	0.233	0.207



LNTOPEST	Statistics	Std. Error
Mean	6.9287	0.003
Median	6.9832	
Std. Deviation	0.3626	
Minimum	6.14	
Maximum	7.64	
Skewness	-0.496	0.207



LNAGE	Statistics	Std. Error
Mean	3.778	0.002
Median	3.810	
Std. Deviation	0.1950	
Minimum	3.26	
Maximum	4.11	
Skewness	-0.612	0.207



WTHT	Statistics	Std. Error
Mean	31.483	0.172
Median	31.250	
Std. Deviation	2.009	
Minimum	28.00	
Maximum	36.00	
Skewness	0.188	0.206

Table C.4

Predicted health costs resulting from pesticide use in rice production (scenario 1)

Parameters	IPM farmers			Non-IPM farmers		
	1	*2*	*3*	*1*	*2*	*3*
CONSTANT	1.806	1.806	1.806	1.806	1.806	1.806
LNTOPES	6.183	6.299	6.403	6.183	6.299	6.403
NA	0.716	0.716	0.716	0.716	0.716	0.716
LNAGE	2.879	2.879	2.879	2.879	2.879	2.879
WTHT	-0.892	-0.892	-0.892	-0.892	-0.892	-0.892
SMOKE	0	0	0	0	0	0
DRINK	0.109	0.109	0.109	0.109	0.109	0.109
IPM	-0.201	-0.201	-0.201	0	0	0
Ln of health cost	10.6	10.716	10.820	10.801	10.917	11.021
Estimated health cost [1]	40,135	45,105	50,032	49,070	55,147	61,171
Average heath cost [2]	53.51	53.06	52.67	65.43	65.18	64.63
Marginal health cost [3]	49.98	49.56	49.19	61.11	60.60	60.14

Notes: The table uses coefficients estimated in the health cost model and the following assumption values: a 41 year-old farmer weighing 51kg and 1.6 metres tall (WTHT ratio of 31.87). A non-smoking, but drinking farmer. Effects of pesticide doses applied at 750, 850, and 950 grams a.i./ha/crop are presented in columns 1, 2 and 3, respectively. Number of pesticide applications is 4 times per crop per season.

[1] Estimated heath cost of farmers (VND per season)

[2] Average health cost of farmers (VND/ gram a.i.)

[3] Marginal health cost(MC) calculated as: MC = estimated pesticide coefficient X (health cost/pesticide dose).

Table C.5

Predicted health costs resulting from pesticide use in rice production (scenario 2)

Parameters	**IPM farmers**			**Non-IPM farmers**		
	1	***2***	***3***	***1***	***2***	***3***
CONSTANT	1.806	1.806	1.806	1.806	1.806	1.806
LNTOPES	6.183	6.299	6.403	6.183	6.299	6.403
NA	0.895	0.895	0.895	0.895	0.895	0.895
LNAGE	2.879	2.879	2.879	2.879	2.879	2.879
WTHT	-0.892	-0.892	-0.892	-0.892	-0.892	-0.892
SMOKE	0	0	0	0	0	0
DRINK	0.109	0.109	0.109	0.109	0.109	0.109
IPM	-0.201	-0.201	-0.201	0	0	0
Ln of health cost	10.779	10.896	10.999	10.980	11.097	11.200
Estimated health cost [1]	48,002	53,947	59,840	58,689	65,956	73,161
Average heath cost [2]	64.00	63.46	62.99	78.25	77.96	77.30
Marginal health cost [3]	59.78	59.28	58.83	73.09	72.47	71.93

Notes: The table uses coefficients estimated in the health cost model. Assumption values for scenario 2 are similar to those of scenario 1, except that the number of pesticide applications is 5 times per crop per season.

[1] Estimate heath cost of farmers (VND per season)

[2] Average health cost of farmers (VND/ gram a.i.)

[3] Marginal health cost (MC) calculated as: MC = estimated pesticide coefficient X (health cost/pesticide dose)

Table C.6

Surface water quality standards in Vietnam

Indicator	Unit	Limit value	
		A standard	*B standard*
BOD_5	mg/litre	<4	<25
COD	mg/litre	<10	<35
NH_3-N	mg/litre	0.05	1.0
NO_3-N	mg/litre	10	15
NO_2-N	mg/litre	0.01	0.05
TCB[1]	MPN/100ml	5,000	10,000

Notes: A standard = surface water used as a source for household water supply; B standard = surface water used for other purposes (excluding agricultural and aquaculture).

[1] TCB (Total *Coli* form Bacteria): A collection of relatively harmless micro-organisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. A specific subgroup of this collection is the fecal *coli* form bacteria, whose presence in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals (NEA\VEM-2003).

Source: 'Vietnam Standards TCVN 5942-1995. Surface Water Quality Standards'.

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