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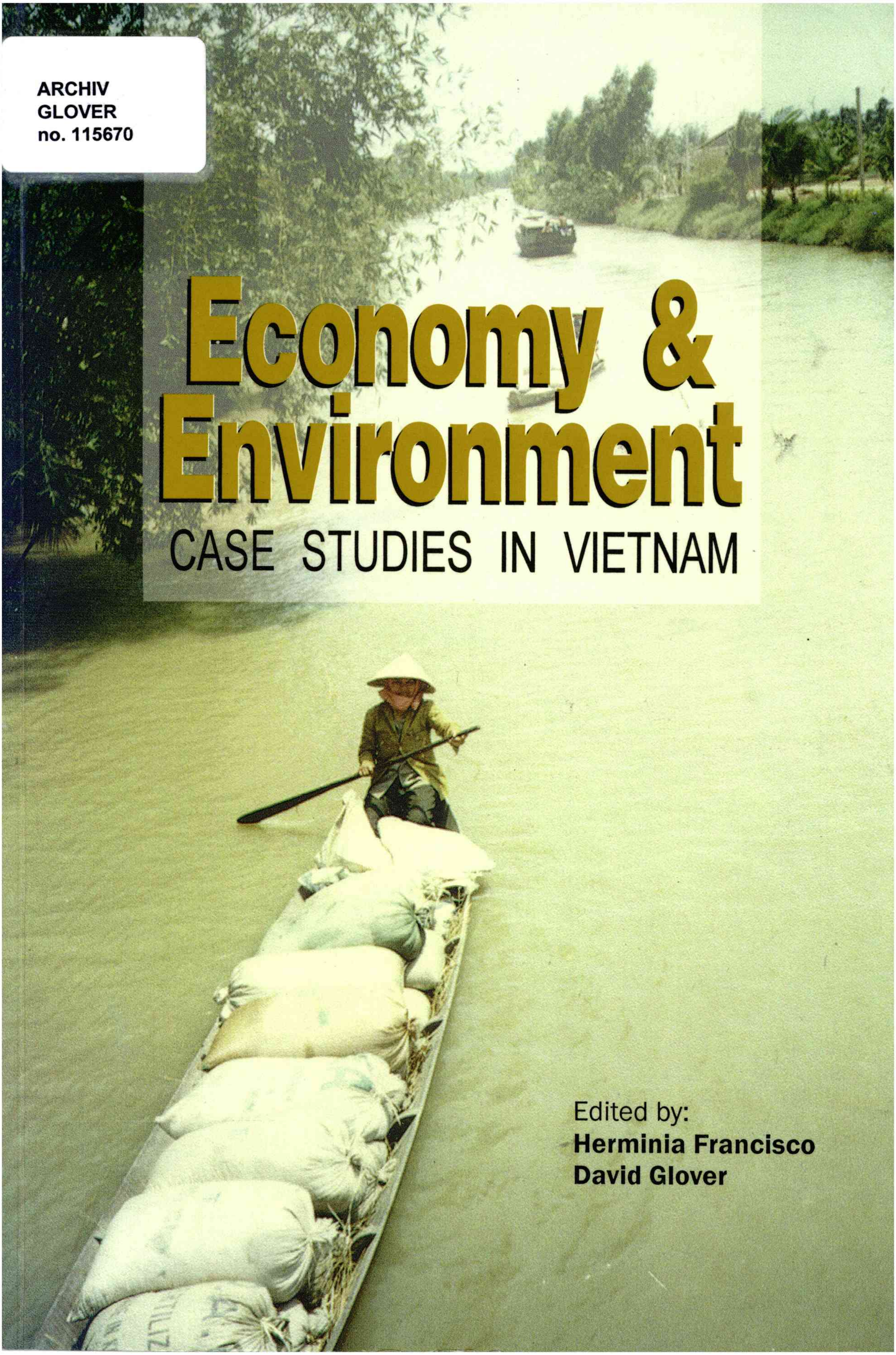

Economy & Environment

CASE STUDIES IN VIETNAM

Edited by:
Herminia Francisco
David Glover

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ECONOMY & ENVIRONMENT

Case Studies in Vietnam

The Economy and Environment Program for Southeast Asia (EEPSEA) was established in May, 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Laos, China, Papua New Guinea and Sri Lanka.

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CONTENTS

FOREWORD

In recent years, Vietnam has modernized its economic policies. Positive results include an economic growth rate averaging 8 percent per annum (1985-1996), increased foreign investment, and improved living standards for its citizens. However, along with rapid economic growth and industrialisation, Vietnam is facing serious environmental degradation such as water and air pollution from factories; deforestation; soil erosion; and contaminated water sources due to the over-use of chemical fertilisers and pesticides.

To attain sustainable development, Vietnam must immediately address the environmental degradation situation through a mixture of measures such as: laws and regulations, environmental technology, environmental economic policies, enhanced people participation, and increased environmental awareness of different stakeholders.

In order to enhance Vietnam's capacity to devise such measures, the Economy and Environment Program for Southeast Asia (EEPSEA) helped Vietnam organise two training courses in environmental economics in 1995 and 1996. Lasting about two months each, these were held at the Agriculture and Forestry University in Ho Chi Minh City. Participants included foreign instructors from the Philippines, Canada, France and England; teaching staff in economics, agriculture and forestry from Vietnamese universities; and others from provincial departments of science and technology, agriculture and forestry, and environment.

To apply the skills acquired, EEPSEA also supported the formation of the Vietnam Environmental Economics Research Network, through which the graduates can also become productive researchers. Through a small grants program, the trainees conducted research on various subjects such as industrial pollution, forests and mangrove, agrochemicals, and valuation methods. The researchers were provided with technical advice by Dr. Herminia Francisco, Dr. Agnes Rola, Dr. David O' Connor and Dr. Camille Bann.

This research program was managed by the Environmental Economics Unit of the Faculty of Economics, National University, Ho Chi Minh City. This document is the product of that research program.

However, this book signifies something more - the EEPSEA and the Vietnam government's shared efforts for capacity building and strengthening of environmental economics research in Vietnam. This is our first step in environmental economics, a new field for the country. I hope it provides a helpful reference for methodologies and case studies that may be used in training and policymaking for government officials and others working in environmental management.

On behalf of the Vietnamese researchers and colleagues, we would like to introduce this book to readers and express our gratitude to EEPSEA as well as the resource persons of the Vietnam Environmental Economics Research Network, and to the editors and donors who have assisted us to produce this book.

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Impact of Agrochemical Use on Productivity and Health

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Using the Travel Cost Method to Evaluate the Tourism Benefits of Cuc Phuong National Park

Nguyen Thi Hai, Lecturer, Faculty of Geography, Hanoi National University of
Natural Science, Hanoi
Tran Duc Thanh, Lecturer, Faculty of Tourism Studies, Hanoi National University
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Valuation of Non-timber Forest Products in Luong Son District, Hoa Binh Province

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An Economics Analysis of Agroforestry Systems in Central Vietnam

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Principal Adviser: Herminia Francisco

An Economic Analysis of the Can Gio Mangrove Scheme in Ho Chi Minh City

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Economic and Environmental Impacts of Rice-Shrimp Farming Systems in the Mekong Delta

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Le Canh Dung, Lecturer, Mekong Delta Farming Systems R&D Institute, Cantho University, Cantho City
Principal Adviser: Camille Bann

TABLES & FIGURES

1 FEASIBILITY OF AN INDUSTRIAL EFFLUENT CHARGE FOR THE FOOD PROCESSING INDUSTRY

2 IMPACT OF AGROCHEMICAL USE ON PRODUCTIVITY AND HEALTH

3 USING THE TRAVEL COST METHOD TO EVALUATE THE TOURISM BENEFITS OF CUC PHUONG NATIONAL PARK

6 AN ECONOMIC ANALYSIS OF THE CAN GIO MANGROVE SCHEME IN HO CHI MINH CITY

FEASIBILITY OF AN INDUSTRIAL EFFLUENT CHARGE FOR THE FOOD PROCESSING INDUSTRY

1

FEASIBILITY OF AN INDUSTRIAL EFFLUENT CHARGE FOR THE FOOD PROCESSING INDUSTRY

Do Thi Huyen, Le Ha Thanh, Nguyen Thi Lan, Phung Thuy Phuong, Nguyen Tran Quan and Ky Quang Vinh*

SUMMARY

One hundred food processing firms in Ho Chi Minh City, Can Tho, Da Nang, and Hanoi were studied to assess the feasibility of an industrial effluent charge. The sample size for calculating the BOD value was 93 and 87 for total abatement cost (TAC). Based on the analysis and an estimation of marginal abatement cost (MAC), the impact of different charge rates for BOD on effluent levels and on industry was studied. The charge rate of 5.1 million VND per ton of BOD load is well above the standard needed to achieve 100 percent compliance by small, medium, and large firms. The charge would be fair to firms since the TAC/REV ratio was just about 1 percent. For firms with TAC/REV ratio above 10 percent, it would be more difficult to abate pollution either by installation of wastewater treatment facilities or paying the charge. These were the heavily polluted firms or ineffective firms and may need to be relocated or renovated or closed down in the future.

The feasibility of an alternative charge was also discussed for the following: on pollution load standard; on the presumed pollution or concentration according to a standard formula (e.g. material, water consumption, wastewater flow rate, volume of production); and on product charge. Lastly, policy recommendation was given on the gradual implementation of the effluent charge in three phases within a span of 9-12 years.

1.0 INTRODUCTION

Water pollution in Vietnam has increased recently because of population growth, rapid industrialization, and insufficient wastewater treatment infrastructure in the urban areas. Prevention and control of water pollution are fundamental environmental protection tasks in Vietnam.

The chemical industry (rubber, paint, fertilizer, battery, and detergent), textile and tannery, pulp and paper, and food processing plants mainly contribute to the serious water pollution problem in the cities. The outdated technology and second-hand equipment make the industrial effluent serious hazards. Almost all industrial plants and factories discharge wastewater directly into natural water bodies without any treatment. Some firms have plans to install pollution control devices or wastewater treatment facilities. Some have now installed them. However, only a few effective wastewater treatment stations are operational. National effluent standards exist, but their enforcement has been weak. Consequently, many firms have not been complying with the standards.

Setting standards is the most popular approach to environmental pollution control. This is called "command and control" (CAC) approach because it consists of public authorities announcing certain limits on

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polluters, then enforcing these limits with appropriate enforcement institutions. Standards are often set by engineers based on technical parameters. Since marginal abatement costs differ among sources, uniform standards cannot be cost-effective. Technology standards undermine incentives to look for better ways of reducing emissions. Although emission standards create positive incentives for research and development in pollution control, these are weaker than the economic-incentive type of pollution control policies.

The incentive approach seeks to change a situation where there has been little incentive for people to think about the environmental consequences of their actions and to economize on the use of these environmental resources. There are basically two types of incentive policies: (1) taxes and subsidies and (2) transferable discharge permits. The first is a centralized system requiring an administering agency to implement the program and to deal directly and continuously with polluters. The second is a decentralized approach. Once such a system has been established and basic rules set, it is expected to work more or less automatically through the interactions among polluters themselves, or between polluters and other interested parties.

In recent years, U.S. environmental laws have begun to incorporate many types of transferable discharge permit (TDP) systems. However, such systems require a large pollution market, which is absent in developing countries. In other countries, particularly in Europe, greater reliance is being put on programs of emission taxes. Pollution charge and levy systems are the most popular economic instruments for water pollution control in Asian countries such as China, Thailand, Malaysia, the Philippines, and Singapore. However, since no single type of policy is likely to be the best in all circumstances, it is important to find an appropriate approach to pollution control.

The main advantage of emissions taxes is their efficiency. Firms faced with the tax are free to adjust their own emission rates. The second major advantage of emission taxes is that they produce a strong incentive to innovate or to discover cheaper ways of reducing emission. However, taxes pose a different type of enforcement problem than standards. Any tax system requires accurate information on the item to be taxed. Emission taxes require effective monitoring. It is probably fair to say that the monitoring requirements of an emission tax policy are at least as stringent as those for the typical standards program. The lack of high quality monitoring and reporting procedures makes effluent charge policies more difficult to enforce. The other advantage of taxes is that they provide a source of revenue for public authorities.

Despite difficulties and enforcement problems, applying economic instruments for water pollution control is necessary to improve water quality. Choosing an instrument and a policy that is effective, fair and easy to apply is the most important issue. It is also important to set the rate of the effluent charge for each sector of industries to provide economic incentives to firms that control their pollution.

1.1 Statement of the Problem

Vietnam's rapid industrial development poses a growing threat to environmental quality. Even at this early stage of development, industrial pollution is getting more and more severe. In general, the level of technology is low, the equipment is obsolete or second-hand, and very few factories have treatment systems. Wastewater from nearly all the industries is discharged into the receiving stream without any treatment. The polluters are not well aware of or not concerned with environmental problems, despite the Environmental Law of Vietnam (1993) and supporting regulations. Many firms face financial constraints and thus lack the capital to modernize their operations in order to cope with increasing competition. They have limited resources to invest in pollution control technologies.

Wastewater from the industry accounts for only a part of the total amount of wastewater. However, owing to its high pollutant concentration, it is the main source of water pollution, particularly of toxic chemicals. The food processing industry generates a huge volume of wastewater with high suspended solid (SS) content and high chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Wastewater from different plants varies in almost all parameters (pH, SS, COD, BOD, etc.). Even wastewater from different stages in the same production line performs rather differently in most parameters. Wastewater quality depends on raw materials, technology, production line as well as environmental performance of firms. The BOD variation may be used to evaluate a firm's environmental performance. A high content of suspended solids in wastewater could lead to sedimentation, causing damages to the drainage systems as well as to the aquatic life in receiving waters. Wastewater with high demand on oxygen (COD and BOD) would decrease the dissolved oxygen (DO) in the receiving water which would affect microphytes, macrophytes, bentic, and fish.

Moreover, in the production of some processed food, wastewater contains other toxic substances such as heavy metals and organic compounds. Wastewater from the food processing industry is high in organic matter, which consists of carbon, nitrogen and phosphorus. Organic matters are easily decayed by bacteria, which cause the unpleasant odor and pollution for the receiving water. Wastewater from meat, fish, and milk processing firms contains a high number of microorganisms which may poison the water body and affect the people's health. The pH value of wastewater from sugar mills, and vegetable and fruit processing plants is very low (high acidity) or very high (high alkalinity). Other sectors of the food processing industry also discharge highly polluted wastewater, which should be considered.

Together with technology upgrading, applying economic instruments to control water pollution is necessary to improve water quality. The Polluter Pays Principle (PPP), which is mentioned in the International Environmental Law as well as in the Environmental Law of Vietnam, points out that the person who causes pollution should pay. As the Government seeks to implement the Environmental Law and apply the PPP, economic instruments are being reviewed as one policy approach. From the perspective of social costs, economic instruments are in principle more cost-effective than regulatory approaches.

This study evaluated the feasibility of using economic instruments in the Vietnamese context, focusing on effluent charge schemes. The economic and environmental performance of firms in the food processing industry was examined. Based on the analysis and an estimation of marginal abatement costs, the impact of different charge rates for BOD on effluent levels and on industry was studied. The main products of the food processing industry were noodles, seafoods, meats, canned fruits, nuts, and beverages. The cities covered in the study were Ho Chi Minh City, Can Tho, Da Nang, and Hanoi. The food processing industry in the cities was rapidly growing to meet the demand for domestic use and export. Statistics showed that since 1990, the gross output of the food industry in Vietnam has increased by about 10 percent per year, and accounted for about 34 percent of the total industrial output in 1994. These firms also produced high organic pollution loads which made natural purification difficult.

An effective policy approach would be one that provides incentives for sizable reductions in BOD load while minimizing the cost burden on industry. The study sought to identify a feasible charge scheme with these characteristics.

1.2 Objectives

This study sought to provide information to policy makers on three questions:

a. What factors explain the differences between firms in their environmental performance?
b. What policy options are likely to prove effective in raising the level of environmental performance of the food processing industry?
c. What impact would a particular charge or other policy instrument has on the economic performance of the industry under study?

The result of this research is expected to be a valuable reference on industrial pollution in Vietnam. Though the research scope was limited to a feasible charge system for BOD discharge in the food processing industry, policy makers and researchers may find applicability to other industries, especially in terms of approaches and methodology.

1.3 Background and Current State of Knowledge

Like most countries, Vietnam has relied on its Environmental Law and other related laws and regulations to protect the environment and to control pollution. Unfortunately, the legislative instruments have been hampered by difficulties in enforcement and high administrative costs. National standards on BOD and other wastewater exist, but enforcement has been weak. Consequently, many firms have not been complying with the standard. They consider the environment an "open access" resource.

Together with the environmental standards, some other approaches have been employed. For example, Ho Chi Minh City has an annual Black Book listing the worst polluters. This approach has been effective to a certain extent in improving environmental performance through public awareness.

While the Environmental Law requires a polluting firm to pay the full costs of measures taken to reduce pollution to the level prescribed by the authorities, the law does not provide for a specific environmental tax system or policy mix to implement the PPP. In the major implementing regulation, the National Environmental Agency (NEA) and Ministry of Finance (MOF) are authorized to study and recommend a system of pollution charges. This research project was designed to contribute to the ongoing review of a system suitable for Vietnam. Policy makers in Ho Chi Minh City are especially interested in the appropriate method and rate of charges for specific industrial pollutants. A number of studies have shown the advantages of using market-based instruments (MBIs), otherwise known as economic instruments (EIs), to complement existing "command and control" (CAC) policies. Among the most common MBIs are effluent charges. These charges can create the fund for environmental management and the level of the charge makes an important difference to how industry will be affected. High charge rates may not be politically feasible, at least without some rebate or subsidy.

The water pollution charge approach is used in several European countries (e.g., France, Germany, and the Netherlands). Most countries in Asia (e.g., China, Korea, Malaysia, and Thailand) that levy a pollution charge use a non-compliance fee. As the name suggests, this charge or fee is levied only on discharges that exceed mandated effluent standards.

In Vietnam, some recent studies bear on this research. The study done for the Ministry of Science, Technology, and Environment (MOSTE - 1995) analyzed pollution charges, but its proposal to link charges to the firms' profits was not considered advisable, given the questionable underlying assumption about the association between firm profitability and environmental performance. The above study and several other case studies done in other countries are evidence of the efforts of governments in designing and executing various MBIs to complement CAC alternatives in an effort to curtail environmental damages.

However, several questions still need to be considered by Vietnam. Would a system of effluent charges work in Vietnam? (The experiences of countries using charges are quite varied) At what level should the charges be set? On what parameters should the charge be based? Should the charge be levied on all discharges or only as a non-compliance fee?

If the charge is very low, the industry correspondingly would have a small incentive to reduce its discharge. One weakness of the simple non- compliance fee is that it provides no incentive for industry to improve its environmental performance once it has complied with effluent standards, since discharges within the standard are essentially free.

The last question touches on combining economic instruments such as a charge-subsidy scheme that will deal with equity implications of the emissions charge and the use of revenues generated by the charges.

The remainder of this study tackles the following:

a. Relationship between firm characteristics and environmental performance;
b. Effect of different levels of pollution charge on abatement levels and on firm performance; and
c. Evaluation of a feasible pollution charge scheme, including considerations for environmental effectiveness, cost-effectiveness, equity, administrative feasibility, and political acceptability.

2.0 WATER POLLUTION PROFILE

2.1 Major Policies and Institutional Framework on Environmental Protection

2.1.1 Major policies of the government on environmental protection

In the 1992 United Nations Conference on Environment and Development (UNCED) in Brazil, Vietnam reported that environmental management actions in the past had been limited because they had been largely the result of piecemeal work and had faced various constraints, including the fact that the Government had higher priorities in national development. Also, there was a general lack of awareness on environmental issues, the legislative framework and the information base were weak and incomplete, and the resource base was severely limited.

Before this, in the 1982 Directives of the Council of Ministers, environmental protection was recognized as a major issue to be given top priority in all governmental branches and localities in Vietnam. In 1985, with the promulgation of Resolution

No. 246 of the Council of Ministers on "The Survey and Rational Use of Natural Resources and Environmental Protection," environmental protection became a concern of the entire population. In June 1991, the "National Plan on Environmental and Sustainable Development 1991-2000" was approved by the Council of Ministers. Considering these, Vietnam had major policies on environmental protection starting from the early 1980s.

Nowadays, legal environmental protection instruments in Vietnam include the following documents:

a. Decree of the Council of the Republic Socialist of Vietnam in 1992, Article 39, mentioning environmental protection in economic, cultural, and social activities

b. Environmental Law which came into effect in 1994, which include the following :

1. Polluter Pays Principle

"Organizations and individuals making use of components of the environment for production or business purposes shall, if necessary, contribute financially to environmental protection.

Any organization or individual whose activities cause damage to the environment shall make compensation thereof according to the regulations by the Law." *(Article 7)*

"In carrying out production, business and other activities, all organizations and individuals must implement measures for environmental sanitation and have appropriate waste treatment equipment to ensure compliance with environmental standards and to prevent and combat environmental degradation environmental pollution and environmental incident." *(Article 16).*

2. Setting standards, compliance with standards, reporting of violation

"The Government shall stipulate the nomenclature of environmental standards and delegate the authority at different levels for promulgating and supervising the implementation of such standards." *(Article 16)*

3. Environmental impact assessment (EIA)

"Organizations and individuals in charge of the management of economic, scientific, technical, health, cultural, social, security and defense establishments that have begun operation prior to the promulgation of this law must submit an EIA report on their respective establishments for appraisal by the State management agency for environmental protection." *(Article 17)*

"In case of failure to meet environmental standards, the organizations or individuals concerned must take remedial measures within a given period of time as stipulated by the State management agency for environmental protection. Upon expiry of the stipulated time limit, if they still fail to meet the requirements of the State management agency for environmental protection, the latter shall report to the higher State authority at the next level to consider and decide on the suspension of operation or other penalizing measures."

c. *Decision No. 175/CP* (October 1994): guideline for the implementation of the Environmental Law

In carrying out production and businesses, organizations and individuals in the following cases must pay the environmental protection charge:

1. Exploiting oil, gas, and other mineral resources
2. Airport, port, bus station
3. Means of transport
4. Other fields of production with polluted environmental operation

Foreign organizations and individuals carrying out their production and businesses that cause environmental pollution must pay the environmental protection charge.

The amount of charge will be based on the degree of bad effects of production operation on environmental safety.

The MOSTE and the Finance Ministry will have concrete instructions about collecting and using the environmental protection charge.

d. Decision No. 26/CP (April 1996): regulation on fines for violation of standards on transportation and treatment of wastewater and rubbish:

1. Punishable by warning or a fine of 100,000 VND-500,000 VND:

   a) Transporting rubbish and pollutants violating environmental protection principles.
   b) Not treating wastewater and rubbish before discharge.

2. Punishable by a fine of 500,000 VND - 2,000,000 VND: repeated acts of 1a.

3. Punishable by a fine of 2,000,000 VND - 8,000,000 VND: repeated acts of 1b.

4. Supplementary punishments

   a) Suspension of the environment license for 6 months for violating 1 and 2 above.
   b) Suspension of business operations, use of remedial methods, and payment of damage compensation for violating 1, 2 and 3 above.

e. Environmental Standards (1995)

1. National ambient standards, including water quality (class A and B)
2. Standards for industrial effluent (Class A, B, and C)

BOD standards are as follows:

BOD Ambient Standard		BOD Effluent Standard		
Class A	Class B	Class A	Class B	Class C
<4 mg/l	<25 mg/l	20 mg/l	50 mg/l	100 mg/l

2.1.2 Institutional framework

The State Committee for Sciences was upgraded to the new Ministry of Science, Technology and Environment (MOSTE) at the National Assembly in September 1992. The MOSTE has overall responsibility for the environmental sector and serves as a focal point of all environment- related activities.

The National Environment Agency and other state agencies for environmental protection assist the Council of Ministers and People's Committees at all levels to fulfill the tasks of environmental protection all over the country and in each locality.

Other agencies responsible for the environmental sector are the Environmental Departments of the line ministries and Environmental Protection Centers which are national bodies. At the provincial level, there are Provincial Departments of Science, Technology, and Environment (DOSTE). In Ho Chi Minh City, there is an Environmental Committee (ENCO) beside the DOSTE.

2.1.3 Monitoring and enforcement system

While Vietnam has the Environmental Law and other related regulations, its monitoring and enforcement system is still very weak. Budgetary constraints, lack of resource persons, lack of experience to enforce the law, and lack of equipment to monitor pollution are among the major reasons for the weakness. Moreover, it is difficult to change the polluters' attitudes and behavior.

Most firms were built and began to operate many years ago. Because of the obsolescence of their equipment and technology as well as the absence of environmental legislation, firms did not install pollution control systems and wastewater treatment facilities. Most industrial plants discharge wastewater directly into the receiving water body. They have no funds or land for wastewater treatment systems. They also have no environmental experts or plans for environmental improvement. All of the above mentioned reasons explain the high percentage of firms not complying with the standards.

2.2 Hanoi

2.2.1 Geographical and socio-economic characteristics

Hanoi is situated in 20°57′ north and from 105°35′ to 106°25′ east. The distance from the north to the south is 93 km; the width from the east to the west is 30 km. Hanoi's climate is tropical monsoon with an average moisture of 81-82 percent. The average temperature is 23-24°C. It drops to 5°C in winter and rises to 37-38°C in summer. About 9-10 storms pass Hanoi every year. It rains about 140-160 days a year with annual rainfall at 1500 mm. The maximum rainfall in 24 hours is 400 mm or 93.9 mm in an hour. Main wind direction is southeast monsoon in summer and northeast monsoon in winter.

Hanoi is located in the Red River Delta. The urban area and the adjacent districts are situated between the Red River and Nhue River. The water level in the Red River fluctuates from 2 m - 12 m. The average water flow is 380-436 m^3/s. The water level in Nhue River is about 5.35-5.63 m. There are four small rivers, namely: To Lich, Set, Lu, and Kim Nguu, which also receive wastewater discharge.

The population of Hanoi is rapidly increasing. It is estimated at approximately 3 million, of which 1,070,400 live in the urban area. In addition, 10,000 visitors arrive at Hanoi daily and thousands of workers from other places go to Hanoi to find jobs.

With its favorable geographic location, Hanoi is not only the capital of the country but also the major junction of roads, railways, and airways. The annual economic growth rate of Hanoi has been 11 percent since 1990. The income per capita is about USD 600.

Urbanization and industrialization have been hastened since Hanoi is also a major trading and commercial center of the country. Networks of hotels, restaurants, representative offices and agencies are being built and established. Tourism is blooming; its revenue is increasing. Agriculture is considerably stable with high productivity in cultivation of rice, maize, soybean, industrial crops, fruits, and vegetables. The number of livestock is also increasing.

A total of 274 big industrial plants are located in the city, of which 68 are heavy polluters. In addition, there are 540 service firms, 450 handicraft cooperatives, 3,350 small manufacturing firms, 20 hospitals, and 10,000 of latrines and coal ovens, which altogether make the pollution problem in Hanoi very serious. The major sources of industrial pollutants include the chemical, food processing, leather, paper, and battery industries. Domestic wastes and wastes from hospitals, slaughter houses, and unsanitary latrines contribute to the problem.

2.2.2 Water pollution in Hanoi

Groundwater

Hanoi is located in the northern delta (Red River Delta) which possesses a long and complicated geologic history. There was once infiltration erosion and other inflow activities forming silt deposit in the area. The geological activities resulted in the formation of a rather thick tertiary layer (80-100 m) with silt deposited fields of loose and changeable structure. Generally, the formation of the "tertiary layer" can be divided into two parts. The upper layer is formed by silt, mainly soft grains such as clay, sand, and mixed clay and sand. The lower layer is formed by gravel and crude sand. The neogene layer below the tertiary layer is formed by agglutinated rocks, clay, and broken stones. Within Hanoi, the lower layer of the tertiary layer is the main receiver, which has been used for water exploitation and water supply. The total daily capacity of all water plants is 320,000 m^3. On the other hand, it is estimated that Hanoi would need up to 700,000 m^3 daily in 2005. Unplanned or random groundwater extraction would result in immeasurable consequences such as depletion of water resource, intensified pollution, and land subsidence.

The groundwater quality is assessed by chemical components such as sodium, magnesium, iron, chloride, sulfur, nitrogen, nitrate, nitrite, and total soluble solid, the hardness, pH, and volatile solid. The analytical results of water samples from 162 aquifers and deep wells showed that groundwater quality satisfied the WHO standards, except for the high content of manganese, iron, and ammonium in some places such as Phap Van, Tuong Mai, and Ha Dinh. The Hanoi Water Supply Company reported that in those areas, iron content was 10-30 mg/l and ammonium was up to 30 mg/l.

Water pollution has had the following negative effects on groundwater in Hanoi:

a. *Groundwater depletion.* In some aquifers, the water source had been exhausted because of over-pumping.
b. *Groundwater contamination.* A large amount of domestic wastes from the urban area pollutes the groundwater and surface water. The high ammonium content in the groundwater may have resulted from leaching of dumping sites, and from surface water or solid wastes. The main sources of groundwater contamination may be surface water pollution, unhygienic dumping of solid wastes, and runoff from agriculture land.
c. *Land subsidence.* The areas most affected by land subsidy are Phap Van and Tuong Mai, which sink at the rate of 40 mm per year. The other areas are Ha Dinh, Ha Dong, Vong, and Van Dien which sink at the rate of 20 mm per year.

Surface water

Hanoi is on the banks of the Red River Delta, the biggest river in northern Vietnam. In addition, Nhue and Duong Rivers are sources of agricultural irrigation. Four other small rivers, namely: To Lich, Kim Nguu, Lu, and Set receive and discharge wastewater from the city. Nhue River and four other small ones are being considered for immediate rehabilitation and protection since they are heavily polluted. The drainage system in Hanoi is a combined one that discharges storm water, domestic sewage, and industrial wastewater. The system is operated with a self-flow principle. Wastewater from Hanoi is discharged into above mentioned rivers, then dispatched onto Nhue River after passing through the Thanh Liet Dam. The rivers are also used for irrigation in Thanh Tri and Tu Liem districts. Nhue River also helps irrigate 107,000 ha in Hanoi, Ha Tay, and Nam Ha provinces. The total length of the four rivers is 38 km. To Lich River, once a beautiful blue river used by ships, boats, and other naval transportation going to ancient Thang Long, has turned into a small black canal with the unpleasant odor of wastewater. Ponds and lakes in Hanoi, which are part of the attraction of the city, are under threat of becoming wastewater reservoirs. Hoan Kiem Lake (Lake of Restored Sword), Ho Tay (West Lake), Truc Bach, Bay Mau, and other lakes are in eutrophical conditions.

a. Lakes of Hanoi

Hanoi has over a hundred ponds and lakes. Their total surface area is about 2180 ha. The 20 large lakes in the city have a total area of 592 ha. These lakes include Ho Tay (West Lake), Hoan Kiem Lake, Bay Mau, Van Chuong, Ngoc Khanh, Giang Vo, Truc Bach, Dong Da, Thanh Cong, and Thu Le. The lakes give a beautiful scenery to the city and contribute to the pleasant microclimate in Hanoi. Furthermore, they serve as reservoirs of storm water, receiving water body for wastewater, and places for the natural purification of wastewater. In addition, the lakes are used for aquaculture. The average depth of the lakes is 2-3 m. The water level fluctuates from 0.5 to 1.5 m, depending on the season. However, most of the lakes are seriously polluted because of the large amount of untreated wastewater and floating solid wastes. Siltation and sedimentation have increased the lakes' bed level up by 0.5-1.0 m, especially in Van Chuong, Linh Quang, and Bay Mau lakes. Because of the low regulating ability of most of the lakes, there is frequent flooding in the rainy season. The water pollution in some typical lakes in Hanoi is illustrated in Table 1.

Ho Tay (West Lake), the biggest lake, occupies an area of 446 ha; it has a length of 5 km, width of 1.5-2.5 km, and average depth of 1.5-2 m. Its mud layer is 50-80 cm thick. The lake is almost enclosed except for some wastewater inlets. It is slightly polluted although the daily volume of wastewater discharge into the lake amounts to 3,000-4,000 m^3. Although the lake is in eutrophical conditions, the water quality in West Lake is still the best among the water bodies in Hanoi. Dissolved oxygen (DO) was 6.3-8 mg/l. Biochemical oxygen demand (BOD)

Table 1. Water quality of the lakes in Hanoi

Parameter	West Lake Ho Tay	Bay Mau Lake Ho Bay Mau	Sword Lake Ho Hoan Kiem	Thu Le Lake Ho Thu Le
Temperature, ^0C	20-30	20-31	20-30	20-30
DO, mg/l	6.44	1.0	6.0	3.20
COD, mg/l	34.00	310.0	281.0	110.00
BOD, mg/l	8.10	81.0	126.0	-
NH_4^+, mg/l	0.56	3.5	-	-
NO_2^-, mg/l	0.09	3.6	-	0.06
PO_4^{3+}, mg/l	0.48	0.8	0.1	0.15

Source: Report on the Environmental Situation in Hanoi was 10-21.6 mg/l. There was a low concentration of nitrate, nitrite, and ammonium which proved that the water in the lake was only slightly contaminated.

Bay Mau Lake appears to have the worst water quality among the lakes. Fish was observed to die from lack of dissolved oxygen. The daily wastewater flow into the lake totals 5,000 - 12,000 m^3. This lake is the starting point for Set River. It is heavily polluted; it was three times higher in total suspended solids (TSS) than the allowable limit. High BOD (59 - 81 mg/l) and low dissolved oxygen (sometimes dropping to 0) indicate serious pollution level. Moreover, the high content of phosphorus and ammonium poses a great harm to the aquatic life. The amount of coliform in the water sample was a thousand times higher than that of clean water.

Ngoc Khanh and Giang Vo Lakes are polluted, too. They smell because of their anaerobic conditions. Thu Le, Thanh Cong, and Dong Da Lakes are only slightly polluted, thanks to their large areas or the small amount of wastewater discharge they receive.

Besides the lakes mentioned above, there are other little lakes such as Van Chuong, Trung Tu, Thien Quang, Linh Quang, and Thanh Nhan which are heavily polluted also. In these lakes, the dissolved oxygen drops to 0.1 mg/l. BOD is as high as 110 mg/l.

Generally speaking, ponds and lakes in Hanoi are polluted. The pollutants' sources are domestic and industrial wastewater, which is discharged into the water bodies without proper treatment.

b. The Rivers

Four rivers are part of Hanoi's sewage system, namely: To Lich, Set, Lu, and Kim Nguu. The total length of the rivers is 36.8 km; their width is 20-45 m. The rivers were dredged in 1980 but they are filled again with sediments. Water in the rivers is heavily polluted.

To Lich River is the largest among the four rivers. It is 13.5 km long, 30-40 m wide, and its deepest point is about 4 m. To Lich River starts at the Phan Dinh Phung drain basin and passes Thuy Khe Canal. It passes Tu Liem and Thanh Tri districts, joins the other three rivers and flows into Nhue River through Thanh Liet Dam. The river receives 2,900-3,000 m^3 of domestic wastewater from 30,000 inhabitants and 22,000 m^3 of industrial wastewater from 33 plants.

The water analysis showed its high pollution level. Table 2 indicates the water quality of To Lich River. Total suspended

Table 2. Water quality of To Lich River

Parameter	Cau Moi site	Kim Giang site	Nghia Do site
PH	7.7-8.2	7.50	7.50
Suspended solid, mg/l	230-570	545.00	211.00
COD, mg/l	183-325	242.00	149.00
BOD, mg/l	21-120	17.25	40.20
NO_3, mg/l	0.39	0.66	0.61
NH_4, mg/l	5.2-17.1	9.70	9.60
DO, mg/l	2-2.6	3.00	0.18
H_2S, mg/l	3.2	29.75	

Source: Dinh Van Sam et al. 1996

solid and BOD were 5-10 times higher than the surface water standard (for zone C). In particular, sulfur hydrogen in Thuong Dinh area reaches up to 29.75 mg/l. The wastewater from the Thuong Dinh industrial outlet is remarkably polluted. The high organic content is the cause of BOD of water. The BOD of the water sample rose up to as high as 176 mg/l. This makes To Lich River a seriously polluted water body in Hanoi. Moreover, wastewater from Rang Dong Lamp and Thermos Manufacturing Factory consists of toxic cyanide at 224 mg/l.

Another is Kim Nguu River, which receives wastewater from the following basins:

1. *Lo Duc basin:* with an area of 351.8 ha and a population of 180,000 inhabitants. The daily water flow rate in this basin is 36,000 m^3.

2. *Thanh Nhan, Minh Khai basin:* with an area of 418.2 ha and a population of 85,000 residents. In addition, wastewater from industrial plants and hospitals in the area also flows into the river. The daily water flow rate in this basin is 22,000 m^3.

3. *The basin of Vinh Tuy industrial area:* This industrial area has textile plants, which use chemicals for bleaching and dyeing. Daily water flow rate in this basin is 12,000 m^3.

4. *Van Dien basin:* The area is a residential, agricultural and industrial zone (fertilizer, battery, paint, engineering workshops). The daily water flow rate in this basin is 10,000 m^3.

The wastewater from the basin of Nguyen Cong Tru, Hoa Binh market, and Ba Trieu drains into Bay Mau lake which flows into Set River and discharges into Kim Nguu River. The daily water flow rate is 60,000 m^3.

The total daily water flow of Kim Nguu River is 139,000 m^3. The river collects wastewater from different sources. Therefore, Kim Nguu is the most polluted among all water bodies in Hanoi. Dissolved oxygen in the water is very low. The river has anaerobic conditions with eutrophic and algae blooming as a result of high hydrogen sulfide (H2S) content (11 mg/l). Biochemical oxygen demand and chemical oxygen demand (COD) are also high at 129 and 495 mg/l, respectively.

Lu River helps form the chain of rivers and lakes that compose a typical drainage system in Hanoi. It has a rather strong self-purification process though its water is still polluted because of the big amount of wastewater draining into it.

The characteristics of water quality of Kim Nguu river are shown in Table 3 and Table 4.

2.2.3 Pollution sources

Hanoi daily discharges into its drainage system about 330,000 m^3 of untreated wastewater, of which more than 100,000 m^3 come from industries (including chemical industry). The others are toxic wastewater from hospitals and domestic wastewater. The drainage system is a combined one, which helps discharge storm water with wastewater, therefore it causes serious pollution.

a. Domestic wastewater

The domestic wastewater of over 220,000 m^3 per day accounts for the largest volume among the wastewater sources. The water from septic tanks, unhygienic latrines, and domestic chemicals

Table 3. Water quality of Kim Nguu River

Parameter	Lo Duc		Thanh Liet	
	March	April	March	April
PH	7.40	7.4	7.55	7.3
Suspended solid, mg/l	158.00	335.0	21.00	60.2
COD, mg/l	99.40	44.5	49.30	55.6
BOD, mg/l	27.50	21.1	5.30	6.2
N total, mg/l	12.00	15.6	7.30	12.3
NH_4, mg/l	5.10	9.3	3.41	7.2
DO, mg/l	0.48	0.2	5.10	11.0
Water flow, Q m^3/h	1.600	1.700-3.000	6.600-7.600	4.700-23.400

Source: Reports on Environmental Situation in Hanoi

Table 4. Characteristics of wastewater outlet in Kim Nguu River in the dry season

No.	Outlet	Flow rate, m^3/s	pH	SS mg/l	DO Mg/l	BOD mg/l
	Lo Duc drain	0.467	7.4	220	0.5	110-140
	Right bank					
1	Mai Huong- Quynh Loi Canal	0.027	7.4	200	1.0	80
2	Quynh Loi living quarter drain	0.00176	7.0	215	1.0	60
3	8-3 living quarter drain	0.00087	6.8	215	1.0	70
4	Minh Khai drain	0.0124	6.9	180	1.0	80
5	Mai Dong Mechanic factory drain	0.043	7.2	150	1.0	80
6	Mai Dong Canal	0.005	6.8	200	1.0	50
7	Set River outlet	0.858			1.0	26
	Left bank					
1	Lac Trung Canal	0.024		180	1.0	80
2	Minh Kha Textile Canal	0.10	7.0	175	0.5	100
3	Minh Khai street drain	0.07		175	0.5	80
4	8-3 Textile factory drain	0.138	9.5	150	1.0	120
5	The old Kim Nguu River	0.09	7.1	150	1.5	50
6	Other small drains	0.087				

Source: Tran Hieu Nhue, 1996. Wastewater Treatment in Vietnam

is a serious source of pollution. Hanoi as an urban area suffers from environmental degradation and pollution due to overpopulation, high population density, low living standard, cramped residential areas, lack of sanitation, and un-integrated drainage system. The average waste per capita is about 6-12 grams of nitrogen, 1-3 grams of phosphorus, and 400 kinds of bacteria, germs and protozoa, hundreds of which affect the people's health. Domestic wastewater is high in nitrogen, phosphorus, and bacteria, especially coliform bacteria. The most probable number (MPN) of bacteria in 100 ml of wastewater is 10^9-10^{10}; coliform MPN is 10^6-10^9, of which 10^5-10^6 is *E.Coli.* The domestic wastewater usually consists of approximately 60-150 mg of chloride, 25-90 mg of ammonium, 150-400 mg of total suspended solids, and biochemical oxygen demand of 60-170 mg/l. Wastewater, gutters, and canals are breeding places for flies, mosquitoes, and other diseases transmitting insects, which can cause widespread epidemics.

b. Industrial wastewater

Over 100,000 m^3 of industrial wastewater daily discharges into water bodies causing heavy pollution with toxic substances such as heavy metals, high organic content and inorganic substances. High BOD and COD reduce the amount of dissolved oxygen in the water and directly affect the aquatic life and aquatic system. Industrial plants in Hanoi using obsolete technology and equipment and without wastewater treatment facilities make the pollution problem more serious. The amount of waste in the plants is much higher than that of standard production line. The National Effluent Standards were set in 1995, and are still to be applied. Most of the firms that required installation of wastewater treatment facilities are short of funds and do not have access to relevant technology. Therefore, the pollution problem has remained unsolved.

A big portion of the wastewater comes from 274 plants and thousands of small manufacturing and servicing units which discharge daily 100,000 m^3 of very highly concentrated pollutants. The Thuong Dinh industrial zone comprises a lamp and thermos factories, the Golden Star Rubber company, a soap factory, and a tobacco company which daily discharge 9,000 m^3 of wastewater into To Lich River. The water quality of the river has been affected by these discharges. Results of water analyses showed that the biochemical oxygen demand was 30-155 mg/l, chemical oxygen demand was 800-2,080 mg/l, total suspended solid was 60-450 mg/l, ammonium content was 206 mg/l, and phosphorus content was 1.7-8 mg/l. Some organic substances such as synthetic washing powders, rubber, and glycerin are not biodegradable. They can harm aquatic life and microorganisms essential for the river's self-purification. Dissolved oxygen in water is considerably reduced as wastewater is drained into the river. Its water has turned dark brown-blackish. The upstream and downstream water quality of To Lich River is given in Table 5. Wastewater from the food processing industry such as confectionery, alcohol, and beverage has high organic content (BOD of 1,000 mg/l). Wastewater from other companies such as Hanoi Beverage Company, Viet Ha Beverage Company, Hanoi Alcohol Company, and a canned food factory also has high BOD and COD value (200-500 and up to 2,360 mg/l, respectively). Suspended solids in wastewater from a textile company and the paper industry consist of lignin, which prevents cellulose degradation. Such wastewater also has high BOD and COD. On the other hand, wastewater from Thuy Khe Leather Company contains chromium (0.1 mg/l).

Wastewater from the refinery and gasoline station contains phenols, which are toxic pollutants; that from lamp and thermos production has cyanide which is also toxic to aquatic life. The high content of ammonium and phosphorus in wastewater from the fertilizer industry has caused the algae to bloom. It is also harmful to the fish. Heavy metals such as lead, chromium, and mercury discharged by battery, paint and electronic manufacturers are also hazardous to the ecosystem. These substances remain undegraded for a long time or accumulate in animals in the food chain, and could affect people's health. The environmental protection policy, including the Environment Law and related decisions and regulations, is new and its effect has not yet been felt. On the other hand, many joint-venture companies that

Table 5. Water quality of To Lich River in Thuong Dinh area

Parameter	Upstream	Downstream
COD	20-45	40-180
BOD	15-20	20-25
NH_4^+	5-8	17-20
PO_4^{3-}	0.15-2	0.4-5

Source: Pham Ngoc Dang et al. (1996). KT-02-03 Project Report import new technology could save money by cutting expenses on environmental pollution control and treatment. Table 6 shows the total pollution load from industrial wastewater in To Lich and Kim Nguu Rivers.

c. Wastewater from hospitals

Wastewater from hospitals is extremely hazardous and, hence, needs to be properly managed. A research by Nguyen Huu Hung and Luu Xuan Hung (1996), showed that wastewater from hospitals is voluminous and contains many contaminated organic substances, chemicals, and infectious bacteria. Most of the hospitals do not have wastewater treatment facilities. In some hospitals, wastewater treatment equipment has been installed but is not used because of the high cost of operation and lack of proper drainage system.

The discharge of these pollutants without treatment into the city's drainage system or even into the lakes and ponds surrounding the hospitals has an adverse impact on the environment and people's health. Table 7 shows the amount of wastewater from 14 hospitals in Hanoi.

Table 6. Amount of industrial wastewater discharged into To Lich and Kim Nguu Rivers by 30 factories

Pollutant	Pollution Loading (kg/day)		
	To Lich	Kim Nguu	Total
COD	11,340	11,785	23,125
BOD	2,522	2,510	5,032
Suspended solid	2,946	1,427	4,373
Evaporatable solid	1,065	1,177	2,242
$N\text{-}NH_3$	60	80	140
N total	160	175	335
P total	9	9	18
Cr^{+6}	60	54	114
Ni^{+2}	6	22	28
F^-	0	77	77
Flow rate, m^3/day	18,168	17,316	35,484

Source: Dinh Van Sam et al. (1996). Research on Industrial Water Pollution in Hanoi

Table 7. Waste management in hospitals in Hanoi

No.	Hospital	Area (ha)	No. of Beds	Waste Water		Solid Waste	
				Flow Rate m^3/day	Treatment System	Amount 3/day	Amount Collect
1	Bach Mai Polyclinic	14.00	1,000	450	No	126	117
2	Saint Paul Polyclinic	1.92	500	300	No	60	32
3	Dong Da Polyclinic	2.00	300	160	No	22	7
4	Traditional Medical		250	100	No	30	30
5	K-Hospital		150	30	No	13	11
6	Huu Nghi Hospital	2.00	350	700	Yes	22	15
7	Children's Hospital		450	600	Yes	40	30
8	Maternity Hospital	2.20	200	120	No	30	21
9	Optical Center Hospital	0.25	220	148	No	30	30
10	108 Hospital	10.00	600	350	Yes	55	45
11	Turberculosis Hospital	3.30	375	200	Yes	50	21
12	Viet Duc Hospital	3.00	600	300	Yes	63	40
13	Hai Ba Trung Hospital		375		Yes	50	21
14	Railway Hospital		300	170	No	20	11

Source: Nguyen Huu Sung and Luu Xuan Hung (1996), Hospital Waste Management in Hanoi

d. Wastewater from agricultural runoff

Runoff from paddy fields, cereal or vegetable, and fruit gardens carries with it a great amount of agro-chemicals from fertilizers and pesticides, which are intensively applied to increase yields. Chemical fertilizers are rich in ammonium, nitrate, and phosphate, causing eutrophication of lakes, ponds, and rivers. Pesticides are dangerous to the ecosystem because of toxic organic compounds (e.g., halogenated compounds, arsenic, or chromium). Farmers in the suburban area of Hanoi apply night soil and manure to vegetable and other crops, which contaminate the water and food with protozoa, germs, bacteria, and *E. coli*.

2.3 Ho Chi Minh City

2.3.1 Geographical and socio-economic characteristics

Ho Chi Minh City is the biggest city in Vietnam. It is an important center for culture, science, economy, trade, and international exchange. It also faces a big water pollution problem due to domestic and industrial wastewater. Ho Chi Minh City has an area of 2,084 km^2, of which urban districts cover 139.4 km^2. The population density of the whole city is 1,921 persons/ km^2 with the highest density in the Fifth District (53,170 persons/km^2) and the lowest in Duyen Hai District (67 persons/ km^2). Ho Chi Minh City is located in the transitional zone of the east southern region and the Cuu Long River Delta. The river and canal system in Ho Chi Minh City is influenced by the semidiurnal solar tide. The level of tides is highest in October-November and lowest in June-July. Intrusion of saline water by tide influences the whole river and canal system.

The population of Ho Chi Minh City is more than 4.7 million inhabitants, accounting for about 6 percent of the country's total population. On the other hand, the industrial production of the city accounts for a third of the whole country's industrial production.

Ho Chi Minh City has 680 factories/ plants of which 500 are in the inner city. It has approximately 22 industrial zones: the main industries include textile, paper, food, chemical, sugar, soap, detergent, beverage, plastic, rubber, and machines. In addition, Ho Chi Minh City has almost 24,000 small-scale industrial companies/ cooperatives, of which 89 percent are located in the residential areas of the inner city.

There is no wastewater treatment plant in almost all the existing factories. All the wastewater is discharged directly into the sewerage system of the city or into receiving water bodies. The flow rate of industrial wastewater is smaller than that of domestic wastewater but the pollutant concentration of the former is much higher and more dangerous. The factories and small-scale industries in the city contribute significantly to the economy, but they also significantly pollute the environment.

2.3.2 Water sources

Dong Nai River System

Dong Nai River System consists of three main rivers (Dong Nai, Nha Be, and Soai Rap) and four small ones (La Nga, Song Be, Sai Gon and Vam Co) in the southeast and southwest region. The total length of Dong Nai River System is 1,816 km, covering a total area of 68,520 km^2. The river and canal system in Ho Chi Minh City is exceptionally dense. Moreover, owing to the semidiurnal solar tide, the system is very complicated in hydrology. Water in Dong Nai and La Nga Rivers in the upper section (e.g., at Tri An Dam) is of good quality, even usable for household use. However, the lower section of the river is polluted by industrial and domestic wastewater.

Sea Water

The coastal area of Ho Chi Minh City from Can Gio to Dong Hoa has many estuaries, with a total coastline length of 11 km. The estuaries of Soai Rap, Dong Tranh, Nga Bay, and Cai Mep Rivers are where the river system receives tidal water from the sea. In the dry season, saline water enters Tri An Dam on Dong Nai River and Dau Tieng Dam on Sai Gon River. Intrusion of saline water by tide influences the whole river and canal system in Ho Chi Minh City. It aggravates the water pollution problem making it more complex.

2.3.3 Water pollution situation

The surface water pollution in HCM City was assessed by the Environment Committee using data collected on water quality from monitoring stations during the period 1992-1996 as well as from a field survey in Hoc Mon, Binh Chanh, Nha Be areas, and canals inside the city from 1988 to 1991. In each station, monitoring was done four times a month (1st, 8th, 15th, and 22nd day) with a sampling frequency of twice a day at high and low tides for parameters such as SS, total N, total P, DO, BOD_5. COD, coliform, and *E.coli*. Other parameters such as heavy metals (Pb, Hg, Cu, Mn, Cd), oil, and grease content were analyzed once a month.

The report classified pollution into seven types:

1. Organic pollution
2. Bacterial pollution
3. Suspended solid pollution
4. Nutrient pollution
5. Pesticide pollution
6. Heavy metal pollution
7. Oil pollution

To assess the degree of pollution, these parameters were compared with the Vietnamese Standards: TCVN 5942 for surface water, TCVN 5942-A for class A, which can be used for domestic purposes following a prescribed treatment, TCVN 5942-B for class B, which can be used for other purposes; TCVN 5945-A, TCVN 5945-B, and TCVN 5945-C for wastewater. Polluted areas, pollution profile by place and time, and relationship between these parameters were considered. The types of pollution in HCM City were described as follows:

Organic Pollution

BOD_5 and COD are considered as parameters describing organic pollution. The higher their levels, the more polluted the water. The survey data of the Water Supply Company collected in June 1992 in Hoa An Station in Dong Nai River showed that water samples from the left and right river banks as well as the middle of the water course had maximum BOD_5 of 12 mg/l and maximum COD of 25 mg/l.

BOD_5 and COD levels in water from canals within the city are very high. Compared with TCVN 5942-A, they are about 50-80 times higher in Tan Hoa canal, and 1000-1800 times in some other places *(Table 8)*.

BOD_5 and COD levels vary depending on the tide; at base tide, SS, BOD_5, and COD levels are higher than at peak tide. BOD_5 and COD concentrations in water at wastewater discharging points of Nhieu Loc - Thi Nghe Canal are 50-200 times higher than in the canal water *(Table 9)*. BOD_5 and COD concentrations in canal water within the city are higher than TCVN 5945 standard levels for wastewater class B (BOD_5 = 50 mg/l, COD = 100 mg/l) as well as for wastewater class C (BOD_5 = 100 mg/l, COD = 400 mg/l), which are not allowed to be discharged into the environment.

Table 8. Organic and suspended solid pollution in Tan Hoa Canal (Jan. 1993)

Sampling Points	Peak Tide					Base Tide				
	SS mg/l	DO mg/l	BOD mg/l	COD mg/l	BOD/ COD	SS mg/l	DO mg/l	BOD mg/l	COD mg/l	BOD/ COD
T001	1420	0	2900	3318	0.87	1450	0	3800	4291	0.88
T002	1550	0	580	727	0.80	560	0	530	756	0.70
T003	2050	0	590	9273	0.64	540	0	8400	13,450	0.62
TCVN 5942-A	20	6	4	10	-	20	6	4	10	-

Table 9. BOD of Nhieu Loc- Thi Nghe Creek

Outlet Code	BOD mg/l	Discharge Q m^3/h	BOD Load kg/h	Outlet Code	BOD mg/l	Discharge Q m^3/h	BOD Load kg/h
C01	58	125	7.25	C23	95	225	21.37
C02	61	128	7.80	C24	230	212	48.76
C03	80	65	5.20	C25	-	Little	-
C04	105	271	28.45	C26	-	Little	-
C05	87	98	8.52	C27	120	792	95.04
C06	85	96	8.16	C28	69	838	57.82
C07	86	Little	-	C29	82	223	18.28
C08	96	Little	-	C30	90	237	21.33
C09	75	Little	-	C31	50	518	25.90
C10	136	130	17.68	C32	98	339	33.22
C11	148	Little	-	C33	195	17	3.31
C12	105	193	20.26	C34	185	22	4.07
C13	88	90	7.92	C35	170	113	19.21
C14		Little	-	C36	88	15	1.32
C15		Little	-	C37	60	14	0.84
C16	110	Little	-	C38	62	13	0.80
C17	62	175	10.85	C39	63	173	0.89
C18	98	71	6.95	C40	106	6	0.09
C19	81	180	14.58	C41	125	14	1.78
C20	72	104	7.48	C42	100	86	8.60
C21	95	213	20.23	C43	74	46	3.40
C22				C44	198	15	2.94

Table 10. Bacteria pollution in canals and rivers of HCMC (1993)

No.	Canal/ River	No. of Samples	Coliform	10^3MPN/ 100 ml		*E. coli*	10^3MPN/ 100 ml	
			Max	Min	Ave.	Max	Min	Ave.
1	Tan Hoa	6	432	33.7	194.5	421	83	156.5
2	Tham Luong	14	49	20	46.4	43	12	26.5
3	Kenh Doi	12	48	5	19.7	23	2	7.9
4	Tau Hu	12	37	12	23.2	17	6	10.2
5	Nha Be	6	43	27	36.8	34	19	28
6	Nhieu Loc	20	43	8	26.1	16	4	10.2

Water quality monitoring data collected monthly in other canals of HCM City during the period 1993-1995 showed that BOD_5 and COD concentrations had a range of 5-10 mg/l and 5-20 mg/l, respectively. Thus, organic pollution in the river and canal system of Ho Chi Minh City is at the average level, which is 1.5-2.5 times higher than the standard for surface water (TCVN 5942-A). In some places such as Hoa An and Thu Dau Mot Water Supply Station, however, the pollution level is more serious and the standard for water supply is not met.

On the whole, the data showed that organic pollution is very serious in canals within city and the suburbs, which directly receive domestic and industrial wastewater from HCM City.

Bacterial Pollution

Bacterial pollution caused by human and animal wastes is indicated by the amount of *E.coli* and coliform. Maximum amounts of coliform allowed in standard TCVN 5942-A and TCVN 5942-B are 5000 MPN/100 ml and 10000 MPN/100 ml, respectively.

The amount of *E.coli* and coliform fluctuates widely depending on the tide as well as source of wastewater. Generally, the number of bacteria at base tide is higher than at peak tide. Water in Sai Gon River from Binh Phuoc Bridge to Nha Rong, Cho Dem River, and Nha Be River has about 3-4 times higher coliform amount than allowed by TCVN 5942-A standard. In canals that directly receive wastewater from the city, the coliform level is about 10-40 times higher than the standard *(Table 10)*.

Coliform and *E.coli* levels in big rivers of HCM City vary widely. Water quality monitoring data in 1995 showed that in Sai Gon and Dong Nai riverheads, *E.coli* was 2-5 times less than the total amount of coliform; in some places, the difference reached 40 times *(Table 11)*.

Compared with the TCVN 5942-A standard the highest number of coliform in big rivers of HCM City was 1.1-93 times higher; however, the average value in Hoa An, Ben Than, and Phuoc Binh indicates that there is no bacterial pollution in the water source. Along Sai Gon River from Ben Than to Nha Be, the degree of bacterial pollution increased with the

Table 11. Bacterial pollution at water quality monitoring stations, 1995

No.	River Station	Coliform	10^3 MPN/ 100 ml			*E.coli*	10^3 MPN/100 ml		
		No. of samples	Max	Min	Ave	No. of Samples	Max	Min	Ave
1	Hoa An Dong Nai	10	11	0.390	2.296	10	4.3	0.39	1.438
2	Ben Than Sai Gon	24	46	0.043	3.662	24	4.3	0.002	0.777
3	Binh Phuoc Sai Gon	22	110	0.750	4.062	22	110.0	0.21	7.773
4	Nha Rong Sai Gon	24	930	460	17.071	24	430.0	0.57	96.354
5	Nha Be Nha Be	24	460	7	20.227	24	9.3	0.004	20.208
6	Binh Dien Cho Dem	24	460	43	14.375	24	46.0	0.009	35.104
7	Tam Hiep Long Tau	13	21	9	20.342	9	0.9	0.004	3.161
8	Ly Nhon Soai Rap	12	46	7	39.728	10	2.1	0.004	2.406
	TCVN 5942	A-B			5-10				

amount of coliform, which was about 3-4 times higher than the allowed level.

Suspended Solid Pollution

Suspended solid pollution can be classified to four levels as follows:

1. Low level : SS < 20 mg/l
2. Medium level : SS = 20 - 80 mg/l
3. High level : SS = 80 - 200 mg/l
4. Very high : SS > 200mg/l

The above classification is based on the allowed limits or standards for surface and wastewater: TCVN 5942-A with SS = 20 mg/l, TCVN 5942-B with SS = 80 mg/l, and TCVN 5945-B with SS = 200 mg/l. The canals within the city and Nha Be River have high SS concentration. On the other hand, there was no SS pollution in the upper part of Sai Gon and Dong Nai Rivers, but within HCM City, water is polluted by SS from district 1 to the estuary *(Table 12)*.

Water in Dong Nai, Sai Gon, and Vam Co Rivers, canals with high acidity, and sea water had low SS concentration. In the rainy season, the SS level increases because pollutants are washed out from the basin to the canals.

Nutrient Pollution

Nutrient pollution is indicated by total N (Nt) and total P (Pt). Total N is divided into four levels:

1. Low : Nt = 0 - 0.5 mg/l
2. Medium : Nt = 0.5 - 1.0 mg/l
3. High : Nt = 1.0 - 1.5 mg/l
4. Very high : Nt >1.5 mg/l

Total P is also classified into four levels:

1. Low : Pt = 0 - 0.05 mg/l
2. Medium : Pt = 0.05 - 0.1 mg/l
3. High : Pt = 0.1- 0.3 mg/l
4. Very high : Pt > 0.3mg/l

Table 12. SS concentration at water quality monitoring stations, 1995

No.	River Station	No. of Samples	SS Ave. mg/l	SS Max. mg/l	Day/max	SS Min. mg/l
1	Hoa An, Dong Nai	48	11.9	41.0	22/6	3.0
2	Ben Go, Dong Nai	48	11.3	58.4	15/6	1.2
3	Ben Than, Sai Gon	96	8.5	43.2	1/8	0.8
4	Binh Phuoc, Sai Gon	96	16.2	35.0	8/9	5.0
5*	Nha Rong, Sai Gon	96	52.5	142.0	41/4	0.4
6*	Tan Thuan, Sai Gon	48	27.8	143.6	15/1	1.2
7*	Thi Nghe, Thi Nghe	48	12.5	50.8	15/2	0
8	Nha Be, Nha Be	96	45.5	256	15/2	0.4
9	Binh Dien, Cho Dem	96	73.9	373	15/2	0.4
10*	Phu Dinh, Rach Cat	48	75.0	423	1/3	2.0
11	T.T. Hiep, Long Tau	48	75.9	230	22/12	5.2
12	Ly Nhon, Soai Rap	48	105.5	686	22/12	3.2
	TCVN 5942	A, B	20;80			

* areas within the city

Total N and total P of canals within the city and in the suburb are between high and very high levels. Total P is also high in water crossing areas of rivers and canals, as well as water stored in inner fields.

Very high nutrient concentration, meaning more than 0.1 and 0.5 mg/l Nt and Pt, respectively, can cause eutrophication of water bodies. Therefore, eutrophication commonly happens in canals within the city and suburb. Eutrophication causes algae to bloom within a certain period of time and when they die, the water becomes more polluted.

Variations of Nt and Pt levels are very complicated, depending on their supply sources. Generally, Nt and Pt vary by time and tide and their interrelations. In Tan Hoa canal within the city, Nt and Pt concentrations are very high: Nt_{max} = 52 mg/l, Pt_{max} = 8.2 mg/l (data of Dec. 1994). The difference of Nt and Pt levels between base and peak tides is 2-5 and 2-3 mg/l, respectively. In Binh Dien Station of Cho Dem Canal, the difference is 0.6 -2.9 mg/l for Nt and 0.05 - 0.53 mg/l for Pt.

The Nt/Pt ratio indicates the nutrient level in an aquatic environment. The condition is good for algae growth when Nt/Pt = 7. When the ratio is less than 7, nutrient is limited. The same is true when the ratio is higher than 7.

For example, data on water quality between Tham Luong Canal, which directly receives wastewater, and An Ha Canal, which does not directly receive wastewater showed that Pt is the limited nutrient *(Table 13)*. Thus, surface water in HCM City is a P-limited and N-rich environment.

Pesticide Pollution

In 1995, the concentration of 25 pesticides, especially DDT, was monitored every 15th of the month at eight sampling points, namely: Ben Than, Binh Phuoc, Nha Rong in Sai Gon River; Hoa An, Nha Be, Ly Nhon in Dong Nai, Nha Be, and Soai Rap Rivers; Tam That Hiep in Long Tau River; and Binh Dien in Cho Dem River. DDT was not found at Hoa An, Ben Than, and Nha Rong sampling stations. The highest concentration of DDT at Binh Phuoc Station was found in June (0.1942 µg/l); at Binh Dien Station - August (0.0176 µg/l); at Nha Be Station, March (0.1902 µg/l); at Ly Nhon Station, June and August (0.0654 µg/l and 0.3012 µg/l, respectively); and at Ton That Hiep Station, June (0.1145 µg/l). DDT was found

Table 13. Water quality of Tham Luong and An Ha Canals (Aug. 1995) (mg/l)

Place	Tham Luong Bridge	Cho Cau Bridge	Tan Thoi Hiep	Kenh C Bridge	Tan Tao Bridge	An Ha Sewer	Nhi Xuan	An Ha Bridge
Parameter	Tham Luong - Ba Hom Canal					An Ha Canal		
NO_3-N	0.83	1.42	1.36	0.06	2.18	0.07	0.06	0.220
NH_4-N	0	0	0	1.17	0.009	0.436	0.45	0.406
Nt	1.88	2.24	2	2.61	3.68	0.802	0.75	0.990
Pt	0.12	0.31	0.30	0.10	0.28	0.05	0.07	0.080
Nt/Pt	15.54	7.20	6.67	26.10	13.14	15.04	10.71	12.380
PH	6.39	6.39	6.11	4.77	6.15	3.05	3.10	3.440

in water samples mainly at the start and in the middle of the rainy season. This is because DDT is washed out from agricultural areas. In addition, other pesticides were also found at eight sampling stations with an average concentration of 1-2 μg/l. In March, pesticide concentrations at Ben Than, Nha Be, and Binh Dien sampling stations reached 4-5 μg/l. Compared with the TCVN 5942-B standard, the concentrations of DDT and other pesticide in the rivers and canals in HCM City are lower than the allowed levels (0.01 and 0.15 μg/l, respectively).

In summary, pesticide traces have been found in Dong Nai River and in other rivers and canals of HCM City. Because of their acute toxicity and carcinogencity, continued monitoring is needed. If the levels rise significantly, stronger control measures may be needed.

Heavy Metal Pollution

This type of pollution is indicated by high concentrations of heavy metals such as Hg, Pb, Mn, and Cu in water. Compared with the allowed TCVN 5942-A standard level of 0.05 mg/l, 71.4 percent of water samples collected from Tham Luong Canal and 33.3 percent from Tan Hoa Canal had higher Pb concentration. The highest Pb levels for Tham Luong and Tan Hoa Canals were 0.17 and 0.1 mg/l, respectively. However, Mn pollution was not observed. In some places such as canals outside the city and areas near Districts 4 and 8, traces of heavy metals were found also, but their concentrations were below the standard level, except Cu in Ben Da Canal, Hoc Mon town, which was 0.1 mg/l. Data collected at peak and base tides on the 5^{th} and 6^{th} of Jan. 1993 at Tham Luong and Tan Hoa Canals showed that Hg level in all water samples was higher than the TCVN 5942-A standard (0.001 mg/l), as well as TCVN 5942-B standard (0.002 mg/l) for 42.9-66.7 percent of the samples. At low tide, (H min), Hg level was 0.007 mg/l for the sample from the end of Tham Luong Canal and 0.01 mg/l for the sample from Hoa Binh Bridge in Tan Hoa Canal which were 3.5 and 5 times higher than TCVN 5942-B standard, respectively.

Heavy metal concentrations in water samples from 10 monitoring stations in the big rivers of HCM City taken from 1994 to 1995 were below the TCVN 5942-A standard. Thus, the rivers are not polluted by heavy metals. Heavy metal pollution, notably mercury, is concentrated in Tan Hoa and Tham Luong Canals within the city and a part of Hoc Mon District.

Oil Pollution

From 1994 to 1996, three oil spills occurred in Dong Nai and Long Tau Rivers of HCM City *(Table 14)*. The DO oil spilling incident by the ship Neptune Aries in Cat Lai Bay was very serious because a large amount of oil spilled out, and it happened in the area near the water supply source of HCM City in Dong Nai River. Survey data and results of oil analyses in water and sediment showed that the spread and accumulation of oil were very complicated. Oil contamination in the main stream was more serious than in Nha Be riverside.

Table 15 shows that oil content in water from all rivers and canals of HCM City was higher than the TCVN 5942-A standard level of 0 mg/l. In some areas, it was more than the TCVN 5942-B standard level (0.3 mg/l). In Hoa An and Ben Than, the water source was contaminated with oil and did not meet the standard for water supply.

In conclusion, among the seven types of surface water pollution in HCM City, organic pollution is the heaviest, followed by bacterial pollution (which has central points of contamination within the city) and oil pollution. Pesticide pollution is slight.

2.3.4 Sources of water pollution

Each of the seven types of surface water pollution in HCM City is due to different pollution sources or mixed sources. The main sources of surface water pollution in HCM City are:

1. Wastewater from industries, minor handicrafts shops, residential homes, and commercial services.
2. Human and domestic wastes from houses built over and near canals as well as from ships and boats.
3. Accumulated pollutants such as feces, garbage, sludge, soil, sand, and gravel washed out to the rivers and canals.
4. Pesticides and fertilizers from agricultural areas in Dong Nai basin flowing to the canals in HCM City.
5. Dust, smoke, and toxic gases in polluted air carried with the rain as well as eroded soil containing toxic substances.
6. Leached chemicals and oil spilled by ships resulting from accidents in waterway transportation.
7. Polluted sea water, as a result of oil exploitation in Vung Tau or accidents in waterway transportation.
8. Leftover feeds of sea product farming in rivers and canals.
9. Contaminated water in lakes, ponds, or lowland areas in the dry season, which is washed out by tide to rivers during the rainy season.
10. Leachate from solid waste dump sites of the city and suburban areas.

Table 14. Oil spilling incidents in rivers of HCMC, 1994-1996

No.	Characteristic	Humanity (Taiwan) & Transco-01 (Hai Phong, Vietnam)	Neptune Aries (Singapore)	Gemini (Singapore)
1	Time	9:00	13:30	11:15
2	Date	8 May 1994	3 Oct. 1994	27 Jan. 1996
3	Place	Tam Thon Hiep, Can Gio district	Cat Lai Port, Thu Duc district	Cat Lai Port, Thu Duc district
4	River	Long Tau	Dong Nai	Dong Nai
5	Reason	2 ships crashed	Crashing to the port bridge A1	Crashing to the port bridge A1
6	Oil types	FO	DO	crude, light
7	Spilling oil, t	130	1,680	32
8	Polluted areas, km^2	4	40	1

Table 15. Oil concentration in the river water in HCMC, 1995

River Station	Ben Than	Binh Phuoc	Nha Rong	An Hoa	Nha Be	Binh Dien	Tam That Hiep	Ly Nhon
		Sai Gon		Dong Nai	Nha Be	Cho Dem	Long Tau	Soai Rap
No. of samples	12	12	12	5	12	12	8	6
Max mg/l	0.72	0.6	0.008	0.48	0.8	2.4	0.56	0.65
Average mg/l	0.31	0.32	0.005	0.27	0.28	0.57	0.25	0.36

These pollution sources can be divided into two kinds:

1. Point source which refers to wastewater discharged from plants, factories, commercial centers or sewers of the city.
2. Non-point source which refers to pollutants coming from the upper part of Dong Nai - Sai Gon Rivers to HCM City, or from HCM City areas to the rivers and canals as well as from the rain.

Wastewater from Industries, Minor Handicraft Shops, Residential Houses, and Commercial Establishments

HCM City has five canal systems that directly receive wastewater from the city and its suburbs. The main canal is 60 km in length; tributaries are 100 km long. There are 95 main discharging points to rivers.

The Water and Sewerage Company reported that the total volume of discharged water into the canals is 461,291 m^3/day, of which 44,868.1 m^3/day (10%) come from industries and minor handicrafts, 405,582 m^3/day (88%) from domestic wastewater, and 10,931 m^3/day (2%) from hospitals and schools.

Domestic wastewater contains large amount of feces, urine, and garbage, from houses and toilets built over and near the canals, passing ships and boats, and toilets without septic tanks. This and wastewater from commercial establishments are the main sources of organic, bacterial, and nutrient pollution.

About 30-31 percent (130,174 m^3/day) of wastewater from domestic uses and commercial establisments is discharged into Doi-Tau Hu-Kenh Te and Nhieu Loc-Thi Nghe Canals; 16 percent (66,303 m^3/day) into Ben Nghe-Sai Gon Canals; 14 percent (58,520 m^3/day) into Tan Hoa-Lo Gom Canals; and 9 percent into Tham Luong-Ben Cat-Vam Thuat Canals. For wastewater from industries and minor handicrafts, 46 percent (20,454 m^3/day) is discharged into Tham Luong-Ben Cat-Vam Thuat Canals and 17 percent (7,830 m^3/day) into Tan Hoa - Lo Gom Canals.

Most of industrial factories and minor handicraft enterprises of HCM City have existed for more than 20 years; most have obsolete equipment and technology (50% of their machines were produced before 1985). Almost all of them do not have waste treatment system. Therefore, water and air pollution in HCM City is quite serious and a growing concern.

One characteristic that should be considered in the economic development of HCM City is the performance of the different industries. In 1995, the manufacturing industry accounted for 85.7 percent of the gross industrial product; it has a growth rate of 14.2 percent (that for the non-state sector is 22.2%). This industry consumes a large amount of water and its wastewater contains a lot of organic substances. Moreover, many of the non-state sector enterprises do not have wastewater treatment facilities. In HCM City, a "Black Book" has been published, listing 43 plants that cause heavy environmental pollution, particularly water pollution. These plants and medium- and small-scale enterprises cause water pollution mainly in the basin of Tan Hoa-Lo Gom, Tau Hu, Tham Luong Canals and Cai Spring in Thu Duc District. Besides the sources in HCM City, wastewater also comes from industrial estates in the following provinces: Dong Nai, Song Be, Ba Ria-Vung Tau such as Bien Hoa, Thuan An, Go Dau, Phu My, etc. Attention should be paid to wastewater from the Bien Hoa industrial estate, which is discharged into Dong Nai River at a point near the Hoa An Water Supply Station of HCM City, and from Go Dau area with VEDAN plant, which presently causes water pollution in Thi Vai River.

Rain water dissolves dusts and toxic gases in the air, forming acid rain. The quality of rain water in 1995 showed that acid rain occurs in Nha Be-Can Gio areas. Since, this is also a source of water pollution, this situation should be considered.

Domestic Waste

Wastes also come from houses built over canals and from passing ships and boats. Records of the House and Land Department in 1994 showed that there were 67,000 units of sub-standard houses occupying a total area of 200 ha within the city, and 24,000 units on 60 ha located near or over canals. A total of 300,000 people lived in these houses, which comprised 9.22 percent of the city population. At a disposal rate of 0.5 kg/ day/person everyday, canals receive 150 tons of garbage. Add to this the more than 500 passing ships and boats with a disposal rate of 1 kg/day/boat and about 400,000 people living near the canal, each day the canals receive about 1,000 tons of solid waste, composing 30 percent of the solid wastes of HCM City.

Likewise, non-biodegradable, solid waste, plastic waste especially plastic waste, is a concern. Since river waste collection services do not exist, plastic and other non-biodegrable wastes flow to the East Sea, contaminating it. Furthermore, many households grow water spinach in canals, which slows the flow of water and increases accumulation of pollutants. As a result of the uneven semidiurnal tide of the East Sea, sedimentation of alluvium and contaminated substances and accumulation of pollutants happen. As discussed above, water in some canals has BOD_5 concentrations higher than at discharging points in the canals. Moreover, wastewater from livestock breeding farms and organic humus in soil and water also contribute to the water pollution.

Water pollution in HCM City can be classified into four levels: low, medium, high, and very high. Water within the city is polluted at a very high degree. Hence, HCM City needs to invest in cleaning technology and in the construction of treatment plants for wastewater. It should also conduct research on the food and drink manufacturing industry.

Table 16. Projected volume of wastewater of industrial zones in HCMC (in 2000 to 2010)

No.	Name of Industrial Zone	Area			Wastewater Volume (1,000 m^3/day)		
		2000	2005	2010	2000	2005	2010
1	Hiep Phuoc- Nha Be	1000		2,000	35	35	70
2	Tan Tao - Binh Chanh	200			7	7	7
3	Tan Quy - Cu Chi	100		150	3.5	3.5	5.25
4	Cat Lai - Thu Duc	400		1,000	14	14	35
5	Bac Thu Duc	200		500	7	4	17.5
6	Phu My - Nha Be		100	150		3.5	5.25
7	An Ha - Binh Chanh		100	200		3.5	7
8	Vinh Loc - Binh Chanh		100	150		3.5	5.25
9	Tan Phu Trung - Cu Chi		200	500		7	17.5
10	Tay Bac - Cu Chi		200	100		7	10.5
11	Tan Thoi Thiep - Hoc Mon		300	500		10.5	17.5
12	Hitech Thu Duc		300	1,000		10.5	28
	Total	1,900	1,300	6,250	66.5	112	225.8

2.3.5 Food-foodstuff processing industry in Ho Chi Minh City

Between 1990 and 1992, the average growth rate of the food-foodstuff industry was 8 percent. The industry, which has various groups of commodities, is one of the largest industries in HCM City. The commodities can be divided into seven groups:

a. *Husking and processing of rice and cereal:* Total capacity is more than 1 million t/year, including wheat milling capacity of more than 240,000 t/year and cereal processing of 150,000 t/year. The main products are dry rice noodles, rice sheet, Chinese noodles, and cereal noodles. Almost all of these products are exportable. The husking factories cause air pollution because of the suspended dust as well as noise pollution. On the other hand, the processing of rice and cereal produces water pollution.

b. *Flour processing:* The flour processing capacity is 240,000 t/year. The factories cause air pollution.

c. *Processing of marine and animal products:* This entails freezing, cold preservation, and processing of meat, fish, cuttle fish, and shrimps. The factories use a lot of water and cause heavy pollution because of the by-products.

d. *Vegetable and fruit processing:* The prominent canned fruits for export are pineapple, mango, and rambutan. The factories use water to clean the fruits; they cause light water pollution.

e. *Alcohol, beer, and beverages:* The beer and beverage industry is developing rapidly. The total beer and beverage output in 1992 in HCMC reached more than 200 million liters. These factories are heavy users of water and cause heavy pollution.

f. *Milk and milk products:* This processing industry is concentrated mainly in HCMC and Bienhoa industrial zone. Thong Nhat Milk Enterprise has a capacity of 96 million cans/year; Truong Tho Enterprise, 75 million cans/year; and Dielac Milk Powder Enterprise, 7,500 cans/year.

HCMC also has processing industries for vegetable oil, spices, fish sauce, soyabean sauce, and sugar.

2.4 Can Tho

2.4.1 Industrial Profile

Can Tho Province is located in the central zone of Mekong Delta, 180 km southwest of Ho Chi Minh City, along the lovely Hau River which provides clean water for the inhabitants throughout the year. It has a tropical wet monsoon climate.

The province's total area is 2,968 km^2. The population size is 1,855,830, of which 957,661 are female. Population density is 625 persons/km^2. Cantho City is the biggest city in the province; it has 359,164 inhabitants. The rest of the population live in the six rural districts of the province. The average annual population growth rate is 1.94 percent. There are 842,168 workers, of which 47,907 are industrial workers; only about 7 percent are agricultural workers.

The industry is most developed in Cantho City, even if it is traditionally an agricultural city in existence for 120 years. After the city was established, the urban population began turning to handicraft and industrial jobs. To support the agricultural activities of 11 western provinces, Cantho City and other big communities in Mekong Delta developed rice husking factories and tool repair shops. In the early 1970s, the government established the Tranoc industrial zone. However, since there are now two big ferry boats between Saigon and Cantho, the zone is no longer considered attractive by investors because of the difficulty of transportating goods. Consequently, the Tranoc zone did not develop well.

2.4.2 Status of water pollution

Surface water pollution is present in Cantho City. In rural districts, surface water pollution is caused by use of agro-chemicals.

a. The River System of Cantho City

Cantho City has many rivers, all of them affected by Mekong River's hydrography. They can be divided into several subsystems, as follows:

1. Tranoc and northern canal system
2. Binhthuy and southwestern canal system
3. Cantho River and its canal system

There are also two shallow ponds: Ancu pond (6 ha) and Rachngong pond (24 ha). Total water surface of Cantho City is about 1,096 ha.

b. Surface Water Pollution

I. Surface water pollution comes from three sources:
   A. Wastewater and solid wastes from household and livestocks
   B. Untreated wastes from hospitals
   C. Industrial wastes, especially food processing wastes

II. The canal systems can also be classified according to organic pollution levels:
   A. Clean water system like Hau River, which has low BOD_5 level of 1 - 5mg/l
   B. Lightly polluted water system, with BOD_5 level of 5 - <15mg/l. Included are Binhthuy and Tranoc canals systems and Cantho River
   C. Heavily polluted canal system, with BOD level of >15mg/l. Included are Caikhe and Thamtuong canals

III. Caikhe and Thamtuong canals are contaminated mostly by household, handicraft, and animal wastes. The contamination of these canals, which are inside the city, has direct negative impacts on the public's health and city landscape. Thamtuong has BOD_5 level of about 30 mg/l and Caikhe, about 17 mg/l.

IV. Cantho canals have a high flow rate, therefore, they are less contaminated even though they are directly connected to Thamtuong and Caikhe canals.

V. Some firms located upstream of Hau River may cause contamination of the city's water supply source.

VI. According to a recent research of Cantho's DOSTE, the industrial organic contamination is only 10 percent of the household organic contamination. The research also showed that the canal system of Cantho City receives daily 30.9 tons of BOD_5; 4.6 tons of N, 0.57 tons of P, and 87.5 tons of SS. On the average, one square meter of surface water receives daily 2,800 mg BOD_5. Water pollution in the canal system though is highly seasonal. In October, BOD_5 of surface water is at its highest level. It is lowest in March and April.

If no proper measures will be adopted to solve the pollution problem in the next five years, 70 percent of the surface water is projected to be polluted by organic matters. If there will be no treatment of contaminated sources, all of Cantho City's canal systems would be heavily contaminated in the next 10 years.

Water pollution was monitored in 66 stations on 17 rivers and canals. Parameters such as pH, BOD, COD, DO, total nitrogen, total phosphorus, SS, turbidity, sulfate, coliform, microphyte, benthos, and benthic were observed. Monitoring was done four times in 1995 (in both rainy and dry seasons).

c. *Water Pollution in the Hau River System*

Hau River is one of the biggest rivers with a high flow rate in Vietnam. It is relatively slightly polluted. Its organic content varies from 4 to 8 mg/l; sometimes during the flooding season or in small canals and estuaries, the BOD level rises to 17-18 mg/l because of wastewater discharged from the industrial areas, residential areas, and from Cantho River. In the narrow canal and creeks such as Bong Vang Creek, Ong Tuong Canal, and Suc creek, BOD level is moderately high (15-30 mg/l); in some places it increases to 40 mg/l. Water in Big San Trang Creek is slightly polluted (BOD level of 8-12 mg/l). On the other hand, water in the Small San Trang Creek is moderately polluted (BOD level of 12-30 mg/l) because of the wastewater from the industrial processing zone.

The monitoring data in January 1996 showed that BOD levels Trom and Noc Creeks were relatively high (20-50 mg/l). These creeks receive domestic wastewater and agricultural runoff only, hence, continuous monitoring is needed.

The Cai Khe Creek is the most heavily polluted creek in the city, with BOD level of 20-50 mg/l, or sometimes as high as 70 mg/l.

Generally speaking, the level of water pollution depends on the pollution source, pollution load, and the ability of the receiving water body to assimilate waste. Water quality in the Hau River system depends mostly on the pollution load.

d. *Water Pollution in the Cantho River System*

The BOD level in Cantho River which passes the city's center, also depends on the pollution load. The flow rate of the river is high. The most polluted area is Cai Rang Bridge and the city's center, which is the most overpopulated area. BOD value in these points is as high as 20-30 mg/l. The river between these points is slightly polluted (BOD level of 8-12 mg/l). Organic content level in Bong Vang and Cai Son Creeks (small ones) changes from point to point, while BOD value varies from 10-15 mg/l to 40-50 mg/l at the joining point of Binh Thuy and Tra Noc Creeks.

The other big creeks are Cai Sau, Cai Doi, Cai Nai, and Cai Da. However, because they are interlaced, the water flow rate is low and the BOD value is high (12-15 mg/l at the point near Cantho River and 30-50 mg/l up to 70-80 mg/l at the point near Cai Sau creek). Cai Sau Creek (a big creek) is also polluted (BOD value is as high as 20-30 mg/l) because it receives polluted water from Cai Nai, Cai Doi, and Cai Da Creeks.

e. Seasonal Changes in Water Pollution

Owing to the hydrology of Cantho's river system, water pollution is influenced by seasonal changes. The heaviest pollution is observed in October due to floodings and high peak tide. Water with high organic content could not be quickly discharged into the sea, which in turn influences water quality of rivers and creeks. In November, the flood carries organic matter and agricultural runoff from upstream. Moreover, in the flooding season, the turbidity of water slows the photosynthetic process of microphytes, hence, reducing DO level and increasing pollution level.

Slight pollution is observed in January during the dry season and period of base tide because organic matter content from runoff is low. From March to June, BOD value increases since water flow is small compared with the amount of discharged wastewater. The start of the rainy season in June also influences water pollution because of storm water and runoff.

The BOD value corresponded with COD, TDS, and DO values in the 1995 monitoring data. This showed that organic pollutant is the most important pollution source.

2.4.3 Water pollution by industrial wastewater

Most industrial firms in Can Tho are located in the city center. Many plants such as beverage, liquor, and mechanic workshops are located inside the densely populated areas. In Tranoc, a food processing plant is near a fodder plant and the feather processing plant. Most of the plants discharge their wastewater into creeks, rivers or sewage without proper treatment. Results from water analyses showed high BOD values (from 120-300 mg/l to as high as 900-1200 mg/l in some industrial plants). Industrial wastewater amounts to 5,090 m^3 per day while total BOD reaches 3.13 t/day. Therefore, industrial wastewater is a big source of water pollution in rivers, canals, and creeks in Cantho City.

Although the BOD load from industrial wastewater accounts for only 10 percent of the pollution load, the industrial wastewater is hazardous to the environment as well as to people's health. It is possible that the lack of an effective monitoring system may have resulted in lower values obtained than the actual pollution level.

2.5 Danang

2.5.1 The environment of Danang City

Located in the central region of Vietnam, Danang City is 95.2 km^2 in area. Its population is 449,000 with a density of 4,716 persons/km^2. The natural population growth rate is 1.558 percent according to the "Environmental Impact Assessment of Danang City and Environmental Status of the Area." There is also significant immigration from rural areas. It is the political and socio-economic center of Quang Nam-Danang province and the central region. Owing to its strategic location, Danang has been recognized as the second urban center by the Prime Minister (Decision No. 219/TTg dated 5 October 1993). It has become a main economic hub of central Vietnam. Its GDP growth rate is 14.4 percent. Of its total area, 1,500 hectares are agricultural lands.

2.5.2 Environmental problems in Danang City

Most industrial plants, services, and health organizations discharge wastewater without any treatment into Han River. The "Environmental Impact Assessment of Danang City and Environmental Status of the Area" report showed that its BOD content exceeds the Vietnamese standard 1.4 to 4 times. Coliform content also exceeds the Vietnamese standard 14 to 160 times. Most wastewater samples had heavy metals such as mercury, which was 1.2 to 2.4 times higher than allowable. Heavy metal pollution comes from the industrial factories.

In the whole region, 80 percent of wastes are collected, mainly in the central area. In districts far from the city center, particularly those adjacent to the coastal banks, wastes collection is minimal. The wastes are discharged into the sea and rivers or are buried or burned. Most of the collected waste is brought at the Khanh Son dumping site. The present system, however, does not ensure safety because of dumpsite overloading. Further, the waste is not classified into industrial, hospital, and non-biodegradable wastes; and are all disposed of in the dumpsite. The open-air dumping causes serious pollution. Also the leachate from the dumpsite contributes to water pollution in the surrounding area.

The results of air quality analysis at the Khanh Son waste site showed that the dust content in the air exceeds the Vietnamese standard 13.9 to 46 times; SO_2 content exceeds it nearly 2 times; NH_3 content, 9 times; and H_2S content, 10 times. Similarly, Cyanide content exceeds the standard 13 times; BOD_5, 2.9 times; Phenol, 3.5 times; and coliform, 140 times. Analysis of the underground water quality in the ambient area of Khanh Son waste site also revealed that coliform content exceeds Vietnamese standard 4,600 times.

A special concern that has to be addressed is the establishment of factories and industrial enterprises without due consideration of the environmental aspects. The marine product processing area is being developed as a tourism zone. However, the bad odor of wastewater and the factories affects the tourist landscape. The An Don export processing zone (EPZ), which is adjacent to the coastal bank, is at present a well planned clean industry but it is not certain if it will remain a clean industry zone in the future.

2.5.3 Industrial overview

Among Danang's industries, the best developed are the food and foodstuff processing (including beer, beverage, and sea products), textile, and paper industry. Forty-six factories and enterprises have obsolete technology and equipment, which produce high waste load. These factories directly discharge wastewater and smoke into the environment. Most of them do not have an air pollution control system. The others have simple wastewater treatment systems, but they lack operators, therefore, the capacity to clean wastewater is limited.

The total annual volume of wastewater discharged by the above mentioned plants into the environment is 2,194,015 m^3/year (BOD level of 205.75 t/year, COD of 2,005.75 t/year, and SS of 549.38 t/year).

Almost all of the firms exceed the government standards for pollutants in industrial wastewater (BOD: 50mg/l; COD: 100mg/l; SS: 100mg/l). Some of the firms discharge a rather high wastewater load into the environment (e.g., one beer and beverage factory discharges 400 m^3 per day). Serious pollution is also caused by a sea product processing enterprise and a soft drinks company, among others.

3.0 LITERATURE REVIEW

3.1 Abatement Cost

In a study of "Water Pollution Abatement in the Tanning Industry" by Mendoza (1995), the abatement cost was calculated based on the wastewater treatment process for the tanning industry. The capital cost was calculated for small-, medium-, and large-size plants by four stages of the wastewater treatment process *(Figure 1)*. The maintenance and operating expenses (MOE) covered only the cost of electricity to operate the pumps and the labor cost. Hence, the abatement cost is the sum of annual depreciation of capital and the maintenance and operating expenses.

In Thailand, the abatement cost (about 47 Baht/kg BOD/year) was calculated using the average of capital costs for treatment facility construction per cubic meter used. This cost corresponded to the values used in Germany. The effluent charge in Thailand was estimated at 55 baht/kg BOD (Thailand Research Paper on Application of Economic Instrument for Effluent Control in Thailand).

In the experience of Southeast Asian countries, investments on wastewater treatment plants and pollution control make up 4-10 percent of the manufacturing plant cost (ESCAP, 1995).

The costs for the other industries are:

- Fertilizer: 2-2.5 percent of the project cost
- Sugar: US$670,000/1,000 kg of BOD/day
- Brewery and distillery: US$170/1,000 kg BOD/day
- Palm oil: US$8,330-47,500 or US$0.15-0.32/ton of fresh fruit/hr
- Fish processing: US$28,000 for aerated lagoon; US$88,000 for screening, flotation, and extended aeration; US$66,000 for screening, flotation, and aerated lagoon

In the Philippines, the initial and operating costs (in Philippine peso) for coconut oil mill are as follows:

WW Volume m^3/d	Initial Cost $/m^3/day$	Operating Cost
153	3,780	4.84
65	5,430	5.73
23	7,340	5.77
13	13,300	15.80

Initial and operating costs (in Philippine peso) for food/meat processing are:

WW Volume m^3/d	Initial Cost $/m^3/day$	Operating Cost
4,845	764	0.59
436	857	0.76
386	843	0.44
375	3,600	2.58
82	1,920	2.29
55	88	

However, other costs need to be considered to calculate the marginal abatement cost to remove 1 kg of BOD.

In their study of water pollution abatement, James and Murty (1996) estimated the costs based on survey data in India. A questionnaire-based survey was conducted and complemented by selected factory visits, in order to compile the data on influent and effluent quality as well as on costs and input prices.

The questionnaires were sent to large- and medium-sized firms that are considered highly-polluting as identified in the Water Act of 1977 and the Central Pollution Control Board. A sample size of 82 was used to estimate the aggregate marginal abatement cost function. Only two inputs were considered: capital and labor. Instead of viewing influent quality and effluent quality as separate variables, the ratio of influent to effluent quality was calculated in the cost function. Capital costs were converted into constant values despite different vintages. The price of capital was estimated and used to come up with annual estimates of the cost of capital. The price of capital was derived using a value-added approach and secondary data from the Annual Survey of Industries, assuming that the capital and labor invested in the effluent treatment plant were perfectly substitutable with those employed in the main plant.

The value added by the production plant is the turnover less the sum of material inputs used in production. This is also equivalent to the value added by the primary factors: labor and capital. Subtracting labor cost yields the value added due to capital alone. Dividing this by the relevant estimate of invested capital yields the rate of return on capital. Adding to this the rate of depreciation yields an estimate of the price of capital services.

Results of the study showed that although a full Translog specification, a truncated Translog specification, and a full

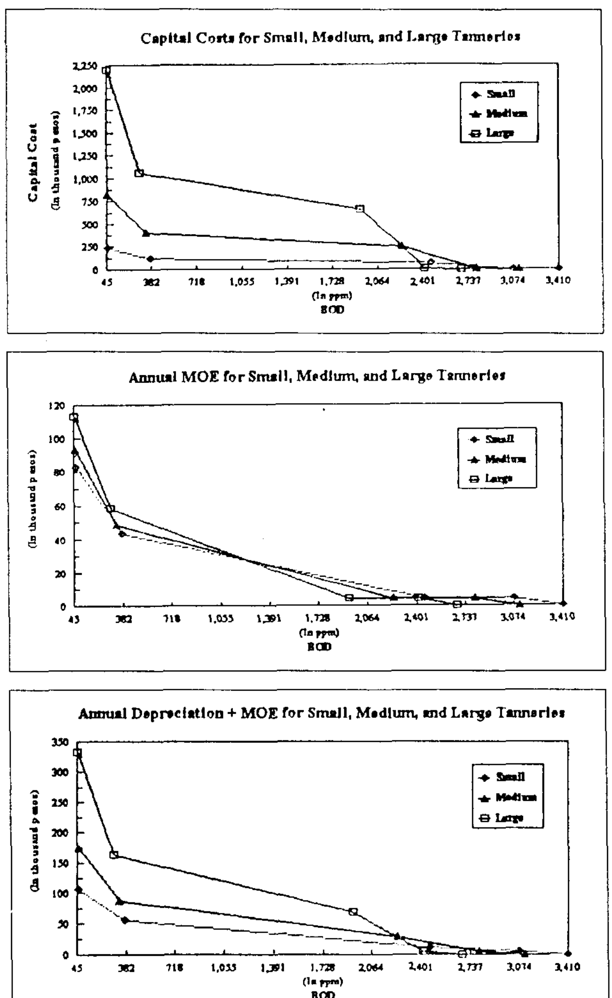


Figure 1. Comparison of abatement cost among different firm sizes

Cobb-Douglas specification of the total abatement cost function were tried, these were found to give a poor fit to the data. The cost function was estimated with the COD ratio without input prices, the BOD ratio and input prices, and an index which converted BOD ratios into COD ratios using fixed weights.

The four corresponding regression equations are detailed below while the results of these estimations are presented in Table 17.

Estimation 1:
$LogC = \alpha_O + \alpha_V logVOLUME + \alpha_C log\ (CODinf/CODeff) + \alpha_{WK} log\omega_K + \alpha_{WL} log\omega_L$

Estimation 2:
$LogC = \alpha_O + \alpha_V\ logVOLUME + \alpha_C log\ (CODinf/CODeff)$

Estimation 3:
$LogC = \alpha_O + \alpha_V logVOLUME + \alpha_B log\ (BODinf/BODeff)$

Estimation 4:
$LogC = \alpha_O + \alpha_V logVOLUME + \alpha_C log\ (COD_{ININF}/COD_{INEFF})$

where COD_{ININF} and COD_{INEFF} refer to the COD index of influent quality and effluent quality, respectively.

Using factory level data provided by China's National Environmental Protection Agency (NEPA) and the Tianjin Environmental Protection Bureau, Dasgupta et al. (1996) estimated the costs of water pollution abatement for the Chinese industry. Traditionally, abatement cost estimates have been based on plants' reported direct costs of installing and operating pollution control equipment. However, environmental economics has recognized that the direct abatement costs provide incomplete measure of the cost of pollution reduction. Hence, the abatement cost functions are dual to abatement function which relate inputs of capital, labor, energy, and materials to pollution reduction.

Table 17. Parameter estimates of total abatement cost function 1 to 4

	Estimation 1	Estimation 2	Estimation 3	Estimation 4
α_O	-1.5920	-5.044	4.8721	-5.0270
	(-0.980)	(-8.667)	(-9.012)	(-8.842)
α_V	-0.1115	-0.20289	0.47281	0.48397
	(-1.649)	(-2.536)	(13.630)	(13.726)
α_C	0.46108	0.49185	-	-0.21251
	(10.996)	(13.514)		(-2.586)
α_B	-	-	-0.18190	-
			(-2.352)	
α_{WK}	1.15710	-	-	-
	(6.564)			
α_{WL}	0.53402	-	-	-
	(2.871)			
R^2	0.7502	0.5674	0.5661	0.5689
Adjusted R^2	0.7372	0.5564	0.5551	0.5580

The figures in parentheses are heteroscedasticity-corrected t-statistics

To measure the costs of abatement, Dasgupta et al. (1996) used joint abatement cost functions that relate total costs to treatment volume and the simultaneous effect of reductions in suspended solids, chemical oxygen demand, biochemical oxygen demand, and other pollutants. Tests of alternative functional forms suggested that a simple (constant elasticity) model fits the data as well as a complex (translog) model does, permitting sophisticated policy experiments with relatively simple calculation. The results of the study suggested that the magnitudes are very large. They draw on equation to estimate marginal cost of abatement in annual dollars/ton by pollutants for plants in five sectors and three abatement size classes *(Table 18)*.

3.2 Effluent Charge

One important objective of this study was to review a number of alternative economic instruments that could be applied to address the problems of water pollution from industry in Vietnam. The study focused mainly on having a pollution charge system, that would be most suitable in the Vietnamese context. Many countries in the world, especially the OECD countries and several countries in the region (China, Korea, the Philippines, Thailand, Malaysia) apply pollution charge as an economic instrument for environmental improvement. Learning from other countries' experience, particularly regarding the formula used for industrial wastewater charge, is a significant advantage for the study.

a. Effluent Charge

Industries and households located in a particular basin are to pay a specific charge to a water authority based on a charge formula which normally includes a measure of the wastewater volume and various pollutants (e.g., BOD/COD, SS, heavy metals).

The effluent charge can be determined in various ways. The preferred one from an economic standpoint (i.e., the least distortion) would be to levy the charge directly on the measured effluent load. The more parameters enter into the determination of the charge, the more costly it becomes to calculate. Thus there is an advantage, at least initially, to focus on one or two priority pollutants (e.g., BOD/COD,

Table 18. Estimated marginal cost of abatement

	Rate of Abatement	Small	Medium	Large
Food Processing	0.10	0.86	0.05	0.02
	0.30	1.20	0.07	0.03
	0.60	2.53	0.15	0.07
	0.90	15.98	0.93	0.44
Textile	0.10	1.01	0.52	0.41
	0.30	1.41	0.72	0.57
	0.60	2.97	1.52	1.19
	0.90	18.76	9.60	7.54
Paper	0.10	0.26	0.13	0.06
	0.30	0.37	0.18	0.09
	0.60	0.77	0.38	0.18
	0.90	4.88	2.38	1.15

SS, perhaps a toxicity index). Strictly speaking, an effluent charge should be calculated to reflect the marginal damage cost of a particular pollutant, but in practice, damage cost functions are notoriously difficult to estimate. As an alternative, the charge may be set so as to achieve the target ambient quality standard. This may require adjustment of the charge, since the precise relationship between the charge rate and environmental quality is difficult to know.

b. Presumptive Charge

A charge could then be levied on the presumed pollution load or concentration according to a standard formula. All factories would be required to pay the full amount of the input charge unless they could demonstrate that their pollution levels are below the presumed ones.

c. Non-compliance Fees

As the name suggests, these charges (or fees) would be levied only on discharges that exceed mandated effluent standards, but it involves a degree of predictability, transparency, and automatically, which generally are not associated with fines and penalties. Thus, whereas with a system of fines a polluter may be able to mount a legal challenge to delay payment (or make a smaller side payment to avoid the actual fine), a non-compliance fee is not subject to the discretion of the regulatory agency or the fine collector. It would be payable according to a pre-announced fee schedule.

d. Production Charge

Another economic instrument that may be appropriate is a product charge. This is necessarily a second-best instrument, since it only indirectly targets the actual pollution that damages the environment or human health. The more closely linked the use of the particular product (whether in production or in consumption) is to the actual level of pollution, the more effective a product charge is likely to be. Certain toxic substances may be suitable candidates for product charges.

4.0 RESEARCH DESIGN AND METHODOLOGY

4.1 Data Collection and Data Quality

One hundred food processing firms in Ho Chi Minh City, Hanoi, Danang, and Cantho were studied on the feasibility of an Industrial Effluent Charge. The sample size was 12 in Can Tho, 15 in Da Nang, 30 in Hanoi, and 44 in Ho Chi Minh City. Three firms from Hanoi and 11 firms from Ho Chi Minh City were excluded due to incomplete information. The sample size was 93 for BOD value and 87 for total abatement cost (TAC) calculation. Firms with different sizes (small, medium, large), with/without wastewater treatment facilities, were included in the sample. Firm size was determined by annual discharged wastewater volume (Q_{WW}). Small firms made up 74.7 percent of the sample. There were only two large firms. Therefore, small firm bias could not be avoided.

To come up with the marginal abatement cost (MAC) (demand curve for environmental disposal service), a number of firms with wastewater treatment facilities was an essential part of the sample. Unfortunately, there were only a few firms with wastewater treatment plants. Therefore, related information from Southeast Asian countries (Thailand, Philippines, and Malaysia) was used for this purpose. This information from literature was used as source of function transfer to estimate the MAC curve and pollution charge level. Primary and secondary data were both collected. Primary data were collected by visiting the sample firms, through survey, and two wastewater samplings. Basic information such as input and output of production as well as types and volumes of pollutants, method of treatment, pollution regulation, and pollution control was obtained from survey questionnaires. Environmental Impact Assessment (EIA) reports carried out by environmental agencies were unavailable for the study.

It was difficult to get accurate data using only one or two water samples. The sampling site in the firms also affected the wastewater parameters since wastewater from different stages of the production line had different qualities. Amount of water consumption and wastewater flow rate reported by the firms were also erroneous since many firms were using water from their own source (deep well and ground water pump); consumption was not based on metered volume of water. Moreover, since wastewater was discharged without control, it was also difficult to accurately estimate its value.

4.2 Methodologies

4.2.1 Regression analysis of variance in environmental performance

The regression specification included two groups of independent variables, one relating to firm characteristics (e.g., ownership, revenue, profitability, technology) and another relating to external influences on the firm's environmental performance (e.g., population density, environmental policy enforcement). The regression coefficient of each variable indicates the impact or the elasticity of each independent variable to the total BOD load (i.e., the degree of pollution).

4.2.2 Estimation of abatement costs and pollution charge

Since only a few firms monitored their effluent quality and almost no information on the small firms regarding this aspect was available, two water samples were collected and analyzed for each firm surveyed.

The survey was conducted for firms with available wastewater quality data. Other data on firm characteristics (such as ownership, branch, location, age of equipment, financial condition) were used to identify variables most closely linked to environmental performance. The survey encountered several problems. Many small firms did not have any information on environmental pollution control. Some firms were not forthcoming with actual data regarding their production process and financial condition. In some cases, questions were misunderstood, resulting in missing information or wrong data. Data problems occurred especially in three areas: BOD analysis of water samples, information on wastewater treatment facilities/ equipment, and wastewater flow rate as well as water consumption. At times, those taking water samples did not have the opportunity to select the wastewater sampling point but were directed by the company as to where to take the samples.

There were three components of the analysis:

a. Relationship between firm characteristics and environmental performance

b. Effect of different levels of pollution charge on abatement levels and on firms' economic performance

c. Evaluation of a feasible pollution charge scheme, considering environmental effectiveness, cost-effectiveness, equity, administrative feasibility, and political acceptability

5.0 RESEARCH RESULTS

5.1 The Environmental Performance of Food Processing Firms

5.1.1 Analysis of variance in performance

The most important parameter in monitoring wastewater from food processing industry is organic pollution which is indicated by BOD. The BOD values in the effluent of almost all the examined plants were higher than the value allowed by the Vietnamese Standard. Figure 2 shows the frequency distribution of firms by BOD level. There were 18 firms with BOD value of 100-150 mg/l and nine firms with BOD value of 150-200 mg/l. Only two firms had BOD values below Standard A; two firms had very high BOD values (nearly 1000 mg/l) while 28 firms had BOD values above 300 mg/l.

Only two firms out of the 93 firms sampled comply with standard A; these two firms belonged to the beverage sector. They had installed a wastewater treatment system costing US$1,400,000, which worked very effectively.

Seven firms complied with standard B (five in Ho Chi Minh City and two in Hanoi). On the other hand, 25 firms complied with standard C (13 in Ho Chi Minh City, 3 in Hanoi, 4 in Can Tho, and 4 in Da Nang). Figure 3 shows the percentage of firms complying with the standards. Table 19 shows some characteristics of complying and seriously non-complying firms (i.e., firms with BOD values more than 300 mg/l).

State-owned firms were far more frequently represented in the seriously non-complying group than in the complying group. Both groups had similar percentage (32%) of firms with environmental impact assessment report. On the other hand, 14 seriously non-complying firms reported treating their water before discharging them. However, their treatment was only primary such as filtration to separate solid waste or by-product from wastewater. This method of treatment cannot reduce significantly the BOD level. Only five of the 25 complying firms reported having wastewater treatment facilities; only one of the five has a modern wastewater treatment plant (HCM15). It could be due to several reasons. One, the BOD level of those firms may be unsuitable. Two, there may be technical problems such as improper sampling method and analytical error. Three, difference in sampling site or sampling time can yield varying BOD values. Four, formulation of the questions in the survey questionnaire could also lead to the error. Fifteen out of 27 firms in Hanoi, three out of 12 in Cantho, and eight out of 15 in Danang had primary wastewater treatment. However, only five out of 44 firms in Ho Chi Minh City answered positively to this question. It may be that the firms in Ho Chi Minh City interpreted the question as referring to a wastewater treatment plant instead of wastewater treatment equipment.

The figures about firms with existing environmental plans or environmental specialists seemed contrary to expectation. They were higher for seriously non-complying firms than for complying firms. However, it was possible that the non-complying firms were aware of environmental problems and environmental policy, and were planning to reduce pollution in the near future. The number of firms receiving complaints from surrounding communities or having to pay compensation to people living there was

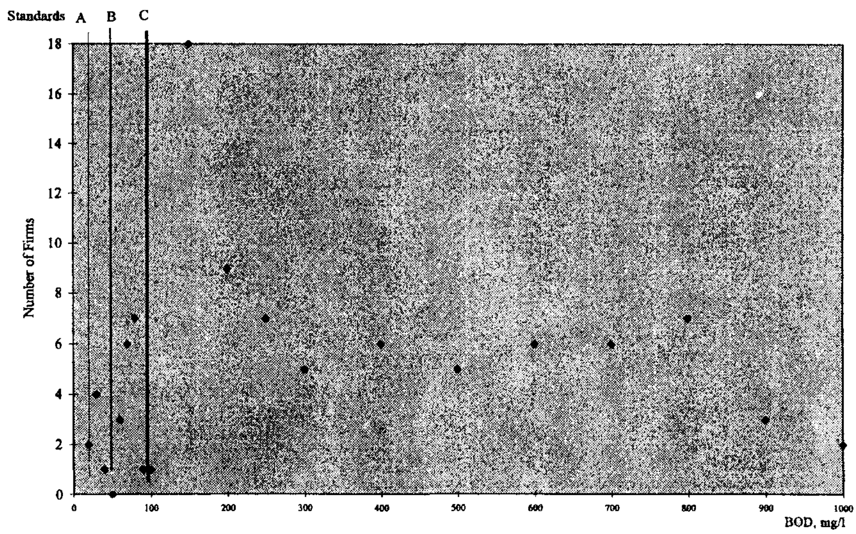
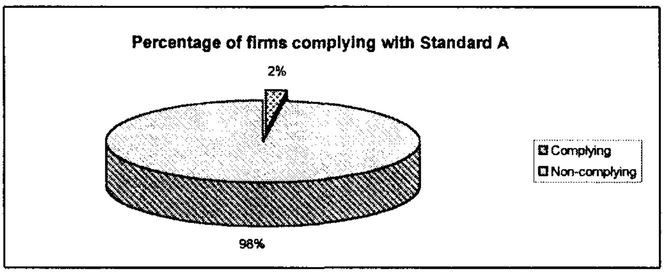
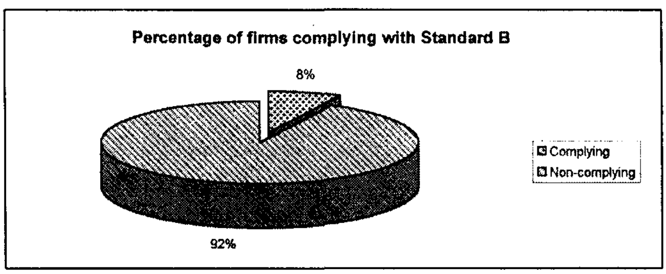


Figure 2. Distribution of firms with biochemical oxygen demand





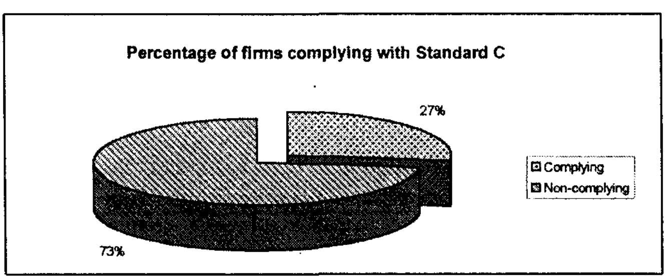


Figure 3. Percentage of firms in sample complying with standard

Table 19. Difference in profile between complying and seriously non-complying firms (Standard C BOD = 100 mg/l)

Characteristic	Complying Firms		Seriously Non-complying Firm*	
	Number	Percentage	Number	Percentage
Large size	1	4	1	3.8
Medium size	2	8	10	38.5
Small size	22	88	15	58.7
State	7	28	17	65.4
Joint-Venture	4	16	1	3.8
Private	14	56	8	31.8
With Wastewater Treatment	5	20	14	53.8
With EIA	8	32	8	31.8
Draft Environmental Plan	9	36	12	46.0
Environmental Person	4	16	9	34.6
Received complaint from surrounding community or paid compensation	1	4	12	46.0

Note: * Serious non-compliance is defined as BOD>300 mg/l

consistent with expectation. That is, about 46 percent of seriously non-complying firms received complaints for environmental pollution while only 4 percent of complying firms did so.

5.1.2 Regression analysis

One of the most important objectives of this study was to identify characteristics of the firms that are strongly associated with environmental performance. Regression analysis was used for this purpose. The following log equation was used to analyze this relationship.

$$\ln BODL = \alpha_0 + \alpha_1 \ln REV + \alpha_2 D_{BV} + \alpha_3 D_{ST} + \alpha 4 \ln PROF2 + \alpha_5 \ln POP + \alpha_6 \ln REWK + \alpha_7 D_{EIA} + \alpha_8 D_{CONF} + \alpha_9 D_{DAIRY}$$

where BODL = Total annual BOD load (t/year)

REV = Total annual revenue (million VND)

PROF2 = Number of profitable years in the last five years

POP = Population density of the city (person/km^2)

REWK = Revenue per worker (mill.VND)

D = Dummy variables

ST = State

BV = Beverages

CONF = Confectionery

DAIRY = Dairy

EIA = Environmental Impact Assessment

The result of the regression analysis was:

$$
\begin{aligned}
LnBODL = {} & 3.9971 + 0.8202\,Ln\,REV + 1.3717\,D_{BV} + 0.9343\,D_{ST} \\
& (2.0344^{*})\quad (5.7733^{*})\qquad (2.1961^{*})\qquad (1.7237^{**}) \\
& + 0.4958\,Ln\,PROF2 - 0.4445\,Ln\,POP - 0.4867\,Ln\,REWK - 0.828\,D_{EIA} \\
& (3.4207^{*})\qquad (1.7190^{**})\qquad (2.3967^{*})\qquad (1.7587^{**}) \\
& + 1.1681\,D_{CONF} + 0.7270\,D_{DAIRY} \\
& (1.3302)\qquad (0.7310)
\end{aligned}
$$

Adj R^2: 0.4908

Note: Values in parentheses are t - value

** significant at 5 % level

* significant at 10 % level

The regression coefficient of each logged variable indicates an elasticity or sensitivity of the independent variable (total BOD load) with respect to changes in that independent variable. The degree of fitness to the data was quite good (adjusted R^2 = 0.49).

Nearly all the parameters had the expected sign and a moderate to high level of statistical significance, except for sectoral dummy variables for confectionery and dairy. A 10 percent increase in revenue is associated with an 8.2 percent increase in total BOD load. A 10 percent increase in the number of profitable year will result in a 4.96 percent increase in BOD load. A 10 percent increase in population density will reduce the level of pollution by 4.45 percent. A 10 percent increase in revenue per worker will reduce the pollution level by 4.87 percent.

The results of regression analysis suggest that both groups of factors referred to above (internal and external to the firm) can explain the differences in the firms' environmental performance. With respect to the first group of factors, the sign of "revenue" independent was positive, indicating that the more goods and services the firm produces, the more pollution it creates. In general, the "positive relationship" between quantity of products and pollution produced was evident.

It was noted that pollution load had a lower rate of increase than that of output, which may be indicative of the economies of scale in pollution reduction control. The positive sign of "profitable years" was more difficult to interpret. It seems plausible that the more profitable the firm, the greater its financial capacity to invest in treatment facility and, therefore, the lower the BOD load should be.

Some sectoral dummy and ownership variables were also included in the equation on the hypothesis that sector and ownership effects are significant indicators of the environmental performance of the firms. The regression result confirmed that some of these effects (such as beverage firms, state-owned firms) remained significant. Among the selected firms, the most polluted sector was beverages. The sign of "state ownership" was positive and highly significant, reflecting the fact that state-owned enterprises are often highly inefficient.

The second group of factors consisted of environmental indicators. The population density information of the different cities reflected the degree of exposure to pollution in each place and, therefore, the expected damage costs. Where those costs were high, it was hypothesized that pressures for strict environmental enforcement will be greater. The sign of the dummy variable "EIA" was negative, which indicates that environmental performance of the firm is strongly affected by control and regulation of authorized agency. The stricter the enforcement imposed on the firms, the less would be the environmental pollution.

5.2 Estimating Abatement Cost and Pollution Charge

5.2.1 Estimation of abatement cost for sampled food processing firms

Owing to lack of data, abatement cost could be estimated for some food processing firms only *(Table 20)*. The calculated data showed that the cost of BOD reduction varied from firm to firm and from sector to sector. It also depended on wastewater treatment equipment and process. These data were much higher than the Chinese data. Therefore, the application of Chinese function as "benefit transfer" was found suitable for this study in terms of estimating the marginal abatement cost for pollution control.

5.2.3 Calculation of total abatement cost (TAC)

As mentioned above, very few firms had installed wastewater treatment facilities. Consequently, the study obtained only a few data on abatement cost for the food processing industry in Vietnam. EIA reports for plants or projects were also not available. Therefore, the study opted to apply the function from a study by Dasgupta, et al. (1996) on estimation of costs of water pollution abatement for the Chinese industry. The MAC was calculated from the rate of Chinese data but corrected using abatement cost for Vietnamese firms. The following MAC rates were applied to calculate the cost in VND of 1 ton of BOD reduction.

Table 20. Estimation of abatement cost for some food processing firms in Vietnam

No.	Parameter	Unit	VBL (Heineken)	Seafood (Cantho)	Seafood (Danang)
1	Sector		Beer	Seafood	Seafood
2	Treatment process		Activated Sludge	Aerobic	Activated Sludge
3	Capacity	m^3/day	2,515 (Large)	300 (Medium)	100 (Small)
4	BOD influent	mg/l	950	550	450
6	BOD effluent	mg/l	20	50	50
7	Capital cost	Mil VND	15,400	300	225
8	BOD reduction	t/year	888	43.8	16.425
9	Salary	Mil VND /month	6.6	1.2	0.6
10	Electricity	Mil VND /month	55.44	10.08	5
11	Capital cost/year	Mil VND	770	15	11.25
12	O+M cost/year	Mil VND	744.48	135.360	78.45
13	Cost of treatment/year	Mil VND	1,514.48	150.36	89.7
14	Cost of treatment/m^3 WW	VND/m3	1,650	1,373	2,149
15	Price of BOD reduction	VND/t BOD	1,705,000	3,433,000	4,776,000

The following calculations were done to analyze the TAC and charge.

a. Abatement rate or BOD reduction rate:
$A\text{-}R\ (\%) = (BOD_i - BOD_{std}) / BOD_i \times 100\%$

b. Classification of firms by annual wastewater volume:
$Q_{WW} < 100.000\ m^3 \Rightarrow$ Small (S)
$100.000\ m^3 < Q_{WW} < 500.000\ m^3 \Rightarrow$ Medium (M)
$Q_{WW} > 500.000\ m^3 \Rightarrow$ Large (L)

c. BOD Load (BODL)
$BODL = BOD\ (mg/l) \times Q_{WW}\ (m^3)/1000000$
$= BODL\ (T/year)$

d. Total Abatement Cost (TAC) which corresponds to 10 percent, 30 percent, 60 percent, and > 60 percent BOD reduction using rates given in Table 21

e. Percentage ratio of TAC to revenue

The distribution of firms by abatement rate (or BOD reduction rate) is shown in Figure 4. Figure 5 shows the corresponding average abatement cost to revenue ratio. Appendix Table 1 shows the abatement rate of firms. TAC and the percentage of TAC to revenue of the firms not complying with standard C are presented in Appendix Table 2. Applying Chinese abatement functions provided a rough approximation of the costs to the firms in the study's sample.

Another caveat concerns the measure of BOD concentration of the sampled firms' wastewater. Many BOD values seemed low when compared with data from the food processing industry of the other countries. Hence, before applying a specific charge, data quality needs to be improved. Ideally, as more Vietnamese firms install their own treatment plants in the future, a local abatement cost function could be estimated.

5.2.4 Estimated charge rate to achieve compliance

The conceptual framework of the study followed the Polluter Pays Principle (PPP), which requires the polluting firm to pay the full cost to reduce pollution to the permitted levels to protect the environment from the pollution resulting from its activities. The appropriate emission charge to achieve 100 percent compliance with the Vietnamese class C standard is set at the marginal abatement cost (MAC) of meeting the effluent standard for the firm with the highest MAC.

The MAC was calculated for four levels of abatement rate and three sizes of firm, based on the wastewater volume (large, medium, small). Table 22 shows the distribution of firms by abatement rate and size. An important point to note is that the small factories accounted for about 77 percent of the selected polluting firms.

Table 21. Estimation of MAC for the food processing industry (million VND)

BOD Rate of Reduction	Small Firm	Medium Firm	Big Firm
0-10%	0.53	0.38	0.15
10-30%	0.76	0.55	0.24
30-60%	1.63	1.17	0.56
>60%	10.23	7.34	3.55

Source: Calculated based on Table 20 and rate of MAC in Table 18 of Dasgupta et al. 1996

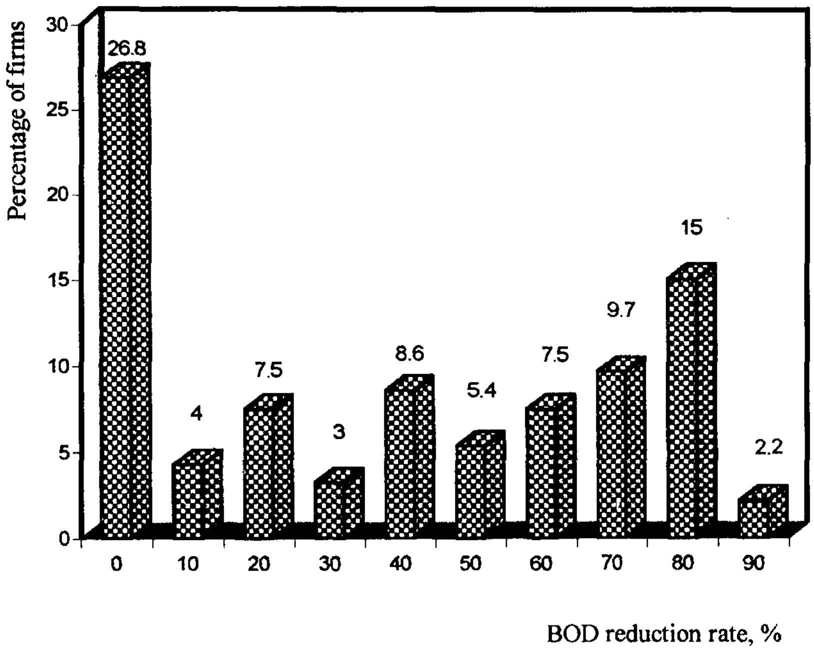


Figure 4. Distribution of firms with BOD reduction rate

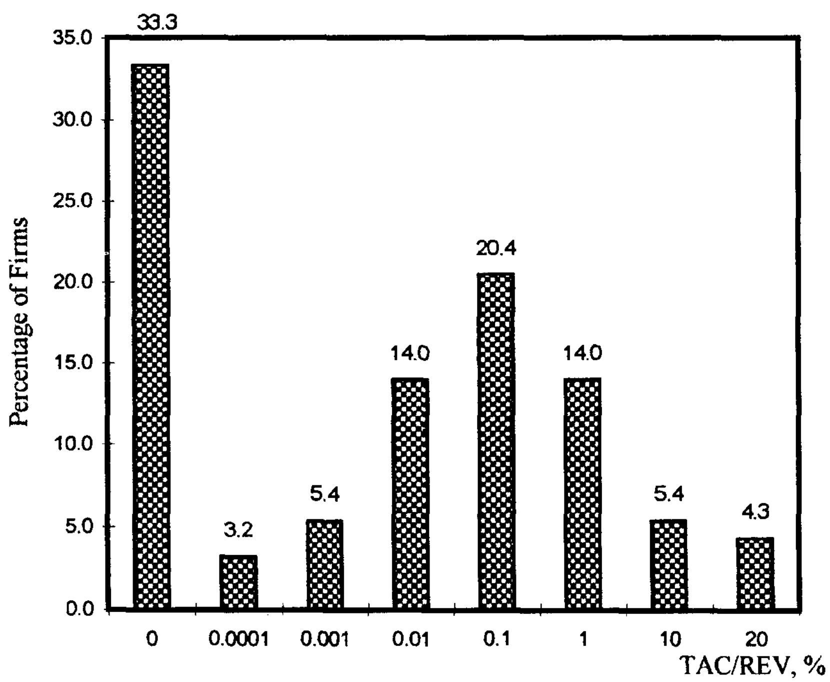


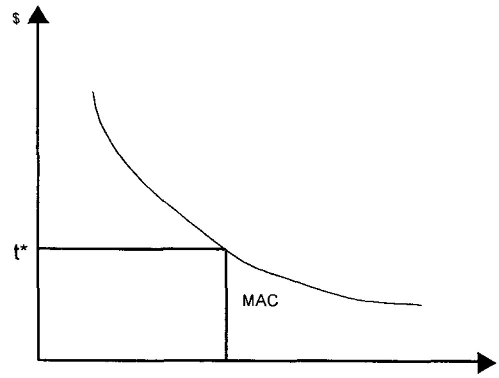
Figure 5. Average TAC/REV ratio

The data showed that the marginal costs varied across firms. At the same abatement rate, the MAC ratio between small and large firms can be as high as 43:1 or 40:1 for 10 percent and 30 percent abatement, respectively. Of the 100 surveyed factories from four different cities, 75 factories had BOD concentration that exceeded the standard (class C). However, due to unavailability of data from some firms, only 62 firms were included in the subsequent analysis. The average abatement rate of the firms was 74.8 percent, which was equivalent to 1,412.124 tons of BOD reduction per year.

Based on Appendix Table 2 the total calculated abatement cost was 3,125.532 million VND. As mentioned earlier, the MAC should serve as basis for setting the charge formula for Vietnam. The charge rate must be set high enough to change the behavior of the marginal polluter in order to reduce pollution.

Table 22. Distribution of firms at different levels of abatement

Abatement Rate	Small	Medium	Large
0 - 10%	4		
11% -30%	7	1	
31% - 60%	18	1	
61% - 90%	17	11	1
> 90%	2		
Σ	48	13	1
Total firms		62	



Where Q* : permitted level of omissions (defined by effluent standard)
t* : emission charge to achieve compliance with standard
MAC : marginal abatement cost of polluting firm
Q* : Q (emissions)

Figure 6. The emission charge

Considering all of these, a schedule of charges to achieve the targeted compliance level was used to determine the most appropriate charge level for Vietnam *(Table 23)*. The charge rate, which induces the overall average abatement rate of 75 percent, would be 5.1 million VND/t of BOD load beyond the standard. A comparison was made (see Figure 7) between the firms' abatement costs under a pollution charge at that rate and their total

Table 23. Summary statistics for the overall abatement rate

Average A-R	74.8%
Total BOD Reduction	1,412 Ton
TAC	3,125.532 Mill VND
Average AC/Rev	1.111 %
Average AC/Rev (Small)	0.872 %
Average AC/Rev (Medium)	1.982 %
Average AC/Rev (Large)	0.222 %

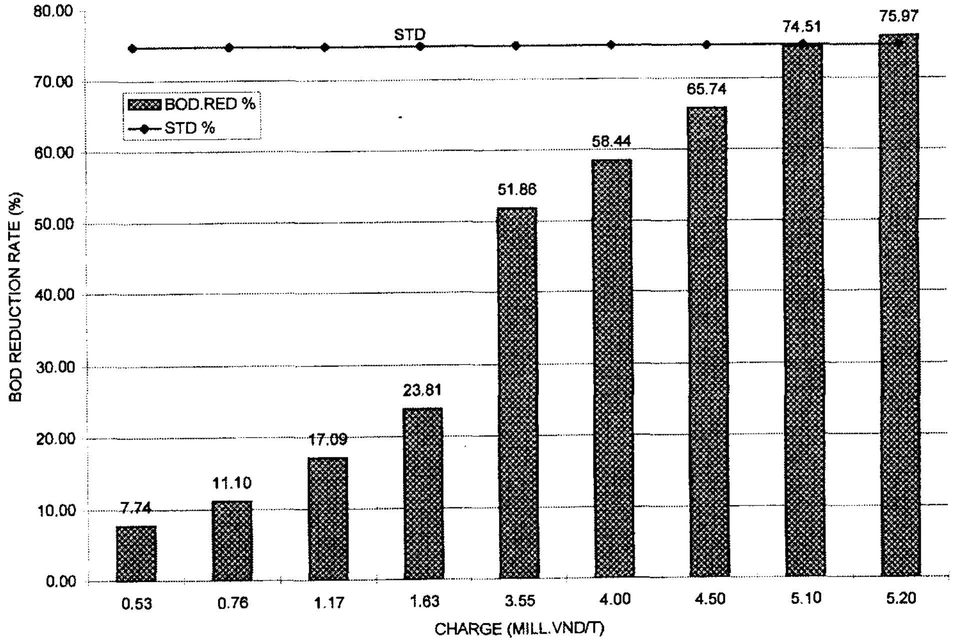


Figure 7. BOD reduction under different charge rates

Table 24. BOD reduction under different charge rates

Charge	Average Abatement Rate	Actual BOD Reduction	Cost	Rev	Cost/Rev
VND/T	%	%	Million VND	Million VND	%
0.53	74.8	7.74	748.36	1960442	0.0382
0.76	74.8	11.10	1073.12	1960442	0.0547
1.17	74.8	17.09	1652.04	1960442	0.0843
1.63	74.8	23.81	2301.56	1960442	0.1174
3.55	74.8	51.86	5012.60	1960442	0.2557
4.00	74.8	58.44	5648.00	1960442	0.2881
4.50	74.8	65.74	6354.00	1960442	0.3241
5.10	74.8	74.51	7201.20	1960442	0.3673
5.20	74.8	75.97	7342.40	1960442	0.3745
5.50	74.8	80.35	7766.00	1960442	0.3961

revenues. On the average, the firms' abatement costs were slightly more than 1.11 percent of the total revenue.

As mentioned earlier, the effluent charge would be set at the level that would achieve 100 percent compliance with class C standard. The charge level was determined by the MAC of the small firms, which tended to be the highest cost abatement due to significant economies of scale in treatment technologies *(Table 24)*.

The charge rate of 5.1 million VND/t of BOD load is well above the standard needed to achieve 100 percent compliance by small, medium, and large firms. The charge would be fair to firms since the TAC/REV ratio was just about 1 percent. For firms with TAC/REV ratio above 10 percent, it would be more difficult to abate pollution either by installation of wastewater treatment facilities or paying the charge. These were the heavily polluted firms or ineffective firms. They may need to be relocated or renovated or closed down in the near future. The feasibility of the charge and the charging scheme are shown in the following section.

6.0 ELEMENTS OF AN EFFLUENT CHARGE SCHEME

6.1 Feasibility of an Alternative Charge

The effluent charge could help the firms have a better environmental pollution control. If the charge is much lower than the abatement cost, firms would not install the pollution control system; then the charge would not play an important role in environmental management activities. On the other hand, if the charge is big enough to help finance pollution control activities, the firms may not able to afford it.

The monitoring system in Vietnam has been so poorly invested that it is ineffective. Technical standards set by technological experts were copied from other countries. According to economists, marginal abatement costs differ among sources hence, uniform standards cannot be cost-effective. Conversely, firms are fined only for pollution above standards, which does not support the "polluter pays principle." The other options that could be applied are the charge on pollutant load, presumptive charge, and product charge.

a. Charge on pollution load standard

The charge on pollution load would be more suitable and equitable. The USA, Indonesia, and other countries have set the standard for pollution load. The pollution load is the total pollutants (result of wastewater volume multiplied by pollutant's concentration), hence it fairly reflects the pollution that a firm discharges into the environment. Setting the BOD load standard for each sector of the food processing industry would lead the firms to reduce the total amount of pollutants but not the concentration. However, it is more difficult to monitor the BOD load so that it complies with the standard. More information is needed to set the standard such as how many cubic meters of wastewater the firm discharges per one ton of product and the concentration of the pollutant. The monitoring system has to work properly and effectively to provide such information.

b. Presumptive charge on proxy for pollution (material, water consumption, wastewater flow rate, volume of production)

A charge could be levied on the presumed pollution load or concentration according to a standard formula. All factories would be required to pay the full amount of the input charge unless they could demonstrate that their pollution levels are below the presumed ones. The presumptive charge would count the material consumption, water consumption, energy consumption as well as technology of the production line. It is also more complicated to calculate and monitor. Regarding water consumption, it was not easy to get the actual volume since many firms used ground water from wells. Only metered water consumption can be reported accurately. Consumption also varied between firms and the right data were difficult to get from the firms' report. This means that the monitoring system will need more information on the technology and technical parameters of the production line.

c. *Product charge*

Another economic instrument that may be appropriate is the product charge. This is necessarily a second-best instrument since it only indirectly targets the actual pollution that damages the environment or human health. The more closely linked the use of the particular product (whether in production or in consumption) is to the actual level of pollution, the more effective a product charge is likely to be. Certain toxic substances may be suitable candidates for product charges. The product charge could be applied to the food processing industry such as charge on beverage, seafood, and beer.

The product charge seems easy to calculate and may be included in tax, a part of which would be for environmental management. However, tax on containers may be suitable for solid waste reduction but not water pollution. On the other hand, the tax on some productions is quite high at present (e.g., 50% for beer or liquor), which makes environmental tax more difficult to apply. A practicable alternative would be to allocate some part of production tax to environmental management and pollution control purposes.

6.2 Policy Recommendations

6.2.1 Application of the effluent charge

As mentioned above, most of the wastewater is not properly treated. The wastewater pollutes the water bodies in Hanoi, Ho Chi Minh City, Danang, and Cantho, thus, affecting the environment and the people's health. The main causes of water pollution (See Section 2) include the incompleteness of laws and policy system on environmental management. The lack of integration between economic development and drainage system aggravates the pollution problem.

On the other hand, overpopulation and rapid urbanization apparently multiply the pollution load. The budget shortage for maintaining and developing the degraded drainage system leaves the problem unresolved. Theoretical and practical experiences from other countries showed that applying economic instruments in pollution control could highly eliminate the above mentioned causes. It is suitable to apply economic instruments (i.e., effluent charge) for effective water pollution control. Practically, effluent charge is considered as a pollution cost that polluters discharging pollutants have to pay as compensation for the damage they cause on the surrounding environment and people living in it.

The analysis of pollution charges in this study focused on the food processing industry although a charge scheme could be designed for any or all industries. In selecting the appropriate charge rate, however, abatement costs have to be analyzed for those other industries. On the other hand, a pollution charge program for water pollution control could be designed for other sectors of industry. It is broken down to three periods. These periods are differentiated by the complexity of charge or fee and the various rates as well as the larger areas of polluters that the program covers. The advantages of the method are:

1. The charge will be applied to some enterprises or sectors for testing, then it could be revised and applied to others.

2. The periods for applying pollution charge should be sufficiently long for enterprises to become acquainted with the economic instruments and environmental aims.

3. It could reduce the costs of mistakes occurring when applying new environmental policy.

4. It also gives time for environmental management agencies and enterprises to improve their monitoring systems to assess the pollution level and the impacts on economy, life, environment and society. Therefore, a more equitable perception for applying the pollution charge to enterprises and the whole society could be adapted.

A. The First Period (2 years)

Since pollution charge and other economic instruments have not been applied in Vietnam yet, the first two years are considered as a testing period. This is to find out the advantages and disadvantages of the program in order to adjust and improve it later. The program must be simple and flexible (it could change in time) so that it can be easily applied. On the other hand, the main purpose of the charge in this period is to raise budget funds; changing behavior of the polluters is a secondary objective.

Designing the pollution charge scheme relies on the environmental standards but it is a combined system between economic instrument and command and control strategy. The program also emphasizes the "allowable limit" for pollutants, and the charge rate depends on the pollution load of firms. However, due to the constraint of the monitoring system, the charge scheme would only focus on some typical pollutants (e.g., BOD). Setting the pollution charge scheme based on pollution load would not be complicated since it will be applied to the point source of pollution.

The effluent charge would be initially applied to large- and medium-scale industrial plants which cause heavy pollution of surface water. The monitoring system would be useful for firms as well as for the authority in determining the charge. The following procedures should be applied in order to simplify the effluent charge collection:

1. Application of the pollution charge (i.e., the charge the polluters have to pay to discharge their pollutants into the water bodies).

2. The charge rate is flat for the unit of pollutants (e.g., a ton of BOD) for all enterprises.

3. Only those exceeding the standard pollution would be charged. Since this is the first period, the standard required for all firms will be standard C.

It should be noted that the effluent charge could be collected together with water user's charge, but separately included in the water bill written "water quality improvement fee." This will improve the environmental awareness of industrial plants (or polluters) so that they will protect their surrounding environment. Furthermore, the financial agencies could use this charge to upgrade the drainage system and improve water quality in the city.

Nowadays, 5 percent of the water bill is used for wastewater treatment, pollution monitoring and control. This is actually the user's charge for using the drainage system and wastewater treatment facilities. However, the charge is too low to generate significant revenues for environmental management. It has never been referred to as a user's charge for wastewater service. Consequently, the incentive effect of the charge has been reduced. This charge had not been levied on firms using groundwater from their own pumps. Therefore, in one or two years, the following activities are needed:

1. Separate the user's charge from water consumption cost in the water bill. The charge should be referred to pollution charge for wastewater. To ensure that the charge system would be simple and understandable, the charge rate should be fixed, calculated based on BOD concentration in excess of standard and water consumption, and, if necessary, estimated from product output.

2. Collect the charges and use as funding source for wastewater control, monitoring, and treatment services.

After the first two years of the above mentioned activities, the pollution charge program could contribute significantly to the environmental program. Its contributions include:

1. Providing additional funds for the budget on investment and expense in environmental protection such as wastewater treatment in some heavily polluted sites or dredging sewage and drainage system.

2. Introducing to the public the "Polluter Pays Principle" (PPP). All enterprises and households in Vietnam are used to having open access to water bodies, never having to pay for discharging pollutants into water bodies or drainage system. Once the effluent charge is collected, the administrators of the enterprises would consider the consumption rates and pollution level to avoid or reduce the charge.

If the charge is set according to MAC of small firms, then it would likely exceed MAC of most large firms. Therefore, the large firms may prefer to install wastewater treatment facility instead of paying the large amount of charge. Since large firms always benefit from the economies of scale, they can invest in pollution control and environmental management. At this point, the medium firms may still prefer to pay the charge, but it could change their behavior. They would be aware of the environmental problem and, hopefully, it would lead them to reduce the pollution they produce by designing an environmental plan as well as that of pollution control equipment.

If the monitoring system is not effective, an effluent charge of no more than 0.1 percent of revenue would result in a high rate of compliance. This rate is a little higher than the effluent charge calculated by TAC, which would encourage the firms to monitor their environmental pollution.

B. The Second Period (2 to 5 years)

In this period, it is necessary to enlarge the scope of the pollution charge program and set the different rates for enterprises. At the same time, it is necessary to bring the pollution monitoring and assessment system into the operational stage. On the other hand, monitoring data and pollution level should be used to set the rate of the charge as well as to improve the pollution charge scheme.

Water pollution charge is determined by the BOD load. Standard B would be used since most firms discharge wastewater into the drainage system, which is equivalent to class B of the standard. In this stage, the monitoring system and treatment facilities will be effective in helping the environmental agencies determine the charge for the firms. The rate of 0.2 percent of revenue may be used for firms without a monitoring system.

Different standards would be set for the different sectors of industry. A monitoring system and wastewater treatment facilities (maybe a primary treatment) will be designed for the large and medium firms. The standard may be initially lowered to make the environment cleaner. Standard B means that the receiving water could be used for recreation and transporting purposes.

C. The Third Period (5 years)

In the third period (5 years from start of the pollution charge program), there should already be environmental awareness as well as awareness of PPP. This would indicate that the program has reached one of its objectives. It is planned that in this period, the pollution monitoring and assessment system is properly installed and is operational. This will allow the use of the new set of standards for water pollution charge or charge on all pollutants. Consequently, the pollution charge scheme would be improved and the other objectives could be attained such as encouraging the people to search for better solutions.

The charge would be applied in accordance with MAC for each sector. Hopefully by this time other studies on effluent charge would be available. The charge will be for pollution load. If the BOD load is below the standard, the charge would be much lower than that for BOD load that exceeds the standard.

In this period, the pollution charge program not only provides funds for environmental services but also serves as a pollution control instrument. The pollution charge could prevent heavy pollution in all water bodies as well as limit the unplanned discharge of wastewater into the water environment.

In short, the water pollution charge should be simple at the beginning, gradually becoming complicated as the rates are calculated in more detail based on pollution load from wastewater discharged into the water bodies or drainage system. It is hoped that the polluters would change their behavior toward the environment. Once this happens, it would mean the pollution charge scheme has reached its objective of serving as an incentive for people to search for better pollution control processes. The charge would also help environmental agencies to finance pollution control and abatement activities.

Applying adjustment coefficient in calculating pollution charge

The pollution charge scheme would be more flexible if it includes an adjustment coefficient. The adjustment coefficient for calculating a charge rate is based on pollution load, which depends on the location of firms and ambient environmental quality. Therefore, it would be reasonable to include the adjustment coefficient to reduce or increase the rate. The coefficient could be different for the industrial sector, area, and even for pollutants. Since the pollution problem is more serious in Ho Chi Minh City and Hanoi, the adjustment coefficient for these cities, especially the inner part of the city, could be higher than for Danang and Cantho. Coefficient for the industrial zone may be lower to encourage firms to relocate.

6.2.2 Strengthen environmental monitoring system

Environmental monitoring systems play an important role in pollution control. With the data available, the environmental agencies could know the pollution level and the polluters could be made aware of the environmental problems. Frequent visits of DOSTE to the firms will change the producers' behavior. On the other hand, the EIA report identifies environmental problems and solutions. This should be obligatory for large and medium firms and some important industry sectors. Results of the survey showed that many firms did not write EIA reports. Most small firms never even reported to the DOSTE or anywhere else about environmental performance. Some heavily polluting firms needed to pay compensation to their surrounding communities which complained about annoyance or harm caused by environmental pollution. With the monitoring system working properly, the environmental protection agencies or related authority could prevent pollution before it becomes a serious problem.

In the first stage, environmental protection agencies would encourage the firms to establish their environmental monitoring system, train environmental engineers to do their work, and set up environmental plans as well as install pollution control equipment.

DOSTE and related agencies will assist the firms in monitoring some important pollutants. They will provide training to environmental companies regarding environmental management and pollution control. Moreover, appropriate wastewater treatment systems for the firms will be identified.

At this stage, monitoring data shall be generated based on reports to be submitted at least once a month by small firms, twice a month by medium firms, and three times a month by large firms. The frequency of DOSTE visits would be once a year for small firms, twice for medium firms, and 2-4 times for large firms.

This research project did not aim to promote the new program for water pollution control based on pollution charge scheme for the industry. In order to do this more data and more time for monitoring are needed. Therefore, the above remarks are just suggested environmental policies. Environmental protection and management are still new in Vietnam, hence, the application of economic instruments, particularly the industrial effluent charge, should be carefully considered and subjected to a testing period. After testing, it should be evaluated to improve its advantages and eliminate the disadvantages. After the revision, the pollution charge could be applied to all areas and fields.

REFERENCES

Dasgupta, S., M. Huq, D. Wheeler, and C. Zhang. 1996. Water Pollution Abatement by Chinese Industry. Research Paper, The World Bank. Washington D.C.

Dinh, V. S., et al. 1996. Research on Industrial Water Pollution in Hanoi. Government Project report KT 02-01. MOSTE. Hanoi. (In Vietnamese)

DOSTE Cantho. 1996. Current Situation and Environmental Impact Assessment for Cantho City. Internal Report to MOSTE. (in Vietnamese)

DOSTE Danang. 1996. Current Situation and Environmental Impact Assessment for Danang City. Internal Report to MOSTE. (In Vietnamese)

DOSTE Hanoi. 1996. Current Situation and Environmental Impact Assessment for Hanoi. Internal Report to MOSTE. (In Vietnamese)

ENCO HCMC. 1996. Current Situation and Environmental Impact Assessment for Ho Chi Minh City. Internal Report to MOSTE. (In Vietnamese)

ESCAP. 1995. Guideline for Industrial Pollution Control. UNESCAP, Bangkok, Thailand.

General Statistical Office (GSO). 1995. Statistics Year Book. Hanoi.

Mendoza, M. N. 1995. Water Pollution Abatement in the Tanning Industry in Meycauyan, Bulacan, Philippines. EEPSEA Report. Singapore.

Murry, M. N., A. J. James, Smita Misra. 1996. Economic Instruments and Other Institutions for Water Pollution Abatement. Research Paper, University Enclave India.

Nguyen Huu Sung and Luu Xuan Hung. 1996. Hospital Waste Management in Hanoi. In Environment Newsletter, National Environment Agency.

Pham, N. D., et al. 1996. KT 02-03 Project Report (The Government Research project). MOSTE, Hanoi. (In Vietnamese)

Socialist Republic of Vietnam. 1995. Environmental Protection Law and Regulations. Hanoi: Politics Publishing House. (In Vietnamese)

Tran, H. N. 1996. Wastewater Treatment in Vietnam. Journal Scientific Activities, MOSTE.

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ACRONYMS

BOD	Biochemical oxygen demand
CAC	Command and control
COD	Chemical oxygen demand
DO	Dissolved oxygen
DOSTE	Departments of Science, Technology and Environment
EI	Economic Instrument
EIA	Environmental Impact Assessment
ENCO	Environment Committee
HCMC	Ho Chi Minh City
l	liter
MAC	Marginal abatement cost
MBI	Market-based instrument
MOF	Ministry of Finance
MOSTE	Ministry of Science, Technology and Environment
NEA	National Environmental Agency
PPP	Polluter Pays Principle
SS	Suspended solid
TAC	Total abatement cost
TDP	Tranferable discharge permit
UNCED	United Nations Conference on Environment and Development

APPENDICES

Appendix Table 1. Abatement rate (BOD reduction rate) of firms

No.	CODE	A-RI %	No.	CODE	A-RI %	No.	CODE	A-RI %
1	HCM24	96	32	CT11	65	63	HCM37	17
2	HN04	90	33	HCM01	63	64	HCM18	17
3	HCM07	88	34	HN01	61	65	HN26	9
4	HN22	88	35	CT12	60	66	HCM03	9
5	HCM12	88	36	HCM36	55	67	CT01	7
6	HCM30	88	37	HN07	54	68	CT03	2
7	HCM27	88	38	DN06	54	69	HCM17	0
8	HN14	87	39	HN05	53	70	DN01	0
9	HCM19	87	40	CT04	52	71	DN14	0
10	HCM16	86	41	DN09	51	72	DN02	0
11	HN06	86	42	HN27	47	73	CT07	0
12	HN03	86	43	HN23	47	74	HCM27	0
13	DN07	82	44	DN13	46	75	HCM26	0
14	HCM32	82	45	HN21	46	76	HCM25	0
15	HCM10	82	46	HN25	44	77	HCM21	0
16	HN11	81	47	DN08	40	78	DN03	0
17	HN09	80	48	HN19	38	79	HN02	0
18	HN15	80	49	HCM41	38	80	DN15	0
19	HCM14	79	50	HCM39	38	81	CT02	0
20	DN10	77	51	HN12	35	82	CT08	0
21	DN04	77	52	HN16	33	83	HCM33	0
22	HCM04	77	53	HCM29	33	84	HCM13	0
23	CT10	76	54	DN12	33	85	HCM06	0
24	CT05	75	55	HN20	29	86	CT06	0
25	CT09	73	56	HN18	29	87	HCM31	0
26	HCM20	69	57	HCM28	23	88	HCM09	0
27	HCM11	69	58	HCM23	20	89	HN10	0
28	HN13	68	59	HN24	17	90	HCM34	0
29	DN05	68	60	HN17	17	91	HCM22	0
30	HCM42	67	61	HCM40	17	92	HN08	0
31	HCM43	66	62	HCM38	17	93	HCM15	0

Appendix Table 2. Abatement cost for food processing firms in Vietnam

No	CODE	BOD	A-R1	BODL	BODRED	SIZE	TAC10	TAC30	TAC60	TAC90	TAC	REV	TAC/REV
		MG/L	%	T/Y	T/Y		VND	VND	VND	VND	VND	M.VND	%
1	CT01	107	7	0.515	0.034	S	0.019	0.000	0.000	0.000	0.019	2600	0.000735
2	CT03	102	2	3.849	0.075	S	0.041	0.000	0.000	0.000	0.041	38038	0.000107
3	CT04	210	52	0.221	0.116	S	0.012	0.034	0.079	0.000	0.124	180	0.069041
4	CT05	394	75	43.466	32.434	M	1.652	4.781	15.257	47.856	69.546	30014	0.231711
5	CT09	370	73	41.070	29.970	M	1.561	4.518	14.416	39.189	59.683	33252	0.179487
6	CT10	420	76	0.353	0.269	S	0.019	0.054	0.173	0.584	0.829	1900	0.043641
7	CT11	283	65	1.602	1.036	S	0.085	0.243	0.783	0.764	1.876	8209	0.022852
8	CT12	250	60	40.625	24.375	M	1.544	4.469	14.259	0.000	20.272	317100	0.006393
9	DN04	432	77	46.656	35.856	M	1.773	5.132	16.376	58.217	81.499	35000	0.232853
10	DN05	310	68	40.920	27.720	M	1.555	4.501	14.363	24.028	44.447	87400	0.050855
11	DN06	216	54	6.376	3.424	S	0.338	0.969	2.494	0.000	3.802	38130	0.009970
12	DN07	565	82	101.700	83.700	M	3.865	11.187	35.697	164.225	214.973	1500	14.331564
13	DN08	168	40	2.016	0.816	S	0.107	0.306	0.329	0.000	0.742	30000	0.002473
14	DN09	204	51	36.720	18.720	M	1.395	4.039	9.022	0.000	14.457	40000	0.036142
15	DN10	441	77	31.752	24.552	S	1.683	4.826	15.527	56.273	78.309	32000	0.244716
16	DN12	150	33	3.726	1.242	S	0.197	0.566	0.182	0.000	0.946	600	0.157672
17	DN13	186	46	0.268	0.124	S	0.014	0.041	0.070	0.000	0.125	9000	0.001386
18	HCM03	110	9	0.058	0.005	S	0.003	0.000	0.000	0.000	0.003	28142.661	0.000010
19	HCM04	430	77	7.869	6.039	S	0.417	1.196	3.848	13.479	18.940	4000	0.473503
20	HCM10	560	82	13.978	11.482	S	0.741	2.125	6.835	31.662	41.363	15000	0.275751
21	HCM11	324	69	1.293	0.894	S	0.069	0.196	0.632	1.208	2.105	325379.4	0.000647
22	HCM12	840	88	11.794	10.390	S	0.625	1.793	5.767	33.896	42.081	100000	0.042081
23	HCM14	480	79	2.396	1.897	S	0.127	0.364	1.172	4.698	6.361	93022.748	0.006838
24	HCM18	120	17	0.137	0.023	S	0.007	0.007	0.000	0.000	0.015	131802	0.000011
25	HCM19	750	87	0.405	0.351	S	0.021	0.062	0.198	1.105	1.386	13	10.660846
26	HCM20	325	69	0.811	0.562	S	0.043	0.123	0.397	0.766	1.329	3010	0.044153
27	HCM23	125	20	0.020	0.004	S	0.001	0.001	0.000	0.000	0.003	248	0.001014
28	HCM24	2800	96	0.050	0.049	S	0.003	0.008	0.025	0.188	0.223	29	0.768277
29	HCM28	130	23	0.162	0.037	S	0.009	0.016	0.000	0.000	0.025	43658	0.000056

Appendix Table 2. Abatement cost for food processing firms in Vietnam *(cont.)*

30	HCM29	150	33	0.108	0.036	S	0.006	0.016	0.005	0.000	0.027	495	0.005540
31	HCM30	800	88	9.984	8.736	S	0.529	1.518	4.882	28.087	35.016	60800	0.057593
32	HCM32	560	82	0.030	0.025	S	0.002	0.005	0.015	0.069	0.089	162	0.055239
33	HCM36	220	55	0.020	0.011	S	0.001	0.003	0.008	0.000	0.012	156	0.007774
34	HCM39	160	38	0.038	0.014	S	0.002	0.006	0.005	0.000	0.013	108	0.011925
35	HCM40	120	17	0.019	0.003	S	0.001	0.001	0.000	0.000	0.002	1026	0.000194
36	HN01	254	61	34.107	20.679	M	1.296	3.752	11.972	2.503	19.523	1728	1.129798
37	HN03	705	86	528.750	453.750	L	7.931	25.380	88.830	488.036	610.178	275000	0.221883
38	HN04	1050	90	262.080	237.120	M	9.959	28.829	91.990	577.100	707.878	11000	6.435255
39	HN05	215	53	4.025	2.153	S	2.279	0.612	1.509	0.000	4.400	3000	0.146656
40	HN06	715	86	151.694	130.478	M	5.764	16.686	53.245	289.494	365.189	17300	2.110920
41	HN07	218	54	18.364	9.940	S	0.973	2.791	7.184	0.000	10.949	3000	0.364960
42	HN09	508	80	19.507	15.667	S	1.034	2.965	9.539	40.540	54.078	456	11.859267
43	HN11	515	81	24.720	19.920	S	1.310	3.757	12.088	52.050	69.206	684	10.117825
44	HN12	153	35	1.957	0.678	S	0.104	0.297	0.160	0.000	0.561	670	0.083691
45	HN13	315	68	49.140	33.540	M	1.867	5.405	17.248	28.855	53.376	8000	0.667198
46	HN14	780	87	139.689	121.780	M	5.308	15.366	49.031	276.835	346.540	102600	0.337758
47	HN15	500	80	9.360	7.488	S	0.496	1.423	4.577	19.151	25.646	1000	2.564640
48	HN16	150	33	1.125	0.375	S	0.060	0.171	0.055	0.000	0.286	1150	0.024838
49	HN17	120	17	14.126	2.354	M	0.537	1.321	0.000	0.000	1.858	9120	0.020369
50	HN18	140	29	0.134	0.038	S	0.007	0.019	0.000	0.000	0.027	960	0.002764
51	HN19	160	38	0.108	0.040	S	0.006	0.016	0.014	0.000	0.036	1625	0.002219
52	HN20	140	29	0.142	0.041	S	0.008	0.020	0.000	0.000	0.028	250	0.011209
53	HN21	185	46	5.596	2.571	S	0.297	0.851	1.460	0.000	2.607	3000	0.086891
54	HN22	850	88	30.600	27.000	S	1.622	4.651	14.963	88.387	109.624	3200	3.425738
55	HN23	190	47	0.114	0.054	S	0.006	0.017	0.032	0.000	0.055	200	0.027480
56	HN24	120	17	0.078	0.013	S	0.004	0.004	0.000	0.000	0.008	115	0.007203
57	HN25	180	44	0.173	0.077	S	0.009	0.026	0.039	0.000	0.075	235	0.031854
58	HN26	110	9	0.026	0.002	S	0.001	0.000	0.000	0.000	0.001	180	0.000771
59	HN27	190	47	0.034	0.016	S	0.002	0.005	0.009	0.000	0.016	250	0.006595
60	HCM41	160	37.5	0.064	0.024	S	0.003	0.010	0.008	0.000	0.021	660	0.003252
61	HCM42	300	66.67	1.872	1.248	S	0.099	0.285	0.915	1.277	2.576	2880	0.089440
62	HCM43	290	65.52	0.087	0.057	S	0.005	0.013	0.043	0.049	0.109	204	0.053668

IMPACT OF AGROCHEMICAL USE ON PRODUCTIVITY AND HEALTH

2

IMPACT OF AGROCHEMICAL USE ON PRODUCTIVITY AND HEALTH

Nguyen Huu Dung, Tran Chi Thien, Nguyen Van Hong, Nguyen Thi Loc, Trinh Dinh Thau, Dang Van Minh, Huynh Thi Le Nguyen, Nguyen Tan Phong and Thai Thanh Son

SUMMARY

A total of 86 rice farmers in North Vietnam; 94 rice farmers in Mekong Delta; and 60 vegetable farmers in Ho Chi Minh City were interviewed in 1996 to investigate the extent of imbalance in the use of inorganic fertilizers that could have implications in pest incidence and pesticide use in Vietnam. Data on willingness to pay (WTP) to avoid being sick due to insecticide were also collected among North Vietnam and Ho Chi Minh City farmers.

The micro-level analysis showed that Vietnamese farmers are in general over-using nitrogen and under-using potassium and phosphorous, leading to non-optimal yields and profits. Over-use of nitrogen could also lead to more pest incidence, such as an increase in brown plant hopper and other insect population in rice and vegetables. Most rice and vegetable farmers reported to have experienced acute illnesses due to pesticide exposure such as headaches, skin irritations and dizziness. In the Red River Delta, farmers were willing to pay an average of 250,000 VND to avoid being ill from insecticide exposure. Consumers of ordinary vegetables (not grown organically), were willing to pay about 2,000 VND more for a kilo of safe cabbage and 3,000 VND more for a kilo of safe tomatoes. An econometric production function estimation was done to determine the yield effects of the current mix of fertilizers used by rice and vegetable farmers. It was recommended that research institutions should be pro-active in issues of Integrated Pest Management (IPM) and Integrated Nutrient Management (INM).

1.0 INTRODUCTION

1.1 Background and Objectives

Agrochemicals play an important role in intensive agriculture. They offer the most attractive low cost method of increasing output per hectare of land and give the farmer a high economic return for his labor and investment. The potential for agrochemical application is considerably increased in developing countries where its advantages seem to have not been fully exploited. Vietnam, like any developing economy, promotes the use of agrochemicals.

In recent years, the use of agrochemicals increased considerably. For example, the quantity of agrochemicals used in agriculture increased three times in 1994 as compared to the late 1980s (Ministry of Agriculture and Rural Development). Among these agrochemicals, the inorganic fertilizers were popularly used and reached the level of 3 million t/year where two million tons are imported. Among the chemical fertilizers, nitrogen was introduced into Vietnam earlier than phosphorous and potassium because of its yield effect. Modern varieties are nitrogen responsive. The government has also promoted use of nitrogen by price incentives (Part 2). Due to this, there is a belief that farmers over-use nitrogen.

Many farmers tend to use urea heavily; knowledge about the importance of potassium and phosphorus may not be enough. At present, extension workers and scientists advise farmers to be aware of balanced fertilizer application.

The use of too much urea that lead to unbalanced fertilizer use, is in the long-run not sustainable; too much nitrogen also enhances plant growth that makes it attractive to some insect pests. Thus, this could be a source of increased pesticide use.

Indeed, it was observed that the use of pesticides has increased considerably in recent years, largely due to production incentives given by the government. Currently, Vietnam has used 200 different insecticides, 83 fungicides, 52 herbicides, organophosphates, carbamates, and pyrethroids (Ministry of Agriculture and Rural Development, 1995). Though being restricted in use, organophosphates which are in the WHO hazardous categories I and II, are applied by a larger number of farmers. All farmers used pesticides of all kinds to control pests. About 36 percent of restricted pesticides have been used in Tien Giang province, which increased the farmers' health risk from exposure (Dung, 1994). In addition, with greater market liberalization there is higher tendency to use cheaper, more hazardous pesticides. There is less conformity to guidelines issued by the Department of Plant Protection. In 1993-1994, there were about 600 cases of pesticide poisoning allegedly due to eating contaminated vegetables.

This study aims to investigate the extent of imbalance in the use of inorganic fertilizers in Vietnam. Due to lack of basic information, the analysis only infers on the relationship between the use of inorganic fertilizers with increased pest occurrences, and hence increased pesticide use. Health effects of pesticide use on the producers and consumers are also investigated. This is done to illustrate the consequences of current government policies on use of pesticides.

Studying and valuing the effect of current levels of agrochemical use on productivity and health will be an important input in formulating policy decisions to promote sustainable agriculture and a better quality of life in rural Vietnam.

This report is divided into seven parts. The second and third parts discuss the agrochemical use in Vietnam at the macro level and field levels, respectively. The fourth part details the methodology used in the study; parts 5, 6 and 7 present the results of the case studies done among rice farmers in Red River Delta in North Vietnam, vegetable farmers and consumers in Ho Chi Minh (HCM) city and rice farmers in the Mekong Delta in South Vietnam.

Fertilizer manufacturing is a low– and long – return industry. Government subsidies and support for investments in these projects could be in the form of tax exemptions, guarantees for borrowed funds or low royalties on raw materials. The data on nutrient needs of Vietnam farmers will be important so that these instruments will be more targeted.

1.2 Hypotheses

The case studies presented set out to answer the following hypotheses:

1. Rice and vegetables farmers in Vietnam over-use nitrogen which leads to use of wrong fertilizer mix;

2. The high amount of nitrogen causes high population of brown plant hopper and other pests, in rice and vegetables;

3. High pesticide use leads to frequent exposure by producers, thus, posing health risks;

4. High pesticide residues in vegetables also put consumers at risks.

1.3 Methodology

In order to address the above hypotheses, both secondary and primary data were used. The project duration covered one year thus, long-term experimental trials were not possible. The second hypothesis then was investigated through evidences from literature reviews (Part 3).

The primary data were collected to shed light on the other three hypotheses. A total of 86 rice farmers in North Vietnam; 94 rice farmers in Mekong Delta; and 60 vegetable farmers in HCM City were interviewed from November to December 1996. Farm and household level data were collected. Data on willingness to pay to avoid being sick due to insecticides were also collected among North Vietnam and HCM City farmers. Rice production data pertain to two cropping seasons in 1996-1997. Vegetable production data consisted of cabbage and tomato produced in 1996. The vegetable consumer survey was done in December 1996. Sixty (60) vegetable consumers were interviewed to determine their perceptions and attitudes towards safe vegetables sold in Vietnam. Willingness to pay (WTP) for safe vegetables were also elicited; however the demand function estimation did not yield significant results due to lack of price variation in vegetables sold in HCM market.

An econometric production function estimation was done to determine the yield effects of the current mix of fertilizers used by rice and vegetables farmers (Part 4). First-order conditions for profit maximization was assumed to generate the optimal fertilizer mix. If the coefficient from the regression equation was not significant, the recommended rates from extension service were instead used to come up with a balanced fertilizer mix. Private cost of overuse of nitrogen was also calculated; environmental cost could be inferred from the analysis. Descriptive statistics described the levels of WTP to avoid being ill by rice farmers in the North; and vegetable farmers and consumers in HCM City.

1.4 Summary of Results

1.4.1 Balanced fertilization issue

The micro level analysis showed that Vietnamese farmers are in general, over-using nitrogen and under-using potassium and phosphorous *(Table 1.1)*. This unbalanced use of fertilizer mix has led to non-optimal yields and profits. The analysis shows that farmers can benefit in terms of higher yields and profits if they follow the optimal mix *(Table 1.2)*. The estimates can be subjected to sensitivity analysis to determine the input/output price ratios that could influence farmers' decision to use the optimal amount. Pricing, however, is only one strategy to influence level and mix of fertilizer use.

As observed, especially in Red River Delta, farmers do not produce for maximum profits, but for maximum yields. Thus, the insignificant differences between farmers' practice and the recommended rates (Part 5). In this situation, one will not just depend on pricing strategies to influence farmers' behavior. Farmers need

Table 1.1. Extent of over-use/under-use of fertilizers (in kg/ha) in Vietnam

Fertilizer/Location/Crop	Optimal Amount	Farmers' Practice	Over-use(+)/ Under-use (-)
Red River Delta (rice)			
Spring season			
N	100	122	22
P_2O_5	66	62	-4
K_2O	20	29	9
Autumn season			
N	91	96	5
P_2O_5	54	44	-10
K_2O	16	25	9
Ho Chi Minh City (vege.)			
Cabbage N	210*	210	-
P_2O_5	280	100	-80
K_2O	210	90	-120
Tomato N	250*	250	-
P_2O_5	300	80	-220
K_2O	410	40	-370
Mekong Delta (rice)			
Spring-Autumn			
N	86	113	27
P_2O_5	113	57	-56
K_2O	18*	13	-5

* Recommended rates

Table 1.2. Comparison of yields (in kg/ha) and profits (in 1000 VND/ha) between optimal mix and farmers' practice

Location/Crop	Yield			Profit		
	Optimal mix	Farmers' practice	Difference	Optimal mix	Farmers' practice	Difference
Red River Delta (rice)						
Spring	5813	5750	63	4293	3878	415
Autumn	4241	4020	221	4276	3794	482
Ho Chi Minh City (vegetables)						
Cabbage	4202	3900	302	68	-74	142
Tomato	3937	3460	477	2632	2310	322
Mekong Delta (rice)						
Spring-Autumn	6465	6336	129	123	79	44

Note: US$ = 11,600 VND

Vegetable data are in 1000 m^2

to understand that balanced fertilization in the long-run will be more advantageous in terms of sustainability of yields; and minimum negative impact to the agro-ecosystem. However, in areas where farmers are more integrated in the market, prices of these inputs could include a premium due to environmental costs.

Especially among the market-oriented vegetable farmers and Mekong Delta rice farmers, where there is certainly over-use of N and under-use of P and K, higher N and output prices could lead to more optimal use (Parts 6 and 7). Caution, however, must be taken in interpretation of some estimates. For instance, the optimal amount of phosphorous is much higher than recommended rates. As common in recall studies, measurement errors could create econometric problems. Ideally, a panel data analysis would give more robust estimation of production coefficients, especially if the temporal farmer decisions affect the yield variation.

The role of animal manure is highlighted in the Red River Delta farmers and vegetable farmers. In the North, animal manure is a significant input and minimizes potassium use. In vegetable farmers, there is an over-use. The commercial farmers in Mekong Delta do not use animal manure at all.

1.4.2 Insecticide use

Insecticide use in Red River Delta did not give significant coefficients for the spring season; this coefficient was significant in the autumn. Since the data on pest infestation levels are not available, one could not really determine the productivity of insecticides. However, it was observed that in the spring, many farmers sprayed insecticides periodically even if there was no pest infestation, thus, an over-use of these chemicals. In the autumn season, farmers feel that the weather is not conducive to high pest population so they do not spray too much. Decision parameters on the use of pesticides in general, are not very well defined for all farmers in the study areas.

This is more evident among vegetable farmers who spray insecticides very frequently. The more urgent information that vegetable farmers need to know is the strict compliance to the pre-harvest intervals in using pesticides. Current practice is for farmers to spray as close to one day before harvest to sell good-looking vegetables. This practice, however, poses health risks to consumers especially for those who consume raw vegetables.

1.4.3 Externalities due to agrochemical use

Fertilizers

Over-use of N could lead to more pest incidence. Secondary data indicated that an increase in brown planthopper and other insects pest population in rice as well as diseases especially in vegetables could be triggered by N over-use. On the other hand, under-use of P and K could deplete the natural nutrient contents of the soils that could lead to degraded soils. Use of animal manure is actually found to be a good complement to inorganic fertilizers.

Insecticides

Health risks are evident among farmers due to insecticide exposure. In the Red River Delta, farmers are willing to pay a positive amount to avoid being ill. This WTP was on the average about 250,000 VND.

Vegetable consumers are also willing to pay a premium for safe produce *(Table I.3)*. Among organic market consumers the consumer surplus that was estimated for safe vegetable was 2,200 VND/kg of cabbage and 4,500 VND/kg for tomatoes. This was calculated as the difference between their maximum WTP and the actual price paid for safe vegetables.

For the ordinary market, consumers are willing to pay about 2,000 VND more for a kilo of safe cabbage, and 3,000 VND more for a kilo of safe tomatoes. The study however, pointed out that there is difficulty in identifying the safe vegetables from the high pesticide residue vegetables.

Table 1.3. Willingness to pay for safe vegetables, Ho Chi Minh City, 1996 (In VND/kg)

	WTP Price		Actual Price		Consumer Surplus	
	Ordinary market	Organic market	Ordinary market*	Organic market**	Ordinary market	Organic market
Tomato	4,724	12,000	2,538	9,800	2,182	2,200
Cabbage	8,440	21,800	5,012	17,300	3,428	4,500

* Actual price of the vegetables in the ordinary market

** Actual price of safe vegetables in the organic market

1.5 RECOMMENDATIONS

1.5.1 Towards a balanced fertilizer use

Farmers should be aware of the importance of balanced fertilization. Information campaign is helpful. The village leaders should periodically update the soil analysis in their areas, and advise farmers on the mix of inorganic fertilizers as a complement to the soil nutrients and the seed variety they use. The use of animal manure should also be encouraged.

Though price incentives are important only to market oriented farmers, the prices should include a premium that should possibly indicate environmental costs incurred due to improper use. Urea plants have been producing sufficient amounts of nitrogen; but incentives to increase supply of phosphorous and potassium should be in place. This could be in terms of tax breaks for investors willing to supply these nutrients.

1.5.2 Minimizing pesticide externalities

Vietnamese farmers, like others in the developing world, need to understand the what's, why's and how's of pest management. Currently, there are no definite decision rules that farmers follow to use pesticides. Knowledge of the ecological make-up of the fields is important for farmers to maximize benefits from an insecticide spray. Price is only one factor in maximizing profits, the pest density is another factor. Hence, farmer's training along these, as well as on proper and judicious use of pesticides, will have positive impact on production and health.

1.5.3 The realities of consumer health risks

Pesticides that create high residues in vegetables, thus causing consumer health problems need to be strictly regulated. The Plant Protection Department at HCM City monitors pesticide residues in vegetables. The results of these should be used for regulatory purposes, including restricting sale and use of persistent compounds. Educating vegetable farmers about Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) will translate to safer vegetable produce. This is because high nitrate and high pesticide use contribute to high chemical residues in vegetables.

1.5.4 Further research

Research institutions should be pro-active in issues of IPM and INM. Long-term research should be done to create data bases for the fertilizer-pest-pesticide interaction. Basic research on nutrient management and on cropping patterns and their impact on soil nutrient content should also be on a long-run basis. All these information could be inputted into a policy research that will serve as basis to initiate policy reforms.

2.0 AGROCHEMICAL USE IN VIETNAM

2.1 National Trends

2.1.1 Fertilizer use

Plant nutrient supply through chemical fertilizers is a common and conventional practice. The world use of chemical fertilizers reached 122 million tons in 1979-1980. This number increased to 143.5 million tons during 1989-1990; and reached to 137.5 million tons in 1990-1991 *(Table 2.1)*. According to some estimates, the world fertilizer use is expected to grow from 1990-1991 to 1996-1997 at about 0.9 percent per year in which a rate of 1 percent is for nitrogen, 0.7 percent for phosphate, and 0.8 percent for potash.

The trend of fertiliser use in developing countries, being different from the world trend and the trend in developed countries, showed an increase of 4.5 percent in total fertiliser use. The developed countries recorded a reduction of 10.8 percent in total consumption.

Table 2.1. Trends of total fertilizers ($N + P_2O_5 + K_2O$) use in major regions (million tons)

Region	1979-1980	1989-1990	1990-1991
World	122	143	137.520
Asia	28	53	56.403
India	5	11	12.561
Europe	32	31	26.078
All developing countries	34	63	65.048
All developed countries	78	81	72.472

Source: FAO, 1992. Integrated Plant Nutrition System, 1993

Fertilizer use in Vietnam increased from about 172,000 t/year (in nutrient terms) in 1980-1981 to 428,000 t/year in 1984-1986 to about 500,000 t/year in 1989-1990. However, average fertilizer consumption per ha is not high by East-Asian standards and by the extent of irrigation in the country *(Table 2.2)*.

The National Institute for Agricultural Planning and Projections (NIAPP) survey in 1989-1990, showed that, even though fertilizer levels used in the farmers were on average below those of other Asian countries, there is excess use of nitrogen beyond what was considered the economic optimum. Under utilization of phosphorous (P_2O_5) was particularly evident for virtually all provinces of both the Northern and Southern Central Coastal zones and Hanoi province. In the Mekong Delta, fertilizer use was at the optimum level except possibly for slight over-use of nitrogen (N) in the wet season. Thus, even from an economic optimum standpoint, opportunities exist to reduce some fertilizer application rates (i.e., especially for nitrogenous fertilizer). In fact, the quantity of nitrogen fertilizer used in Vietnam in 1992 increased by around five times as

Table 2.2. Fertilizer use and associated indicators, 1987-1989

	Indonesia	Cambodia	Thailand	VN	Malaysia
AVR paddy yields (t/ha)	3.1	3.2	3.7	2.7	4.0
% rice area under irrigation	25.0	60.0	73.0	45.0	55.0
AVR fertilizer use (kg nutrient/ cultivated ha)	39.0	75.0	151.0	63.0	113.0
AVR size of farm (ha)	3.8	0.6	3.5	2.8	1.1

Source: Various World Bank reports and country statistical reports compared to the 1971 level. The quantity of phosphorous and potash fertilizers did not change much over the same period. Total quantity of NPK (accounted by N, P_2O_5 and K_2O) used in the whole country in 1993 increased 3.3 times compared to 1981 level. The amount of NPK used per hectare in 1993 increased 3.5 times compared to 1981 (Ministry of Agriculture and Rural Development).

2.1.2 Fertilizer market

"It blows hot. It blows cold. It blows hot again!" This is the characteristic of the fertilizer market in Vietnam. The fertilizer market is unpredictable, as is the market of the world trade. As much as 90 percent of urea used are imported.

In 1995, the country imported 1.8 million tons of its total consumption of 1.9 million tons. Between 1990 and 1995, the prices shot up four times and fell three times. Government's interventions at that time to solve the problem were to allocate quotas on a quarterly basis instead of yearly to be more responsive to changes in the international market. The Government also tried to loosen import restriction to curb the monopoly, which had been concentrated in some state-owned fertilizer companies.

In 1991, Agricultural Material Corporation (Vigegam) - a major unit in charge of importing fertilisers - received only 100,000 tons of urea following an agreement between Vietnam and the former Soviet Union. This amount represents 10 percent of import quantity of the previous annual plan. In 1992-1993, there were up to 100 stations importing fertilizers. In 1994, the State decided to reduce the number of fertilizer import stations to only nine and Vigegam was appointed by the Government to import 70 percent of fertilizers' total import demand. However, the company's organization displayed some weaknesses; as a result of which, the plan was not well implemented. In 1995, the stations importing fertilisers increased to 28, of which Vigegam was entrusted to import 60 percent of the total import. This share corresponds to 780,000 tons. Although the requested level was reduced, Vigegam could only import 400,000 tons of fertilizers.

In 1996, 40 percent of total amount of fertilizers imported was given to Vigegam. The weaknesses and difficulties still existed in this company, contributing to the weak situation of the fertilizer market in Vietnam.

The relationship between the prices of fertilizers and prices of rice has remarkably changed since 1989. The farm gate rice price per kg and the fertilizer price per kg have been reduced significantly at the same period *(Table 2.3)*. The price of fertilizer has gone down more quickly than that of rice.

2.1.3 Fertilizer production in Vietnam

According to the Plan of Economic Development of Vietnam, the output of agricultural products will reach 30 million tons by the year 2000 and more than 40 million tons by the year 2010. In this regard, fertilizers will play a very important role in achieving such high outputs. In its aim to achieve this target, the Vietnam fertilizer sector finalized its strategy to meet fertilizer demand by the year 2000. By the year 2010, 2.6 million tons of urea and 3.0 million tons of phosphate fertilizers will be needed.

Vietnam's capacity to produce phosphate and general NPK has improved. Domestic production met 50 percent of the demand between 1990 and 1992 and increased to 75 percent between 1994 and 1995. In 1996, it rose further by five percent. Two joint venture plants have been set up to produce NPK, with a total capacity of 540,000 t/year. The first is a USD35 million joint venture between the Japanese firm - Nissho Iwai and Central Glass and Southern Fertiliser Company of the Vietnam Chemical Corporation. Vietnam's input is 30 percent and the Japanese firm is 70 percent. The plant, in Dong Nai province, is expected to produce 240,000 t/year of NPK. The second was set up by Vietnam Agricultural Material Corporation, Agricultural Material Company of Baria -Vungtau Province and Itachu of Japan and Taiwan Fertiliser. This USD36 million investment will build a general NPK plant in Baria-Vungtau with an initial capacity of 300,000 t/year. Both joint ventures are expected to be in operation by 1998.

Another project underway is a USD 403 million electric power-urea project in Baria-Vungtau, which will produce urea from natural gas. Outside investors include BHP, Agrium, and BSP/Stain. The project, which is being prepared for submission to the government, will provide 800,000 t/year – about 30 to 40 percent of local demand. In addition, VINACHEM will raise overseas funds for a 330,000 t/year DAP plant at Deep Water Port of Ca Lan in Quang Ninh Province. Tomen of Japan has pledged to finance this USD215 million project. It is believed that by the year 2000, Vietnam will be able to meet the domestic demand by producing 1,700,000 tons phosphate and 1,200,000 tons urea.

Despite this optimism, investors are still worried about whether they can gain profit from such a low and long return industry. Therefore, support from the Government to the investment projects in this industry is considered. These could be in the forms of tax exemptions, guarantees for borrowed funds or low royalties on materials used to produce fertilisers, such as appeite, pyrites, serpentine, coal and gas. This study will attempt to determine the nutrient needs of Vietnam agriculture, so that these instruments will be more targeted.

2.1.4 Pesticide use in Vietnam

Available data show that pesticide use in Vietnam is increasing considerably. For example, the quantity of pesticides used in

Table 2.3. Relationship between fertilizers (urea) and rice prices, 1989-1995

Year	Relative Farmgate Prices* (VND/kg, 1989 prices)		
	Fertilizer (1)	Rice (2)	Ratio (3) = (1) : (2)
1989	1604	459	3.49
1990	1339	507	2.64
1991	771	429	1.80
1992	581	341	1.70
1993	518	196	1.75
1994	412	276	1.49
1995	510	294	1.73

Source: IFPRI Survey in Vietnam, 1995-1996; basic data from General Statistics Office (Government of Vietnam), Food and Agriculture Organization (FAO) and World Bank.
Note: Deflated by GDP price index

agriculture increased 1.4 times in 1994 as compared to that of 1991 *(Table 2.4)*. Among the pesticides, mostly insecticides are used.

The use of pesticides has become a popular practice for controlling pests of rice. Because pesticides is used almost unilaterally in crop protection, its expenditure share among Mekong Delta farmers is significantly higher as compared to other Southeast Asian country and in the Red River Delta in North Vietnam *(Table 2.5)* during the period 1990-1991.

2.1.5 Types of pesticides used in Vietnam

All kinds of chemical families have been used by Vietnamese rice farmers including organophosphates, organochlorines, pyrethroids and carbamates. Many of these are considered extremely and moderately hazardous pesticides according to WHO classification. Available data show that about 23 percent of all insecticides used in Vietnam are of the Category IA which is considered extremely hazardous (Plant Protection Department, 1993).

2.1.6 Practices by rice farmers

Farmers are perceived to improperly use hazardous pesticides, with mixtures of chemicals, being the favourite form of application. About 65 percent of farmers read instruction in labels, but only 39 percent of those understood and followed instruction. Besides, more than 60 percent of farmers do not use protective clothing when applying pesticides (Trinh 1994). Thus, the more frequent the application, the higher the exposure. Therefore, the probability of poisoning through inhalation of chemical and other ways are certainly high. In addition, since there are no danger signs posted in the newly sprayed fields, neighbours as well as children in or near these fields may also be exposed to pesticides.

Table 2.4. Amount of pesticides used in agriculture of Vietnam (t/year)

Type	1991		1992		1993		1994	
	Ton	%	Ton	%	ton	%	Ton	%
Insecticide	17,590	82.2	18,100	74.1	17,700	69.2	23,500	68.3
Fungicide	2,770	12.6	2,800	11.5	3,800	24.8	4,650	15.5
Herbicide	500	3.3	2,600	10.6	3,050	11.9	3,500	11.7
Others	410	1.9	915	3.8	1,050	4.1	1,350	4.5
Total	21,400		24,415		25,600		30,000	

Source: Ministry of Agriculture and Rural Development

Table 2.5. Pesticide expenditure and application, 1990-1991

Region/Country	Expenditures (US$/ha)	No. of Application
China	25.6	3.5
India	24.9	2.4
Philippines	26.1	2.0
Indonesia	7.7	2.2
Northern Vietnam	22.3	1.0
Southern Vietnam	39.3	5.3

Source: FAO, 1995

Due to misuse and unsafe handling of hazardous pesticides, poisoning symptoms were observed among rice growing farmers in the Mekong Delta. In one study, approximately 60 percent of farmers surveyed claimed sickness (headache, dizziness, vomiting, allergies) due to pesticide use. The number of actual poisoning cases is higher since most farmers do not go to the hospital. Also, local health officials do not always correctly diagnose pesticide poisoning symptoms.

2.2 Agrochemical Policy in Vietnam

Agricultural productivity and health consequences of agrochemical use could be attributed to a large extent to the policy context that governs such use. As in other countries, the general policies relevant to agrochemical use are in terms of trade, price, regulatory, and investments in training programs.

Table 2.6 summarizes the current policy instruments that influence agrochemical use in Vietnam.

2.2.1 Fertilizer Policy

Before 1991, fertilizers were imported by state units. About 800,000 to 1 million tons of urea were imported in a contract in Vietnam and Soviet Union. The Agricultural Material Corporation was assigned to transact business of about 40 percent to 60 percent of fertilizer importation; while the rest was done by the private sector. Sales tax was also imposed on the domestic sales of fertilizers. However, there are no regulatory policies that governs fertilizer use.

On the other hand, agricultural extension officers teach farmers the use of agrochemicals, both pesticides and fertilizers.

2.2.2 Pesticide Policy

In terms of trade, there was no tax on imports until May 1998. There also was no subsidies to importing pesticide companies. However, in May 1998, a tax was imposed on the importation of all kinds of pesticides *(Table 2.6)*.

Table 2.6. Policy instruments governing agrochemical use in Vietnam, 1997-1998

Policy	Fertilizers	Pesticides
1. Trade	There is quota for importation of fertilizers; Vietnam Fertilizer Development Plan liberalizes trade, but defined targets for supply of urea and phosphates	No tax on raw material imports until May 1998. No subsidies to importing pesticide companies. In May 1998, tax rates are: insecticide 1-3%; herbicide 3%; rodenticide 1%; and fungicide 0%. No quota restrictions.
2. Price	Sales tax	Sales tax, no price control, competitive pricing
3. Regulatory	None	Plant Protection Department of the Ministry of Agriculture and Rural Development regulates the use of pesticides.
4. Investment in training programs	Agricultural extension offices teach farmers on the use of agrochemicals (pesticides and fertilizers)	There is a national IPM program, but limited to rice and with external funding.

Pesticide pricing is competitive. The individual importing companies estimate the market demand and set the prices that are competitive with others in the business. It was however observed that pesticide prices at farm gate are approximately higher than the CIF prices by 10-15 percent. The market share from state pesticide companies is estimated to be about 50 percent; that of foreign companies is 15 percent. The remainder is controlled by private traders.

Regulatory policies ensure that the inherently toxic pesticides are to be used properly. In Vietnam, the Plant Protection Department under the Ministry of Agriculture and Rural Development regulates the use of pesticides. Among the important decrees enacted towards a safe environment in the midst of the chemical era is the decree on plant protection and quarantine that was promulgated by the National Assembly in 1993.

Among the provisions of this decree which are in line with plant protection chemicals are:

1) bio-rational products and integrated pest management are encouraged by the government;

2) a list of permitted, restricted and banned pesticides should be known; banned pesticides should be strictly out of the market;

3) organizations/individuals have to secure license to transact business on pesticides;

4) product stewardship should be observed, pesticide residues in food should be below international standards;

5) pesticide must be registered before making them available to the public.

The test to strict adherence of this promulgation is in the extent of the externalities on health and the environment from the use of these chemicals in agricultural production.

To minimize these externalities, the government sponsored a national program on Integrated Pest Management (IPM). Externally funded at the moment, this program focuses on the rice crop alone. The program teaches farmers on the integrated tactics of controlling pest, with chemical pesticides as the strategy of last resort.

3.0 CONSEQUENCES OF AGROCHEMICAL USE ON AGRICULTURAL PRODUCTIVITY, ENVIRONMENT, AND HEALTH: REVIEW OF EVIDENCE

3.1 Evidence from Field Level Studies in Rice

3.1.1 Fertilizer productivity in rice ecosystem

Available data show that most alluvial soils in Vietnam need substantial nitrogen, and relatively less phosphorus and potassium *(Table 3.1)*.

Some soils do not need high amounts of inorganic fertilizers. The alluvial soil in Cuu Long Delta has high nutrient content. However, the farmers used 120-130 kg nitrogen/ha and in some places, the farmers used more than 200 kg nitrogen/ ha. The experiments of Thai (1994) showed that 100 kg nitrogen/ha on Cuu Long Delta alluvial soil gave a yield of 7 t/ ha in spring seasons. The efficacy of phosphorus in this soil was very low and it was not necessary to use potash fertilizer for this soil.

Table 3.1. Fertilizer efficiency on rice in main soil types of Vietnam

Soil Types	Kg of Rice / kg of NPK		
	Nitrogen (N)	Phosphorous (P_2O_5)	Potash (K_2O)
Alluvial soils (AS) of RRD)	10-12	1-2	0.5-1.0
Alluvial soils of MRD	5-20	2-3	1.0-1.5
Alluvial soils of the Thai Binh river and others	10-12	2-4	0.5-1.0
Slightly AS soils	8-10	5-6	0.3-0.5
Moderately AS soils	5-8	7-10	0.3-0.5
Waterlogged alluvial soils	8-10	4-5	0.3-0.5
Degraded Soils	10-15	2-3	5.0-6.0
Marine sandy soils	10-12	2-3	5.0-6.0

Source: Project INF 842, 248.7 VIE, Fertilizer in Vietnam

Aside from soil, the effectiveness of fertilizer application on crop yield is dependent on other factors such as rice variety, time, and method of application. On high yielding varieties (HYV) such as IR 8, yield responses to fertilizers have been 20 to 25 kg grain/kg nitrogen, producing 2-4 tons of grain/ha with 100 to 120 kg nitrogen/ha. On local varieties such as Chiem Tep and Saiduong 314, yield responses were only 8 to 15 kg grain/kg nitrogen, producing 0.5-1.5 tons of grain/ ha with 60-90 kg nitrogen/ha. Increased use of high yielding varieties thus substantially increases the productivity of fertilizer use.

In the past, the phosphorus fertilizer's efficiency was low. Due to the use of nitrogen responsive varieties, the soil phosphorus content has decreased. This results in a higher yield response to phosphorus applications.

On the other hand, application of potash fertilizer on rice has not shown a very significant response on most soil types except on degraded and sandy soils *(Table 3.1)*. Experts on paddy cultivation reported that response to potash in alluvial soils is currently obtained only 20 years after the land has been taken into rice cultivation.

A study carried out by the Institute of Soils and Fertilizers in the alluvial soils of the Ba River in the Central Highlands (1990) pointed out the importance of balance fertilization. In the experiment, high-yielding varieties of rice were cultivated. In these experiments, nitrogen (0,40,80,120 or 160kg/ha), P_2O_5 (0,40 or 80 kg/ha) and K_2O (0 or 40 kg/ha) were applied in addition to 5 t/ha of farmyard manure. The results showed that at low levels of nitrogen application (0 or 40 kg/ ha), phosphorous fertilization (40 kg/ha) did not increase yield substantially (less than 200 kg/ha), but at the higher nitrogen applications when larger yields were obtained, phosphorous fertilization had a strong positive influence on the yields *(Table 3.2)*. Increasing phosphorous use to 80 kg/ha did not further increase yields. The results pointed out that in intensive cultivation more response, (measured as kg paddy/kg nitrogen) was obtained if phosphorous was applied in addition to nitrogen.

Several studies that were conducted in North Vietnam highlighted the use of animal manure (AM) for sustained rice yields. Most of these studies also came up with recommended levels of fertilizer application to maximize yields *(Table 3.3)*.

Table 3.2. Response of IR-64A rice variety to nitrogen and phosphorus fertilization on the Ba River alluvial soils (winter 1989, spring 1990)

Application rates N-P-K kg / ha	Rice Yield (t/ha)		Response			
			To nitrogen (kg paddy/kg N)		To phosphorous (kg paddy/kg P)	
	A	B	A	B	A	B
0-0-20	2.56	2.20	-	-	-	-
40-0-20	3.70	2.90	20.7	17.5	-	-
80-0-20	4.50	3.80	20.4	19.7	-	-
120-0-20	4.93	4.00	17.5	14.7	-	-
160-0-20	4.76	4.10	12.6	11.7		
0-0-20	2.62	2.30	-	-	1.50	2.50
40-40-20	3.72	3.00	20.0	18.7	0.50	2.50
80-40-20	5.56	4.00	30.9	21.1	26.00	5.00
120-40-20	6.00	4.50	25.0	18.2	27.00	12.50
160-40-20	6.20	4.70	20.4	15.1	36.00	15.00

Source: Project INF 842, 248.7 VIE, Fertilizer in Vietnam
Note: N - nitrogen, P - phosphorus
A - winter 1991 B - spring 1990

Bui Dinh Dinh (1994) estimated that 1 ton of NPK can yield 10-13 tons of rice. Vietnamese farmers apply 122.6 kg NPK/ha paddy which is much less than 245 kg/ha applied in China, and 360kg/ha used in S. Korea.

Although Red River alluviums are fertile, to increase the paddy yield it is necessary to apply AM or green manure equivalent.

On the joint-effect of potassium and AM on paddy yield, Van Bo, et al. (1995) found that with animal manure, potassium effect is reduced because AM contains a lot of potassium. Hence, paddy yields are higher if AM is applied with NPK but that higher amounts of K does not translate to higher rice yields. These data tell us that fertilizer mix should be balanced for maximum effect on yield.

Results of Nguyen Nhu Ha's survey of 210 households in three provinces in the Red River Delta in 1992 and 1993 showed a high rice yield of around 10 t/ha/year. The amounts of chemical fertilizers applied are: 104.2 - 130.9 kg N/13 - 64.6 kg P_2O_5/0 0-25.7 kg K_2O, for the spring season, and 77.3 - 114.49 kg N/13 - 60.4 kg P_2O_5 /0 - 23.8 kg K_2O, for the autumn season. Animal manure was applied at 6.5 - 6.8 t/ha for spring and 4.4 - 6.8 t/ha for autumn.

3.1.2 Previous studies on economics of fertilizers

While the previous section looked at technical recommendations, the question to be asked is whether the level of fertilizer use is economically rationale. Except for one study by Son and Hien (1995), there was no previous study to prove this hence, the current case studies could serve as benchmark information. However, studies in other areas are reviewed for illustration, especially in terms of methodology.

Akimi Fujimoto in 1987 conducted a study for three villages in Thailand (i.e.,

Table 3.3. Fertilizer recommendations from several studies, North Vietnam

Source	Recommended Amount (kg/ha)		
	N	P	K
For yield maximization			
Tran Khai & Nguyen Tu Siem (1994)	100-120	30-70	50-80
Bui Dinh Dinh: (1994)			
- Spring	120	60	30
- Autumn	90	40	30
Tran Thuc Son & Dang Van Hien (1995)	160	90	60
Nguyen Van Bo	120	90	60*
For profit maximization			
Tran Thuc Son & Dang Van Hien (1995)	120	60	30

* with 10 tons animal manure

Phatthalung, Suphan Buri, and Chiang Mai) using the Cobb-Douglas production function. The dependent variable was total production of paddy rice (in kg) while the independent variables are total rice land area (in rai), total labor input (in man-hours regardless of age and sex of the workers), total expenditure on fertilizer (in baht) and a dummy variable for tenure.

The results of estimation presented in Table 3.4 show that the model is best fit for Phatthalung, where more than 91 percent of the yield variation can be explained by the four independent variables, followed by 86 percent in Suphan Buri and 47 percent in Chiang Mai. Dr. Ahmad Saeed Khan and Asghar Ali – used the quadratic and Cobb-Douglas to model production in the irrigated areas of the Punjab. The quadratic equation was right because of non-conformity and inconsistency of results with economic theory.

The Cobb-Douglas function had three variables, N, P, K, and a dummy variable as time shift or for the seven-year data. Results of their sensitivity analysis are shown in Table 3.5. The findings show that prices of paddy drives the increase in use of both nitrogen and phosphorous given constant prices.

Son and Hien (1995) both estimated the N, P, and K rates for yield maximization and for profit maximization *(Table 3.3)*, where they found out that the economic optimum rates are lower than the yield maximum rates.

3.1.3 Relationship between nitrogen and pest population: theory and evidence

The word "pest" is used to represent weed, plant diseases, and insects detrimental to crops. Pest damages crops, resulting to major yield losses as evidenced by: a) weed competes with crop plants for sunlight, water and nutrients; b) insects and their larvae feed on crop plants and act as disease carriers; c) fungi, bacteria and viruses invade and damage the plants; and d) rodents and insects feed on produce, and fungi poison them or make them otherwise unsuitable as food.

Nitrogen helps to increase early growth rate and canopy closing creating a competitive advantage over some weeds to the crop. It also furthers the growth of tall-growing weeds. The elimination of straw and stubble burning has also increased weed problems. To control or to kill the weeds, herbicides and/or traditional mechanical methods like harrowing and ploughing that disrupt and bury the weeds are used. Thus, high nitrogen will result to high growth of weeds and additional use of herbicide.

Apart from weeds, crop diseases are also a serious problem that should be given attention. It is obvious that nitrogen favors the growth of the crops, helping the crops to get the lush. However, this can create some inverse effects to the crops, for it favors the growth and reproduction of parasites. Lush growth can lead to an early closing of the crop canopy, making for humid conditions within the crop, that benefit the fungi. Through the acidifying action of fertilization as well as the high ratio of ammonium to nitrate in the soil, attacks of some root diseases are enhanced while others are impaired.

Table 3.4. Production function estimates in Phatthalung, Suphan Buri, and Chiang Mai, 1984/1985 rainy season

	Phatthalung	Suphan Buri	Chiang Mai
Constant	5.843	5.662	6.479
Land, b1	0.831***	0.925***	0.762***
	(13.072)	(15.818)	(8.241)
Labour, b2	-0.026	0.090*	0.022
	(-0.422)	(1.720)	(0.280)
Fertilizer, b3	0.115***	0.036	0.034
	(2.571)	(1.096)	(1.180)
Tenurial Status,	-0.040	-0.083*	0.062*
B4	(-0.831)	(-1.771)	(1.439)
Sum of Coefficients	0.946	0.932	0.825
R2	0.915	0.859	0.468
DW ratio	1.832	2.111	2.303
N	97	152	129

Note: * significant at 10% ** significant at 5% ***significant at 1%

Table 3.5 Balanced fertilizer optimal doses of nitrogen and phosphorus at their prevailing prices (Rs. 1.30 and Rs. 0.90 per nutrient pound, respectively for the Punjab); Potash fixed at 40 pounds

Prices of Paddy Per Maund	Nitrogen	Phosphorus	Potash
25	55.41	35.84	40
35	81.14	52.48	40
45	107.90	69.79	40
55	135.47	87.62	40
65	163.73	105.90	40
75	192.58	124.55	40

Source: Kham and Ali, no date

These negative effects damage the crop, resulting to yield losses. Therefore, crop protection, using fungicides is imperative. High nitrogen results to widespread plant diseases, needing additional use of fungicides.

The lack of nutrients also results in unbalanced supply of nutrients that can distort plant development and predispose plants to diseases. Properly timed and balanced fertilization is a supporting measure in crop protection. In short, there are many factors that affect pest population and the supply of nitrogen is one of the factors involved.

However, it is a fact that farmers in many developing countries prefer to use nitrogen fertilizers as compared to phosphorous and potassium. This may lead to the wrong mix of NPK ratio that can cause the increase in the pest population resulting to more use of pesticides.

Of the various evidences gathered, the study of the Plant Protection Institute in 1977-1978 showed that the use of high amount of nitrogen caused high population of brown planthopper in the two study sites: Long Binh and Long An *(Table 3.6)*.

The study of Can Tho University and Institute of Agricultural Sciences of South Vietnam in Mekong Delta also showed that nitrogen fertilizer affected the severity of leaf yellowing disease (LYD) in Cai Lay and Vung Liem in 1992 and 1993. An increase in nitrogen application in 1992 from 100 to 140 kg nitrogen/ha led to an increase in the severity of the disease *(Table 3.7)*. Although leaf nitrogen concentration increased with higher nitrogen rates, leaf nitrogen content remained well below the critical value of 2.5 percent. Supplementation with 100 kg P_2O_5/ha and 200 kg K_2O did not show any effect on the disease.

3.1.4 Environmental issues relating to fertilizer use

Environmental issues relating to farming and farming practices have come to the fore in recent years and some of the controversies concern fertilizer use. It is a misconception that the more fertilizer is applied, the more profit can be made. At all times, one should aim for the optimum balance between applied nutrients and those removed from the harvest. This thing will help us to prevent leaching of excessive nutrients to the environment. Apart from that, the time of year when fertilizers are applied should also be a concern because it has an influence on leaching.

Table 3.6. Impacts of nitrogen application to brown planthopper population. Institute of Plant Protection, Summer-Autumn 1997-1998

Location	Nitrogen Quantity (kg/ha)	Number of Brown Planthopper / hill			
		PI	Heading	Milk	Ripening
Long Dinh [1]	90N	12.7	12.2	63.0	36.2
	120N	22.2	32.0	74.2	46.7
Long An [2]	40N	49.5	76.8	612.5	-
	80N	45.6	164.5	708.7	-
	120N	48.9	425.7	961.6	-

Source: Institute of Plant Protection, 1978

[1] Mean of 3 replications, variety IR 2153-V m^2, direct seeding on June 01, 1977

[2] Mean of 4 replications, variety 73-2

Table 3.7. Effect of fertilizers on grain yield and severity of leaf-yellowing disease, Mekong Delta, 1992

Site and Treatment (kg NPK/ha)	Grain Yield (t/ha)	Disease Index (%)	Upper Leaf N at Flowering (%)
Cai Lay			
100-46-0	5.8a	55.7c	1.348b
140-46-0	5.7a	66.0a	1.764a
100-146-0	6.0a	54.8c	1.377b
100-46-200	5.8a	56.9c	1.415b
100-146-200	6.0a	58.2bc	1.403b
104-146-200	5.9a	63.7ab	1.740a
Vung Liem			
100-46-0	5.0c	0.27c	1.42b
140-46-0	5.2bc	3.45b	1.439a
100-146-0	5.2bc	0.44c	1.141b
100-46-200	5.4ab	0.84c	1.181b
100-146-200	5.5ab	1.15c	1.114b
104-146-200	5.7a	7.66a	1.374a

Source: Can Tho University and Institute of Agricultural Sciences of South Vietnam in Mekong Delta, 1992

Note: Within a column, means followed by the same letter do not differ significantly by Duncan's multiple

The environmental effects due to fertilizer use can be listed as follows:

1. Nitrogen (N) and Phosphorus (P): N and P in liquid effluents can contribute to eutrophication in water with a risk of oxygen depletion.

2. Ammonia (NH_3): Ammonia gas can cause haze and contribute to the acidification of soils.

3. Nitrogen oxides (NO_x): Nitrogen oxides can contribute to regional acid precipitation and locally reduced air quality.

4. Sulphur dioxide (SO_2): Sulphur dioxide reacts with other gases and contributes to haze formation and also to regional acid precipitation.

5. Dust: Dust can be a local nuisance and contribute to visible haze.

6. Fluoride (F): In high concentrations, fluoride is dangerous to plants and animals.

Although these effects are not perceptible to the eye, they can accumulate through time and will lead to a serious degradation of the soil and the environment in general. Tai Lake area in China is a typical example. Until now, the area serves as a rice basket of China, but with the present rate of destruction of the biological system, the area will be degraded within 50 years (Source: Environmental Review, 1997).

In developed countries, the levels of fertilizer application are based on regular soil analyses in order to prevent the high content of fertilizers in soil and the negative effects to environment. This is not done in developing countries like Vietnam.

3.1.5 Effects of nitrogen on human health

With the trend of intensive farming to get high yield for crops, more and more nitrogen fertilizer is used in the world without paying attention to their effects.

In 1990, an average of 94.5 kg NPK was used for one cultivated ha in the world. The intensification in agriculture has made the nitrate level in soil increase. In 1956, the world nitrogen fertilizer production was only 3.5 million tons (in nutrient term) but in 1975 this increased to 40 million tons and it is expected to increase to 200 million tons by the year 2000.

When there is surplus nitrogen in the soil, this will be converted to ammonia or nitrate through biochemical processes. In other words, the nitrate content will increase in soil and water resulting to pollution. Nitrate then will be absorbed in the vegetables and cereals leading to excess over the standard nitrate content in food. The standard nitrate in food and drinking water for adult is 300 mg/day and for children is 30 mg/day.

In developed countries, cultivated areas were seriously polluted due to farming intensification. Holland is a typical example. Vegetables of this country, especially in winter, can contain 4,000 mg nitrate/kg. It was calculated that each person here put into his/her stomach 1,100mg nitrate through food and 100 mg nitrate through drinks per day, exceeding the standard level four times. This is more serious with children (Environment Weekly, No. 10/96).

High content of nitrate in drinking water also leads to the nitrate disintegration to nitrite (NO_2) and the creation of nitroamin in the digestive system can cause suffocation, anemia and cancer.

In Vietnam, the use of nitrogen fertilizer has increased remarkably due to the intensification of agriculture. However, up till now, there has been no official research on the effects of over-use of nitrogen fertilizer to environment and farmers' health. Standards as well as detection of nitrate content in soil, food, water, especially drinking water are still very limited.

3.1.6 Effect of pesticides on rice productivity and farmer's health.

In the Southeast Asian setting, impact of pesticides in the rice ecosystem has been widely studied. Most of these studies were done by the International Rice Research Institute (IRRI).

Rice yield increases resulting from insecticide applications reported in the literature are highly variable. Early experiments at IRRI showed that insecticide-protected plots yielded almost twice as much as unprotected plots. However, Litsinger (1987) and Waibel (1986) observed no significant yield differences between the insecticide-treated and untreated plots, in more than half of their study cases. A 1989 survey of 50 rice entomologists from 11 countries estimated average yield losses due to insect pests at 18.5 percent. However, Herdt et al. (1984) concluded that rice yield in farmers' field could be raised by an additional 0.5 - 1 t/ha with prophylactic insecticide applications. Nevertheless, they also concluded that the expected returns to rice production are lower for farmers applying insecticides on a prophylactic basis rather than not applying insecticides at all.

Rola and Pingali (1992) by comparing the returns to prophylactic control, economic threshold level, farmer's practice and natural control found that natural control was the economically dominant pest management strategy in normal times. The dominance of natural control becomes even greater when the health cost of exposure to insecticides are explicitly accounted for (Rola and Pingali, 1993). The positive production benefit of applying insecticides are overwhelmed by the increased health costs. The value of crop loss to pests is invariably lower than the cost of pesticide - related illness (Rola and Pingali, 1993) and the associated loss in farmer productivity (Antle and Pingali, 1995).

From the survey of literature of 70,000 records, a total of 856 papers on pest outbreaks were reported in Asia between 1967 and 1993. However, only 106 of them reported any yield loss (P.L. Pingali et al. 1995). Pingali et al. (1995) also showed that insecticides had a significant positive effect on the mean and significant negative effect on the variance of the yield distribution using Philippine data.

Rice farmers are poisoned from pesticide use in two ways: 1) their exposure to pesticides; and 2) their getting food from paddy ecosystem. Farmers and agricultural workers face chronic health effect due to prolonged exposure to pesticides. Eye, dermal, pulmonary, neurologic and kidney problems were found to be significantly associated with long-term pesticide exposure (Pingali et al. 1995). It was likewise found that health effects in areas of intensive pesticide use are more serious than in areas with less intensive pesticide use. On the other hand, Warburton et al. (1995) reported that 31 percent and 63 percent, respectively of Laguna and Nueva Ecija farmers in the Philippines get food other than rice from the paddy ecosystem. All of these things such as vegetables, root crops, frogs, fish are potentially contaminated by high intensity of pesticide use.

3.2 Agrochemicals in Vegetable Production in Vietnam

3.2.1 Fertilizer and vegetable production

Organic Fertilizer

Organic fertilizers are popularly used in commercial vegetable production in Vietnam. But most vegetable producers in Ho Chi Minh City do not have experience in making compost from animal manure and fresh garbage. Thus, they usually apply fresh garbage directly to the crops. Vegetable producers in Hoc Mon district use fresh urban garbage (raw rubbish fertilizer) in the amount of 35-50

Table 3.8. Average amount of fertilizers applied for cabbage and tomato

Kind of Fertilizers	Cabbage		Tomato
	Hoc Mon	Cu Chi	Hoc Mon
Fresh urban garbage (t/ha)	50	0	35
Animal manure (t/ha)	30	35	35
Oil cake (kg/ha)	400	600	800
Urea(kg/ha)	350	200	200
Superphosphate (kg/ha)	200	200	100
Clorua Potassium (kg/ha)	200	180	150

Source: Plant Protection Department (IAS) t/ha for cabbage. In contrast, Cu Chi district is relatively far from the center, thus farmers do not use fresh urban garbage.

For animal manure, farmers at both sites usually apply dry cattle dung for vegetables with the average amount of 30-35 t/ha *(Table 3.8)*.

Nitrogen Fertilizer

Table 3.9 summarizes the recommendations of fertilizer rates for cabbage and tomatoes from several sources. Many nitrogen experiments for cabbage in the University of Agriculture and Forestry (UAF) in HCM City revealed that suitable amounts of nitrogen varies from 15-18 kg $N/1000m^2$. This is confirmed by Thi (1996) in Red River Delta (Northern Vietnam) where cabbage grown in winter-spring early season should be applied 15-18 kg $N/1000m^2$, whereas cabbage planted early need only 12-15 kg $N/1000m^2$.

UAF researchers reported that applying 15 kg $N/1000m^2$ in cabbage production in Hoc Mon district gave the highest yield and economic efficiency. On the other hand, Quyen et al. (1995) recommended that the most suitable amount of nitrogen for cabbages and tomatoes are 13.8 and 7.5 kg $N/1000m^2$, respectively.

Agricultural Extension Service (AES) of HCM City made a recommendation of 17.4 kg $N/1000m^2$ for tomatoes growing in winter-spring season, while Thang and My (1996) suggested that the suitable amount of nitrogen for tomato growing in Northern Vietnam is about 7.8 kg $N/1000m^2$.

Phosphorous fertilizer

In Red River Delta in Northern Vietnam, Thi (1996) suggested that the most suitable amount of phosphorous for cabbage is 9 kg $P_2O_5/1000m^2$. In most studies conducted by the Vegetable Department of the Institute of Agricultural Science of South Vietnam (IAS), phosphorous of 6 kg $P_2O_5/1000m^2$ is used as a standard for cabbage. Quyen et al. (1995) recommended the amounts of phosphorous for cabbage and tomato growing in Ho Chi Minh City to be 6 and 8 kg $P_2O_5/1000m^2$, respectively.

The amount of phosphorous recommended by the Agricultural Extension Service (AES) of Ho Chi Minh City is about 14.5 kg $P_2O_5/1000m^2$ for tomato planting in winter-spring; while Thang and My (1996) suggested that 10-

Table 3.9. Recommended rate of fertilizers for cabbage and tomato

Kind of Fertilizer	Recommended Rate of Fertilizer (kg/1000 m^2)	
	Cabbage	Tomato
N	13.8 (Quyen et al. 1995)	7.8 (Quyen et al. 1995)
	15 (Kiet and Quyen, 1995)	7.9 (Thang and My, 1996)
	15 - 18 (Thi, 1996)	17.4 (A.E.C., 1996)
	15 - 18 (U.A.F., unpublished)	
P_2O_5	8 (Quyen et al. 1995)	6 (Quyen et al. 1995)
	6 (Kiet and Quyen, 1995)	10 (Thang and My, 1996)
	9 (Thi, 1996)	14.5 (A.E.C., 1996)
K_2O	12.5 (Quyen et al. 1995)	7.5 (Quyen et al. 1995)
	9 (Kiet and Quyen, 1995)	10 (Thang and My, 1996)
	12 (Thi, 1996)	10 (A.E.C., 1996)

U.A.F. = University of Agricultural and Forestry, Ho Chi Minh City, Vietnam
A.E.C. = Agricultural Extension Center for Ho Chi Minh City

14.5 kg P_2O_5/1000m^2 phosphorous for tomato production in Northern Vietnam is most suitable.

Potassium fertilizer

In Northern Vietnam, Thi (1996) suggested a potassium amount of 12 kg K_2O/1000m^2 for cabbage growing in winter-spring season; while the Vegetable Department IAS used 9 kg K_2O/1000m^2 as a standard for many studies on cabbage varietal experiments around the urban district of Ho Chi Minh City. Quyen et al. (1995) suggested that suitable amounts of potassium for cabbage and tomato are 7.5 and 12.5 kg K_2O/1000m^2, respectively.

In Northern Vietnam, Thang and My recommended a rate of 10 kg K_2O/1000m^2 for tomato. Agricultural Extension Service of Ho Chi Minh City also suggested the amount of 10 kg K_2O/1000m^2 for tomato production in winter-spring.

3.2.2 Pesticide use in vegetable production

Although there are about 200 kinds of insecticides available in Vietnam, vegetable farmers only use some familiar ones.

A survey in the vegetable zone of Ho Chi Minh City revealed that farmers use about 16 kinds of insecticides (Hung 1993). The most widely used insecticides are Cidi M50ND, Monitor 70SC, Sherpa 25EC, and Sumicidin. Farmers still use insecticides for vegetables that are banned by the Ministry of Agriculture and Rural Development. These include Methyl parathion, Monitor, Azodrin, Furadan, and Decis.

Most farmers do not have good knowledge in recognizing pests causing damage on their crops. This leads them to use pesticides improperly. Most farmers mix together 2-5 kinds of pesticides. Farmers also use very high dosage of pesticides and spray too many times throughout the season. A survey of IPM programs shows that the majority of cabbage producers apply pesticides 20-30 times for a cabbage crop. Some use pesticides more than 30 times *(Table 3.10)*.

Most farmers do not follow the advice of extension workers in pesticide application. In turn, their practices may harm their health as well as those of the consumers. They usually do not respect the recommended pre-harvest interval. In Hoc Mon district, 78.2 percent of households harvested cabbage and 59 percent picked tomatoes just 1-36 days after spraying pesticide. Sometimes, farmers spray pesticides in the afternoon, and harvest products the following morning. Their products could be contaminated with chemical poisons, which could affect vegetable consumers' health.

Table 3.10. Number of pesticide applications used for a cabbage crop (% households)

Number of Sprays/season	Tan Xuan (%)	Xuan T. (%)	Ba Diem (%)	Vinh Loc (%)	Average (%)
< 20	10	9.5	0	50	17.4
20 – 30	65	85.7	80	50	70.2
> 30	25	4.8	20	0	12.4

Source: Hung et al., 1993

In contrast, the situation of pesticide application in Cu Chi district appears to be relatively better. Perhaps, they have learned a lot from IPM trials conducted in the region. But some farmers in Ap Dinh, Cu Chi state that the time of harvesting usually depends greatly on vegetable dealers and the demand of the market. That is why, in some cases, products are harvested right after pesticide application to meet market demand. Some vegetable dealers also force farmers to spray Azodrin 3-4 days before harvesting to make products look good, smooth and juicy. This insecticide is extremely toxic and banned for use on vegetables. Similarly, most farmers in Red River Delta (Northern Vietnam) apply pesticides to all kinds of vegetables three days before harvesting (Thi 1996).

Because of the very intensive pesticide use in vegetable production and ignorance of the significance of pre-limit methods, report of the South Vietnam Agrochemical Quarantine Center showed that residue on vegetable products taken in Ho Chi Minh is higher than the Maximum Residue Limits set by the FAO-WHO *(Table 3.11)*. These are residues of methamidophos and monocrotophos which are classified as extremely toxic (Category I) by the WHO hazard classification. These high residues pose health risks more so to Vietnamese who consume a lot of raw vegetables. Thus, it is imperative to recommend policies that will promote safe vegetable consumption in Vietnam.

4.0 CASE STUDY METHODOLOGY

4.1 Production Function Approach

Production function analysis is useful for deriving measurements of relations between input use and yields at the farm level. It also enables analysis of the impact of different technologies through measurement of shifts in production functions and changes in factor intensities. It is based on the assumptions that (Kalizrajan 1990):

Table 3.11. Residue levels of methamidophos and monocrotophos on selected crops, Ho Chi Minh City, Vietnam (mm/kg)

Crop Samples	Methamidophos		Monocrotophos	
	Residue on Samples	MRL of FAO	Residue on Samples	MRL of FAO
Tomato	1.71	2	0	
Tomato	1.24	2	2.35	1
Chinese Cabbage	1.21	1	0	
Celery	4.73	1	0	
String bean	6.27	1-2	0	
Haricot	4.45	1-2	0	
Cabbage	24.78	1	33.8	0.2
Leafy onion	106.38	1-2	0	

Source: South Vietnam Agrochemical Quarantine Center

1. The farmers are observed in a range of circumstances at one time, with different sizes of operational holdings and level of input applications;

2. Farmers are price takers in both product and factor markets and factor prices are fixed competitively;

3. All farmers maximize profit based on anticipated output; and

4. Within the study area, all farmers have access to the same information on the technology.

The general functional relationship is expressed as: Y = f (X, Z) (1)

where: Y - yield of the crop per unit of area

X - vector of variable inputs

Z - vector of fixed inputs

4.2 Estimation Procedure

Numerous alternative mathematical forms can be used to estimate a production function. Some of the functions that are specified in the empirical agricultural production literature are the Cobb-Douglas, the transcendental functions and the quadratic functions. The Cobb-Douglas form is popular for the following reasons: 1) it is a simple model, and 2) its unitary elasticity of substitution usually fits a cross-section data very well. Both Cobb-Douglas and translog functions were fitted to the data generated in the case studies. However, the Cobb-Douglas production function was used to estimate physical productivity relationships in rice and vegetables studies.

4.2.1 Empirical model

The following Cobb-Douglas function in a log - linear form is defined:

$$LNYIELD = Ln\alpha o + \alpha_1 IPM + \alpha_2 EDUDUM + \alpha_3 SCLASSDU + \alpha_4 AREADU + \beta_1 LNEXP + \beta_2 LNN + \beta_3 LNP_2O_5 + \beta_4 LNK_2O + \beta_5 LNGAI + \beta_6 LNTODAY \quad (2)$$

where: Y = yield (t/ha)

N = amount of nitrogen (kg/ha)

P_2O_5 = Phosphorous (kg/ha)

K_2O = Potassium (kg/ha)

GAI = total dose of pesticides

TODAY = total man-days

IPM: Integrated Management Program (Dummy variable) 1 for IPM-trained farmers, and 0 otherwise

EXP = Experience of the farmers

SCLASSDU = Soil class (Dummy variable)
0 if soil type is the first grade (Highest quality)
1 for other soil types (Grade 2,3,4,5)

EDUDUM = mean education of adult family members (Dummy variable)
0 if farmer's educational level lower than sixth grade, and 1 otherwise

AREADU = Area of land owned by the farmers 0 if area less than 8000 squared meter, and 1 otherwise

4.2.2 Estimating the optimal amount of fertilizers and the cost of wrong mix of fertilizers

- To determine the optimal amount of fertilizers used in paddy/vegetable production to maximize profits:

We compute for the marginal physical product (MPP) of the factor i, and equate this to the ratio of the input and output prices. From regression coefficient:

$$\varepsilon xi = \partial LnY/\partial Lnxi = (\partial Y/\partial xi)\,(Xi/Y)$$

we have:

$$MPPxi = (\partial Y/\partial xi) = \varepsilon xi\ (Y/xi) \qquad (3)$$

where MPPxi is equal to the Marginal Physical Product of xi
Pxi = the price of nitrogen
Py = the price of the output

We could transform equation 3, by satisfying the following equation:

$$MPPxi \times Py = Pxi \qquad (4)$$

where MPPxi x Py = Marginal Value Product of input xi
Pxi = Marginal Factor cost of input xi

Substituting (3) into (4) gives:

$$\varepsilon xi\ (Y/Xi).Py = Pxi$$

then:

$$Xi^* = \frac{(\varepsilon xi\ Y.Py)}{Pxi}$$

where Xi* is the optimal amount of input Xi.

The optimal mix formula of fertilizers - xN / yP / zK / + AM is established based on the combination of the optimal amount of N/optimal amount of P/ optimal amount of K/ optimal amount of animal manure.

- Comparing the yield of optimal mix formula of fertilizers (Y1) with the yield of the wrong mix of fertilizers (Y2) obtaining the loss to production due to wrong mix (Δ Y):

$$\Delta Y = (Y_2 - Y_1).Py$$

Loss of Farmer Income per hectare due to wrong mix of fertilizers (per ha):

$\Delta I = (Y_2 - Y_1).Py$ *where* Py is the price of output

(Note: to obtain the value of Y1 and Y2 based on the survey data, we do the following: Substitute optimal amounts of N, P, and K, and animal manure in (1), holding other factors constant, and then we compute for Y1. The Y2 is derived using the actual data of farmers.

- One also can calculate the cost/ saving of farmers due to Wrong Mix of NPK:

  $\Delta C = (TC1 - TC2)$

  where TC2 = cost of wrong mix fertilizers + cost of these fertilizers' application:

$$\Sigma\, Xi\ .\ Pxi + \Sigma\, Lxi\ .\ P_L$$

where: Xi = amt. of fertilizer i
Pxi = price of fertilizer; Lxi is labor cost of applying fertilizer and P_L is price of labor

TC1 = cost of optimal mix of fertilizers + cost of these fertilizers' application:

$$\Sigma\, Xi^*\ .\ Pxi + \Sigma\, Lxi\ .\ P_L$$

where: x* is optimal amount of fertilizer i

- Total Loss (cost) / saving per ha of farmers due to wrong mix of Fertilizer:

$$\Delta L = \Delta I - \Delta C$$

Caveats:

We note that the optimum mix is dependent on the price ratios of the inputs and output. In instances where potassium is not available in the area, then we would not have any estimate of the price of this input. Also, if some farmers do not buy animal manure, then we can not compute for the optimal manure amount. There are local recommendations on the optimal mix and amounts by the extension office as seen in the previous discussions. These recommendations could be substituted in the production function to get the yield effects, holding the other variables constant. These yield effects represent the level of yields with current farmer management and using the recommended NPK. One could thus compute for the saving from the use of the optimal mix using this information.

4.2.3 Relationship between the wrong mix of fertilizers and pest population and levels of pesticide use

To determine the effect of nitrogen levels on the pest population, one needs to define a biological model of the dose-response function. We assume that both nitrogen and pest control variables affect pest populations. In turn, pest and natural enemy populations affect yields. Thus, a two-equation model would be of the form:

Pest population = f (Nitrogen, pesticides) (5)

Yield = f (pest population, natural enemy population) (6)

The coefficients of the dose response function can be taken from data derived from experiments and brown plant hopper population *(Table 3.6)*. The short duration of this study did not allow for biological studies and for further estimation of dose response function.

4.2.4 Cost of over-using pesticides as a result of high nitrogen use

Cost of pesticide over-use can be computed by comparing the cost of farmer practice with the cost of control of low pest population levels, i.e., CP = (Σ Qe . Pp + Lp . Pl) - (Cost of control of low pest levels)

where CP = cost of over-using pesticides

Qe = amount of pesticides over-used

Pp = price of pesticides

Lp = labor use for pesticide application (man-days),

Pl = price of labor for pesticide application (D/man-day)

4.2.5 Health cost function of farmers

The approach used in valuing health damage on farmers is a health cost function which is a log-linear regression model defined as follows:

Ln HC = f (LAGE, HEALTH, ACMOK, DRINK, LTODOSE, LINDOSE, LHEDOSE, NACATE12, NACATE34)

where: Ln HC = Log of health cost (cost of treatment + opportunity cost of farmers' time required to recuperate + the value of avoiding illness)

LAGE = log of farmers' age

HEALTH = farmers' weight by height

ACSMOK = dummy for smoking (0 for non-smoker, 1 for smoker)

DRINK = dummy for drinking alcohol (0 for non-drinker, 1 for drinker)

LTODOSE = LOG of total dosage of all pesticide used (kg a.i./ha)

LINDOSE = log of insecticide dosage used (kg. a.i. /ha)

NACATE12 = log of number of application in categories 1 & 2

NACATE34 = log of number of application in categories 3 & 4

Results of this function using data from Mekong Delta are reported in Dung (1997).

4.3 Valuing Health Damages of Vegetable Consumers

The approach used in valuing consumers' health damages is the Contingent Valuation Method (CVM). We generated Willingness to Pay (WTP) for safe vegetables to measure the consumers' value of health impacts of inorganically grown vegetables. We could validate these WTP values with actual prices that are found in the market for safe vegetables.

The data obtained from the CV formal survey include:

1. sample mean of the amount of WTP bid for safe vegetable products
2. respondents' value of clean vegetable products
3. social-economic standing (such as educational attainment, income, age, gender, profession, frequency of eating vegetable, etc.)

5.0 AGROCHEMICALS IN RICE IN THE RED RIVER DELTA

5.1 Overview of the Study Site

5.1.1 The Red River Delta

Red River Delta is the second largest rice growing region in the country after Mekong River Delta. The total rice cultivated area of Red River Delta is 626,100 ha accounting for 13.1 percent total rice area in the country. Red River Delta has alluvial soils generated from two important rivers namely, The Red River and Thai Binh River.

Farmers in this area engage in rice production, which is the main livelihood of the populace. It has the highest population density. In some parts, this density is more than 1000 per km^2. Average population growth rate is 2.2 percent annually. Farmers are also better-off in this area than in other rural regions in Northern Vietnam in terms of income, education, health care facilities and infrastructure.

In terms of agriculture, Red River Delta has a good soil fertility and irrigation system. Nearly 100 percent of cultivated rice land areas has access to irrigation system. Farmers practice two to three annual crops per year of which two rice crops are common. Lowland rice spring season is from Feb. to June, summer-autumn rice season is from July to October. In some areas, the third crop season starts from end of October to January with maize, sweet potato or vegetables as the popular crops grown.

Most rice varieties used are improved and high yielding varieties i.e., IR36, CR203, VN10, and others. Some improved varieties have very high resistance to insects and diseases. Because of high population pressure and lack of agricultural land, farmers have used high doses of agrochemicals such as fertilizers and pesticides for intensive rice agriculture.

It is reported that farmers in the area applied 100-160 kg N/ha of rice produced (Son and Hien, 1995). The rice yield of from 4 to 5 t/ha is common. The survey in Ha Tay province showed that on alluvial soil, the high yield was obtained with an application of 150-160 kg N, in combination with 16 tons of farmyard manure, 90 kg phosphorus, and 60 kg of potassium per hectare. The pesticide use varies widely and depends on the level of pest incidence.

5.1.2 District study site

1. Description of the study site

Two districts belonging to two different provinces were selected for the study. The first is My Van district of Hai Hung province. It is about 50 km east of Hanoi. The other is Duy Tien district of Ha Nam province that is located in Southern Red River Delta and about 60 km from Ha Noi. Both study areas are rice growing.

But cultivated land area per capita is very low. It is 560 and 658 m^2 per capita in My Van and Duy Tien district, respectively *(Table 5.1)*.

Farmers in sample survey sites have high education status *(Table 5.2)*. Fifty to 65.9 percent of them finished secondary school while 19.5-38.6 percent are of high school level.

2. Current cropping system

The common cropping systems in these rice areas are as follows: spring rice-autumn rice; and spring rice-autumn rice-winter crop (sweet potato / corn / potato / vegetable).

3. Fertilizer application recommended by the district Extension Department

Commonly, the district Extension Department advises farmers to use fertilizers based on season and rice variety. In spring season, they advise farmers to apply 100 - 120 kg nitrogen, 80-100 kg

Table 5.1. Description of the district study site

Item	Unit	District	
		My Van	Duy Tien
1. Land area- total natural land			
Lowland rice	Ha	21,203	12,772
Perennial crop land	Ha	13,862	7,838.6
Water surface area	Ha	137	300.4
	Ha	Not available	783.0
2. Population	Person	250,084	123,638
Number of households	Household	61,956	31,016
3. Cultivated land area per ita	m^2	560	658

Table 5.2. Education level of sample household heads n = 87

Education level	Duy Tien (%)	My Van (%)
1 – Elementary School	14.6	9.1
2 – Secondary School	65.9	50.0
3 – High School	19.5	38.6
4 – Other	-	2.3
Number of household survey	43	44

phosphorous, and 40 - 50 kg potassium, for improved varieties, and 40 kg potassium per ha for non-improved varieties. In autumn season, recommended amount of fertilizers applied is slightly lower than that of spring season. Compost and animal manure are applied in the amount of 6-10 t/ha in each crop season.

4. Rice varieties used in the study site

It appears that most farmers in Red River Delta used improved rice variety. These varieties are from Vietnamese Agricultural Research Institute, China, and the International Rice Research Institute (IRRI). There are many varieties that were introduced at the same time. However, it is difficult for farmers to select pest resistant varieties. Farmers usually have a combination of several varieties planted in their plots. The rice varieties used in the study site are: CR203, VN10, C70-71, 1561, CN2 (sources from IRRI and V.N. Research Institutes), Ai32, Q5, TAPGIAO1, KHE UU25 (Hybrid rice varieties from China).

5.2 Analyzing the Effects of Agrochemicals on Rice Yield

5.2.1 Descriptive statistics

Farmers used high quantity of nitrogen; 121.9 kg in spring season, 95.99 kg in autumn season *(Table 5.3)*. Phosphorus and potassium are applied at low levels. They applied much higher amounts of chemicals in the spring season compared to autumn season.

Table 5.4 shows that the larger the farm size, the lower the agrochemical investment. As a result, this gives lower paddy yield. The reason could be that the smaller parcels are usually located nearer the village, so farmers tend to cultivate the area intensively.

For the two crop seasons, household heads who have higher education levels tend to use more fertilizers, pesticides and labor input *(Table 5.5)*. Therefore, their rice yields are higher in comparison with those of farmers with lower education. Perhaps, they understand more clearly the

Table 5.3. Current use of fertilizers and pesticides by farmers in two districts, (per ha), 1996

Inputs and Rice Yield	Unit	Spring Season	Autumn Season
Nitrogen	kg	121.90	95.99
Phosphorus	kg	61.68	44.7
Potassium	kg	29.11	24.66
Animal manure	kg	6.871	3.8
Pesticides	gram a.i.	1972.6	857.5
Insecticides	gram a.i.	1463	622.1
Fungicides	gram a.i.	509.6	235.4
Rice yield	kg	5755.0	4020

Table 5.4. Farm size and agrochemical input use, 1996

Spring season (n=86)								
Farms (m^2)	N (kg)	P (kg)	K	AM (t)	Fungi-cide (g.a.i.)	Insec-ticide (g.a.i)	Man day	Yield (kg)
336-720	126.5	67.2	33.5	7.5	558.8	1628.8	204.8	6019
720-1080	119.4	57.5	26.3	6.2	449.2	1411.0	169.6	5587
>1080	118.0	58.5	25.8	6.8	448.3	1248.0	183.1	5552
Autumn season (n=87)								
Farms (m^2)	N (kg)	P (kg)	K	AM (t)	Fung-cide (g.a.I.)	Insec-ticide (g.a.i)	Man day	Yield (kg)
336-720	101.9	48.6	29.0	4.5	256.4	688.9	164.6	4164
720-1080	97.2	44.6	25.1	3.7	249.1	608.8	165.6	3989
>1080	84.6	38.3	17.3	3.1	177.9	548.1	145.6	3851

Table 5.5. Farmer education and agrochemical use

Spring season (n=86)

Education	No. of HH	N (kg)	P (kg)	K (kg)	AM (t)	Fungi-cide (g.a.i)	Insecti-cide (g.a.i)	Yield (kg/ha)	Man-Day
< 7	36	114.1	56.5	23.8	6.18	452.4	1277.2	5567.3	186.7
> 7	50	127.5	65.4	32.9	6.45	550.1	1597.5	5933.0	187.0

Autumn season (n=87)

Education	N (kg)	P (kg)	K (kg)	AM (t)	Fungi-cide (g.a.i)	Insecti-cide (g.a.i)	Yield (kg/ha)	Man-Day
< 7	83.30	39.7	19.2	3.36	202.5	561.6	152.6	3863.7
> 7	105.8	48.3	29.0	4.23	260.8	671.3	167.0	4140.6

Table 5.6. Yield and agrochemical use

Spring season

Yield (kg/ha)	No. of HH	N (kg)	P (kg)	K (kg)	AM (t)	Fungi-cide (g.a.i)	Insecti-cide (g.a.i)	Man-Day
4139-5695	33	103.8	43.25	15.30	4.61	329.5	963.2	174.1
5694-5913	28	113.7	65.76	34.07	7.01	524.2	1492.3	231.0
5913-7392	25	153.9	82.90	44.15	8.50	748.6	2121.3	192.1

Autumn season

Yield (kg/ha)	No. of HH	N (kg)	P (kg)	K (kg)	AM (t)	Fungi-cide (g.a.i)	Insecti-cide (g.a.i)	Man-Day
2770-4000	30	60.61	26.38	3.52	1.83	100.01	331.70	123.8
4000-4400	37	99.91	48.19	29.7	4.50	270.30	72. 803	169.3
>4400	20	141.8	65.14	47.0	5.66	373.50	1358.90	199.9

need of intensive investment. Or, they might have better economic condition that allows them to invest more.

Tables 5.6 and 5.7 show that higher yield parcels in both seasons had higher investment in agrochemicals. This was found to be true in N, P and K.

Thus, survey results also indicate that farmers rely so much on agrochemicals. A 30 percent increase in price will not affect their current levels of use. However, compared to P and K use, N use will be reduced according to 17 percent of farmers. *(Table 5.8)*

Farmers mentioned that their important source of information for agricultural technologies are the radio, television, and newspapers. The role of extension workers contributed only 27.91-32.56 percent. About 50 percent of farmers relied on their production experience *(Table 5.9).*

5.3 Estimating Agrochemical Effects on Rice Yield

Cobb-Douglas production function was estimated with the following variables:

Table 5.7. Nitrogen use and rice yield

Nitrogen (kg)	No. of HH	P (kg)	K (kg)	AM (t)	Fungi-cide (g.a.i)	Insecti-cide (g.a.i)	Yield (kg/ha)
Spring season							
75.8 – 105	27	47.1	18.7	4.83	369.7	1081.6	5137.8
105 – 139	34	59.3	27.3	6.59	459.8	1325.9	5618.1
139 – 172	25	80.6	42.6	9.40	728.5	2062.9	6607.2
Autumn season							
20 – 79	27	26.28	5.15	1.78	111.12	393.48	3474.0
80 –120	33	45.70	25.3	4.23	239.18	615.37	4055.9
> 120	27	60.81	42.7	5.41	350.70	854.32	4504.2

Table 5.8. Household responses to a 30% price increase of agrochemicals (% of households)

	The same	less than	More than
N	82.0	17.0	1.0
P	90.7	8.1	1.2
K	87.2	6.98	2.33
Pesticide	95.0	5.0	0.0

Table 5.9. Percentage of farmers receiving information on various topics from different sources

Sources	Fertilizer Use	Pesticide Use	Seed Variety Use
Radio	48.84	43.00	27.91
Television	27.91	17.44	10.47
Newspapers	23.26	12.79	8.14
Extension	27.91	32.56	25.58
Cooperative	20.93	22.10	23.16
Other farmers	8.14	5.81	12.79
Seller	1.16	1.17	2.33
Experiences	50.00	29.10	41.86
Others	15.11	27.91	6.98

Table 5.10. Estimated yield equation function for rice, Red River Delta, 1996

Dependent Variable: Ln Yield	Coefficients	
Variables	Spring	Autumn
1. Ln INTERCEPT	7.60	5.02
	(29.4)	(36.15)
2. Ln N	0.068***	0.02***
	(3.76)	(3.12)
3. Ln P	0.038	0.035***
	(3.99)	(4.48)
4. Ln K	0.012***	0.009***
	(3.42)	(3.13)
5. Ln AM	0.015*	0.015**
	(2.25)	(2.48)
6. Ln FUNG	0.029***	0.010***
	(3.54)	(2.92)
7. Ln NSECTI	0.018	0.018**
	(3.47)	(2.26)
8. Ln MANDAY	0.039	0.079**
	(0.8)	(2.61)
9. DSOIL	-0.020	-0.008
	(-1.07)	(-0.96)
10. DEDU	0.023	0.007
	(1.51)	(0.76)
R squared	0.683	0.9301
F computed	18.24***	113.92***
Number of observations	86	87

Note: Data in parentheses are t-statistics
** sigificant at 5% level
*** significant at 1% level

Table 5.11. Marginal Physical Product (MPP) of agrochemicals in rice production, Red River Delta, Vietnam, 1996

Fertilizer (X)	Spring Crop		Autumn Crop	
	X	MPPx	X	MPPx
N	121.90	3.2	95.99	2.6
P	61.68	3.58	44.57	3.2
K	29.11	2.3	24.66	1.5
AM	6.87	12.5	3.85	15.5

Dependent variable:

Rice yield per hectare (kg/ha) of cultivated area in each crop season for the largest parcel of each household

Independent variables:

Dedu is a dummy variable (Dedu = 0 if schooling years < 7; = 1 if schooling years > or 7)
D Soil is all types, a dummy variable Dsoil = 0 if soil class = 1 or 2 DSoil = 1 if soil class = 3 or 4
N is amount of Nitrogen applied in each crop season in kg/ha
P is amount Phosphorus applied in each crop season in kg/ha
K is amount of Potassium applied in each crop season in kg/ha
AM is amount of standard animal manure applied in each crop season in t/ha
where a 1 to AM mixture is composed of

= 1 ton of standard pig waste composted
= 2 tons of cow and buffalo waste composted
= 1/3 tons of chicken or human waste composted.

Fung is fungicides used per hectare in each crop season in gr. a.i.
Insecti is insecticides used per hectare in each crop season in gr. a.i.
Man-day is the amount of labor input per crop per season, in man-day/ha

Separate regression equations are estimated for the two different crop seasons: spring and autumn. In the former, it was warm, highly humid with moderate sunlight - a good condition for pests, fungi and weeds to develop. In the latter, it was very hot with much heavy rain. These different weather conditions lead to different effects of the agrochemicals and other inputs on the rice yield. The above results of the regressions indicate that N, P, K, AM, FUNG and INSECTI are dominant explanatory variables of rice yield in both crop seasons.

Labor input (MANDAY) is also important but more clearly in the autumn crop. This is needed to take out the flood water from the farms during the early stage of the rice crop growth. Soil type does not affect the rice yield so much, as soil fertility in farms in the Red River Delta are not much different. Education also does not affect the rice yield because farmers in the region have been cultivating rice for a long time, and hence, are very experienced, and often exchange this learning to others. The education level is almost uniform across the respondents; this absence of variation cannot capture the education effect on yield.

To estimate the economic efficiency of each agrochemical and AM as well, the first order condition for profit maximization was solved.

From (3), we have

$$MPPxi = \varepsilon xi \frac{Y}{Xi}$$

where: εxi - Coefficient of variable Xi, (also interpreted as production elasticity for input Xi)
Y - Average yield of rice
Xi - Average level of fertilizer i
MPPxi = marginal physical product of input Xi

The MPP of other kinds of fertilizer can be similarly computed. Thus the figures in Table 5.11 show that N, P, K in spring season gave higher rice return than those in autumn season, because there are no yield losses caused by heavy rain and flood. In spring, a one-kg increase in N will result to 3.2 kg increase in paddy yield. Also animal manure in autumn season gave higher rice return compared to that in spring season because the higher temperature makes AM more effective as a nutrient source.

As animal manure becomes more effective, chemical fertilizer becomes secondary sources of nutrient. This is especially true with K, that is available in animal manure and can be extracted by the paddy plant.

5.4 Estimating the economically optimal level of agrochemical application and the over-use levels.

In practice, farmers, in the area only want to maximize yields and not profits. In other words, they do not know how much agrochemicals they need to maximize their profit. The basic idea of determining these economically optimal levels of agrochemical application is to estimate the amount at the profit – maximizing point.

To do so, we use the formula (4)

$Xi^* = (\varepsilon xi.\ Py.Y)/Pxi$

where: Xi^* = optimal level of the input Xi

εx = coefficient of the variable Xi

Py = unit price of rice

Y = average yield of rice

Pxi = unit price of the input Xi

The optimal levels of agrochemical application depend on the yield, price of rice and the unit price of the chemical as well as the coefficient ex. In its turn, ex depends on its application level.

For example: for Spring season:

a) N^* = 0.068213 x 1800 (VD/kg rice) x 5755 kg rice/7012 (VND/kg N) = 100.8 kg
b) P^* = 0.038321 x 1800 (VND/kg) x 5755 kg rice/6000 (VND/kg P_2O_5) = 66.16 kg
c) K^* = 0.011727 x 1800(VND/kg) x 5755 kg rice/6000(VND/kg K_2O) = 20.25 kg

Similarly, we can derive for optimal levels of FUNG, INSECTI for the spring season and that of each agrochemical for the autumn season. The output and input prices are found in Table 5.12. Comparing those with the actual levels, one can determine that agrochemical is over-used although these absolute values may not be statistically significant from zero.

Table 5.12. Current price of input and output

Price	Unit	Spring Season	Autumn
Paddy	VND/kg	1800	2200
N	VND/kg	7012	6000
P	VND/kg	6000	5800
K	VND/kg	6000	5400
Insecticide	VND/gram a.i.	140	125
Fungicide	VND/gram a.i.	800	620
AM	VND/ton	200000	200000
Wage rate	VND/man-day	10000	10000

Table 5.13 indicates that farmers in Red River Delta over-use agrochemicals in rice production, with the exception of phosphorus. In spring season, farmers used more fertilizers and pesticides than in autumn season. However, we need to test whether the difference in the optimal levels and the current practice are statistically significant.

In autumn season, nitrogen, potassium and fungicides were found to be over-used while phosphorus and insecticides were under-used. Caution must be taken in interpreting insecticide use. In this analysis we assumed that pest incidence is the same in both seasons. In reality this might not be the case.

In spring, many farmers sprayed pesticides periodically even if there was no pest infestation. In North Vietnam, a limited training on Integrated Pest Management (IPM) was done. In autumn season, farmers were not worried too much about the pest incidence. Thus, the estimate obtained in the insecticide may not be a normal figure. Productivity of insecticides could only be observed if there is pest infestation. Hence, the figure in Table 5.13 should be taken with caution, i.e., the optimal level of insecticide use should also be a function of pest levels.

5.4.1 Estimating the cost of agrochemical over-use

Cost of chemical over-use is equivalent to 193 kg of paddy in the spring season and 60 kg of paddy in the autumn season *(Table 5.14)*. This was computed based on the method outlined in Chapter 4.

5.4.2 Estimating the optimal mix of NPK and its profitability

The economically optimal mix of NPK on Red River Delta alluvial as estimated from Table 5.13 is as follows: (1) for spring season: N/P/K is 100/66/20; and (2) for autumn season: N/P/K is 91/54/16.

However, the above combination of NPK is true only for 1996 prices of inputs, outputs and yield levels. The optimal combination will be changed if there is a

Table 5.13. Determining over-use of agrochemicals in rice in the Red River Delta, 1996

Chemicals	Spring season			Autumn season		
	Optimal	Actual	Over-use	Optimal	Actual	Over-use
Nitrogen (kg)	100.8	121.90	+12.13	91.0	95.99	+4.99
Phosphorus (kg)	66.2	61.68	-4.48	54.4	44.57	-9.83
Potassium (kg)	20.2	29.11	+8.86	15.6	24.66	+9.06
Fungicides (g.a.i)	378	509.60	+131.6	148.0	235.40	+87.4
Insecticides (g.a.i)	1376	1463	+87	1285.7	622.10	-663.6

Table 5.14. Cost of agrochemical over-use (CAO)

Chemical	Unit	Spring		Autumn	
		Over-use	CAO (VND)	Over-use	CAO (VND)
N	kg	12.13	148,164	4.99	29,940
K_2O	kg	8.86	53,160	9.06	48,924
Fungicides	g.a.i.	131.6	105,280	87.4	54,188
Insecticides	g.a.i.	87	12,180	-	-
Total CAO			*328,788*		*133,052*
Paddy Equivalent	kg		*193*		*60*

change in at least one of these factor prices. Thus, an increase in Nitrogen price, all other prices constant will lead to low use of nitrogen; but an increase in paddy price, all other prices constant will lead to higher nitrogen use. Pricing policy indeed affects input use, in instances that farmers' objective is to maximize profits.

These estimates are not significantly different from the previous estimates of other researches and the Extension Services in other districts, in terms of N and P. However, amount of optimal K is lower in this study than in the previous studies. It is thus highly recommended to check on the said contents in terms of P and K, before local recommendations can be made.

Table 5.15 further shows that use of the optimal mix of N, P, and K results to higher yields and higher profits, as compared to farmers' practice.

5.5 Analyzing the Relationship Between Nitrogen Use and Pest Population on Rice

Available research results (Tran Ngoc Huan, et al. 1996) show that the higher the N, the higher is the brown planthopper population and the faster the yellow leaf disease development. Different mix of fertilizers and different ways to apply fertilizers give different effects on pest and diseases. Experiments in Hanoi Agricultural University (Nguyen Nhu Ha, Ha Quang Ninh 1995) showed that:

1. with no fertilizer applied (control plot), density of pest and percentage of paddy affected by disease is lower than others;

2. with the same amount of NPK equivalent, different frequency of application give similar effect on small leaf folder but different effect on stem borer *(Tryporyza Lurida* Bur). With the same NPK equivalent, the higher frequency of application led to serious stem borer attack;

3. with the same NPK equivalent, different mixes of AM and chemical fertilizer do not affect pest population and diseases, but has an effect on paddy yield, i.e., yield reduces with lower chemical fertilizer/AM rate;

4. if nitrogen and potassium are applied before transplanting time, it makes paddy grow stronger and faster, and hence, can be more resistant to pests and diseases; and

5. summer – autumn cropping without potassium application leads to more pests and diseases, hence, less yield.

The other research by the Plant Protection Institute showed that the high nitrogen amount caused high population of brown plant hopper in Lonh Binh and

Table 5.15. Comparison of yields and profits between optimal mix, farmer practice, and recommended rates

Indicators		Optimal Mix	Farmer Practice	Recommended Rate (by Extension Workers)
N-P-K (kg/ha)	Spring	101-66-20	122-62-24	120-100-50
	Autumn	91-54-16	96-45-25	100-80-40
Yield (kg/ha)	Spring	5813	5750	-
	Autumn	4241	4020	4341
Profit (VND/ha)	Spring	4,292,986	3,877,678	
	Autumn	4,276,288	3,794,00	

Long An province. When nitrogen increased from 90 N to 120 N per ha, the number of brown plant hopper increased from 12.2 /hill to 32.2/hill heading stage of rice.

Although recommended for further research, available evidence supports the hypothesis that over-use of nitrogen will lead to more pest outbreaks hence, more pesticide use. The optimal amount of nitrogen used in rice will lead to lower costs, in terms of private outlay and lower social costs, in terms of savings in health-related expenses.

5.6 Analyzing Impacts of Pesticide Use on Rice Farmers' Health

The frequent exposure to pesticides led to health impairment as shown by previous studies. In this case study, empirical estimation of economic variables was done to assess damage of pesticide exposure on farmers' health.

5.6.1 Descriptive analysis

1. Characteristics of farmer respondents

There are 56 percent and 61 percent farmers smoking, and 60 percent and 59 percent farmers who drink alcohol in Duy Tien and My Van, respectively. Most smokers and drinkers are men who are heads of households *(Tables 5.16 and 5.17)*.

2. Descriptive statistics of pesticide impact on farmers' health

The average distance from farmers' house to the field is 0.65 km and 0.7 km in Duy Tien and My Van, respectively. However, 85 to 90 percent of farmers recognized pesticide odor during crop season from 2-3 days of each spraying period. They can not remember how

Table 5.16 Physical characteristics of rice farmer respondents, Red River Delta, 1996 (n=87)

Farmers' Characteristics	Duy Tien (Nam Ha)	My Van (Hai Hung)
Weight (kg)	52	50
Height (cm)	164	162
Married (%)	93	87
Age (in years)	45	43

Table 5.17. Percentage of farmers who smoke and drink in the Red River Delta, 1996 (n=87)

Farmers' Habit	Duy Tien	My Van
Smoking	56	61
Drinking	60	59

many times they can smell pesticides because there are too many people spraying pesticides in the fields at different times.

All farmers are aware that pesticides affect humans after long term exposure to chemicals. Table 5.18 shows that farmers in Red River Delta used pesticides for a long time. Most of them used pesticides from 5 - 15 years. About 93 percent of farmers in My Van and 65 percent of farmers in Duy Tien said that pesticides have significant effect on farmers' health *(Table 5.19)*.

It appears that most of the farmers reported an increase in the amount and frequency of application of pesticides *(Table 5.20)*. About 40 percent of farmers said that frequency of application increased considerably from first usage to current usage.

Most farmers also reported to have experienced acute illnesses due to pesticide exposure. Most said that they experience headaches *(Table 5.21)*. Farmers are willing to pay a positive amount to avoid being ill *(Table 5.23)*.

They also reported that they have to take days off when stricken with illness *(Table 5.22)*. With respect to chronic effects, studies elsewhere show that an increase in the number of doses would result in higher health costs for rice farmers (Rola and Pingali, 1993).

The recognition by farmers of the negative impact of pesticide use should have some implications for policy. Currently, Vietnam does not have a strong pesticide regulatory policy. Most of efficiency gains in the use of pesticides is via farmer education on the proper pesticide handling, and also the appropriate equipment. There is no policy to educate the farmers along other pest management strategies. Although Vietnam has been aggressive with the training of farmers on Integrated Pest Management (IPM), most of these were conducted in South Vietnam, where intensive rice cultivation is prevalent. However, as North Vietnam becomes more and more commercialized, farmers tend to use more agrochemicals. Thus, it is also relevant for these training to be done in the North.

Table 5.18. Number of years farmers sprayed pesticides in Red River Delta, 1996, (% of farmers, n=87)

Year	Duy Tien	My Van
<5	32	10
5-10	38	38
11-15	15	36
16-20	10	14
>20	5	2

Table 5.19. Farmer perception on the effects of long time application of pesticides, Red River Delta, 1996, (% of farmers, n=87)

Farmers' Perception	Duy Tien (%)	My Van (%)
No effect	0	0
Very little effect	10	0
Little effect	25	7
Much effect	55	36
Very much effect	10	38
Extreme effect	0	19

Table 5.20. Farmer perception regarding changes in the amount and frequency of pesticides applied from the time of first use to the present, Red River Delta, 1996, (% of farmers, n=87)

Perception	Amount	Frequency of Application
Decreased	17	20
No different	3	5
Increased a little	38	35
Increased a lot	42	40

Table 5.21. Symptoms experienced by farmers after applying pesticides in Red River Delta, (% of farmers, n=87)

Symptom	Duy Tien	My Van
Eye irritation	30	6
Headache	78	77
Dizziness	38	38
Vomitting	10	2
Diarrhea	13	0
Shortness of breath	10	17
Heart trouble	13	4
Skin irritation	68	60
Others	40	30

Note: Multiple answers

Table 5.22. Farmers' activities when stricken ill due to acute pesticide exposure, Red River Delta, 1996 (% of farmers, n=87)

Activities	Duy Tien	My Van
Take day off	51	53
Stay in bed	45	53
Go to clinics	8	0
Go to hospital	5	2

Table 5.23. Willingness to pay to avoid being ill, Red River Delta farmers, 1996, (% of farmers, n=87)

Vietnam Dong (VND)	Duy Tien	My Van
<100.00	31	17
100.00-200.00	32	44
200.00-300.00	30	19
300.00-400.00	5	4
>400.00	2	16

Note: 1 US$ = 11600 VND

6.0 AGROCHEMICALS IN VEGETABLES: A CASE STUDY IN HO CHI MINH CITY

6.1 Description of the Study Site

Ho Chi Minh City (HCM) has a population of 4.5 million with a total area of 209,031 ha. Total area for vegetables is about 11,000 ha *(Table 6.1)*. Almost all kinds of tropical vegetables are grown in Ho Chi Minh City.

Local farmers have valuable experience and long tradition in growing vegetables. Most agricultural areas in Ho Chi Minh City are planted to paddy rice during the rainy season with vegetables being grown during the dry season. There are some areas devoted to vegetables for the whole year; one of these is the Cu Chi district.

Location of study site

This study was done in two vegetable-growing districts of Hoc Mon and Cu Chi in HCMC. It is bounded to the North by Binh Duong, to the West by Tay Ninh, to the South by Long An provinces. The study site has a good road system to connect to the other urban districts of Ho Chi Minh City.

Agricultural land

Average land area for growing vegetable per household is relatively small *(Table 6.3)*. The majority of vegetables are produced in a land area of 0.3 - 0.6 ha; very few farmers have land area greater than 0.6 ha. About 28.6 percent of farmers have land area less than 0.3 ha.

Hoc Mon district has a total area of about 15,552 ha. In 1993, vegetable production accounted for 3,500 ha, but this area expanded to 4,112.9 ha in 1995. Vegetable growing areas are scattered on 16 communes. However, they are mainly concentrated in Xuan Thoi Thuong (690 ha), Tan Xuan (647.8 ha), Tan Thoi Hiep (637.2 ha), Tan Thoi Nhi (485 ha), Xuan Thoi Son (374 ha). As an agricultural district, Cu Chi has a total agricultural land of 25,664 hectare of which annual crop land occupies 23,918 ha and perennial crop land 1,746 ha.

Along with the development of Ho Chi Minh City, the vegetable growing areas in Cu Chi district increased gradually in recent years. Vegetable growing area ranks third after rice and peanut.

Weather condition

The climate in the study site is monsoon type with two distinct seasons. The rainy season is from May to November, and the rest of the time is dry season.

Mean annual temperature is 27°C with a range of 16°C between the highest (38°C) and lowest month temperatures (22°C). Mean annual rainfall is 1,800-2,000mm with 130 rainy days. Mean annual humidity is 83%, in which the lowest humidity is in February (75%).

Water sources

At the study site, there are five layers of groundwater that could be used for vegetable production in the dry season. Other sources of water for vegetable production include "Eastern canal", which gets water from Dau Tieng reservoir and many branches of the Saigon River.

The site has an elevation of 3.5 - 5 m above mean sea level. The soil type at both current study sites is sandy loam in grey degraded soil with light texture.

Table 6.1. Effective area of vegetables in the Ho Chi Minh City (ha)

District	Whole Year	Winter-spring (Nov - Feb)	Summer-Autumn (Mar - Jun)	Autumn-Winter (Jul - Oct)
Cu Chi*	2,411	980	737	699
Hoc	3,446	1,761	837	844
Mon*	486	164	162	160
Thu Duc	2,853	1,477	390	986
Binh	5	-	-	5
Chanh	1,636	820	521	295
Nha Be	271	119	103	49
Go Vap	9	5	2	2
Tan Binh	216	69	81	66
Binh				
thanh				
Quan 8				
Total	11,334	5,395	2,833	3,016

*Sites of current study

Source: (Bureau of Agriculture and Rural Development, HCMC, 1993)

Table 6.2. Vegetable growing season in Hoc Mon district and percent of households planting vegetables

Planting Season	Cabbage	Cauliflower	Eggplant	Cucumber	Tomato
Jan. – Mar.	57.3	18.5	0.0	54.1	47.1
Apr. – Jun.	1.1	0.0	0.0	7.8	2.3
Jul. – Sept.	3.3	4.5	23.4	0.0	0.0
Oct. – Dec.	37.3	77.0	76.6	38.1	50.6

Source: Hoc Mon People's Committee 1996

Table 6.3. Average land area for growing vegetables per household (Hung et al., 1993)

Land Area	Percentage of Household (%)
< 0.03 ha	28.6
0.30 - 0.60	58.6
0.61 - 1.0	11.4
> 1 ha	1.4

In general, the soil is acidic and this acidity increases with the depth of soil profile. Carbon content is medium and decreases rapidly at deeper layers. The soil has relatively low nitrogen content. Similarly, phosphorous and potassium contents are also very low.

Although, grey degraded soil is considered of poor quality, the study site has many great potentials such as relatively even and flat terrain, suitable for many kinds of vegetables, and an abundant source of groundwater.

6.2 Demographic Characteristics

The survey was conducted during the dry season of 1996 (November-December). Sixty households of the two districts of Hoc Mon and Cu Chi were interviewed, in which 59 questionnaires have reliable data.

Most of the respondents in the site were males; only three females are decision-makers in vegetable production *(Table 6.4)*. Females are usually responsible for crop care such as handweeding and harvesting. Males are responsible for applying fertilizers and pesticides, and watering.

Education level of most respondents is relatively low (grade 1-9). Many of the farmers are unaware of the composition of fertilizers and their knowledge in insects and pesticide use is limited. Most of the families had 3-5 members above 13 years old. Their total gross income varies from 10-50 million VND. Only 15 households borrowed money from Agricultural Development banks for vegetable production and animal husbandry.

Sources of information

In general, extension network in the study area is very weak. Furthermore, the skill and knowledge of extension workers are still very basic.

Table 6.4. Demographic characteristics of the respondents, Hoc Mon & Cu Chi, 1996

Characteristic		Respondents No.	%
Sex	Female	3	5.1
	Male	56	94.9
Age	< 40	13	22.0
	40 – 49	23	39.0
	50 – 59	17	29.8
	= and > 60	6	10.2
Education	Level 1 (grade ≥5)	25	42.4
	Level 2 (grade 6 - 9)	31	52.5
	Level 3 (grade ≥ 10)	3	5.1
Family size (of members older than 13 years)	2 persons	4	6.8
	3 persons	15	25.4
	4 persons	14	23.7
	5 persons	13	22.0
	6 persons	7	11.9
	7 persons	6	10.2
Gross income (million VND)	< 10	3	5.1
	10 - 19	15	25.4
	20 - 29	19	32.2
	30 - 39	9	15.3
	40 - 49	9	15.3
	= and > 50	4	6.7
Credit (million VND)	0	44	74.6
	0.1 - 2	6	10.2
	2.1 - 3	5	8.4
	> 3	4	6.8

Most of the vegetable producers learned how to apply fertilizer, pesticide and select vegetable varieties from their co-farmers. About 15 percent of tomato growers seek advise from extension workers for new varieties *(Table 6.5)*.

Only 5 percent of farmers read booklets and magazines to learn procedures and techniques for applying fertilizers and pesticides efficiently. About 10 percent of vegetable growers listen to radio programs to know more about fertilizers and pesticides.

Education Level

Survey results indicate that education level of the farmers influences yield of vegetables. Farmers usually prefer nitrogen fertilizers to phosphorous and potassium fertilizers because of its short-term impact on yield. Farmers with high education level (2-3) applied more phosphorous and potassium than those with low education level, thus resulting to higher yield *(Table 6.6)*. Perhaps, farmers with low education level did not know the role of phosphorous and potassium, thus they applied very little phosphorous and potassium fertilizers.

Table 6.5. Percentage of farmers using various sources of information on certain technologies

Technology	Sources of Information: Radio	Book	Extentionist	Co-farmer
		Cabbage		
Fertilizer	10	5	25	90
Pesticide	10	5	30	95
IPM	0	0	35	0
Variety	0	0	0	100
		Tomato		
Fertilizer	10	5	0	82
Pesticide	10	5	12	95
IPM	0	0	20	0
Variety	0	0	15	100

Note: Multiple answers

Table 6.6. Effect of education on agrochemical application and yield of vegetables

Education Level	Number of HH	Yield (kg/1000m2)	Animal Manure (kg/1000m2)	Amounts of Fertilizer (kg/1000m2)			Insecticide (g.a.i.)
				N	P_2O_5	K_2O	
			Cabbage				
1	21	3540	2808	19.1	6.0	1.8	1890
2	35	4071	3277	21.9	11.6	12.7	1231
3	3	4433	3300	25.3	14.5	11.2	1355
			Tomato				
1	25	2950	2699	24.7	5.7	1.8	1035
2	31	3731	3698	26.0	10.0	5.8	907
3	3	5066	3600	25.4	12.1	11.1	675

In recent years, the habit of using fresh urban garbage as fertilizer was gradually reduced in the site. Most of the fresh urban garbage are now buried or brought to factories to produce some kinds organic fertilizers. The use of animal manure in rotation crops show favorable effect on both vegetable, and rice crops by enhancing soil fertility and reducing source of diseases from fresh urban garbage fertilizer.

In general, vegetable producers applied more animal manure and nitrogen fertilizers for tomatoes than for cabbage; whereas cabbages received larger amounts of phosphorous and potassium than tomatoes. This is, perhaps in line with some reports that high nitrogen application on cabbage may lead to high incidence of stem borer.

Farm size

Vegetable farmers with farm size larger that 3,000m^2 had a tendency to use less fertilizer, especially potassium *(Table 6.7)*. This was found to result to lower yields. However, pesticides are applied to control pests.

Total Income

Vegetable producers with total gross income less than 20 million VND apply higher potassium fertilizer for cabbage. This could increase resistance of cabbage to insects and diseases. It was observed that they use lesser pesticides *(Table 6.8)*.

6.3 Results of the Regression Analysis

Multiple regression analysis show that educational level of the farmers have significant effect on yield of cabbage but not on tomato yield *(Table 6.9)*. Perhaps, farmers at the site have a long tradition in growing tomato; and more experience in tomato production. Cabbage was first planted 15 years ago. Cabbage is very susceptible to insects, especially diamond back moth. Farmers with high education level may be able to understand and control this insect better than those with low education.

The estimated equation also indicates that improved tomato varieties gave higher yields than local ones. In contrast, KK-

Table 6.7. Effect of farm size on agrochemical application and yield of vegetables

Farm Size	Number of HH	Yield (kg/ 1000m^2)	Animal Manure (kg/ 1000m^2)	Amounts of Fertilizer (kg/1000m^2			Insecticide (g.a.i./ 1000m^2)
				N	P_2O_5	K_2O	
			Cabbage				
<= 1000	28	3,873	3,436	21.2	9.8	10.0	1,212
= 1000 –3000	22	4,050	2,825	21.8	11.0	9.7	1,662
>3000	9	3,616	2,800	19.1	6.7	2.5	1,813
			Tomato				
≥1000	23	3,713	3,195	26.9	9.3	4.8	913
1000-3000	26	3,340	3,223	26.2	7.8	3.7	954
>3000	10	3,235	3,420	20.3	6.6	4.5	1,034

cross is the only cabbage variety suitable for tropical condition and grown at the two districts.

The site dummy coefficient showed that there was no difference in vegetable yields between the two districts. The coefficient of animal manure in vegetables is also not statistically significant. Perhaps most of the farmers use high amount of animal manure thus contributing very little to the yield of vegetables.

According to many documents, recommended rates of nitrogen application for cabbage and tomatoes is about 150 kg N/ha or 15 kg/1000m^2. The survey data showed that farmers on the average, applied amounts of nitrogen fertilizer higher than the recommended rate *(Table 6.6)*. Thus, nitrogen did not have significant influence on vegetable yields, and had negative effect on marginal productivity.

Similarly, most of the farmers used very high dosage of pesticide and sprayed too many times during the vegetables production season. This could be an over-use and thus did not give significant effect on the yield of vegetables.

Both phosphorous and potassium use had positive effect on the yield of both cabbage and tomato. This indicated that the higher amounts of phosphorous and potassium applied, the more vegetable yield the farmers could get. Potassium fertilizer contributed more than phosphorous in terms of marginal productivity.

The number of man-days contributed by family members during the vegetable production significantly influenced the yield of cabbage and tomatoes. However, hired labor did not affect the yield of vegetables.

6.4 Estimating for Optimum Amount of N, P, K in Vegetables

With the use of first order condition for profit maximization, results indicate that nitrogen application at the study site is an over-use. Optimal levels for phosphorous and potassium can be computed as follows:

a) Optimal amount of phosphorous and potassium in cabbage production

$$P^* = \frac{0.0441 \text{ x } 3900 \text{ kg x } 1000 \text{ VND/kg}}{6111 \text{ VND/kg}} = 28.1$$

$$K^* = \frac{0.0224 \text{ x } 3900 \text{ kg x } 1000 \text{ VND/kg}}{4000 \text{ VND/kg}} = 21.8$$

b) Optimal amount of phosphorous and potassium in tomato production

$$P^* = \frac{0.0297 \text{ x } 3468 \text{ kg x } 1800 \text{ VND/kg}}{6111 \text{ VND/kg}} = 30.3$$

$$K^* = \frac{0.0266 \text{ x } 3468 \text{ kg x } 1800 \text{ VND/kg}}{4000 \text{ VND/kg}} = 41.5$$

Nitrogen fertilizers do not affect the crop yield and have a negative sign. It is then assumed that the recommended rate is the optimal rate of N. Thus, the optimal mix formula of fertilizers for cabbage and tomato productions are as follows:

Optimal mix formula of N, P, K ratio for cabbage is 21/28/21

Optimal mix formula of N, P, K ratio for tomato is 25/30/41

Table 6.8. Effect of total income of farmers and agrochemical application and yield of vegetables

Gross Income (million VND)	Number of HH	Yield (kg/ $1000m^2$)	Amounts of Fertilizer ($kg/1000m^2$)			Insecticide (g.a.i./ $1000m^2$)
			N	P_2O_5	K_2O	
		Cabbage				
< 20	16	4,047	22.3	9.8	9.6	1,007
20 - 40	29	4,074	19.5	8.0	7.2	1,409
> 40	14	4,019	21.1	6.4	4.3	1,441
		Tomato				
< 20	18	3,588	25.4	8.5	2.3	961
20 - 40	28	3,433	27.4	10.0	2.4	940
> 40	13	3,433	23.5	10.4	2.9	933

Table 6.9. Estimated yield function for cabbage and tomatoes, Hoc Mon & Cu Chi districts, Ho Chi Minh City, 1996, (Dependent variable is in yield per hectare), (n=59)

Variable	Cabbage	Tomato
Constant	7.0566	6.4316
	(0.2972) ***	(0.5415)***
EDU (education)	0.0339	0.0310
	(0.0167)**	(0.0283)NS
Variety		0.2202
		(0.0431)***
SIT (site)	0.0024	0.0417
	(0.0131)NS	(0.0329)NS
FS (farmize)	0.0106	0.0531
	(0.0119)NS	(0.0306)*
Ln AM (animal manure)	-0.0031	0.0176
	(0.0034)NS	(0.0348)NS
Ln N (nitrogen)	- 0.0266	- 0.0412
	(0.0446)NS	(0.0352)NS
Ln P (phosphorous)	0.0441	0.0297
	(0.0227)*	(0.0127)**
Ln K (potassium)	0.0224	0.0266
	(0.0070)***	(0.0097)***
Ln Ins)insecticide	0.0127	0.0079
	(0.0106)NS	(0.0224)NS
Ln Flab (family labor)	0.2398	0.3502
	(0.0774)***	(0.1039)***
Ln Hlab (hired labor)	0.0411	- 0.0095
	(0.0376)NS	(0.0754)NS
R^2	0.8313	0.8966

Figures in parenthesis are standard error values
NS = not significant
* = significant at 10% level
** = significant at 5% level
*** = significant at 1% level

In this optimal mix formula, the computed amount of phosphorous and potassium fertilizers are relatively high compared to the recommended rate. This is, perhaps, due to the very low nutrition content of the soil. Another reason is that farmers at the study site apply very little amount of phosphorous and potassium fertilizers for many years, causing P_2O_5 and K_2O deficiency.

6.5 Estimating the Cost of Over-use of Fertilizer

The survey data indicated that farmers applied a higher amount of nitrogen fertilizer than the recommended rate, whereas, the amount of phosphorous and potassium fertilizers applied were lower than the recommended rate. Based on the yield function, optimal mix of fertilizers (N, P, K) gave the highest yield, followed by the recommended rate for both cabbage and tomato. Farmers' practice had the lowest yields for cabbage and tomato.

Optimal mix of fertilizer gave higher profit than recommended rate in the case of cabbage. In contrast, equivalent profit was received between the two levels of fertilizers in the case of tomato. Farmers' practice gave the lowest profit for both cabbage and tomato. At the time of survey, the farmgate prices of cabbage and tomato were 1,000 and 1,800 VND/kg, respectively. With this price, growing tomato had higher profit than cabbage.

Table 6.10. Amount of fertilizers applied in cabbage and tomato production

Kind of Vegetable	Amount of Fertilizer (kg/1000m^2)								
	N			P_2O_5			K_2O		
	FP	RR	O*	FP	RR	O*	FP	RR	O*
Cabbage	21	15	-	9.7	8	28	8.7	12	21
Tomato	25.4	11	-	8.3	10	30	4.4	9	41

FP: (Farmers' practice) Based on result of the survey
O*: (Optimum rate) Based on computation from recommendation in HCMC
RR: Recommended Rates

Table 6.11. Yield and profit for optimal mix, farmers' practice and recommended levels of N, P, K on cabbage and tomato production

Crop		Optimal Mix	Farmers' Practice	Recommended Rate
N - P – K (kg/1000m^2)	Cabbage	21 - 28 – 21	21 - 9.8 - 87	15 - 8 - 12
	Tomato	25 - 30 – 41	25 - 8.3 - 4.4	11 – 10 - 9
Yield (kg/1000m^2)	Cabbage	4202	3900	3960
	Tomato	3937	3460	3645
Gross profit (VND/1000m^2)	Cabbage	1,036,617	893,642	989,819
	Tomato	3,621,773	3,300,583	3,683,965
Net profit [1/] (VND/1000m^2)	Cabbage	68,611	-74,357	21,819
	Tomato	2,631,773	2,310,583	2,693,965

[1/] Minus opportunity cost of family labor

6.6 Nitrogen Application, Pest Population and Pesticide Use on Vegetables

Because of its perceived positive yield effects, farmers at the study site were found to apply very high amount of nitrogen compared to recommended rate. Aside from increased yields, nitrogen application also induces susceptibility of plants to insects and diseases. This is borne by several experiments conducted by the University of Agriculture and Forestry of Ho Chi Minh City. Data showed that pest incidence increased proportionally to the amount of nitrogen applied *(Table 6.12)*.

The wrong mix of fertilizers leads to nutrient imbalance in plants, resulting to low resistance of plants and high pest population. At the study site, farmers with low education levels applied high nitrogen but low phosphorous and potassium, and apply high amounts of pesticides.

In order to reduce amounts of pesticide use in vegetable growing areas at Ho Chi Minh City, farmers need to be guided on how to apply fertilizers correctly. Some pricing policy could be done in order to affect farmers' use of these nutrients. With a balanced use of fertilizers, vegetables would grow to be healthy and highly resistant to insects and diseases. Furthermore, an Integrated Pest Management (IPM) program for vegetables should be implemented soon to help farmers learn to use pesticides judiciously.

6.7 Impact of Pesticide Use on Health of Vegetable Producers

6.7.1 Characteristics of vegetable producers

The pesticide users in vegetable growing areas of Ho Chi Minh City are relatively older, with an average age of 48 years old. They have grown vegetables for more than 18 years. Their average height and weight are 162 cm and 51.6 kg respectively *(Table 6.13)*.

About 50 percent of them are cigarette smokers. They started smoking at about 16.5 years old. Now, they consume, about 20 cigarettes everyday. About 40 percent of farmers like to drink alcohol if they have a chance. The others state that

Table 6.12. Effect of nitrogen application on pest incidences and crop yields of cabbage

Experiment	Nitrogen Application (kg N/ha)						
	60 N	80N	100 N	120 N	140 N	160 N	180 N
Yield	38.52	45.08	47.68	50.40	52.60	54.48	51.92
Pest (%)	3.12	3.12	3.18	3.85	5.38	7.32	8.80
Yield	35.80	38.90	41.20	46.90	48.20	48.20	48.50
Pest (%)	2.80	2.80	3.90	5.50	6.10	6.10	6.10
Yield	40.70	41.50	43.50	48.10	50.00	50.90	49.90
Pest (%)	15.90	16.30	17.30	17.30	20.80	22.20	21.50

Source: Vegetable Department, U.A.F.

Table 6.13. Vegetable producers' socio-economic characteristics

Characteristics		Quantity
Year of age	(year)	48.4
Year of vegetable farming	(year)	18.7
Height	(cm)	162.0
Weight	(kg)	51.6
Smoking farmers	(%)	50
Age started smoking	(year)	16.6
Cigarette/day	(time)	20.5
Alcohol-drinking farmers	(%)	39.3
Age started drinking	(year)	23.5
Alcohol drinking/week	(time)	3.93
Amount of alcohol/time	(ml)	209

they only drink very little amounts of alcohol in parties. The farmers who like to drink alcohol, started drinking at about 23 years old. Now they drink alcohol almost 4 days per week with an average amount of 2000 ml.

6.7.2 Wearing protective clothing while spraying pesticides

Like other third world countries, most vegetable producers in Ho Chi Minh City do not wear protective clothing during pesticide application. About 21 percent of farmers wear long shirts and pants to protect themselves from pesticides. Some said that covering nose and mouth is not comfortable and is inconvenient while working. Another 10 percent of farmers only wear masks to cover nose and mouth but did not wear any other protective clothing *(Table 6.14)*.

Table 6.14. Percent of farmers wearing protective clothing during pesticide use

Wearing Protective Clothing	Percent of Farmers (%)
Long shirts and pants	21.4
Cover nose and mouth	10.7
No protective clothing	67.9

6.7.3 Impact on farmers' health of handling pesticides

Most farmers spray insecticides periodically even if they do not find any insect symptoms. They are afraid that their crops would be sold at low prices because of insect symptoms; especially diamond back moth (DBM) on cabbages. This risk awareness results to a majority of vegetable producers spraying insecticides 13-16 times during one vegetable season. During the seedbed preparation, insecticides are usually applied 2-3 times. At vegetative development stage, farmers spray insecticides every 4-5 days. At flowering stage of tomato or establishing economic organ of cabbage, farmers apply insecticide every 2-3 days.

Some farmers divide their vegetable plot into three parts. Everyday, they apply insecticides for one part. The aim of this method is to maintain odor of insecticides on the one plot so insects would not be attracted to the whole farm area. Some farmers also use "false spraying" method. They apply "false spraying" everyday at low dosage of pesticide to create odor of insecticides. By doing this, insects would be kept at bay. They apply "true spraying" every 4-5 days by mixing at least 2-3 kinds of insecticides at very high dosages.

As a result, the percent of farmers getting ill is proportional to higher frequency of pesticide applications. Survey data indicate that there are about 28.6 percent of producers who get ill, while those who spray pesticides from 13-16 times have higher incidence of getting ill. *(Table 6.15)*. Those applying more than 16 times did not report having been ill. This could be because they have used pesticides recently.

Data showed that the percent of farmers getting ill increased proportionally to the number of years of pesticide use *(Table 6.16)*. Hence farmers who have been exposed to pesticides for less than 10 years did not report incidence of illness. At the study site, the most popular symptoms of pesticide poisoning reported by producers are dizziness, fatigue and shortness of breath. Other symptoms of poisoning are vomiting, skin irritation, headache and belly-ache *(Table 6.17)*.

6.8 Demand for Safe Vegetable in Ho Chi Minh City

6.8.1 Descriptive statistics of variables under study

A survey was conducted in December 1996 at two ordinary and organic markets in Ho Chi Minh City (HMC) to determine the demand for safe vegetables. The survey results are discussed in this section.

Thirty consumers were interviewed in the ordinary market and 30 in the organic market. However, of the 30 consumers in the organic markets, only 20 consumers bought vegetables; the other 10 consumers did not buy vegetable in organic markets. Thus, the 10 could be considered consumers of ordinary markets.

In general, the majority of consumers who bought safe vegetables in organic markets, have high education and income levels. Most of them are female and belong to the age range of 30-40 years *(Table 6.18)*. The majority of consumers like to eat cabbage once a day, 2 days a week; whereas they eat tomato twice a day, 3 days a week *(Table 6.19)*. Some consumers state that eating tomatoes is good for the health but eating cabbage could cause goiter.

Most consumers pay particular attention to the price of vegetables, and then on quality or pest symptoms (i.e., worm in the products) and freshness *(Table 6.20)*. Some consumers state that pesticide residue is a very important attribute in vegetables. However, it is very difficult to determine whether vegetables have high pesticide residues or not. Some consumers like to choose vegetables with pest symptoms because they perceive that pesticide residues are less in the vegetables.

Most consumers believe that eating vegetables with high residues of pesticide would cause stomach ailments. Some state that patients would have diarrhea and vomiting *(Table 6.21)*. The majority of consumers know that farmers apply too much pesticides on cabbages, but most of them think less pesticides are applied in tomato *(Table 6.22)*. In general, this perception is relatively correct because cabbage always have heavy attacks by insects compared to tomato. Our survey data also support this claim.

Table 6.15. Effect of frequent pesticide applications on vegetable producers' health

Number of Pesticide Application	Number of HHs Applying		Percent of Farmers Getting Ill		Total Percent of Farmers Getting Ill	
	No.	%	%	No.	%	No.
< 10	0	0	0	0	0	0/59
11 – 12	8	13	25	2/8	3.4	2/59
13 –14	25	42.4	32	8/25	13.5	8/59
15 – 16	20	33.9	30	6/20	10.1	6/59
> 16	3	5.1	0	0/3	0	0/59

Table 6.16. Effect of number of years using pesticides on the health of farmers

Number of Years Using Pesticide	Number of HHs Applying	Percent of Farmers Getting Ill		Total Percent of Farmers Getting Ill	
		%	No.	%	No.
< 10	2	0	0/2	0	0/59
10 – 14	9	22.2	2/9	3.4	2/59
15 – 19	25	32.0	8/25	13.6	8/59
20 – 24	23	43.5	10/23	16.9	10/59
	59			33.9	20/59

Table 6.17. The popular symptoms of pesticide poisoning among farmers in Hoc Mon and Cu Chi, HCMC, 1996

Symptoms of Pesticide Poisoning	Percent of Farmers Affected (n=59)
Dizziness	6.8%
Vomiting	3.4%
Fatigue	6.8%
Shortness of breath	6.8%
Skin irritation	3.4%
Headache	3.4%
Belly-ache	3.4%

Table 6.18. Demographic characteristics of vegetable consumers

		Ordinary Market (n=40)	Organic Market (n=20)
Occupation	Public Servant	19	8
	Urban Laborer	6	0
	Student	2	2
	Housewife	9	6
	Professional	4	4
Education	Primary school	6	0
	High school	18	6
	University	16	14
Income	< 500.000 VND	8	2
	500,000-1 million VND	19	3
	> 1 Million VND	13	15
Age	< 30 years	4	2
	30 – 40	14	10
	> 40	22	8
Sex	Male	2	1
	Female	38	19

Table 6.19. Frequency of eating cabbage and tomato by consumers (per week)

Frequency of Eating	Respondents			
	Cabbage (n=60)		Tomato (n=60)	
4	0	(0%)	15	(25%)
3	10	(16.7%)	29	(48.3%)
2	33	(55.0%)	15	(25.0%)
1	17	(28.3%)	1	(1.7%)
4	0	(0%)	0	(0%)
3	0	(0%)	0	(0%)
2	11	(18.3%)	35	(58.3%)
1	49	(81.7%)	25	(41.7%)

Table 6.20. Quality of vegetables consumers pay most attention to

Quality	Respondents			
	Cabbage (n=60)		Tomato (n=60)	
Price	21	(35%)	21	(35.0%)
Size	3	(5%)	9	(15.0%)
Freshness	6	(10%)	15	(25.0%)
Quality	18	(30%)	8	(13.3%)
Pesticide residues	12	(20%)	7	(11.7%)

Table 6.21. Consumers' knowledge of poisoning symptoms

Poisoning Symptom	Respondents			
	Cabbage (n=60)		Tomato (n=60)	
Vomiting	8	(13.3%)	8	(13.3%)
Diarrhea	19	(31.7%)	19	(31.7%)
Stomach	60	(100%)	60	(100%)

Table 6.22. Consumers' knowledge of high levels of pesticides applied on vegetables

Knowledge	Respondents			
	Calbage (n=60)		Tomato (n=60)	
Yes	36	(60%)	11	(18.3%)
No	24	(40%)	49	(81.7%)

6.8.2 Estimating the demand for safe vegetable

In general, vegetable demand is price inelastic *(Tables 6.23 and 6.24)*. This indicates that even if the price of vegetables decreases, people would not increase their demand by buying much more vegetables. On the other hand, a reduction in price of safe vegetables could imply more consumers buying these vegetables rather than the ones from the ordinary market.

Maximum willingness to pay for safe vegetables are higher than actual price by about 63 – 82 percent in ordinary markets and 22 – 26 percent in organic markets.

The difference between the WTP for safe vegetables and the actual prices is positive; this implies that consumers are willing to invest a positive amount to avoid being ill from pesticide contaminated products.

Regression analyses were also done to estimate demand for vegetables, but because of too few samples and lack of variation in prices, the estimates were found not to be significant. To pursue this further, a seasonal variation, and with more samples of respondents would be needed.

6.9 Conclusions

Nitrogen fertilizers have perceptible effects on the growth and development of vegetables. Thus, vegetable producers in HCMC over-use nitrogen for their crops; whereas they under-use potassium and phosphorous. This nutrient imbalance may bring about high incidence of insects and diseases for vegetable production.

Farmers have very little knowledge of insects, diseases and pesticides. Without reliable information on what pest can be controlled by which formulations, farmers mix several insecticides together and spray every 3 – 4 days to prevent vegetables

Table 6.23. The actual prices and amounts of products consumers buy in ordinary and organic markets, HCMC, 1996

Vegetable	Average Amount/Visit	Range of Actual Price (VND/kg)	Average Actual Price (VND/kg)
		Ordinary market (n=40)	
Cabbage	0.8 kg	1,800 - 3,500	2,538
Tomato	0.8 kg	4,000 - 7,000	5,012
		Organic market (n=10)	
Cabbage	0.86 kg	9,000 – 10000	9,800
Tomato	0.85 kg	15000 – 20000	17,300

Table 6.24. The WTP prices and amounts of safe vegetables consumers are willing to buy in ordinary and organic markets, HCMC, 1996

Vegetable	Average Amount/Visit	Range of WTP Price (VND/kg)	Average WTP Price (VND/kg)
		Ordinary market (n=30)	
Cabbage	0.64 kg	3,000 - 6,000	4,724
Tomato	0.60 kg	6,000 - 12,000	8,440
		Organic market (n=10)	
Cabbage	0.58 kg	11,000 - 13,000	12,000
Tomato	0.56 kg	19000 - 24,000	21,800

from insects damage. This increases production cost, hazard to human health and the quality of the environment.

Many insecticides banned for use in vegetable production are still utilized widely because farmers could buy these insecticides easily. Vegetable producers prefer these insecticides because they are not only cheaper but also have wider toxicity.

The price of "safe vegetable" is still too high for the majority of people. Besides, nobody can assure the quality of "safe vegetable" sold in supermarket. However, ailments due to pesticide residues are observed by one sample respondent.

7.0 AGROCHEMICAL USE IN RICE IN THE MEKONG RIVER DELTA

7.1 Scope of the Study

This case study focused on the estimation of optimal use of fertilizers and the cost of fertilizer over-use (if any); the relationship is also discussed using data of winter-spring paddy season of 1996-1997. The study respondents were from the Mekong Delta of Vietnam.

The field survey was conducted in three districts of three provinces in the Mekong Delta (MD): Tien giang (Cailay district), Longan (Tantru district) and Cantho (Thotnot) districts. MD produces more than 50 percent of the paddy output of the whole country. The three locations were chosen because they have different levels of intensity of rice cultivation and pesticide application. Intensive cultivation was represented by Cailay district. High pesticide application was represented by Thotnot district while Tantru district represented the low pesticide application location.

7.2 Data Collection

7.2.1 Sampling method

Multi-stage sampling was used to select the study respondents. In the first stage the determinants used to select the provinces were yield, cultivated area, the linkage to central markets and others like the number of crops, rice-production method, and practice of IPM. In the second stage, in each province, subdistricts which best represented the province were chosen. In the third stage, 30 farmers from three villages of each subdistrict were selected randomly to be interviewed.

The survey which lasted for about two months was conducted by researchers from Mekong Delta Rice Research Institute, and co-researchers, staff members of EEU (Department of Economics, NUH), with the cooperation of Agricultural Departments, Plant Protection Departments of subdistricts, People Committee of Communes and others.

7.2.2 Information collected

The data collected through the questionnaire consisted of the following data: sex, age, experience, education, farm size, household members, trend of fertilizer use, pesticide use, and willingness to pay to avoid being ill from pesticide use. Production data at the household level consisted of area cultivated, rice varieties, yield, input utilization (labor, fertilizer, pesticides, other expenses). Input prices and output prices were also collected. The data were processed by different econometric software: SX for summary statistical description, LIMDEP for linear multiple regression with and without constraints.

7.3 Description of the Study Site

7.3.1 General information on the Mekong Delta of Vietnam

The Mekong Delta of Vietnam links Vietnam to other Southeast Asian countries. It is also the country's biggest food area, providing more than half of the total food output, 50 percent of fishery and 60 percent of fruit of the country.

Due to the influence of seasonal winds, the climate of this Delta consists of two distinct seasons: wet season from May to November with west-south seasonal wind and dry season from December to April with east-north seasonal wind. The weather in this Delta is warm every month during the year. The average temperature is about 27°C; the highest temperature does not exceed 30°C and the lowest temperature is not lower that 25°C.

The total area of the Mekong Delta of Vietnam is about 39,574,500 ha, accounting for 12 percent of the country's total area, three times larger than of the Red River Delta. The Mekong Delta accounts for 37 percent of the country's total cultivated area. The arable land per household is also quite high compared with the Red River Delta and the whole country *(Table 7.1)*.

The Mekong river, with a length of 4,200 km and which provides water source of 4.66 billion m^3 per year, is the tenth largest river in the world. Mekong river flows into South - Vietnam through two main ways - Tien and Hau rivers - with a total length of 1,708 km and 137 big

Table 7.1. Average arable land per household and per capita (m^2)

Regions	Land Per Household	Land Per Capita
Whole country	4984	1034
Red River Delta	2281	556
Mekong Delta	10149	1917
Long An	9958	1968
Dong Thap	11345	2099
An Giang	10227	1859
Tien Giang	5995	1205
Kien Giang	14963	2693
Can Tho	9545	1733
Ben Tre	5312	1094
Vinh Long	7263	1415
Tra Vinh	9026	1784
Soc Trang	14737	2704
Minh Hai	15423	2659

Source: General Survey of Rural and Agriculture, Statistical Publishing House, Hanoi, 1995, Vol. 1, p. 406 & 430

Table 7.2. Mekong Delta rice output from 1985 to 1995 (in million tons)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Output (mil.tons)	6.86	7.08	6.45	7.60	8.88	9.48	10.35	10.95	11.07	12.12	12.83

Source: Statistical Data of Agriculture, Forestry and Fishery, 1985-1995, Statistical Publishing House, Hanoi, 1996 irrigation ditches and canals with total length of 2,780 km. It receives an amount of 90 billion m^3 of rain water of which 90 percent are in rainy season. Unfortunately, rainy months and high water flow of Mekong river occur at the same time, and vice versa. This leads to a serious situation in this delta: a flood season and a drought season at the same time.

The Mekong Delta is considered as the country's rice basket. The gross output of paddy in the Mekong Delta increased quite quickly since 1985 *(Table 7.2)*.

Information released from the 1995 Statistical Year Book indicated that the population of the Mekong Delta of Vietnam reached 15.9 million people with the average density of 403 persons/km^2, being nearly double compared with the whole country. The population density of Mekong Delta is the second highest after the River Delta.

In the whole area of the Mekong Delta of Vietnam, 8 percent of residents are Chinese, Khome and Cham people, living in different provinces, mainly in An Giang, Minh Hai, Tai, Tra Vinh, Klen Giang, Soc Trang. Growth rate of population in The Mekong Delta is about 2.1 percent per year.

With this population growth rate, population will reach 17.9 million persons, by the year 2000, and 23.7 million persons by the year 2015. With current land per capita of 0.16 ha/person which is near to the limit of land area, there will not be enough land to provide for the increasing population.

The labor force in the area is quite abundant, but are mostly unskilled, consisting largely of mainly agricultural workers. A research on 16 communes of 16 districts of six provinces in the Mekong Delta of Vietnam carried out by the Science and Social Institute in 1991 showed the serious imbalance between cultivation and breeding, planting paddy and other crops, agricultural sector and other sectors (Table 7.3). Paddy cultivation accounted for 73 percent of total labor time.

Table 7.3. Occuputational groupings in The Mekong Delta of Vietnam, 1991

Career Types	Shares (%)
Paddy cultivation	72.8 %
Breeding	0.1 %
Minor handicraft industry	0.4 %
Gardening	2.3 %
Work for hire	0.8 %
Fishery rearing	3.0 %
Services	3.6 %
Others	17.0 %

Source: Survey on 2,378 persons above 15 years of age implemented by the Science and Social Institute, 1991. The Mekong Delta of Vietnam - Study and Development, Social Science Publisher, Ha Noi, 1995

The population in the Mekong Delta of Vietnam has low education. The number of persons in the high education group consisting of high school, college, university and other university and after university graduates is just equal to 1/3 of the country's level *(Table 7.4)*. Moreover, due to high cost of education, more and more people do not attend school, or go to school later in their lives.

These days, The Mekong Delta of Vietnam is facing problems with environmental pollution. The use of agrochemicals to increase the yields of crops, can also result to damages to fishery, human health due to exposure, soil and water pollution as well as poisonous residues in agricultural products.

Table 7.4. Education level of residents from 10 years of age

Education Level	Mekong Delta of Vietnam	Country
Secondary and under	81.0 %	76.6 %
High School	2.7 %	6.6 %
College, University and above	0.5 %	1.5 %

Source: General Survey on Population

7.3.2 General socio-economic conditions of the study areas

The study site covered three villages from a subdistrict or provinces of the Mekong Delta, namely Long An, Can Tho, and Tien Giang. With the information from a total of 94 households, this section describes the paddy production environment, social-economic conditions and the fertilizer use trend in the Mekong Delta.

Demographic characteristics of sample farmers

There is no significant difference between the provinces or the regions in terms of characteristics. Most farmers stay in their places of birth. This is reflected by the years of residence of 38.9 years for the region *(Table 7.5)*.

Number of persons living in each household is quite high with an average of 6.02 of which the household labour takes more than half (3.25 persons/ household).

1. Education

Education is considered a factor that may influence efficiency or productivity. Usually, any job seems to be done better by highly educated person than low educated ones. In paddy production, experience, not education is the main and necessary factor for the farmers to get high yields.

2. Experience

Agricultural production is traditionally handed down through generation. Most household members begin to get acquainted with farming at a very early age. It is mainly for this reason, that the years of rice farming or experience is very high, at 23.21 years.

Table 7.6 shows that the farmers with high experience had a tendency to use lower rates of agrochemicals, while maintaining their yield at the same levels compared with other farmers using more agrochemicals.

Table 7.5. Socio-economic characteristics of sample farmers

Characteristics	Tien Giang	Can Tho	Long An	Region
Years of residence	41.90	37.6	37.20	38.90
Years of rice farming	22.50	22.89	41.41	26.51
Age of respondents	44.2	43.56	42.89	43.64
Household size (persons)	5.23	6.86	5.26	6.02
female	2.76	3.26	2.84	3.02
Household labor (persons)	2.76	3.77	2.73	3.25
female	1.50	1.72	1.60	1.63
IPM-trained farmers (%)	43.33	37.78	68.42	45.74
Farm size (m^2)	4,625	11,780	8,921	8,926
Average education level	8.53	5.69	9.74	7.42
Yield (kg/ha)	7,160	6,444	4,692	

Source: Sample Survey, 1997

Other characteristics

1. Soil types

There are many types of soils in the Mekong Delta of Vietnam: grades 1, 2, 3, 4 and 5, which are classified in terms of quality by the Government. However, soil classes 2, 3, 4 and 5 seem to be the same in quality according to soil class. Hence, one can divide class into two groups - class 1 and others.

In the three provinces, soil class 1 (high quality) takes quite a large ratio, accounting for 54.26 percent. It is obvious that high quality soils give higher yield than low quality soils, at the same inputs, or even lower inputs (Table 7.7).

2. IPM training

The proportion of farmers in the sample who took part in IPM training is 45.7 percent. IPM practice leads to the remarkable reduction in pesticide use and minimize environmental pollution and pesticide residues in food. It also helps farmers to apply fertilizers appropriately and at the right time.

In some cases, IPM practice may lead to the fall in yield due to low use, even non- use of pesticide. However, evidence shows that IPM practice has brought a profit of VND994,330 per ha to Dong Nai farmers compared with non-IPM practice. *(Science, Technology and Environment News Week, Spring Issue, 1997).*

Table 7.6. Relationship between farmers' experience and agrochemical use and yield in Tien Giang, Can Tho, and Long An

Experience	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Pesticide (g.a.i./ha)	Yield (t/ha)
Less than 24-year experience	118.2	61.19	13.45	1.384	6.282
More than 24-year experience	101.4	48.47	14.48	1.182	6.246
Overall	112.1	56.59	13.79	1.310	6.269

Source: Sample survey, 1997

Table 7.7. Relationship between soil class and agrochemical use and yield in Tien Giang, Can Tho, and Long An

Soil	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Pesticide (g.a.i/ha)	Yield (t/ha)
Soil class 1	109.1	41.77	13.00	990.5	6.419
Soil class 2, 3, 4	115.7	69.88	14.68	1,402	6.265
Overall	112.6	56.88	13.90	1,302	6.336

Source: Sample survey, 1997

Table 7.8. Relationship between IPM and agrochemical use and yield in Tien Giang, Can Tho, and Long An

Practice	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Pesticide (g.a.i/ha)	Yield (t/ha)
Non-IPM practice	112.5	54.93	12.93	1,465	6.505
IPM practice	112.7	59.24	15.08	1,104	6.131
Overall	112.6	56.88	13.09	1,302	6.336

In this survey, the application of IPM has reduced pesticide use to 1,104 compared with 1,465 for non-IPM practice *(Table 7.8)*.

7.4 Fertilizer Use in the Mekong Delta of Vietnam

According to the farmers' opinion, the use of fertilizers has increased remarkably *(Table 7.9)*. In the past, there was only one crop in a year and the farmers did not pay much attention about fertilizer application because every year, the alluvium raised the level of the rice farm with full nutrients. It is different now. The fact that farmers increase the number of crops to two, even three crops per year affected soil quality. The natural soil nutrients are much more reduced. To maintain or increase the productivity, a large amount of chemical fertilizer has to be applied.

The use of high yielding varieties (HYV) has raised the yield significantly. However, these varieties are fertilizer and water responsive. In the winter-spring season of 1996, the fertilizer use in the study areas is shown in Table 7.10.

The farmers might have based these on the different characteristics of the soil and the rice variety. However, they use fertlizers based on their instinct only, not on any official recommendation or analysis.

There are several sources of information that farmers can access in their decisions relating to agrochemical use. In the survey, eight main sources of information are given: experience for fertilizer use, and agricultural extension for pesticide and seeds *(Table 7.11)*

Table 7.9. Farmers' perception on the trend of chemical fertilizer application since early use

Amount	Tien Giang	Can Tho	Long An	Region
Decrease	7.4	2.2	15.8	6.6
Similar	37.0	22.2	15.8	25.3
Slight increase	22.2	20.0	26.3	22.0
Significant increase	33.3	55.6	42.1	46.2

Table 7.10. Fertilizer use and yield per ha in Tien Giang, Can Tho and Long An, 1996

Fertilizer	Tien Giang	Can Tho	Long An	Region
N (kg)	131.80	108.8	90.09	112
P_2O_5 (kg)	81.93	41.75	52.95	56.59
K_2O (kg)	17.45	9.98	7.80	13.79
Yield (t)	7.16	6.44	4.69	6.34

Survey data is autumn 1996-1997

7.5 Results of Regression Analysis

The Cobb-Douglas production function is estimated for 94 farmers applying agrochemicals. The results are presented in Table 7.12. Long-an respondents' data are for summer-autumn, while the other two are for winter-spring.

With the positive sign, the variable *"Experience"* (LNEXP) reflects a positive, but weak relationship to yield. The most important variables in this regression analysis are agrochemical use variables - LNN (Nitrogen), LNP_2O_5 (Phosphorous), LNK_2O (Potash), and LNGAI (Pesticide). Coefficient of LNN and LNP_2O_5 have positive signs. LNK_2O and LNGAI, coefficient show negative signs. Potash coefficient is not significantly different from zero. The pesticide variable is an aggregate of all pesticides used, and is not an ideal measure to explain yields. Different kinds of pesticides have different impacts on yield. The non-significance of labor could be due to data measurement problems.

Of all the variables, SEASON has the strongest effect on yield with the coefficient of 0.3798 and significant level at 1 percent. Average yield in the winter-spring is 6,000 kg, while that in the summer autumn is 4,698 kg.

7.6 Estimating the Optimal Use of N, P, K

The optimal levels of agro-chemical use can be determined by the following formula: $Xi^* = (exi. Py.Y)/Pxi$

With the unit price of 1,300 for a kg of paddy and with average yield of 6,336 kg/ha in the three provinces and 6,731 kg/ha in Cantho and Tiem Giang, the coefficients of variables, and unit price of kg fertilizers and pesticide, and the optimal use and P can be calculated as follows:

$$N^* = (0.0613 \times 6336 \times 1300)/5869 = 86 \text{ kg}$$

$$P^* = (0.0641 \times 6336 \times 1300)/4659 = 113 \text{ kg}$$

Table 7.11. Source of Information of farmers in input application (% of farmers)

Information Source	Fertilizers	Pesticides	Seeds
Other farmers	6.4	9.6	14.9
Agricultural extension	27.7	30.9	45.7
Television	3.2	3.2	-
Radio	3.2	4.3	-
Newsletter	-	-	1.1
Input sellers	2.1	13.8	-
Experience	47.9	29.8	22.3
Other sources	9.6	8.5	16.0

7.7 Estimates of the Cost of Over-use/Under-use of Fertilizers in the Region

The estimation for the over-use/under-use of fertilizers from the sample showed that nitrogen is over-used in the region by about 27 kg/ha *(Table7.14)*. Phosphorous and potash are under-used by 56 and 5 kg/ha, respectively.

The over-use and under-use of fertilizers, apart from the non-economic effects, have led to a cost of VND 43,390/ha to the farmers in the Mekong Delta of Vietnam. Although this amount is not so for that the farmers to worry about, this will be quite big for the whole region. For the 3,190,000 ha of paddy cultivated area in the Mekong Delta, the total cost will reach to the number of VND141 billion for one crop *(Table 7.15)*.

Table 7.12. Multiple Regression analysis for yield function for the Mekong Delta

Variables	Coefficients	Standard Errors
Constant	1.20 *	0.24
IPM *(1 with IPM training, and 0 otherwise)*	-0.03NS	0.023
EDUDUM (Education) (0 if education is primary school and under, 1 if education is above primary school)	-0.04NS	0.03
SEASON ((0 for Summer-Autumn season, 1 for Winter-Spring season)	0.38*	0.04
SCLASSDUM (Soil Class) (0 for soil type no.1, and 1 for soil type no. 2,3,4,5)	-0.034NS	0.03
AREADU (area) (0 if area is equal or smaller than 8000m^2, and 1 if area is larger than 8000m^2)	-0.01NS	0.03
LNEXP (Experience)	0.02NS	0.012
LNN (Nitrogen)	0.06***	0.03
LNP205 (Phosphorous)	0.06**	0.02
LNK20 (Potassium)	-0.01NS	0.01
LNGAI (Pesticides)	-0.01***	0.01
LNTODAY (Total labor in days)	-0.02NS	0.03
R-Squared	0.68	
F-Value (df)	15.7	

NS = Not significant * = Significant at 1% level
** = Significant at 5% level *** = Significant at 10% Level

Table 7.13. Fertilizer optimal levels in comparison with that of the North

Fertilizers	Economical Optimal Level		
	Red River Delta[1]	Mekong Delta[2]	Sample Survey (Actual)
1. Nitrogen (N)	100	99.65	86
2. Phosphorous (P)	60	62.96	113
3. Potash (K)	20	20.86	18[3]

Source: [1] Report on impact of agrochemicals on productivity and health: The case of rice production in Red River Delta, Tran Thi Chien and et al., Environment Economics Research Workshop, Aug. 26-29, 1997, EFPSEA & EEU

[2] Computed from a survey of 180 samples in four main provinces of the Mekong Delta of Vietnam in winter-spring season 1997, Thai Thanh Son, M.A. Thesis, Vietnam-Netherlands Project

[3] The optimal amount of K_20 based on the recommended level from previous studies

Table 7.14. Over-use/Under-use of fertilizers in the region

Fertilizers	Optimal Amount	Farmers' Practice	Over-use/ Under-use
1. N	86	113	27
2. P_2O_5	113	57	-56
3. K_20	18[1]	13	-5

[1] The optimal amount is based on the recommended level from previous studies

Table 7.15. The Cost of over-use and under-use of fertilizers in the region, rice season 1996-1997 (in VND)

Yield from Optimal Use (kg)	Yield from Practical Use (kg)	Add. yield from Optimal Use (kg)	Benefit from Additional Yield	Cost of Optimal Use	Cost of Practical Use	Benefit from the Optimal Use	Final Profit of Optimal Use
6,465	6,336	129	167,700	1,085.201	961,891	123,310	44,390

Source: Computed from the survey data, 1997

Note:

Yield from optimal use is calculated by replacing optimal uses of N, P, K into the equation when keeping other variables constant

Benefit from additional yield = additional yield from optimal use (54 kg) x price of kg paddy (VND1,300)

Cost of optimal use = cost of optimal uses of nitrogen + of phosphorous + of potash

Cost of practical use = cost of practical uses of nitrogen + of phosphorous + of potash = mean of fertilizer cost

Benefit from optimal use = cost of practical use - cost of optimal use

Final profit of optimal use = benefit from additional yield + benefit from optimal use

LITERATURE CITED

Antle, J. M. and P. L. Pingali. 1995. 'Pesticides Productivity and Farmers Health: A Philippine Case Study.' In P.L. Pingali and P.A. Roger (Eds.). Impact of Pesticides on Farmer Health and the Rice Environment, IRRI. Kluwer Academic Publishers.

Dung, N. H. 1994. 'Profitability and Rice Response of Rice Production System in the Mekong Delta', MSc. Thesis. Chaingmai University, Thailand.

FAO (1993). Industry Fertilizer Working Group. Rome, Italy: FAO.

FAO (1994). The State of Food and Agriculture. Rome, Italy: FAO.

Fujimoto, A. and Matshuda. 1989. Thai Rice Farming in Transition. World Planning.

Hans, P. B. et al. 1991. Technology Change and Commercialization in Agriculture. Washington, D.C.: World Bank.

Herdt, R. W., C. Castillo and S. Jayasuriya. 1984. 'The Economics of Insect Control in the Philippines'. In IRRI, Judicious and Efficient Use of Insecticides. Los Baños, Philippines: IRRI.

Hoc Mon People's Committe. 1996. Outline on Research and Development of "Clean Vegetable Production in Ho Chi Minh City from 1996-2000."

Huan, T. N. et al. 1996. Effect of Nitrogen and Transplanting Density on Yield and Disease and Pest Population. Hanoi, Vietnam: Agricultural Publishing House.

Hung, N., L. P. Quy, C. H. Huynh, and N. V. Minh. 1993. Survey on Vegetable Production in Ho Chi Minh city and Diamond Back Moth Damage on Cabbage. Paper presented in the Annual Scientific Conference at the Institute of Agricultural Science of South Vietnam.

Khan, A. S. and A. Ali. 'Production Function Analysis of Nitrogenous and Phosphatic Fertilizers in Rice Production in the Irrigated Areas of the Punjab'. Research paper, Punjab, Pakistan.

Kalizrajan, K. 1990. Rice Production: An Econometric Analysis. New Delhi: IBH Publishing.

Litsinger, J. A. 1990. 'Integrated Pest Management in Rice: Impact of Pesticide'. Workshop on Environmental and Health Impacts of Pesticide Use in Culture, Los Baños, Laguna, Philippines: IRRI.

Litsinger, J. A. 1987. 'Integrated Pest Management Assessment in Farm Communities'. Paper presented at the Workshop on IPM and INM on Rice, IRRI, pp 28-29.

Ministry of Agriculture and Rural Development. 1995. 'Procedure on Survey of Pest Infestation on Crops', Hanoi, Vietnam.

Ministry of Agriculture and Food Industries. 1994. Strategies on Agriculture for the Future. Ministry of Agriculture and Food Industries.

Pingali, P. L. et al. 1995. We can live without pesticides for tropical rice? Los Baños, Laguna: IRRI.

Quyen, M. V., L. T. V. Nhi, N. Q. Vinh, N. T. Hoa, N. T. Kiet, and V. V. Binh. 1995. Handbook for Growing Vegetable. Ho Chi Minh City, Vietnam: Agriculture Publishing.

Rola, A.C. 1994. Impact of Pesticides on Farmer Health: Review of Evidence from the Philippines. Journal of Crop Science, UPLB.

Rola, A.C. and P. L. Pingali. 1992. 'Choice of Crop Protection Technologies Under Risk: An Expected Utility Maximization Framework'. The Philippine Journal of Crop Science 17(1).

Rola, A.C. and P. L. Pingali. 1993. Pesticides, Farmers' Health and Rice Productivity: An Economic Assessment, WRI, Washington D. C. and IRRI, College, Laguna.

Rola, A. C. and P. L. Pingali. 1992. Choice of Crop Protection Technologies Under Pests. Phil. Journal of Crop Science, UPLB.

Thang, N. V., and B. T. My. 1996. Technique for Growing Tomato, Potato, Onion and Garlic. Hanoi, Vietnam: Agriculture Publishing.

Thi, T. K. 1996. Technique for Growing Clean Vegetable. Hanoi Vietnam: Agriculture Publishing.

Vietnam News, Volume VII, Number 2088, June 2, 1997

Vietnam News, Volume VII, Number 2092, June 6, 1997

Vietnam News, Volume VII, Number 2093, June 7, 1997

Vietnam News, Volume VII, Number 2124, June 8, 1997

Vietnam News, Volume VII, Number 2125, June 9, 1997

Waibel, H. 1996. 'The Economics of Integrated Pest Control in Irrigated Rice: A Case Study from the Philippines'. Crop Protection Monographs. Berlin: Springer-Verlag.

Warburton H., F.G. Palis and P. L. Pingali. 1995. 'Farmer Perceptions, Knowledge and Pesticide Use Practices' In P. L. Pingali and P. A. Roger (Eds.). Impact of Pesticides on Farmer Health and the Rice Environment, Los Baños: IRRI. Kluwer Academic Publishers.

Warburton, H., F.G. Palis and P.L Pingali. 1995. Farmer Perceptions, Knowledge and Pesticide Use Practice. Los Baños, Philippines: IRRI.

World Bank. 1990. Agricultural Marketing: The World Bank's Experience. Washington D. C.: World Bank. pp. 17-85

World Bank. 1994. 'Environment Impact Assessment', Vietnam-North Binh Chanh Irrigation Rehabilitation Project - Report EO076. Washington D. C.: World Bank.

World Bank. 1977. Commodity Markets and the Developing Countries - A World Bank Quarterly. Washington D. C.: World Bank

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USING THE TRAVEL COST METHOD TO EVALUATE THE TOURISM BENEFITS OF CUC PHUONG NATIONAL PARK

3

USING THE TRAVEL COST METHOD TO EVALUATE THE TOURISM BENEFITS OF CUC PHUONG NATIONAL PARK

Nguyen Thi Hai and Tran Duc Thanh

SUMMARY

This study estimated the willingness of tourists to pay to visit the Cuc Phuong National Park in its current state, and with improved facilities.

The study used the travel cost method (TCM) to derive a demand curve for recreation in the Park and the contingent valuation method (CVM) to assess visitors' willingness to pay (WTP) for improved facilities in the Park.

Results showed that the total recreation benefit of domestic visitors to the Park was VND 1,502 million per annum with a consumer surplus of VND 105 million per year. Visitors were willing to pay for improvements in the road network in the area and in the establishment of a confinement space for wildlife in the amount of VND 288.47 million for domestic visitors and VND 215.57 million for foreign visitors.

1.0 INTRODUCTION

1.1 Research Problem

One important natural resource in Vietnam is its tropical forest that has high use and non-use economic values. Large forest areas, however, have been heavily deforested during the last 50 years due to many reasons. Virgin forests with rich flora and fauna were destroyed by loggers and are now in critical condition. The Vietnamese Government has tried to restrict deforestation to conserve the original forest zones, but this has failed due to conflicting interests that arose from the need to exploit the resource to fuel the economic development of the area. As a result, not one of the 14 restricted regions (including Cuc Phuong, the first National Park) had been successfully protected.

The Cuc Phuong forest zone is one of the original tropical rain forest zones; it was established as a National Park in 1961. Trees and animals were preserved for laboratory or scientific research, and tourism and recreational purposes. This zone had been managed by the state for almost 30 years, but activities of people living within this zone had been so destructive that government development and protection efforts had failed. A settlement area is found within a 100-km circumference of the zone. Many inhabitants in the place engage in deforestation to acquire a piece of land to cultivate. They penetrate the park to cut trees for firewood and timber. Animal hunting also frequently occurs, making most wild animals extinct. Squirrels that used to abound in the area can now be seen only in the deep forest.

The park has 118 workers, but it requires 193 employees to be able to provide ample protection to the site. Three guards are needed per 1,000 ha. The Park also has inadequate facilities to make protection efforts more successful. Cooperation and assistance from different sectors and line agencies to protect the resource are also inadequate.

Cuc Phuong forest has high value, coming from both the use (timber, non-timber resources, and recreation) and non-use values consisting mostly of biodiversity, cultural, and ecological functions. The value of timber, firewood, and many forest products are easier to calculate, but no valuation of these products has been done in the area. What is only accounted for in some studies is the monetary benefit derived from entrance fees collected at the Park. Hence, there has been no sound basis for formulating good proposals to develop the resource. It is therefore necessary to do a more reliable accounting of the total economic value that could be derived from the Park to measure losses caused by destructive activities in the area.

1.2 Objectives

Specifically, the study hopes to:

a. Identify the tourism benefits of the Park;

b. Estimate the consumer surplus; and

c. Derive the willingness to pay (WTP) value for improved facilities in the Park.

1.3 Hypotheses

a. The Cuc Phuong tourism benefit calculated in accordance with TCM is larger compared with the total revenue derived from entrance fees.

b. The total economic value of the forest is much greater than the tourism benefit because it includes the tourism value, biodiversity, cultural, and environmental protection values.

c. The better the forest is preserved, the more visitors will come, hence, the greater the tourism benefits.

2.0 METHODOLOGY

2.1 Analytical Framework

2.1.1 Travel cost methodology

The travel cost method is the oldest of the nonmarket valuation techniques. It is predominantly used in outdoor recreation modeling, with fishing, hunting, boating, and forest visits as the most popular applications.

TCM seeks to place a value on nonmarket environmental goods by using consumption behavior in related markets. Specifically, costs of consuming services of the environmental asset are used as a proxy for price. These consumption costs include travel costs, entrance fees, on-site expenditures, and foregone income for time spent traveling and into the site. The method assumes a weak complementarity between the environmental asset and consumption expenditure. This implies that when consumption expenditure is zero, the marginal utility of the public good is also zero. So, if traveling to a forest becomes so expensive that no one goes there any more, the marginal social cost of a decrease in the quality of that forest is also zero. TCM cannot estimate non-user values. An implicit assumption made in most travel cost studies is that the representative visitor's utility function is "separable" in the recreation activity being modeled. This means that, if the activity of interest is fishing, then the utility function is such that demand for fishing trips can be estimated independently of demand, say, for cinema trips (alternative leisure activity) or for heating oil (alternative marketed nonleisure good). A full discussion of separability in travel cost models is given by Fletcher et al. (1990).

Travel costs by visitor i to site j (TCij) depend on several variables:

$$TCij = TC\ (DCij,\ Tij,\ Fi) \quad i = 1...n, \quad j = 1...m \qquad (1)$$

Here, DC is the distance cost for each individual "i", dependent on how far the person has to travel to visit the site and the cost per km of traveling. T is the time cost which depends on how long it takes to get to the site and the value of the individual's time. F is the fee, if any, which is charged for entrance to site j. Travel costs (TC) are included in a trip generating function (TGF), which predicts how many visits (V) will be undertaken by any individual i to site j. Also included in the TGF for an individual would be socio-economic characteristics such as income, education, and age level, as well as variables giving information on the type of trip. Examples of this case are dummy variables on whether a visit to the site is the sole purpose of that individual's journey from home, or whether the individual is on holiday or is a local day-tripper.

The alternative to the individual TCM as described earlier is the zonal TCM. The zonal approach entails dividing the area surrounding the site to be valued into "zones of origin." These may be concentric rings around the site, but are more likely to be selected with regard to local government administrative districts. This is because the zonal TCM must also include population levels for each zone to predict trips per zone. Population data are more readily available at the local government level than for concentric rings around a site. The number of zones used can be quite large. The TGF for the zonal model is:

$$V_{zj} = V\ (TC_{zj},\ P_z,\ S_z) \quad z = 1...z \qquad (2)$$

where V_{zj} are visits from zone z to site j, P is the population of zone z and S_z are socio-economic variables such as income averaged for each zone. The dependent variable is often expressed as (V_{zj}/P_z), or trips per capita.

Once a TGF such as (2) has been estimated using multiple regression, a demand relationship is estimated by simulating what would happen to visits per annum (individual TCM) or visits from each zone in the zonal model as the "fee" is increased. In this way, a demand curve is traced out for each site. The fee is driven up until visits either go to zero or to less than one (depending on the functional form of the TGF). This is shown in Figure 1, where total existing visits from all zones are V_T. The TGF is used to trace out the demand curve D, which shows that visits

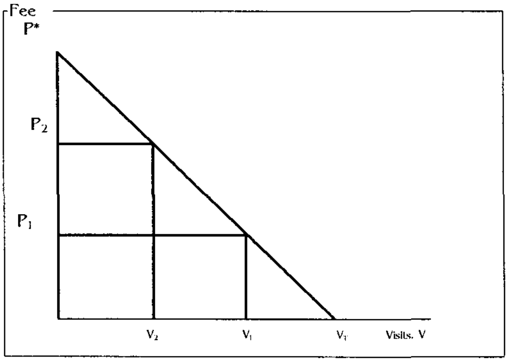

Figure 1. Demand curve for recreation visits

will be made to the site so long as the cost of the visit stays below P^*. For example, at a fee of P_1, visits are predicted to fall from V_T to V_1, and a further increase in the fee to P_2 reduces visits to V_2. These fee/visit combinations (with the exception of the zero additional fee/V_T combination) are all predictions based on the observed relationship between travel costs and visits. The key assumption behind the demand curve is that as travel costs defined in equation (1) increase, the number of visits fall.

Measuring the area under the demand curve and above the price line gives an estimate of consumers' surplus. This value is most usually reported as consumers' surplus per visit. If the log of visits is regressed on travel costs, etc., then this has the convenient property that the reciprocal of the travel cost coefficient gives consumers' surplus per visit.

2.1.2 Contingent valuation methodology

Contingent valuation method (CVM) is often used to reveal how people would value certain changes by directly asking a sample of the population. Such changes, and the market in which they are to be valued are hypothetical. In principle, CVM is applicable to many circumstances in reality in which environments are threatened or conversely to value proposed improvements. The most common method is the use of a survey questionnaire. Results from the sample survey are then aggregated to represent the total valuation likely to be placed by the whole population. The accuracy of this process can be improved if the declared values can be related to personal characteristics such as income, education, environmental consciousness, and other factors.

If people clearly understand the change in environmental quality being offered and answer truthfully, CVM is ideal because it precisely measures what the analyst wants to know – the individual's strength of preference for the proposed change. Its principal drawback is that it depends on what people say rather than on what they do. The issue is whether the intentions people indicate ex ante (before the change) will accurately describe their behavior ex-post (after the change) when they face no penalty or cost associated with a discrepancy between the two. Biases in responses, however, can be minimized by a careful survey design.

An important advantage of CVM is that it is applicable, technically, to all circumstances. It is the only practical method for uncovering existence value which generally does not pass through markets and does not have substitutes or complements that pass through markets. A constructed market can also account for the existence of uncertainty and is therefore the only source of evidence on the value of future changes in environmental quality. Further, it is suggested that, if sequenced properly, constructed markets provide the opportunity to estimate an internally consistent set of value components (use and non-use values) that can be aggregated into a true measure of total economic value.

CVM therefore has great potential as a source of data in areas where other techniques are not feasible. It is also useful as a check on data obtained by other methods. It is increasingly common to find CVM being used in combination with other techniques.

The aim of CVM is to elicit valuations or "bids" which are close to those that would be revealed if an actual market existed. The hypothetical market–the questioner, questionnaire, and respondent–must therefore be as close as possible to a real market.

2.2 Survey Technique and Sampling

2.2.1 Questionnaire design

Both TCM and CVM used a questionnaire to acquire information on travel cost or to elicit the amount of WTP. The questionnaire had four parts: visitor's socioeconomic data, travel cost, information on visits to the park, and WTP questions.

Socio-economic data. Both TCM and CVM were affected, if not determined by information, such as respondents' social and economic conditions, namely, income, education, age, and sex. Such information is not only useful for a better understanding of the rationale of visitors' behavior, but also for demand projections for tourism and plan of facility improvement.

We also needed to know whether visitors were foreigners or local people. The foreigners' purpose for visiting may have been business, an official mission, or recreation. If the foreigners were tourists, travel cost to Cuc Phuong was added to the cost to transfer from their country to Vietnam.

Travel cost data. Questions in this part were designed to obtain information on travel cost. First was means of transport, because the park is far from the public transport stations. Means of transportation to Cuc Phuong Park include train, hired car, hired motorcycle, and others. Specific questions were asked on the means of transportation which were used to estimate travel time and cost.

Second was the purpose of the visit. Visitors may have come to Cuc Phuong for recreation or scientific research. Hence, a series of questions elicited information to estimate the travel cost to Cuc Phuong. Majority of the visitors to Cuc Phuong were tourists. Only a small portion of visitors were researchers, students, and others. Rarely did visitors go there for a workshop because Cuc Phuong is far from the main city.

It was very difficult to exactly determine the travel cost if value of time is carefully considered. Opportunity costs of visitors who went there for leisure were lower than that of visitors who sacrificed work and other priorities to travel to Cuc Phuong.

Experience on visits to the Park. Visitors to Cuc Phuong enjoy many activities such as walks, sight-seeing, watching strange and wild animals, birds, or plants, and visiting caves, historical remains, and other tourist spots in the park.

Cuc Phuong is quite far from the city. People tend to go there just to satisfy their curiosity. Thus, people visit the place once a year or after every few years.

Substitute place. The study also needed to know where people tended to go instead of going to Cuc Phuong as an alternative to calculate the travel cost.

WTP questions. These questions were used to elicit WTP information. Respondents were asked whether they were willing to pay for the improvement of the facility. Respondents were also asked what they wish the Phuong management to do to improve services and facilities, and if they were willing to contribute for such a purpose. This was to avoid bias.

The questionnaire design took into account specific conditions relevant to this study. Although the questionnaire was divided into five sections, the relationship of each part to the other was carefully considered in the analysis and discussion.

2.2.2 Sampling

Much care has been put in the sampling process to reduce errors and biases as much as possible. Most respondents, especially the Vietnamese, did not seem to be familiar with this type of survey. During the interview, interviewers had to thoroughly explain questions to respondents who had a hard time comprehending the questions. Moreover, only visitors who stayed overnight at the Park completely answered the questionnaires. Respondents who had to return home before night time did not care to return the questionnaires.

The survey was conducted from October to January of the following year. Domestic visitors who came during this period were students. Only a few businessmen, urban workers, or household leaders came, because this period was the busiest time of the year. During January, people are busy preparing for the Tet holiday (New Lunar Year). Visitors from the civil service did not stay overnight. Hence, the study did not have this type of respondents.

Since the survey was not conducted during the summer, when many visitors come for vacation, no respondents from the south and central part of Vietnam were obtained. This was a weakness of the sampling process – hence, domestic visitors throughout many provinces of Vietnam were not well represented.

Of the 630 questionnaires distributed, only 282 were returned. Of these 253 were used for TCM and CVM analysis. This sample size may be small, but it could still provide a sound basis for estimating the demand for tourism uses and WTP figures at a statistically significant level.

3.0 THE CUC PHUONG NATIONAL PARK

3.1 Attributes of the Park

The Cuc Phuong National Park is the first area in the Socialist Republic of Vietnam that was restricted to protect and preserve trees and animals, for conducting scientific research, and for tourism and recreation.

It lies 100 km south of Hanoi, on the edge of the Red River delta. It is the most populous region in Vietnam with a total area of 22,200 ha. It is situated on three provinces: Ninh Binh, Hoa Binh, and Thanh Hoa. Ninh Binh occupies over 50 percent of the total area.

3.1.1 Natural characteristics of the Park

Topography. The lime mountain in Cuc Phuong is the highest part of the Northwest lime mountain that consists of two mountain systems stretching in the northwest-southeast direction. There are low hills (hillocks) at the base with clay-shale intermingling in the two systems. The valleys are about 200-350 m above sea level and are separated by trails such as Dang, Voi, and Xeo.

Cuc Phuong mountain is bound in the north by narrow fields on the side of highway 12, in the west and southwest by fields on the banks of the river, and in the southeast by lowland fields in Hoang Long district (Ninh Binh).

The main topography of Cuc Phuong is mountainous. The highest part is May Bac (656 m) in the northwest, and the lower sides are on both sides of the southwest and southeast. Besides the main river flowing to the northwest, there are many shallow streams that have water only in the rainy season. The harsh topography is considered typical. The area has many caves, water gathering wells, and subterranean spring.

Geology and soil. Cuc Phuong is mainly Trias lime intermingled with other rocks such as schist, argalit, aleurolit, and gneiss. Its soils are mainly from lime rock and the so-called argalit. Soil color varies from the foot to the top of the mountain: red, yellowish, yellowish gray, and black. The soil has high porosity (60-65%) and a humus content of 4-5 percent.

Climate and hydrology

Climate. Cuc Phuong has a monsoon tropical climate. The average temperature is 20.6 °C. It has a maximum average temperature of 24.7 °C, and a minimum average temperature of 16.6 °C. The highest recorded temperature so far is 39 °C (May 7, 1979 and August 9, 1979). The lowest recorded temperature is 0.7 °C recorded on January 18, 1967. The average rainfall is 2,157.2 mm. The average relative humidity is 90 percent. There are two distinct seasons in a year: rainy and hot season from May to November and from December to April, respectively. The average temperature during the rainy season is 23 °C and rainfall is 1,922.9 mm or 89 percent of the annual total rainfall. During the dry season, the average temperature is 15 °C. Rainfall during this season is 224.3 mm or 11 percent of the annual total rainfall. Wind direction all year-round is towards the southeast, south, and east. The wind speed is from 4 to 12 m/s. The wind often brings cold air and drizzles; Cuc Phuong experiences heavy storms.

The average rainfall in Cuc Phuong is high but it is not equally distributed, hence, the occurrence of two distinct seasons. The relative humidity is high year-round. The humidity varies over the months in a year and among different areas are not big.

Generally, the average temperature in Cuc Phuong is low. It is cool even during summer. The temperature is 2-3 °C lower than in Hanoi, as Cuc Phuong lies 300-400 m above sea level.

Autumn in Cuc Phuong is also rather rainy. Humidity level is above 90 percent favoring vegetation growth. The temperature, however, drops during winter, because this is considered the dry season. It can drop to as low as 2-3 °C or even 0.5 °C. During this season, neither mosquitoes nor leeches survive.

Hydrology. Given the rugged topography, Cuc Phuong has a few streamlines. Buoi and Ngang are the only two rivers with water all year-round. Shallow brooks occasionally have water. After the rain, dry silts lead water to the karts well, then water is sipped underground. Temporary flood occurs wherever water is not absorbed by the ground right away.

3.2 Social Characteristics

Population and distribution density. The Cuc Phuong National Park runs across 15 communes belonging to four districts in three provinces. The population is over 30,000, composed mostly of Muong.

The people rely heavily on agricultural activities and forest products as a source of income. They grow rice on paddy land, but people slash and burn forest areas too, to obtain land for growing other crops.

Generally, the economy is poor. Forest protection is also not reported important. Hence, forest products are often used indiscriminately.

3.3 The Park's Value

The place has rich and diverse plant species, many of which are considered rare and endemic. There are also highly valuable herbs and high-value materials for fossil biology and geology. In addition, the place is rich with historic sites for lessons in history, arts, and literature. It also has an elegant landscape.

Cuc Phuong has a considerable primary forest located in the valleys, primarily in the lime mountains surrounding the valleys leading to the mainland.

The forest here is a typical evergreen-humid tropical forest. The five layers of the forest are readily observable even from a distance: three layers of woods, one layer of bushes, and a layer of grass.

The top of the canopy (Al) consists of 40-50 m high trees. Evergreen trees found here are Chochi *(Parasorea assamica)*, Chonhai *(Annamocarpa sinensis)*, and Choxanh *(Terminalia myriocarpa)*, a leaf-falling tree.

A2 is the biologically superior tree layer with a fairly continuous canopy consisting of 20-35 m high trees and species such as *sang, bohon, calo, choxanh,* and *re, de* families.

A3, on the other hand, consists of 10-20 m high trees whose canopy is not continuous. Most trees here are evergreens, including *ngat, vanganh, sang, vangtrung,* and *boiloi*.

The bush layer (B) is not higher than 8 m, consisting of *na, che, gai,* and the castor oil plant family.

The grass layer (C) is the unimpacted part of the forest that is underdeveloped. However, when the forest canopy is opened, this layer develops vigorously. Species components are very complicated, comprising of representatives of moss to seed plants.

On the side of the lime mountain, the soil layer is thinner and rocky. The forest here has only three layers.

One is the top of the canopy layer which is 15-30 m high and comprises of large timbers such as *voicui* with big leaves, *longmang, lathoa, truong,* and *mun*. Another is the forest canopy layer which is fairly continuous and is 10-15 m high. These are mainly *may*, bamboo, *na* family, and *thi* family representatives like the single-leaf sprouts *buong bang* and *bason* palm. The third layer is very thinly distributed small bushes and plants which belong to the *oro, gai,* coffee, and *rang* families. Three to four species of nettles are often seen here.

On top of the mountain are some soil found in rock hollows. There are small woods or bushes like *hoi nui, soi, chan chim,* and *huyet giac*. The lower layer comprises mainly of bamboo and some trees belonging to the horn tree family that grow on dry land.

Due to suitable climate and high humidity, all kinds of vegetation found in the tropical forest are found here such as creeping woods, parasitic plants, symbiotes, on-trunk fruit trees, and *banh ve*. There are over 20 species of 10 families of creeping woods. Worth noting is the *bam bam* and *na buom* creeper which has a diameter of over 20 cm and a length of 30-40 m. This species hangs from big timbers and swings like a hammock.

Symbiosis is very common in the forest especially among orchid families and mistletoes. Worth noting too is the so-called suffocating symbiosis phenomenon. At first, small plants cling to the trunk of the main tree through their roots which attach to the trunk. As soon as the roots touch the soil, these plants grow quickly and become like cables, suffocating the main tree until it dies. The frequently seen representatives of the suffocating symbiosis group are *Sohefflera* and *Fagraea oborata.*

Parasitism is also quite common. Besides familiar plants belonging to the mistletoe family (*Loranthaeae*) there are five species of *Balansphora* that live on the roots of *de, may teo,* and *huyet du.*

The broadened branch phenomenon is also observed in different plant families in Cuc Phuong. This is evident on 8 m *sapindus* and 5 m high *Thung.*

Flora. Cuc Phuong flora has two typical characteristics: abundance of components and a concentration of different vegetation currents.

There are 1,880 species, 887 branches, and 221 vegetation families in Cuc Phuong *(Table 1).*

Cuc Phuong (22,200 ha) is 700 times smaller than the North and 1,500 times smaller than the whole Vietnam area. Cuc Phuong flora consist of 76.6 percent families, 48.6 percent branches, and 30 percent other species in the North; 68.9 percent families, 43.6 percent branches, and 24.6 percent other species in Vietnam.

There are 10 families and over 30 other species in Cuc Phuong. These are castor oil plants (102 species) grass (86), bean (72), coffee (72), chrysanthemum (65), mulberry (54), camphor (54), reed (54), orchid (51), and *oro* (36). The most abundant plants are mulberry, bead trees, and camphor.

Documents show that Cuc Phuong has contributed four new species and one new secondary species belonging to coated-seed vegetation.

Local vegetation. Evergreen trees with big leaves like the *vu huong, ca lo, vang anh,* and *goi nep* are among the local vegetation at Cuc Phuong. The temperate zone vegetation consists of species from the *ho dao* family, and *thichken.* These trees lose leaves in winter.

The dry vegetation from India-Myanmar includes species like *cho xanh, cho nhai, sang,* soap berry, and others. They lose leaves during the dry season.

The humid tropical vegetation from the south include oil tree families of three species and three branches such as *cho chi, thi nuoc,* and *seo hon gai.*

With its abundant vegetation, Cuc Phuong may be considered a botanic garden, a good place for sight-seeing, and

Table 1. Plant species found in Cuc Phuong Park, 1997

Vegetation	Number of Families	Number of Branches	Number of Species
Dai vegetation	33	80	140
Quyet vegetation	31	57	149
Uncoated seed	3	3	3
Coated seed	154	747	1,588
Total	221	887	1,880

as a laboratory for forestry students in conducting research.

Fauna. Cuc Phuong has an abundant fauna. Table 2 shows some 255 vertebrate animal species present in Cuc Phuong.

Table 2. Animal Species found in Cuc Phuong Park, 1997

Class	Assortment	Family	Species
Animal	1	25	64
Bird	16	42	137
Reptile	3	12	36
Bisexual	1	5	17
Fish	1	1	1
Total	22	85	255

The invertebrate animal group is not well studied.

There are 1,800 different kinds of insects belonging to 200 families, and 24 assortments gathered from the park. The names for branches and species of this collection, however, have not been defined yet.

There has not been any count conducted on the number of animals living in the Park. However, it has been commonly observed that the number of animals in Cuc Phuong at present has considerably decreased compared with the 1962 population when the National Park was established. Animals like the tiger, panther, and birds like the peacock and loplura can now hardly be seen.

Hunting activities of natives living in Cuc Phuong has seriously reduced animal species. Resource protection in the area therefore is a felt need. Some measures have to be adopted to protect Cuc Phuong's fauna. Illegal hunting of trappus birds and wild animals should be strictly prohibited.

3.3.1 Historical and cultural value of the Park

There are a lot of attractive spots in Cuc Phuong. These include old forest growths, caves, magnificent mountains, river systems, and hot springs.

Archaeological excavations had been made in caves, and these activities had contributed to the riches of the local museum.

A cave named Hang Dang or Dong Nguoi Xua (Cave of Primitive Man) was found to contain vestiges of life 7,000 years ago. Tombs made of stone had been found with the dead presumably buried according to a certain ritual. The Con Moong cave contains even older vestiges of human life, estimated to have existed some 12,000 years ago.

3.3.2 Tourist value of the Park

Cuc Phuong is a place of many magnificent mountains with verdant forest, many ancient trees, and many beautiful caves which attract a lot of visitors. It is a good place for tourists, specially nature lovers.

- *Cay cho ngan nam (Temninalia myrioearpa* hourak et Muell*)*: this great tree lose leaves in the dry season. It is 45 m high and the lower trunk circumference is about 25 m. It has two combined trunks in the broad part. The diameter of one trunk is 2.5 m and the other is 3.6 m. At a height of 8 m, it divides into two branches and at 12 m, one of the two branches divides again.

- *Cay cho chien thang (Temninalia myrioearpa Hourak et Muell):* This is 45 m high and its diameter at breast height is about 4 m. It is a single-trunk tree and the broadened trunk at its foot divides into four branches growing to about 8-9 m from the root. It takes 35-40 minutes to walk from Bong to this tree.

- *Cay cho chi (Shorea assimica* Dyer*)*: This is an evergreen timber which is 55 m high and its diameter at the height of a person's chest is 1.2 m. It has a round trunk and its very high canopy concentrates at the top with well- divided branches.

- *Cay sau (Dracontomelum dao* Merr, et Rolse*)*: This is an evergreen timber which is 40 m high. The diameter of the tip is 1.5 m. Its large broadened part is 5 m high. This part is 7-8 m from the root.

- *Cay dang (Tetramelenudiflera* R. Bes*)*: This is a big wood with falling leaves. It is 45 m high, and its diameter after the broad part is 1.2 m.

- *Cay vu huong (Cinamomum balansao* H. Lec*)*: This is a big evergreen tree which is 45 m high. Its diameter at breast height is 2.5 m.

- *May Bac mountain:* This is a lime mountain with a height of 656 m. It is situated in the northwestern side of the Park. There are many sharp rocks with rough sides that are almost 90 steep, making the mountain very difficult to climb.

- *Ancient people cave (Hang Dang)*: Hang Dang literally means bat cave. The cave lies in a dense forest in Cuc Phuong measuring 45 m high. It is far from the river and brooks. Hang Dang has two stories. The upper story has a dark and narrow entrance with no evidence of people's existence. It also has a way through to the lower cave. The cave's entrance is 3.1 m high and 4 m wide. The cave is oval with two separate compartments. In the outer room the largest area is 8.4 m wide and 6.5 m deep. The cave's floor has two levels. The outer floor is 30 cm higher than the inner floor and it is also brighter and more ventilated. There are some evidences of human existence. The inner part, on the other hand, is wet and dark with no evidence of people's existence. The cultural floor is 1.6 - 2 m thick with many shells, ash, and baked soil. Hang Dang has three ancient tombs said to be 7,000 years old. The way to the ancient people cave (Hang Dang) is through a system consisting of six iron stairs and hundreds of stone steps. It has a length of 113 m and a height of 60 m.

- *Con Moong Cave:* Con Moong Cave is situated towards the direction of Thanh Hoa. Con Moong literally means "animal" in local language. This cave is called as such because of an animal-looking rock rising at the top of the cave. The cave is located in the lime mountain and is near a large and beautiful valley overlooking a small path. It is nearly 20 m high compared with the dried brook surface. A short distance away from the cave is a big stream flowing all throughout the year. The cave is 6 m high and 5 m wide and with a rather thick floor. Archaeological relics in Con Moong cave include rocks and earthwares.

- *Vui Xuan Cave (Cheerful Spring Cave)*: This cave is situated in the southwest side of the Park, about 2 km away from Con Moong Cave. The way to the cave is rather difficult.

- *Trang Khuyet Cave (Crescent Cave):* This cave is located near the main road in Cuc Phuong.

3.4 Visitors and Facilities of the Park

3.4.1 Visitors

Secondary data were obtained only from 1991 to 1996. No data were obtained before this period. Since 1991, the number of visitors increased rapidly *(Table 3)*. Visitors in 1992 increased by 147 percent, compared with 1991, 164 percent in 1993-1992, and 113 percent in 1994-1993.

Visitors to the park in the last three years (1994, 1995, and 1996) however, have not increased much due mainly to bad weather (e.g., typhoons) which brought about other problems like flood and bad roads.

3.4.2 Facilities in the Park

Communication. The 15 km long road from Nho Quan to the gate of Cuc Phuong is asphalted. There is no traffic problem here.

From the gate to the center of the forest - Bong station, is an 18 km road of which 5 km is asphalted and the rest is being concretized.

There are lanes in the botanical garden (3.2 km long, and 3.5 m wide asphalted road); paths and foot trails run up to about 40 km.

Electricity. Electricity lines at Cuc Phuong stretches for 10 km (high voltage) and another 10 km (low voltage) for resthouses and offices. There is one 180 KWA transformer.

Water supply. Available water sources include a drilled well, an artesian well, and a water tank. In Cuc Phuong water is scarce, because the streams had already dried up.

Communication. Communication is still a problem in Cuc Phuong.

Accommodation. Resthouses are scarce. The few available ones have poor facilities and are not generally comfortable. There is only one restaurant that serves food regularly.

Table 3. Number of visitors to the Cuc Phuong Park, 1991-1996

	1991		1992		1993		1994		1995		1996	
	Domestic	Foreigner	Domestic	Foreigner	Domestic	Foreigner	Domestic	Foreigner	Domestic	Foreigner	Domestic	Foreigner
Jan.	342	12	145	15	507	21	1,526	77	640	211	1416	214
Feb.	91	11	621	23	3,870	19	670	18	3,843	166	933	105
Mar.	1,328	15	1,113	21	2,860	20	3,553	51	3,591	146	3797	219
Apr.	1,100	24	1,122	25	2,313	10	2,679	121	2,936	172	2495	165
May	670	40	789	30	1,320	9	1,856	65	1,959	129	2014	70
Jun.	297	11	707	15	1,121	16	1,073	12	1,711	99	1794	39
Jul.	483	19	342	17	899	19	841	88	645	148	1825	84
Aug.	365	16	1,084	21	1,208	55	1,100	146	944	142	1061	117
Sep.	494	10	1,429	18	626	34	545	37	839	125	759	104
Oct.	1,265	19	1,636	25	2,045	82	1,522	273	998	137	2219	256
Nov.	1,107	26	1,156	35	1,913	64	3,871	300	1,350	215	1373	257
Dec.	697	7	2,069	29	1,434	46	2,534	275	1,470	195	2053	179
Total	8,239	210	12,213	274	20,106	395	21,756	1,463	20,926	1,885	21,739	1,809

Source: Secondary data from Cuc Phuong National Park

3.4.3 Plan for improvement

There had been plans to improve the facilities and conditions at the Park, but due to financial constraints, the plan had not been pushed through. These plans include:

1. Stretching the main road from the gate to the Park, from 13 - 18 km long. This will also be concreted.

2. Constructing a new concrete road for tourists measuring 40 km long and 1 m wide. The road will lead to the attractive and beautiful sites within the Park.

3. Providing a steel fence to confine some wild animals which are also a tourist attraction of the Park. This will measure 2.5 m high and 5 km long.

3.5 Cuc Phuong National Park Objectives

The National Park was established for several reasons:

1. *For ecological purposes.* The establishment of the Park will help preserve precious species of plants and animals and also help reforest barren areas of the forest.
2. *For experiment purposes.* The Park can serve as a laboratory for students and researchers.
3. *For tourism purposes.* The Park has many natural attractions considered as tourist spots.

Foreign experts undertaking studies on plants and animals are using the Park as a study site. Information on environmental protection is disseminated to people within the vicinity of the Park.

Management and protection of the Park has been a major problem. People living in the area are generally poor and uneducated, and their environmental protection knowledge is low. Hence, slash-and-burn activities are rampant for two reasons: to have a farm to till and to gather firewood and timber. Hunting activities are also rampant.

To help solve the problem, foresters coordinate with government authorities to prohibit the issuance of clearance permits to cut trees. The authorities also conduct environmental awareness and protection programs.

Scientific studies. The following scientific studies had been accomplished:

1. Researched, collected, and preserved over 10,000 samples of plant species.
2. Classified and listed 1,967 species.
3. Prepared and formulated a soil map (scale:1/10,000).
4. Discovered four new species: Chiroptera, Callosoiusus, Orythinacus Cuc Phuongnensis, and Silurus Cuc Phuongnensis Yen.
5. Surveyed and classified the forest (limestone).
6. Constructed four meteorological stations.
7. Discovered several precious wood trees.
8. Discovered and bred a herd of roe-deer.
9. Coordinated with the Institute of Archaeology regarding the Nguoi Xua cave and Con Moong cave where valuable artifacts and documents had been excavated.
10. Established a museum containing samples of resources present in the Park.

Tourism and education. The facilities and services offered by the Park partly satisfied the demands of visitors, but they still need improvement. The following are some of the problems:

1. Lack of facilities for recreation and research
2. Tourist places need to be developed and improved
3. Untrained tourist guides
4. Lack of brochures and other materials needed to promote the Park

Generally therefore, investment on the Park has not been enough as evidenced by poor facilities, lack of communication systems, and poor marketing and promotion.

3.6 Management of the Park

Cuc Phuong National Park is being managed by the Ministry of Forestry. It is now being manned and maintained by 118 people, including a doctor, 17 university graduates, 41 college graduates, and 59 workers.

To meet the Park's goals and functions, efficient and adequate manpower should be provided. Offices and number of persons needed are:

1. Plan, Finance, and Material Dept.: 12 people
2. Administration: 9 people
3. Science Dept.: 4 people

Other units also have the following manpower needs:

1. Guards: 66 assigned in nine stations and a group of mobile patrol.
2. Science study station: 52 people to coordinate and assist in undertaking projects, experiments, and in the management of the botanical garden, museum, and library.
3. For road maintenance: 35 people.
4. Tourist guides and promotion: 15 people.
   Total: 193 people needed

Annual budget

The Park's main source of income are entrance fees and accommodation. Expenses incurred include those paid for salaries of employees and management facilities, and maintenance of equipment. The remaining amount goes to the Ministry of Forestry.

Expenses for forest planting, forest improvement, conduct of studies, road construction and repair, and other facilities need the approval of the Ministry. The Park has no other sponsors.

4.0 OVERALL FEATURES OF THE SAMPLE

4.1 Socio-economic Characteristics of the Respondents

The respondents of the study include 193 domestic respondents and 60 foreigners *(Table 4).* Foreign visitors are further classified into foreign-tourists and foreign-domestic visitors. The latter consists of foreigners who have a longer duration of stay in Vietnam, either due to a project, a consultancy job, or a university position.

Table 4. Type of visitors

Type	Frequency	Percent
Domestic	193	76.3
Foreign	60	23.7
Total	253	100.0

4.1.1 Foreign respondents

The 60 foreign respondents include: 35 tourists (58%), whose duration of stay in Vietnam was from 24 to 27 days; and 25 foreign-domestic visitors (42%), whose duration of visit to Vietnam was from 1 month to 3 years *(Table 5)*. The purpose of visiting the site varied: business, study, and teaching other languages *(Table 6)*.

Table 5. Origin of foreign respondents

Origin	Frequency	Percent
Australia	14	23
Asia	4	7
Europe	31	52
America	11	18
Total	60	100

Table 6. Purposes of visit to Vietnam

Purposes	Frequency	Percent
Travel	34	56.7
Business	10	16.7
Teaching	12	20.0
Studying	4	6.7
Total	60	100.0

Majority (52%) of foreigners interviewed came from Europe and from countries like Australia, Asia, and America. Of the 60 visitors, 38 were male and 22 were female *(Table 7)*. Their age ranged from 21 to 71 years old, but most of them belonged to the 21-50 age ranges. Their income were higher than the Vietnamese, with 20 percent each earning a monthly income of USD 1,100-1,500 and USD 2,100 to 3,000. Almost all of the foreigners covered in the sample are professionals.

4.1.2 Domestic visitors

There were more male than female tourists among the 193 Vietnamese visitors. Their ages ranged from 17 to 70 years old but most belong to the 21-30 age bracket *(Table 8)*. Majority of travelers have high educational level showing that the purpose of their visit to Cuc Phuong National Park is more scientific in nature. Income of domestic visitors is much lower than that of the foreigners.

Table 7. Socio-demographic characteristics and income of foreign visitors

Characteristics	Frequency	Percent
Sex		
Male	38	63.3
Female	22	36.7
Total	60	100
Age		
<20	0	0.0
21 - 30	15	25.0
31 - 40	20	33.3
41 - 50	15	25.0
51 - 60	4	6.7
61 - 70	5	8.3
71 - above	1	1.7
Total	60	100
Education		
Doctor	5	8.3
Master	20	33.3
University	33	50.0
High school	2	3.3
Total	60	100
Income (USD)		
500.00		
500- 1,000	11	18.3
1,100- 1,500	12	20.0
1,600- 2,000	9	15.0
2,100- 3,000	12	20.0
3,100- 5,000	10	16.7
>5,000.00	5	8.3
Total	60	100

4.2 Activities in the Park

Almost all respondents came to visit the Park in groups. Vietnamese visitors came in big groups of 30-50 persons *(Table 9)*.

Table 8. Socio-demographic characteristics and income of domestic visitors

Characteristics	Frequency	Percent
Sex		
Male	106	54.9
Female	87	45.1
Total	193	100.0
Age		
<20	33	17.2
21 - 30	82	42.2
31 - 40	34	17.7
41 - 50	32	16.7
51 - 60	10	5.2
61 -70	2	1.0
71 above	0	0.0
Total	193	100.0
Education		
Doctor	10	5.2
Master	17	8.8
University	140	72.4
High school	19	9.9
Secondary	7	3.6
Total	193	100
VND ('000)		
<300	29	15.1
300 – 500	93	47.9
500 - 1,000	52	27.1
>1000	15	7.8
No answer	4	2.1
Total	193	100.0

Table 9. Number of persons per group

Number of Persons	Frequency	Percent
2 - 4	25	13.0
5 - 12	40	20.7
13 - 24	69	35.8
More than 25	59	30.6
Total	193	100.0

Most respondents came to the Park for varied purposes, but they liked hiking most, followed by cave visiting. Table 10 shows the favorite activities of visitors.

Many respondents complained about the facilities, services, and environment of the Park. They did not see the many kinds of trees because of bad roads and lack of trails. Generally, the environment in the Park was not good because of too much trash. Table 11 shows the respondents' perceptions of the park.

Because Cuc Phuong is far from the urban center, most respondents seldom visited the Park. They came only once a year or once every few years. Some came to the Park only once.

Table 10. Favorite activities of visitor-respondents

Favorite activities	Frequency	Percent
Hiking	80	31.6
Cave visiting	52	20.6
Tree watching	35	13.8
Bird & animal Watching	28	11.1
Sight-seeing	40	15.8
Others	18	7.1

Table 11. Perceptions about the Park environment

Perception	Frequency	Percent
Bad	46	18.2
Tolerable	181	71.5
Good	26	10.3
Total	253	100.0

Duration of stay in the Park sometimes depends on travel distance. A one-day round trip is possible for people living not far from the Park. For people who live further than 150 km away, staying overnight was necessary if they wanted to visit some places in the Park.

North Vietnam has other parks and tourist spots. These include: Ba Vi, Cat Ba, and Ba Be (national parks); Tam Dao and Sa Pa (famous mountains); and Ha Long Bay, the world heritage.

4.3 Expenses

Expenses incurred going to the Park include transportation cost, entrance fee, guide fee, food and drink, accommodations, and souvenirs. The different fees and costs are shown in Table 12.

4.3.1 WTP for improvements

Majority of the respondents (90.5%) were willing to pay for improvements in the Park, whereas the rest did not. Their reasons for not willing to pay for improvements are shown in Table 13.

Table 14 shows the amounts that both domestic and foreign visitors are willing to pay for Park improvements, such as roads, foot trails, and confined animal area.

5.0 ANALYSES

Two analyses were made in this section: demand for recreation against travel cost and willingness to pay (WTP) for improvement.

Table 12. Park fees and associated costs

Expenses/person ('000VND)	Frequency	Percent
5	63	32.6
6	81	42.0
8	2	1.0
10	47	24.4
Transportation costs		
10.00-20.00	29	15.0
21.00-40.00	46	23.8
41.00-60.00	55	28.5
61.00-100.00	36	18.6
>100.00	27	14.0
Foods and drinks/day		
>10.00	9	4.7
11.00-20.00	46	23.8
21.00-30.00	102	52.8
> 30.00	36	18.6
Accommodation/day		
0.00	54	28.0
5.00-10.00	50	25.9
15.00-30.00	44	22.8
50.00-100.00	32	16.6
>100.00	13	6.7
Cost of souvenirs		
0.00	123	63.7
5.00-10.00	27	14.0
11.00-20.00	23	11.9
21.00-30.00	20	10.4
Guide fees		
0.00	130	67.4
1.00-30.00	63	32.6

Table 13. Reasons for respondents' unwillingness to pay

Reasons	Frequency	Percent
Negative impact on environment of the Park	13	54.20
Low income	5	20.80
Price of accommodation is too high; a part of savings should be invested in improvement	2	8.30
Have to study further to answer the question	4	16.70

Table 14. WTP for improvement of Park facilities by visitors

	Domestic visitors			Foreign visitors		
	Amount ('000VND)	Frequency	Percent	Amount (US$)	Frequency	Percent
Road	0.00	10	5.2	0.00	14	23.30
	1.00-5.00	135	70.0	1.00-5.00	22	36.70
	6.00-10.00	37	19.2	6.00-10.00	24	40.00
	>10.00	11	5.7	>10.00	0	0.00
Foot trail	0.00	21	10.9	0.00	22	36.67
	1.00-5.00	131	67.9	1.00-5.00	24	40.00
	6.00-10.00	29	15.0	6.00-10.00	13	21.67
	>10.00	12	6.2	>10.00	1	1.66
Confined animal area	0.00	21	10.9	0.00	37	61.67
	1.00-5.00	150	77.7	1.00-5.00	14	23.33
	6.00-10.00	12	6.2	6.00-10.00	8	13.33
	>10.00	10	5.2	>10.00	1	1.67

5.1 Demand for Recreation

5.1.1 Zone of origin and visitation rate

Zone of origin. The surrounding area (only north part of Vietnam) of the Park is divided into six zones of increasing distance. Considering the road system and population statistics, a spatial division was made according to administrative areas, including 30 provinces and cities with their districts *(Table 15 and Figure 2).*

Travel distance. Travel distance was calculated from a point within the area of the zone to the Park gate.

For the two inner zones, a one day round trip was possible; in fact all of the respondents from the two inner zones did not stay in the Park overnight.

For visitors from the four other zones, overnight stay was necessary. But these visitors went to the Park for multiple purposes.

Visitation rate. The number of visits from each zone was added. Visitation rate was calculated by dividing yearly visits by the total adult population in the same zone *(Table 16).*

Table 15. Characteristics of zones

Zone	Distance (km)	Administrative Districts and Provinces	Total adult pop. ('000)
1	34.5	Some districts of Ninh binh, Hoa binh, and Thanhhoa	467
2	69.8	Districts of Ninh binh, Hoa binh, Hanam, Nam dinh, Thaibinh, and Thanh hoa	2,195
3	120.1	Districts of Hoa binh, Hatay, Hanoi, Hungyen, Nam dinh, Thaibinh, and Thanh hoa	5,103
4	145.3	Districts of Phutho, Vinhphuc, Hanoi, Bacninh, Haiduong, Haiphong, Thanhhoa, and Hoabinh	3,341
5	204.2	Districts of Sonla, Yenbai, Tuyenquang, Phutho, Thainguyen, Bacgiang, Langson, Quangninh, and Nghean	4,208
6	475.0	Districts of Sonla, Laichau, Laocai, Yenbai, Hagiang, Tuyenquang, Caobang, Langson, Quangninh, Nghean, Hatinh, Quangbinh, and Quangtri	3,003

Table 16. Visitation rate by zone

Zone	Number of Sample by Zone	Visits/year	Total Adult Population ('000)	Visitation Rate (visit/1,000 pop.)
1	11	1,212	467	2.6
2	41	4,489	2,195	2.1
3	84	9,197	5,103	1.8
4	34	3,723	3,241	1.2
5	19	2,080	4,208	0.5
6	4	438	3,003	0.2

5.1.2 Travel cost estimation

Total travel costs consisted of three components: transport cost, time cost, and other expenses.

Cost of transport. Cost of transport depended on distance and means of transport. Table 17 shows the various means of transportation taken by both foreign and local visitors.

The Park is far from the national road, and no public transportation goes there. Hence, a hired car is the most popular means of transportation used by many. Based on the survey data, more than 80 percent of the sample used this means of transportation. Visitors from the three nearest zones also used motorbikes.

Transportation expenditures of visitors varied because of the type and class of car used. From Hanoi to Cuc Phuong, a group of four visitors using a four-seater car had to pay VND250,000/person for a round trip, whereas a group of 30 using a 25 to 30-seater vehicle, paid only VND30,000/person.

This explains why an adjusted cost of transport was used in this study. It was assumed that visitors came to Cuc Phuong in groups of 25 and that they hired a vehicle for VND 350.00/km. This amounted to about VND 150/km/person for a one day trip. But if the car was used overnight, visitors have to pay VND 4,000 / person/night. Cost of transport increased with distance and duration of journey. Cost of transport for each zone is presented in Table 18.

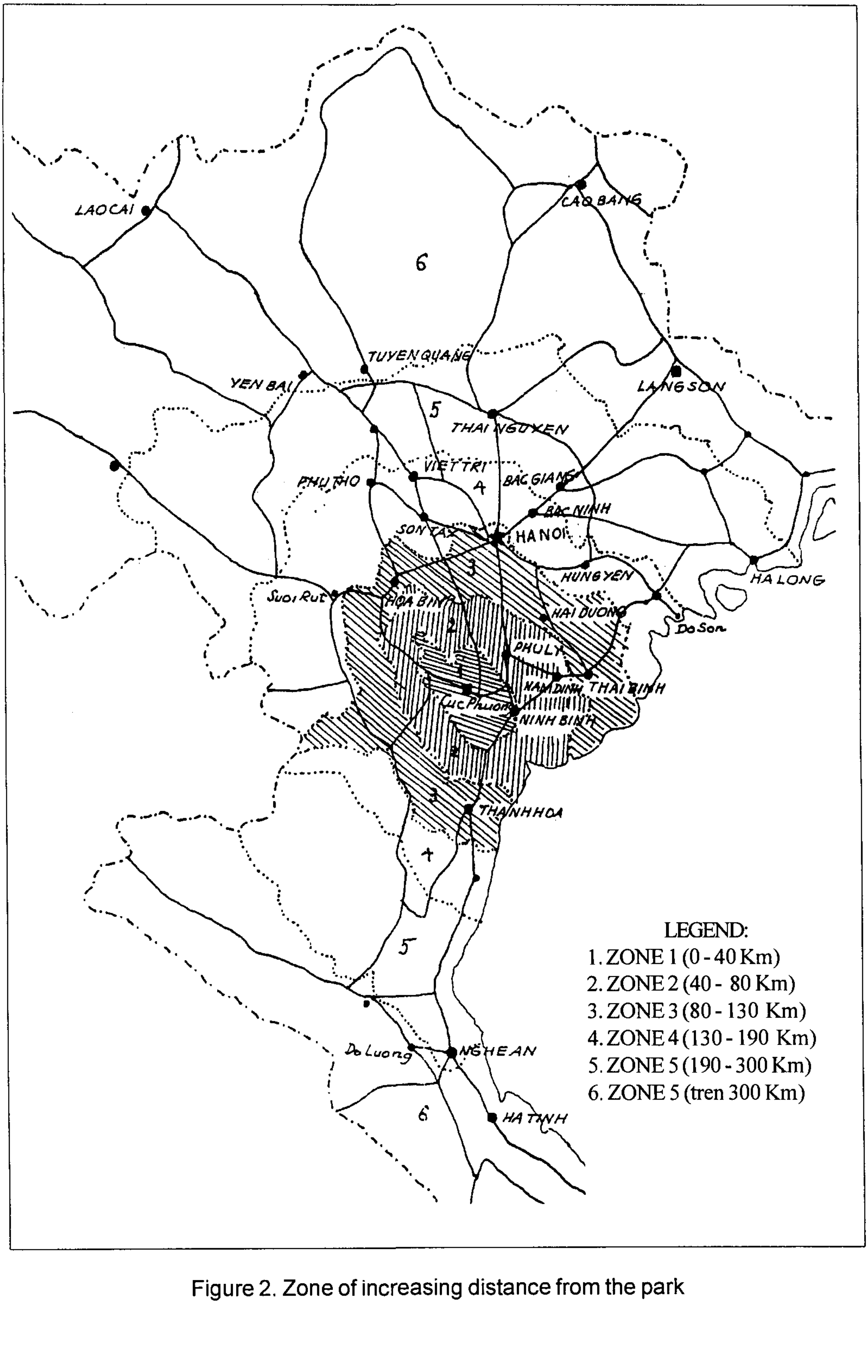

Figure 2. Zone of increasing distance from the park

Table 17. Means of transport of Park visitors

Means of transport	Foreign		Domestic	
	Frequency	Percent	Frequency	Percent
Hired car	47	78.3	158	81.9
Bus + motorbike	4	6.7	4	2.0
Private car	1	1.7	6	3.1
Tour bus	6	10.0	0	0.0
Train + hired car	2	3.3	0	0.0
Motorbike	0	0.0	25	13.0
Total	60	100.0	193	100.0

Table 18. Round-trip transportation cost

Zone	Distance (km)	Transportation
1	34.5	10,350
2	69.8	20,940
3	120.1	40,036
4	145.3	47,596
5	204.2	69,263
6	475.0	158,500

Table 19. Adjusted time cost, according to zone

Zone	Full Wage Rate	1/3 Wage Rate
1	20.00	6.66
2	20.00	6.66
3	40.00	13.00
4	40.00	13.33
5	60.00	20.00
6	100.00	33.33

Time cost. Estimating the value of travel time of a trip is a sticky issue. Some have suggested using the full wage to value recreational travel time. Others have suggested the use of 1/3 wage rate to value the commuter's time. In this study, we used both the full wage rate and 1/3 wage rate.

Calculation of wage rate is based on average income per urban resident, which is estimated to be 6 million VND in 1996, or 500,000 VND per month or 20,000 VND per workday. In Vietnam, a farmer's income is on average half of the urban employee's salary. Because almost all visitors who go to the Park are urban residents, the wage rate from the urban sector was adopted.

Differential change in wage rate did not have much impact on travel cost, thus, in the demand analysis, only full wage rate was used for illustration. Depending on the time spent, calculation of time cost for each zone was adopted *(Table 19).*

Other expenditures. These included entrance fee, guide fee, food and drinks, accommodation, and souvenir items.

The average expected expenses or amounts of entrance fees, food and drinks, and accommodation were calculated for each zone *(Table 20).* For visitors from zones 1 and 2, a one-day round trip is possible so accommodation was not included in the calculations. Visitors from zones 3-6 usually stayed the night in the Park. Hence, the cost of accommodation was included in the calculations. Expenses for guide fees, souvenir items, etc. were not included in travel cost because not many sample respondents spent on these.

Total travel cost. In this study, this included three components: cost of transport, time cost, and other expenses. The total cost is presented in Table 21. Note that the figures in this table are adjusted values for multiple purposes or for several site visits. The data gathered in the

Table 20. Other expenditures included in computing travel costs to Cuc Phuong

Zone	Entrance Fee	Food & Drink	Accommodation
1	5.730	19.550	
2	6.585	26.340	
3	6.548	59.900	27.655
4	6.706	58.400	32.920
5	6.000	80.850	43.160
6	10.000	150.000	120.000

survey showed that 40 percent of visitors in zones 3 and 4 visited the Park for multiple purposes; 60 percent of visitors from zone 5 also came to the Park for various reasons. All visitors zone 6 had multiple reasons for visiting the park. Thirty percent of the travel time and cost was attributed to recreation.

5.1.3 Demand function

The relationship between visitation rate (VR) and travel cost (TC) is linear. Using VR as a dependent variable and TC as an independent variable, two types of regression analyses were made to find the best fit functional form.

The first type of function took a linear form:

$$VR = a + b\,(TC)$$

where a = 3.5681 (full WR)
b = -0.017374 (full WR)
r^2 = 0.9104

and a = 3.4092 (1/3 WR)
b = -0.018840 (1/3 WR)
r^2 = 0.9198

Details of parameters and statistics are:

Predictor	Variable			
	coefficient	std error	student's t	p
constant	3.5681	0.36725	9.72	0.0006
tc-fullwr	- 0.017374	0.002725	-6.38	0.0031
r^2	0.9104			
constant	3.4092	0.32408	10.52	0.0005
tc-1/3wr	-0.01884	0.002782	-6.77	0.0025
r^2	0.9198			

The semilogarithmic form was also regressed using the same set of data. The correlation, however, was not as good as the linear form:

$$\ln (VR) = a + b\,(TC)$$

where: a = 2.2976 (full WR)
b = 0.018383 (full WR)
r^2 = 0.7564

and: a = 2.1337 (1/3 WR)
b = 0.019973 (1/3 WR)
r^2 = 0.7672

Parameters for other quality levels are also listed as:

Predictor	Variable			
	coefficient	std error	student's t	p
constant	3.5681	0.36725	9.72	0.0006
tc-fullwr	- 0.017374	0.002725	-6.38	0.0031
r^2	0.9104			
constant	3.4092	0.32408	10.52	0.0005
tc-1/3wr	-0.01884	0.002782	-6.77	0.0025
r^2	0.9198			

Table 21. Total travel cost and visitation rate

Zone	Total Travel Cost (VND)		Visitation Rate at Full Wage Rate (Visit/1000 pop'n)
	(Using full wage rate)	(Using 1/3 wage rate)	
1	55.163	42.290	2.6
2	73.865	60.525	2.1
3	132.241	112.239	1.8
4	140.953	120.951	1.2
5	168.679	148.040	0.5
6	185.990	163.790	0.2

5.1.4 Demand curve

Using the data on visitation rate and total TC at full WR, a demand curve was constructed *(Figure 3)*. As facilities are improved, the demand curve moved outward and the amount of benefits further increased.

5.1.5 Estimation of benefit

The area under the demand curve was used as an estimate of benefit of Park users. Using the linearly connected points, the benefits were calculated.

Areas below the demand curve and above the average travel costs were used as an estimate of consumer surplus of Park users from each zone. This value was most usually reported as consumers' surplus per visit. Using number of visits/year for each zone, the consumer surplus of each zone was estimated.

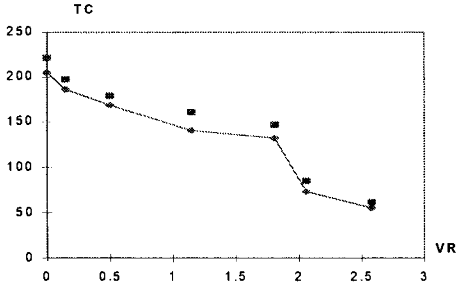

Figure 3. Demand curve for tourism in the Cucphuong National Park (unit: 1000 VND)

The consumer surplus from all zones was added together to estimate the total consumer surplus for users of the Park.

Using visitation rate (VR), average travel cost (TC) and visits/year for each zone, the amount of benefit and consumer surplus were calculated *(Table 22)*.

5.2 WTP Analysis

In the WTP analysis, we estimated the 1996 WTP for facility improvement, the benefit of improvement facility, and examined what variables most likely affected WTP figures.

5.2.1 1996 WTP estimation

Average WTP figures are given in Tables 23a-23c together with some statistical description of the sample.

Foreigner-domestic visitors were willing to pay much more than the foreigner-tourist visitors *(Table 23b)*.

Based on these average data and number of visits, the 1996 WTP was calculated and estimates are presented in Table 23c.

- WTP of domestic visitors: 13,270.00 VND x 21,739 = 288.48 million
- WTP of foreign visitors: 119,167.00 VND x 1809 = 215.57 million

Table 22. Tourism benefit and consumer surplus of Park users (unit: 1000VND)

Zone	Benefit	Consumer Surplus
1	40,808.00	5,747.79
2	115,653.50	32,752.87
3	829,134.40	26,434.94
4	374,644.60	33,552.61
5	129,099.90	6,300.84
6	12,846.00	626.45
Total	1,502,186.40	105,415.50

Table 23a. WTP ('000 VND) estimation for 1996

	Foreign Visitors			Domestic Visitors		
	Min.	Max.	Mean	Min.	Max.	Mean
Road	0.00	110	50.967	0.00	20.0	4.451
Foot trails	0.00	165	42.167	0.00	30.0	4.508
Confined animal area	0.00	165	26.033	0.00	40.0	4.311

Table 23b. WTP of foreigner-domestic and foreigner-tourist respondents

WTP ('$US)	Foreigner-Domestic	Foreigner-Tourist
Road	10.0	5.0
Foot trails	8.0	2.8
Confined animal area	6.6	1.5
Total	24.6	9.9

Table 23c. WTP estimation for Park visitors (unit:1000VND)

	Foreign Visitors		Domestic Visitors	
	Average/person	1996 WTP	Average/person	1996 WTP
Road	50.967	92,199.30	4.451	96,760.29
Foot trail	42.167	76,280.10	4.508	97,999.41
Confined animal area	26.033	47,093.70	4.311	93,716.83
Total	119.167	215,573.10	13.270	288,476.53

5.2.2 Factors affecting WTP

The graphs *(Figure 4)* show how visitors' background or information on income, age, and education affect on WTP for the six zones.

As the facility improved, the demand curve moved outward and the amount of benefit was further increased.

Using the same set of data, the benefits were calculated for each zone (Table 24).

Table 24. Benefits of improvement

Zone	Benefit Under Existing Conditions	Benefit Under Improved Conditions	Benefit of Improvement
1	40808.0	46184.0	5375.99
2	115653.5	129995.8	14342.33
3	829134.4	931960.5	102826.10
4	374644.6	410217.8	35573.22
5	129099.9	136718.4	7618.50
6	12846.0	13742.1	896.15
Total	1502186.4	1668818.6	166632.29

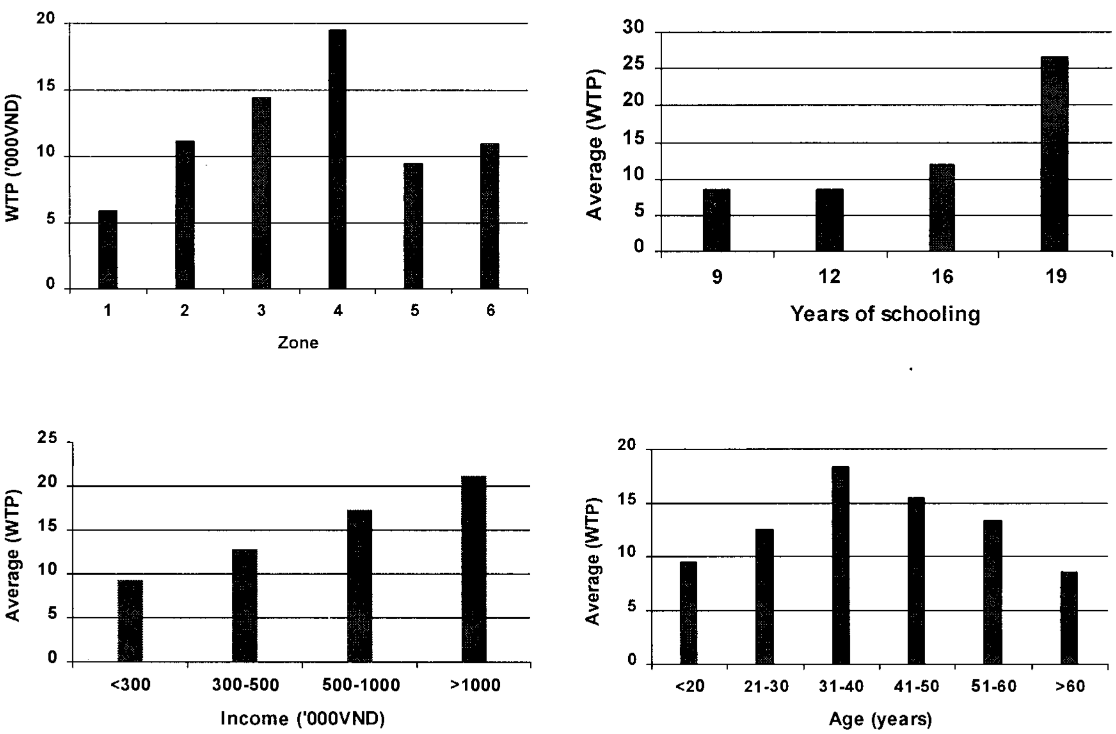

Figure 4. Effect of income, education, and age on WTP

6.0 CONCLUSIONS AND RECOMMENDATIONS

Cuc Phuong National Park is a recreational site of national significance. Thousands of people come here to hike, watch trees and animals, or visit caves, each year. The site has natural, historical, and cultural value. Lately, however, many tourists had been complaining about the Park's facilities, services, and environment. People now do not visit Cuc Phuong very often. A move to improve facilities and services and protect the environment of the Park should therefore be undertaken.

With this purpose, a survey was designed to evaluate the tourism benefits of Cuc Phuong and find the WTP for improved facilities. The survey was conducted from October 1996 to January 1997. Due to time constraints, the survey did not cover all seasons of the year. Spring and summer could have been an ideal period to conduct the survey because this is the time when most visitors are expected. Respondents of the study all came from the north part of Vietnam. Moreover, in October and November, it was raining so much that Cuc Phuong had some flood. These were some of the problems encountered during the survey.

Using the information gathered from 253 questionnaires, two analyses with TCM and CVM were done. Based on the analyses, the following conclusions were drawn:

Travel Cost

Each year about 22,000 visits are made to the Cuc Phuong National Park. Visitation rate decreased drastically with distance from the Park from 2.6 per capita per annum in zone 1 to 0.2 in zone 6. Travel cost per visit increased from 55,630.00 VND in zone 1 to 185,990.00 in zone 6, at full wage rate. Regression analyses suggested that a linear form better represents the demand function between visitation rate and travel cost than a semilog form, as indicated by the regression coefficient (r^2) of 0.91 for the former and 0.75 for the latter. Total recreation benefit as measured through linearly connected points was 1,502 million per annum and total consumer surplus was 105 million per year. The benefit estimate per year did not include foreign visitors who accounted for 8-9 percent of total number of visitors.

Improved facilities shifted the demand curve outward. There was little difference in the curvature of the demand function. The main change was the outward movement of the intercepts when facilities improved. The addition of benefits from existing to improved level was 166 million per annum.

WTP

Average WTP from domestic visitors were 4,045; 4,508; 4,311 VND per person for improved road, foot trail, and confined animal area. Foreign visitors have their corresponding WTP of 50,967; 42,167; 26,033 VND per person, respectively for the three items. The total estimated benefit for improved facilities for 1996 from domestic visitors is 288.47 million VND, and from foreign visitors, 215.57 million VND.

As facilities improve, the total recreation benefit is expected to increase too. The benefit from improvement was estimated to be 166 million VND.

WTP was independent of travel costs and distances, but dependent on income, and education. Age did not seem to have much impact on WTP.

Only 10 percent of the respondents were not willing to spend for Park improvements. The reasons for their refusal were low income, not enough time to study the questions, negative impact on the Park's environment, and price of accommodation is too high. Some respondents suggested that some amount be invested in facility improvement. Among them, 54 percent believed that if facilities were improved, the number of visits/visitors will increase.

METHODOLOGICAL IMPLICATIONS

TCM is a well established method for estimating the demand for recreational facilities, and hence their preservation and enhancement value. However, some issues need to be considered:

1. Cuc Phuong is a recreation site located in a mountainous rural area, but almost all of the visitors are urban residents. Local residents living around the forest zone seem not to have interest to go to the Park. Dividing the area into zones to estimate visitation rates is rather difficult.

2. There is no public transport to the recreation site. Hired cars are therefore the most widely used means of transport. About 82 percent of the respondents hired vehicles to visit Cuc Phuong. Transport costs varied greatly depending on the type and class of car and the number of persons/ group. So an adjusted cost of transport was used to estimate the average travel cost for six zones.

3. The treatment of time is rather tricky. In comparison with transport and other direct expenses, time cost can be insignificant as wage rate is low. In this analysis, the value of travel time used both full wage rate and 1/3 wage rate.

4. Calculation of wage rate was based on income. Reported salaries declared by visitor-respondents, however, may not be that reliable. Some respondents reported only income from work. Income derived from other sources may be much higher than wages or salaries. Most students also indicated that they did not have any income at all. And since almost all visitors were urban residents, the average urban income was adopted. Visitors with multiple reasons for coming to the Park spent 30 percent of travel time and cost on recreation.

5. The method was not applied directly to foreign visitors, which would be a complicated procedure.

Policy Implications

Cuc Phuong National Park and the other national parks in Vietnam could be better appreciated. The recreation benefits as measured could be quite high as shown by the survey results. The standing forest is only one of the attractions of the Park. Other benefits include harvestable products, ecological services, potential for biodiversity, and historical and cultural values.

To help preserve the value of the Park, efforts must be made to stop activities like illegal cutting of trees, hunting, and catching birds and wild animals in the vicinity of the Park. Villagers have been traditionally dependent on the forest and other resources of the Park such as forest products and agricultural lands for cultivation of rice and other crops. Establishment and preservation of the Park had accordingly affected the economy of the local population because they lost access to the Park and its resources. The Park manager on the one hand should promote activities such as protection, conservation, and education. On the other hand, the tourism benefit can be used to help devise a compensation scheme for local villagers who have lost part of their economic base from the Park's use as a recreational site.

This study is useful in making a rational decision about whether or not to protect and improve the Park.

The demand for tourism and recreation benefits are increasing day by day in Vietnam. Policies guarding against forest exploitation and promoting or advocating forest protection and preservation of resources are necessary to meet the tourism demands of the population.

REFERENCES CITED

Cameron, T.A. 1992. Combining Contingent Valuation and Travel Cost Data for Valuation of Nonmarket Goods. Land Economics.

Dixon, J.A., L.F. Scura, R.A. Carpenter, and P.B. Sherman. 1994. Economic Analysis of Environmental Impacts. London: Earthscan Publications Ltd.

Fletcher, J., W. Adamowicz, and T. Graham-Tomasi. 1990. The Travel Cost Model of Recreation Demand. Leisure Science.

Group on Economic and Environment Policy Integration. *nd.* Environmental Project and Policy Appraisal: A Manual for Policy Analysts. Env/epoc/geei (95) 5.

Hanley, N. and C.L. Spash. 1993. Cost Benefit Analyses and the Environment. England: Edward Elgar Publishing Limited.

Hanley, N., J.F. Shogren, and B. White. 1997. Environmental Economics. London: Macmillan Press Ltd.

Tobias, D. and R. Mendelsohn. 1991. Valuing Ecotourism in a Tropical Rainforest Reserve. Ambio.20(2).

Walsh, R.G., D.M. Johnson, and J.R. Mc Kean. 1992. Benefit Transfer of Outdoor Recreation Demand Studies, 1968-88. Water Resources Research, 28 (3).

ACRONYMS

TCM	Travel cost method
CVM	Contingent valuation method
WTP	Willingness to pay
VR	Visitation rate
TC	Travel cost

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VALUATION OF NON-TIMBER FOREST PRODUCTS IN LUONG SON DISTRICT, HOA BINH PROVINCE

4

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SUMMARY

Truong Son, located 10 km away from the Luong Son district town and 60 km from Hanoi, Vietnam's capital, occupies 5,260 hectares. The main non-timber forest products (NTFPs) collected in Truong Son commune were *Dendrocalamus patellaris, Neohouzeana dulloa*, bamboo shoots, firewood, medicinal plants, livestock fodder, *Imperata cylindrica*, and *Phyrynium capitalum* Wild. About 87 percent of the households exploited *Dendrocalamus patellaris, Neohouzeana dulloa*, bamboo shoots, and livestock fodder. Some 66.7 percent of households cut *Imperata cylindrica* for roofing which could also be eaten as wild vegetables. Also 9.5 percent of the households used wild plants as livestock feeds.

The results of the forestry inventory conducted on three standard plots showed that the total value of the forest trees in the plots were 1,417,709 VND/ha; 1,672,670.5 VND/ha, and 1,818,434 VND/ha, respectively. The net values of the NTFPs were 406,400 VND/ha; 312,900 VND/ha, and 631,700 VND/ha, accounting for 29 percent, 19.2 percent, and 34.7 percent of the total value of forest products in plots no. 1, no. 2, and no. 3, respectively. Recommended are continuing education, funding and technical support for households; establishment of economic-ecological models and agro-forestry cultivation systems suitable to the natural and socio-economic conditions of the locality; collection of basic data on the composition, distribution, and ecological characteristics of NTFP to guide rational use; and the adoption of suitable policies to rehabilitate forests and develop NTFPs.

1.0 INTRODUCTION

Vietnam's forest resources are seriously degraded. The Ministry of Agriculture and Rural Development has reported that during the past 50 years, about 5 million ha of forest have been lost, or an average of 100,000 ha per year. In 1995, the forest cover of the whole country was only 28.1 percent; primary forest cover was only 4 percent. The average forest acreage per capita was 0.13 ha, which was lower than the global average.

The forests have been exploited for both timber and non-timber products. Of late, non-timber forest products (NTFPs) have played an increasingly important role in the forestry economy and the lives of the people in the mountain and midland regions in Vietnam. This is not only because NTFPs have great economic value, but also because their exploitation has many advantages such as low investment, high profit, short business cycle, and relatively simple extraction and processing practices.

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Forest exploitation for NTFPs has a great social importance: it provides jobs for many people of different ages, actively contributing to hunger eradication and poverty alleviation, and increasing the income and living standards of the people in the mountain regions. It likewise does not cause as much environmental damage. Many species used for NTFPs are vines and shrubs, therefore their use could cause less adverse effects or destruction on the setup of the forest. As a result, the forest and consequently, timber supply would be maintained.

To rehabilitate and develop the country's forests, the State has adopted a series of forest extension policies, including the policy of land and forest allocation. In support of this, a rational exploitation of NTFP could improve the living standard of the population as well as minimize the decline of forest cover.

This project selected Truong Son commune, Luong Son district, and Hoa Binh province as the case study area. Hoa Binh is a mountain province, bounded in the east by Hanoi City. It links the Red River Delta and the northwest mountain region, and is populated by many ethnic groups such as Muong, Giao, and Thai. Its inhabitants practice mainly agriculture, largely on sloping areas. Extraction of NTFPs plays an important role in the economic life of the people.

Truong Son commune represents the features of Hoa Binh province. It has diverse landscapes, limestone mountains, and hills and valleys along rivers and streams. It has abundant forest resources but these are being seriously degraded. Hence, the result of the study could provide the basis for defining effective strategies to rationally exploit, protect, and develop the forest so that the living standards of the people in the whole mountain region could be improved.

This report is divided into three parts. Part I provides an analysis of the biophysical characteristics and forest resources of Truong Son commune. Part II examines the socio-economic and management mechanisms in the commune. Part III summarizes the results of the study, and presents recommendations for policy development.

1.1 Objectives

The study had four objectives:

a) To assess the value and the role of NTFPs in the livelihood of the mountain people;
b) To compare the value of timber and non-timber resources;
c) To analyze the forest management mechanism adopted by the community; and
d) To recommend policies on the rational exploitation of forests.

1.2 Methodologies

A. *Household survey.* Seventy-two households in eight villages of the commune were surveyed to determine the socio-economic condition in the commune, population characteristic, and income structure.

B. *Forest inventory.* This activity enabled the determination of the quantity of timber and non-timber resources so that their values can be estimated. The inventory was conducted in three mixed wood and bamboo forests, which represent varying forest conditions in Hoa Binh.

C. *Key informant interview.* Through this method, information was gathered on forest extraction, forest management mechanism, and forest land allocation.

2.0 FOREST RESOURCES IN TRUONG SON COMMUNE

2.1 Biophysical Characteristics

2.1.1 Geographic location

Truong Son commune is located in the central area of Luong Son district, Hoa Binh province, on the inter-commune road running from Bai Lang to Xom Mau, Kim Boi district. It has a total land area of 5,260 ha, averaging 3.26 ha per capita. It is bounded by Lam Son commune in the north, Kim Boi district in the south, Tan Vinh commune in the east, and Cao Ram commune in the west.

Truong Son is strategically located, being only 10 km away from the Luong Son district town and 60 km from Hanoi, Vietnam's capital. The establishment of the Xuan Mai, Hoa Lac industrial areas, Vietnam cultural village, and the National University could fuel the production and processing of forest products and handicrafts for exports in the Luong Son district. When this happens, Truong Son is in a strategic position to supply the raw materials needed for the commercial economy of the district.

2.1.2 Natural conditions

Truong Son is located in the tropical monsoon area. It has two clearly defined seasons: the hot but rainy season from April to October and the cold, relatively dry season from November to March. The annual mean air temperature is 23.6 °C (maximum of 28.1 °C and minimum of 20.4 °C). The highest air temperature was recorded in August 1990 at 39 °C and the lowest in January 1993 at 6.6 °C. The temperature is usually highest between June and September and lowest in January and February.

The area has an average of 1,667 sunny hours per year. The mean annual rainfall ranges from 1,085 mm (1991) to 1,856 mm (1990) with an average of 1,578 mm. Rains usually come in May to October with June, July, and August having the maximum rainfall (average of 300-500 mm per month). Some rains last 2-3 days reaching 150 - 200 mm, and cause high floods in Bui stream (also called the Bui river), which has its catchment area within Truong Son. The annual mean humidity is 84.5 percent, ranging from 56.7 percent to 97.7 percent.

The climatic conditions in Truong Son carry the characteristic features of the climate in low mountain areas of the northern provinces. These favor the generation and development of natural tropical woody and herbaceous forests.

2.1.3 Land use

Land in the commune has been used mainly for agricultural and forest development. Forest lands accounted for 4,840 ha or 92 percent of the total area (5,260 ha), agricultural lands, 205 ha (3.9%); and residential land, 5 ha (0.1%). According to the Vietnamese law, land is a national property. In the past, the government provided lands to cooperatives or state forest farms. Hence, most of the lands in the area were under the control of cooperatives and state forest farms. Only 5 percent of the land was privately farmed. This setup, however, does not encourage production activities. Thus, throughout Vietnam, it is common to see higher productivity in the private farms than in collective farms.

The resulting lack of food has made the people invade the forest in search of food, fuelwood, and other products. Consequently, the forest has been degraded. Since the Vietnamese government began to implement the "doi moi" policies, there has been a big change in land management. Farmers have been given long-term land use right. This policy provides a big incentive to farmers to increase farm production.

2.2 Forest Resources

The commune's forest land covers 4,840 ha and is distributed as follows:

- rehabilitated natural forest – 1,468 ha
- mixed wood and bamboo forest – 1,450 ha
- wood forest – 840 ha
- forest on limestone mountains – 360 ha
- bamboo forest – 210 ha
- planted forest – 56 ha
- unforested land – 456 ha

By the end of 1996, the People's Committee of the commune had allocated 2,074 ha of forest land to the various families for rehabilitation. The remaining unallocated areas were mostly the inaccessible parts or were on limestone mountains.

The NTFPs were mainly obtained from bamboo forest and mixed wood-bamboo forest. Both types accounted for 34 percent of Truong Son's forestland. According to Thai Van Trung (1978), these forests were classified as rehabilitated secondary forests and were very popular in Vietnam's mountain areas. They were distributed densely along Da River, which runs through Hoa Binh, Lai Chau, and Son La provinces. They were also concentrated in other provinces such as Quang Ninh, Thanh Hoa, and Binh Dinh. Gia Rai, Binh Duong, and Binh Phuoc.

The interviews and the data provided by the Agro-forestry Committee of the commune showed that:

A. There were 48 bamboo species in the provinces of North Vietnam. The natural bamboo forest in Truong Son mainly consisted of *Dendrocalamus patellaris, Gigantochloa screbuenia, Arundinaria racemosa, Neohoujeana dulloa, Arundinaria Sat and Phyllostachys pulesens* (Statistics from Forest Inventory and Planning Institute 1994). These species regenerate well and are easy to grow. They provide bountiful harvests of high economic value and have a wide market. They also provide foodstuffs (bamboo shoots), wood used for construction of houses (scaffolding in construction) and raw materials in the production of handicraft articles for export (e.g., chopsticks made of *Gigantochloa screbuenia,* fans and blinds made of *Dendrocalamus patellaris).*

B. In Luong Son market, a kg of fresh bamboo shoots was sold at 2,500 VND; 1 kg of dry bamboo shoots, 20,000-45,000 VND; one piece of *Arundinaria racemosa* 1,000-2,500 VND; and one piece of *Gigantochloa screbuenia,* 10,000-15,000 VND. Thus, with a density of 10,000-15,000 trees of *Gigantochloa screbuenia in* 1 ha of single species forest or 3,000-5,000 trees for mixed forest, the value of a bamboo forest was considerable.

C. Most of the wood forests were rehabilitated secondary forests. They had a density of 800-1,500 trees/ha (only trees aged more than 2 years were considered). These were composed of 200 species of wood trees and over 100 species of shrub trees, climbers, and herbaceous plants (many species of which have pharmaceutical value and were widely consumed in the market such as: *Fructus amoni, Amomum tsaoko, Eucomia unmoides,* and *Fibraurea tinetoria).* Some species are food sources such as: *Pillenic indica, Artocarpus tonkinensis, Canarium alebum,* and *Biophytum sensitium.*

Other species include *Phrynium parviflorum,* a kind of leaf used for wrapping square cake, a popular cake in Vietnam; *Auricularia politricha,* a high value commodity (30,000-50,000 VND/kg in dry state). Some species were used as dyes such as *Diosconae cirrhosa, Sapium sebifenum,* and especially *Bixa overllana* from which a dye called *Rocou or Arnatto* in the international market was obtained

2.3 Forest Inventory

Based on the forest resources status map and the survey results, three sites were identified for detailed investigation. Forest inventory was carried out in three plots of mixed wood-bamboo forests. The investigating team consisted of experts and local people who helped determine the local names and uses of the forest plants.

2.3.1 Inventory method

A linear survey was done to determine the composition of the plant species and the present situation of the forest (density, reserve, regeneration situation, and others). Each plot, which measured 2,000 m^2, was divided into 10 strips. Each strip was investigated by measuring the diameter of all trees and height of those with diameters of 6 cm and above. Also, the scientific and local names of all trees in the plot were determined. Both the local people and the plants' presence in the market were used as sources of information on the use value and the sale price of the products.

Bamboo was counted by determining the number of trees in a shrub and measuring the space between shrubs. The number of tree species growing in a plot was also counted.

2.3.2 Calculation of timber and bamboo resources in a plot

The timber resource was calculated as follows:

$$V_I = \frac{\pi}{4} d^2 hf$$

where d: is the diameter of the tree at a distance of 1.3 m
h: is the height of the tree
f: is the constant parameter used in the northern part of Vietnam = 0.45.
V_i: Volume of tree number i

The timber resource per hectare was determined by the formula:

$$M/ha = M_{plot} \times \frac{10{,}000}{S_{plot}}$$

where M_{plot} : is the timber reserve in the inventory plot
S_{plot} : 2,000 m^2
M_{plot} : $\sum V_I$
M : ?

In the case of bamboo, the number of trees/ha of *Neohouzeana dulloa* and *Dendrocalamus patcllaris* (bush trees) was determined as follows:

$$\text{No. of trees/ha} = \text{No. of trees/bush} \times \frac{10{,}000}{L^2}$$

where L is the distance between bushes

For *Phyllostachys pubescens* forest, the formula was:

$$\text{No. of trees/ha} = \text{No. of trees/plot} \times 5$$

2.3.3 Results of the inventory

Plot 1

Located 200 m away from the inter-communal road, this area of the forest was under the care of the Bo family. This plot had 58 trees, 50 of which belonged to the hard and middle wood species, which do not have to be tended, and 8 were soft wood species (e.g., *Bridelia tomentosa, Ficus hispida, Symblocos dung*) which reproduce by cuttings. Spacing between trees was 6.5m x 6.5m. The number of trees with economic value would ensure the maintenance of the stand (49 trees per plot, corresponding to 245 trees/ha).

Among the species with regenerative ability (e.g., *Pithecolobium clyperia, Mallotus cochinechinewsis,* and *Listsea sebifera*), *Pithecolobium clyperia* predominated the forest, hence, the maintenance of its stand in the future was relatively assured.

The plot had 27 timber species and 16 non-timber plants. The following NTFPs can be obtained: animal fodder, fire wood, construction materials, medicinal plants, resin, oil, and foodstuff.

Five species had a single use value, and 16 species with three or more uses. *Phynostachys pubescent* had a high density (1,300 trees per ha) and thus was the most exploited for NTFPs.

Plot 2

This was a state forest, located 8 km from the inter-communal road. It had 46 timber species and 11 non-timber species. This was a regenerated forest. The trees had a common height of 6-10 m; diameter at this height was usually 10-20 cm. The predominant species included *Castanopsia tonkinensis, Bridenlia tomentosa,* and *Littea sebifera.* The wood resource was estimated at 18 m^3/ha. The main NTFPs were firewood, foodstuff, and medicinal plants. There were two species with a single use value, and 16 species with more than two uses.

The fruit trees were *Flacourtia rukam, Sanarangense,* and *Sterenlia lanceoceta.* The main medicinal plants included *Amonuun echinosphaena, Antidesma buniria,* and *Mierodesmis cesaeriaefoli.* Some species such as *Ficus anriculata* and *Ficus fulva* were quite dense and needed to be trimmed to improve the habitat for the more valuable trees. The fast growing species in the plot were *Mallotus cochinensis, Pterospernum hetenophylum, Diospyros chevalier,* and *Aphanamixis grandifolia.* Most of the trees were medium-sized, usually less than 25 cm in diameter when mature.

Plot 3

The third plot was located 1 km from the inter-communal road and was under the care of the Dang family. It had 54 tree species, of which 50 were timber species and 4 were non-timber species. The main timber trees were *Pichecolobium clyperia, Marlea begoniaefolia,* and *Littea sebifera.* The total timber resource from trees with diameter over 5 cm was 12.5 m^3/ha. *Phyllostachys pubescens* had a density of 3,500 trees/ha and was the most exploited species.

Table 1. Number of plant species in the three inventory plots

Plot	Timber	Bamboo	Climbers	Inferior Growing Trees and Weeds	Total
1	58	3	3	11	75
2	46	2	3	6	57
3	50	1	0	3	54

Table 2. Number of species with local use value in the three inventory plots

Plot	Wood & Fuel Wood	Material	Fuel	Food	Animal Food	Medicine	Others
1	56	3	71	9	1	15	14
2	43	2	52	15	5	11	15
3	48	1	52	5	2	8	6

Table 3. Wood volume in the three inventory plots (Unit: m^3)

Plot	Total Volume	Diameter				
		5 - 10 (cm)	> 10 - 17 cm		> 17 cm	
		Fuel Wood	Fuel Wood	Timber for Construction	Fuel Wood	Timber for Furniture
1	2.1403366	0.5454317	0.102089	0.4040999	0	1.088716
2	3.6020540	0.5281471	0.034194	0.9066679	0.35325	1.779795
3	2.5115015	0.5700448	0	1.0730667	0	0.868390

2.4 Valuation of Timber and Non-timber Resources

2.4.1 Valuation of timber resource

Peter et al. (1989) valued trees on an individual basis, rather than on a per species level. Their method enabled a better accounting of the wide variation in production levels and harvesting cost among individual trees of the same species. In this study, the stumpage price of the market species was estimated as the difference between the market price and distribution and transportation charges plus certain amount for mark-up or profit. The stumpage price measures the value of the standing tree. The data used in the calculation of the stumpage price are given below:

Price of 1 m^3 timber for furniture at forest gate, 600.000 VND
Price of 1 m^3 timber for construction at forest gate, 400.000 VND
Price of 1 m^3 fuel wood at forest gate, 120.000 VND
Transport cost of 1 m^3 timber per 1 km, 2.500 VND
Cutting cost of 1 m^3 timber, 25.000 VND
Percentage of timber in a cut tree, 60%
Margin for profit or mark-up, 30% of the cost

The timber resource in the three plots ranged from 2.1 m^3 to 3.6 m^3 per plot and its present value from 759,860 VND to 1,210,847 VND (plot 1 and plot 3), respectively. The value of the timber trees and other plants in the area ranged from 253,286- 403,616 VND or equivalent to 1,266,430- 2,018,080 VND/ha. The value of the timber trees alone grew yearly by 1,063,956 VND to 1,828,578 VND. Based on the data from the contracts between the households and people's committee, the annual income from 1 ha of natural forest ranged from 638,397 VND to 1,097,146 VND for timber alone; the actual income depended on the location of the forest.

2.4.2 Valuation of NTFPs

2.4.2.1 Definition and characteristics of NTFPs

Non-timber forest products refer to all biological materials other than timber that are extracted from natural forests for human use. These include foods, medicine, spices, essential oils, resins, foams, latex, tannins, dyes, ornament plants, wildlife (products and live animal), fuelwood, and raw materials notably rattan, bamboo, small wood, and fibers (Debeer and Mc Dermott, 1989).

According to Lampiette and Dixon (1995), there are five characteristics that make it difficult to value NTFPs, namely:

- There is inadequate information about their price and quantity.
- They can be non-excludable.
- Their biological dimensions are poorly understood.
- They require an extended planning horizon.
- They are joint products.

NTFPs can be divided into broad categories:

(a) NTFPs with extractive value, which refers to goods such as plants and animals that can be harvested from the forest.

(b) NTFPs with non-extractive value, which refers to services provided by the forest such as sites for recreation, watersheds, and carbon sequestration.

(c) NTFPs with preservation values, including option value, which refers to the amount an individual is willing to pay to conserve a forest for the future generation.

Although NTFPs have not been investigated much in Vietnam, a report on "Non-timber Forest Plant Groups of North Vietnam" (Forest Inventory and Planning Institute, 1994), cited some groups of NTFPs with high economic value, as follows:

Fibre plants

a) Bamboo: In the northern provinces, 10 families, 48 species, 4 types, and 2 classes of bamboo have been recorded. There are not only diverse varieties but numerous stands of bamboo also. They grow in almost all districts and are mainly used as construction materials and raw materials for the paper industry, handicrafts, and art products.

b) Rattan: There are 5 families and 25 species of rattans in Vietnam. The families consist of *Korthalsia, Myrialepis, Plectocomia, Daenonorops,* and *Calamus L.* Rattans are mainly used for making art products and domestic utensils, and for binding.

Table 4. Valuation of wood in the three inventory plots

Plot	Type of Wood	Volume (m^3)	Value	Transportation Cost	Cutting Cost	Mark-up for Profit	Net Value (VND)	Net Value1 (VND)
1	Construction wood	0.2424599	96,983.96	121.20	6,061.50	1,854.81	30,901.3	90,801.26
	Furniture wood	0.6532299	391,937.94	326.60	16,330.70	4,997.19	375,280.6	375,280.64
	Fuel wood	1.2446475	149,357.70	622.30	31,116.20	9,521.55	117,619.2	117,619.20
	Total	*2.1403373*	*638,279.60*	*1,070.10*	*53,508.40*	*16,373.55*	*583,801.1*	*583,701.10*
2	Construction wood	0.5440007	217,600.28	10,880.00	13,600.00	7,344.00	193,120.3	193,120.30
	Furniture wood	1.0678771	640,726.26	21,357.50	26,696.90	14,416.32	592,671.3	592,671.35
	Fuel wood	1.9901771	238,821.25	39,803.60	49,754.50	26,867.43	149,263.3	149,263.15
	Total	*3.6020549*	*1,097,147.79*	*72,041.10*	*90,051.40*	*48,627.75*	*935,054.9*	*935,054.80*
3	Construction wood	0.6438400	257,536.00	1,609.70	16,096.50	5,311.86	239,837.8	239,829.80
	Furniture wood	0.5210340	312,620.40	1,302.60	13,025.90	4,298.55	298,291.9	298,291.90
	Fuel wood	1.3466275	161, 595.30	3,366.60	33,665.70	11,109.69	124,563.0	124,563.00
	Total	*2.5115015*	*731,751.70*	*6,278.90*	*62,788.10*	*20,720.10*	*662,692.7*	*662,684.70*

Price per m^3
Construction = 400,000 VND
Furniture = 600,000 VND
Fuel = 120,000 VND

Medicinal plants

Vietnam has diverse resources of medicinal plants. A basic survey of the pharmaceutical products resources of Vietnam from 1961 to 1985 showed that it had 1,863 plant species (263 families) used for medicine. Many precious medicinal plants such as *Morinda officinalis* Show, *Cinnamonum cassia* Blune, *Illicium verum* Hookef, and *Amomoum tsao-ko* Crevost et Lem have been domestically and partially exported.

Food plants

There are three groups of edible flora: vegetables plants, fruit trees, and starch-giving plants.

a) *Vegetable plants*: Some plants are used as vegetables such as *Ceratopteris thalictroides*, *Peperomia leptostachya*, and most bamboos for the shoots.

b) *Fruit trees*: Some edible fruit trees have edible fruits which are harvested in various seasons. Some species that are quite common are *Ficus roxburdrii*, *Canarium* spp., *Dracontumelium dupperreanum*, *Baccaurea apida*, *Garcinia* spp., and *Artocarpus* spp.

c) *Starch-giving plants*: Starch is usually present in the seeds, fruits, and tubers of plants. Plants that are abundant in starch come from the following families: *Dioscoreaceae*, *Sterculiaceae*, *Araceae*, *and Gnetum montanum*.

Oil-and-resin giving plant groups

a) *Essence-giving plants*: Nearly 500 species of essence-giving plants have been recorded, of which about 160 species have economic value. They are distributed widely in many types of forests, from low to high areas. The important plant families include: orange (36 species), castor (18 species), *Mimosa* (18 species), ginger (18 species), rose (14 species), and mango (9 species). About 40 of the essence-giving trees are of wood stem, 58 are shrub trees, and 4 are creeping plants.

b) *Oil-giving plants*: In Vietnam, about 260 species of forest plants are sources of oils, which supply the industrial requirements for producing lubricants, printing inks, paints, solvents, hair oil, cosmetics, as well as the demand for food production. A total of 265 species of forest plants have been recorded to provide oils. The species with great economic importance are: *Aleurites mamntana*, *Eberhardtia tonkinensis*, *Madhuaca pasquieri*, *Claidiocarpon cavalieri*, *Hodsonia macrocarpa*, and *Camellia sasanqua*.

c) *Resin-giving plants*:

Lac is a resin secreted by insects. Vietnam has over 20 species of host trees on which the insects deposit their resin. The best host trees are *Protium serratum*, *Casanus indicus*, *Albizzia lucida*, *Pteracarya tonkinensis*, and *Saraca dives*.

Plant resins: Vietnam has many species of forest trees giving resins, of which the most noteworthy are *Styrax tonkinensis*, *Pinus spp.*, *Canarium spp.*, *Rhus chinennsis*, and *Fagaceae*.

Tannin trees: About 600 species of trees can supply tannin, accounting for about 10 percent of the higher plant species.

2.4.2.2 Calculation of the economic value of NTFP

If economic activities are defined as those associated with the production, distribution, and consumption of goods and services, then economic value is the value of goods and services used by people either for direct consumption, for exchange by barter, for sale, or in the production of other goods and services. Therefore, the "economic value" of NTFP can be taken to mean their "use value."

The basis for assigning monetary value to any product is its price, actual or shadow. In a free market, prices reflect the true value of a good. They provide a signal to producers and consumers, which leads to the allocation of scarce resources to the uses that maximize economic welfare.

The economic value should include use and non-use value. The value at the various levels of society (e.g., rural household, and regional and national) may also considered. While non-use values could be important, studies which attempt to cover use value alone (cash and non-cash) may be sufficient.

To value meat from the wild animals in Sarawak, Caldicott (1988b) used various techniques to estimate the total quantity of game consumed, whether marketed or not, and multiplied the result by the local market price.

To calculate the value of NTFPs in the three plots inventoried for this study, it was necessary to determine the number of species as well as the quantity and quality of each species. The prices of NTFPs were determined by market observations and interviews of sellers. For example, a small tree used for fuelwood only was valued at 100 VND; if it has other uses, it was valued at 200 VND. Some decorative plants like orchid or *Lycopodium camplanatum* received a high value at 7,000 VND per tree. Grass used for roofing, medicinal plants, spice plants, fruit plants, vegetable plants, and those used as animal feeds were estimated by kg, using their market prices.

In cases where market prices were unavailable, the price of substitute products was used. For example, a bundle of leaves can make a cup of medicine to cure diarrhea or flu. If its market price was unknown, the value of the number of tablets to be taken at one time to cure the illness was used instead.

For products with available market prices, the values were calculated by multiplying the quantity of product with the price per unit, then subtracting the costs of collection, transportation, and processing, when applicable.

To get the value of a medicinal tree called *Amomum echinosphaera* which sold at 11,000 VND per kg in dry state, the study estimated the amount of time spent on collecting the materials, transporting them, then cutting and drying them. The wage rate in the area was not stable. It depended on the time of the year. During season of peak demand (e.g., planting or harvesting rice), the daily wage was 15,000 VND. But in slack periods, the average wage was only 5,000-7,000 VND per day. Since NTFPs were always collected in the slack/low season, the low season wage rate was used in calculating the collection cost. If products were taken to the market, the resource tax had to be deducted. After subtracting all the costs, the net value of NTFPs in one inventory plot was estimated. Table 5 presents the value of NTFPs in the three plots.

It must be noted that there are other NTFPs such as bees and animals that were not included in the calculation.

Table 5. Value (VND) of non-timber resources in the three plots

Plot	Total Value	Collection Cost	Net Value
1	133,050	64,520	68,530
2	123,700	87,000	36,700
3	238,000	136,250	101,750

2.4.2.3 Summary of valuation of timber and non-timber forest resources

Plot 1

The timber resource was 2.1 m^3 for this plot. After subtracting the expenses for collecting and transporting the materials, the net value of the timber resource was calculated at 456,182 VND corresponding to 2,280,910 VND/ha. The value of NTFPs was 186,149 VND, corresponding to 930,745 VND/ha. It accounted for 29 percent of the total value of the forest.

Plot 2

This plot had the largest timber resource, but the number of NTFP species was the lowest among the three plots investigated. The total forest product value was 971,755 VND, corresponding to 4,858,775 VND/ha. The NTFPs accounted for 19.1 percent of the total value of the forest and the timber resources, 80.9 percent.

Plot 3

This plot had a high ratio of NTFP value (42%) over that of timber resources. The total value of the forest botanical resource was 765,443 VND, corresponding to 3,827,215 VND/ha, of which 29.6 percent was accounted for by NTFPs and 70.4 percent by the timber resources. The tree species with high economic value were *Phyllostachys pubescens, Castanopsis tonkinensis, Sterenlia lanceoceta,* and *Garcina fusca.*

The survey showed that a household can get 60 percent of the value of timber and 100 percent of the value of non-timber products in the forest allocated to its use. The annual income potential from forestry activities to the family during the contract period ranged from 4,939,006 VND to 8,678,449 VND for both timber and non-timber products. The value of NTFPs fluctuated from 3,945,000 VND to 7,735,000 VND.

Table 6. Valuation (VND) of timber and non-timber resources in the three inventory plots

Plot	Total Value of Standing Resource	Value of Timber Resource (TR)	Value of Non-timber Resource (NTR)	Ratio of NTR & TR (%)	Ratio of NTR & Total Value (%)
1	642,331	456,182	186,149	40.8	29.0
2	87,155	785,792	185,963	23.7	19.1
3	764,443	538,130	226,313	42.1	29.6

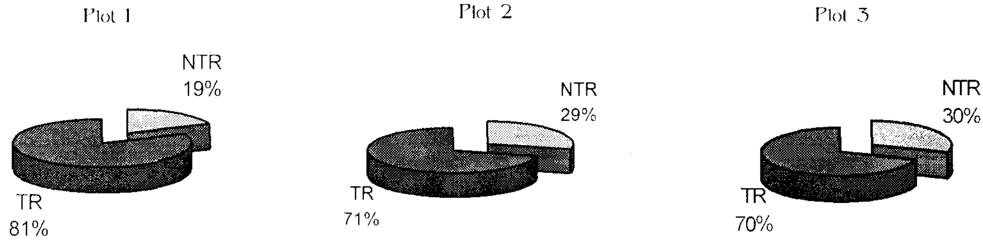

Figure 1. Comparison of timber and non-timber value

It was found that NTFPs did not compete with timber products. Collection of the former did not threaten the maintenance of forest cover in Truong Son commune. The households managing the allocated areas had been very responsible in protecting and taking care of the forest. The income potential of the households from forestry activities in the future may be equivalent to the income from other activities (including agriculture, trade and livestock). This means that the forest allocation land policy can enhance the development of the forest as well as its managers – the local households.

3.0 THE PEOPLE AND THEIR UTILIZATION OF THE FOREST

3.1 Socioeconomic Characteristics

3.1.1 Population

This commune was considered sparsely populated. It had 317 households with 1,615 inhabitants composed of Muong (92.5%), Kinh (4.2%), and Giao (3.3%). Its population grew at the rate was 3.3 percent a year. In contrast to the Muong and Giao living in high mountain areas of Hoa Binh province, the Muong and Giao families in the commune tended to conduct a sedentary life. The population was rather young, with those belonging to 15 years and below accounting for 48.3 percent; those in the working age bracket composed 45.1 percent, while the older people accounted for only 6.6 percent. The average number of family was five to six.

Most of the households settled in the commune between the 1970s and 1980s as a result of the government's migration policy. There were some though who had been in the area as early as 1938. Most of the migrants were Muong who had to move out of the Hoa Binh reservoir area when the government built a hydropower plant. The survey also showed that very few family had members coming from three generations; most families were nuclear family with three to four children.

The customs of the people were characteristically Muong. They usually organized various lavish festivities and rituals such as weddings, funerals, and the fifth birthday of children. The whole village would be invited to attend the parties, which lasted 2-3 days. Aside from new year festivals which lasted many days, five other festivals were celebrated each year. The expenses for those events were very high. Unlike the Kinh, however, the Muong and Giao considered such celebration as opportunities to "open their faces" to the community, whether or not they can afford to do so. This practice was considered one of the causes of poverty in the community.

3.1.2 Agricultural production

Only 205 ha (3.9%) of the commune's total land area of 5,260 ha were cultivated. The agricultural land averaged 1,639 m^2 per household. There were 197 ha devoted to annual crops and the remaining eight hectares grown to perennial crops. Cereals (rice, maize, and cassava) were the main annual crops. Owing to the lack of capital for intensive farming, the yield of cereal crop had been low (rice yield was only 2 t/ha). Cereal production was also often affected by natural calamities, particularly flash floods. Over-exploitation of the remaining forest was a major problem of the whole society that threatened cereal production, which depended much on nature.

As regards animal husbandry, the commune had 311 buffaloes and 23 oxen, which were reared mainly for farm work. There were 457 pigs of the mountain region breed; most roamed freely. The average weight when sold was 50 kg. Each household also had some poultry. Most of the animals were intended for the festivities and rituals. Agricultural production alone therefore cannot meet the needs of the people so that they had to get supplemental income from the forest. The utilization of forest by the different people groups were not the same; it depended on the customs and economic conditions of each community.

3.1.3 Forest utilization

The results of the survey and evaluation showed that Truong Son commune had different forest utilization patterns.

The Kinh were the least attached to the forest but all three groups were interested in large trees (wood and bamboo) from which they obtained materials for construction, fire wood and food (e.g., bamboo shoots) to meet the requirements of their families, and partially to exchange for other commodities. The Muong and Giao were interested in the forest in a more comprehensive manner since their lives had been attached to forests for a long time. For them, taking advantage of forest products was an inherited activity. They had more experience in this matter.

Primarily, the forest was their source of food supply: wild fowls and beasts (now a scarce commodity), vegetables, bamboo shoots, mushrooms, and others. The forest was also a source of medicine for curing human and animal diseases and for strengthening human health (herbs, honey, galls and horns of animals, etc.). It contained various pharmaceutical materials: leaves of trees used as antiseptic and aphrodisiac, and leaves used by mothers to recover quickly after birth and for bathing babies; and natural poisons used in hunting arrows, curing some skin diseases, and others. However, the lack of knowledge of the people on the commercial and scientific information of the various NTFPs had prevented the communities from appreciating the commercial value of the forest products, especially of forest products other than wood.

People in Truong Son exhibited their distinct ethnic culture and customs. For example, the Kinh people usually lived in plain areas and earned a living by cultivating paddy rice and raising animals and poultry. In Truong Son, the Kinh specialized in agricultural and trade activities. They were the least attached to the forest. The Muong people, which made up the majority of Truong Son's population, also depended more on agriculture and had settled down to a sedentary life. They were experienced in cultivating rice in sloping areas, in raising animals, and in collecting NTFPs.

There were some social organizations in the commune such as the farmers' association, women's association, elderly association, and youth union. These organizations cooperated to promote the community's social life. The political structure consisted of the communist party cell, the people's committee, and representatives of mass organizations. In the past, when Vietnam had not yet implemented its open and reform policy, all the goods were provided by the cooperative. With the Doi Moi policy, the farmers can buy what they needed in the market, and they can sell their products directly to traders or merchants.

However, the commune was still a very poor area. Agricultural production was insufficient for the needs of the people. Most of the houses had grass roofs and were unstable. Although it is close to Hoa Binh hydropower plant, the commune had no electricity. Only a few families had TV sets and durable goods. The people traveled mainly by foot or by bicycle. Although there was an inter-commune road where cars and vans can pass, public transport services did not go through the area. The commune had a clinic where people went for treatment of simple diseases. The clinic had only a nurse to take care of the people's health. For treatment of serious injuries or diseases, the people had to go to the district hospital which was about 10 km from the commune. All school age children went to school. There was a primary school with 12 classes from grade 1 to grade 5, two classes of grade 6, and one class of grade 7. Children who wanted to study beyond grade 7 had to go to the school in the other commune or in the town, which was quite costly. This was why very few children in the commune went to college or the university.

3.2 Forest Management

The management strategy for a forest is considered the most important factor in its maintenance or degradation. If the forest is always open to the people and there are no incentives for its protection and development, the forest would be prone to exploitation. To solve the problem of deforestation, the Vietnamese government allocated forest lands to households for their management and protection.

3.2.1 Forest land allocation policy

Allocating forest lands for the purpose of stable and long-term use depends on availability of land, local planning, household requirement, and the ability of households and individuals to provide labour, capital, management, and forest protection. Truong Son is the first commune in Luong Son district to implement the policy of land allocation and forest contract in 1994. This policy had helped prevent deforestation and encouraged forest protection.

3.2.2 Bases for land allocation

All forests and forest lands without forest cover can be allocated to the people for stable and long-term use and protection. The allocation was based on the land budget and the forestry plan of the locality as well as the demand and the capability of organizations and individuals to use forest lands. Households submitted applications for land allocation, then the commune authority and the Farmer's Association examined the applications and endorsed them for approval of the higher authority.

Since some households had reclaimed some wastelands before the implementation of the land allocation policy, the authority also granted land based on the area the household had already occupied or used before. Additional areas were given to households that occupied/managed smaller areas.

Between 1994 and 1996, 2,074 ha of forest lands had been allocated by contract to family households in Truong Son, with each household managing an average of 6.5 ha (range of 2-10 ha). There were a few families, mostly commune leaders, who managed big tracts of forest land ranging from 50 to 70 ha. There were also families (around 30 of them) who were contracted to reforest the bare areas. The trees planted included *Caracium, Dracontumelum, Acacia, Castanopsis tonkinensis,* and *Eucalyptuses.* These could be harvested after 10 years.

3.2.3 Terms of allocating forest land

The forest land allocation contract was for a term of 50 years for protective forest and special land uses, and for one economic cycle of the productive forest. When the contract expires and the family or individual still wishes to use the land, their application shall be examined for re-allocation. The lease term was 50 years because of the long business cycle for forest activities. Moreover, the state of forest before lease was bad so that several years were needed improve the forest condition.

3.2.4 Rights and obligations of the contracted households

Rights

1. To be issued the land use right certificate in order to have their legitimate rights and interests protected by the State within the forest land allocated to them.

2. To receive the fruits of their labour and of the investments on the land allocated to them. For productive forest, 60 percent of the value of the product shall belong to the contracting family and 40 percent shall be returned to the State.

3. To receive support through needed policy reform in the protection and development of the forest (e.g. exemption from or reduction in taxes in the case of reforestation of bare lands).

4. To be compensated and refunded of their expenses in the forestland (inclusive of value of labour spent and other expenditures) according to current market situations in case of revocation of contract as provided for in the law.

5. To bequeath, assign, mortgage, and transfer the right to use the forest land allocated according to the provisions of the law.

6. To collect non-timber products in the allocated forest land to exploit and develop the common forest animal sources, except the precious and rare species that the State has stipulated to be protected and for which hunting is prohibited.

7. To combine agricultural production in open forest areas or under the forest canopy and to receive all the products therefrom.

8. The contracting household may be given land for residence, usually 1000 m^2 in the mountain area or 240 m^2 in the plain. The authority also permits villagers to buy timber for use in making their houses.

Obligations

1. The contracting household shall have the obligation to implement all the commitments on management, protection, and development of the forest land allocated as stated in the allocation contract.

2. To pay the owner of the revoked land allocated to them at the current market price.

3. To pay the royalty tax according to the provisions of the law.

When transported across the boundary of the commune, non-timber products shall be subjected to a tax equal to 5-10 percent of their value.

The authorities and functional agencies in the locality have the following rules regarding forest management:

a) The commune authority, together with the Agricultural and Forestry Office of the district, must define clearly the allocated area and its present situation, and the location of the boundaries in the map and in the field of the forest land plots of the commune.

b) To certify the need, the labour force, and the capability of households for the district authorities to have the basis for issuing the decision to allocate land and forest.

c) To organise a protection team in the commune to prevent indiscriminate deforestation.

d) To disseminate information and educate the people on the protection of the forest, and to help the contracting households by providing them with loans for development of forest production.

3.2.5 Communal forestry

Aside from the forests allocated to the households, there were also 378.49 ha of communal forests in Truong Son, which was about 6.5 percent of the total forest area. These forests were located in remote areas that were difficult for individual families to protect and manage. The communal forests were under the control of the chief of the village. From 1991 to 1995, the commune collected forest fees worth 50 million VND; in 1996 it obtained 19 million VND. These fees had been spent mainly for the construction of offices and for meetings and community activities, and not for the protection and development of the forest resources.

In 1991-1995, the local authorities organized and mobilized the people to plant 42.7 ha of forest area, 20 ha of tea plants, and 20 ha of fruits orchard. The commune's people's committee directly managed the local forest resources. Any citizen who violates the forest law for the first time shall be subjected to education or warning, a second time violator shall be subjected to administrative sanction, and a third time violator shall be subjected to the revocation of the forest land use rights.

Communal forests have existed in Vietnam for long time. They are usually in the remote and off-the-road areas. They are mostly protected forests and are very difficult to access. In some areas, the people consider these forests as holy land and everyone has the responsibility to preserve them.

In Truong Son, the integrated use of educational, economic, and legal measures to protect the forest had minimized the indiscriminate exploitation of forests and the burning of forest for cultivation. In this area, the forest resources were being recovered and developed.

3.3 The Role of NTFP in the Life of the Population

3.3.1 Income structure

In the study area, the people depended mainly on agriculture for their livelihood. Agricultural production, however, was only sufficient for local use/consumption. Hence, the forest was exploited for forest products that brought in cash income.

The survey result showed that all households combined agricultural production with forest product exploitation, and that 9.7 percent of the households were engaged in trading of consumer goods. Figure 2 shows the average income of families in the commune from various sources: agriculture (70%), NTFPs (24%), salaries and pension (5%), and trade (1%).

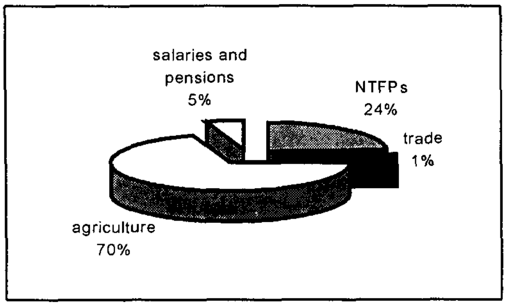

Figure 2. Income from agriculture, trade, wage, and NTFPs

The average income of each household was 7,165,590 VND/year. The village with the highest family income was Bai Yen (9,166,222 VND/year); and the one with the lowest was Suoi Bu (4,648,900 VND/year).

Cereal crops (rice, maize, cassava) were the main crops. The average yield obtained by each family was only 1,047.6 kg of paddy and 476 kg of maize and cassava equivalent to 186 kg of paddy and 84 kg of maize and cassava per year per capita. The production level was just enough for the family needs. Animal husbandry (pigs, buffaloes and chicken) was still undeveloped and limited to family scale only. Animal husbandry contributed 1,765,694 VND/household/year which was equivalent to 313,910 VND per capita per year or 35 percent of the total value of agricultural production. The income structures of the villages in the commune were not much different from each other. Income from agricultural production accounted for 59 percent in Suoi Bu to 88 percent in Bai Yen of the total income; and income from NTFPs accounted for 11 percent (Bai Yen) to 36 percent (Suoi Bu). None of the villages had income from salaries exceeding 9 percent; and there were four villages without income from trading.

3.3.2 The role of NTFPs in the household income

The income from NTFPs ranked second to agricultural production in the income structure of the households. The sale of NTFPs and a small amount of livestock enabled the families in the commune to have money to spend for everyday expenses, for production needs, and for education and health needs. The average family income from NTFPs was 1,705,073 VND/year or 303,112 VND per capita. However, this income level from NTFPs was still underestimated.

The main NTFPs collected in Truong Son were *Dendrocalannus patellaris, Neohouzea dulloa,* bamboo shoots, firewood, medicinal plants, animal fodder, roofing materials, *Phyrynium capitalum* leafs, and foodstuffs, of which only *Dendrocalamus patellaris, Neohouzeana dulloa,* bamboo shoots, and firewood were sold. The families mostly consumed the other NTFPs.

The survey results showed that all families collected firewood, foodstuff, medicinal plants, and *Phyrynium capitalum* leafs. There were 87 percent who exploited *Dendrocalamus patelaris, Neohouzeana dulloa,* bamboo shoots, and animal fodder; and 66.7 percent of the households who cut *Imperata cylindrica* for roofing.

To calculate the income from NTFPs, the number of times NTFPs were collected in one year was multiplied with the quantity collected and the unit price. Of the household income from NTFPs, *Dendrocalamus patellaris* had the highest value, followed by firewood, foodstuff, *Neohouzeana dulloa*, and bamboo shoot *(Table 7)*.

Mostly growing along rivers and streams, *Dendrocalamus patellaris* and *Neohouzeana dulloa* are easy to exploit and transport. They also have short recovery period (3-5 years). Each household collected *Dendrocalamus patellaris* 62 times per year, on the average, and *Neohouzeana dulloa*, 25 times per year. The average household income from *Dendrocalamus patellaris* was 595,200 VND per year and from Neohouzeana dulloa, 166,276 VND per year. Dendrocalamus patellaris and *Neohouzeana dulloa* were sold without processing. Private traders bought them at some central points in Cot Bai, Thay Mo, and Suoi Bu villages and along the inter-district road running through the commune.

Firewood was a cheap and easily exploited fuel in the locality. Every month, a household collected an average of 263 kg of firewood, equivalent to 21,000 VND. In Truong Son, kerosene was used only for lamps; firewood was used for cooking.

Bamboo shoots are an important food of the mountainous population. The study showed that each household collected bamboo shoots at an average of 35 times per year with a value of 210,000 VND. Some of the bamboo shoots were sold in the district market. Other foodstuffs collected from the forest consisted of vegetables, fruits, and tubers. Two-thirds of the households consumed forest vegetables all throughout the year (equivalent to two months). Vegetables were collected mainly in spring when the leaves are fresh and tender. The popular tree species for vegetables were *Cyclosorus parasiticus raubeo, mitrung, dom, maungot, Ficus glomerata*, and *Ficus variegata* for their fruits; and *Dioscorea oppositofolia* for tuber. In a year, one family could also collect about 3 kg of mushroom and 2-3 kg of *Auricularia politricha*.

About 95 percent of the households used wild vegetables as feeds for pigs such as Mon thuc, banana, *Ficus glomerata* leaves, *Ficus variegata* leaves, Rau Rang, Mung rung, and Khoai meo. Medicinal plants collected from the forest included Perilla, mugwort (*Artemissia vulgaris*), bamboo leaves and buds, *Paederia*

Table 7. Income from NTFPs of Truong Son commune

Type of NTFPs	Value VND/year	Average per HH VND/year	% to total NTFP Income
Dendrocalamus patellaris	142,852,563	450,639	26.4
Neohouzeana dulloa	54,418,439	171,667	10.1
Bamboo Shoot	45,106,564	142,292	8.3
Firewood	79,926,161	252,133	14.8
Foodstuff	79,250,000	250,000	14.7
Fodder	56,998,502	179,805	10.6
Others	81,956,229	258,537	15.1
Total income from NTFPs	540,508,141	1,705,073	100.0

tomentosa leaves were used to treat colds, colic, dysentry, cough, convulsion, headache, and others. These medicinal materials were valued at 60,000 VND per household per year.

The wildlife resources in the area were scarce. However, people still hunted for some species such as deer, civet, jungle fowl, and snake. Other animal forms that were caught for food included crabs, fish, eel, and snails from the streams.

The survey data clearly showed that the NTFPs were exploited for cash income and for household consumption.

4.0 SUMMARY, CONCLUSION, AND RECOMMENDATIONS

4.1 Summary and Conclusion

Truong Son is a mountainous commune in Hoa Binh province. It had 317 households with 1,615 inhabitants and was composed of the Muong (92.5%), Kinh (4.2%), and Giao (3.3%) ethnic groups. Agricultural production practices were still traditional; agriculture thus was not an adequate source of livelihood of the people. The vast forest resources of the commune offers a big potential to support the economic requirements of the people.

The total forestry acreage of the commune was 4,740 ha, composed of 456 ha of open land, 360 ha of forest on limestone mountains, 56 ha of planted forest, 1,468 ha of regenerated forest, 210 ha of bamboo forest, 840 ha of timber forest, and 1,450 ha of mixed timber and bamboo forest. In the past, the forest in the locality had been severely damaged. However, as a result of the implementation of the forest allocation policy in 1994, the forest resources have been gradually restored, protected, rehabilitated, and developed. To support community and household efforts to manage the forests, however, some outstanding problems have to be solved such as lack of knowledge of forestry strategies and lack of funds for forest development.

Agricultural production was the major source of income in the locality, but it was not sufficient to meet the basic needs of the households. Forest product extraction thus played an important role in the economic life of the commune, both as a source of consumption goods and also as a source of income. On the average, 70 percent of the household income came from agriculture, 24 percent from NTFP exploitation, 5 percent from salaries, and 1 percent from trade.

In Truong Son, two types of forest management were practiced: private forestry and communal forestry. Private forest management was the more common practice; communal forests accounted for only 6.5 percent of the total forestland. In areas considered by some religious groups as holy land, the communal forest management was deemed more appropriate.

The main NTFPs collected in Truong Son commune were *Dendrocalamus patellaris Neohouzeana dulloa*, bamboo shoots, firewood, medicinal plants, livestock fodder, *Imperata cylindrica*, and *Phrynium capitalum Wild.* About 87 percent of the households exploited *Dendrocalamus patellaris, Neohouzeana dulloa*, bamboo shoots, and livestock fodder. Some 66.7 percent of households cut *Imperata cylindrica* for roofing which could also be eaten as wild vegetables. Also, 95.5 percent of the households used wild plants as livestock feeds.

The following NTFPs provided income to households, in decreasing order: *Dendrocalamus patellaris,* firewood, foodstuff, *Neohouzeana dulloa,* and bamboo shoots. Of these, only *Dendrocalamus patellaris, Neohouzeana dulloa,* and part of bamboo shoots and firewood were sold. Other NTFPs were just consumed by the families.

The results of the forestry inventory conducted on three standard plots showed that the total value of the forest trees in the plots was 1,417,709 VND/ha; 1,672,670.5 VND/ha, and 1,818,434 VND/ha. The net values of the NTFPs were 406,400 VND/ha; 312,900 VND/ha, and 631,700 VND/ha, accounting for 29 percent, 19.2 percent, and 34.7 percent of the total value of the forest products in plots no.1, no.2, and no.3, respectively.

In a situation where exploitation and exportation of wood are banned by the government, NTFP collection is one of the most effective measures to improve the people's living standard in mountainous areas. It also encourages the people to have more responsibility over the forest.

The role of NTFPs in the national economy and in the daily life of rural people in Vietnam as well as in many countries has long been overlooked. Many of these products are significant trade items in the domestic or export market. They constitute an essential element of the security base of many rural people. A shift of attention toward the NTFPs would simultaneously foster both economic development and forest conservation, since, as traditional forest-dwellers have demonstrated, these products can be sustainably harvested in a way that does not degrade the forest resource.

4.2 Recommendations

Individual household and community play significant roles in forest protection and management. While household-based forest management is the main strategy for forest development, well-managed communal forests still exist in some areas. Either type of forest management approach should be continued where appropriate.

Education is necessary so that people will understand their benefits from and responsibility toward the forestland allocated to them. It is also necessary to provide funding and technical support for households contracted to manage the forest to help them carry out the forestry development plan of the local authorities.

Economic-ecological models and agro-forestry cultivation systems suitable to the natural and socio-economic conditions of the locality should be established to promote production, protection of land from erosion, rehabilitation of forest resources, maintenance of the ecological environment, and improvement of the living standard of the people. The forest fees collected by the locality must be used for the purpose of supporting forestry development.

It is likewise necessary to carry out basic investigation to collect data and information on the composition, distribution, and ecological characteristics of NTFP to guide the population in their rational exploitation, processing to increase the value of the commodity, zoning for cultivation, and trading of some NTFP species.

Finally, it is necessary to adopt suitable policies and active measures to encourage the people in the mountainous region to rehabilitate forests and develop NTFPs. The forest allocation policy of the government needs to be encouraged and supported.

LITERATURE CITED

Caldicott, J. 1988b. Hunting and Wildlife Management in Sarawak. IUCN, Gland and Cambridge.

Debeer, J. H. and M. J. Mc. Dernott. 1989. The Economic Value of Non-timber Forest Product in South Asia with Emphasis on Indonesia, Malaysia and Thailand. Netherlands Committee for IUCN.

Forest Inventory and Planning Institute. 1994. Report of Non-timber Forest Tree Groups of North Vietnam. Ministry of Forestry, Hanoi, Vietnam. (In Vietnamese)

Lampiette J. A. and Dixon, J. A. 1995. To See the Forest for the Trees: A Guide to Non-timber Forest Benefits.

Peter, et al. 1989. Valuation of an Amazonian Rain Forest. Nature 339: 655-656.

Trung, T. V. 1978. Forest Cover of Vietnam. Hanoi, Vietnam: Science and Technique Publishing House. (In Vietnamese)

ACRONYMS

NTFP	Non-Timber Forest Products

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AN ECONOMIC ANALYSIS OF AGROFORESTRY SYSTEMS IN CENTRAL VIETNAM

5

AN ECONOMIC ANALYSIS OF AGROFORESTRY SYSTEMS IN CENTRAL VIETNAM

Tran Ngoc Kham and Lai Xuan Thuy

SUMMARY

This study offers a comparative analysis of the economic returns from agroforestry systems (rubber-based) and traditional cropping systems (cassava-based) in two provinces. Thua Thien Hue and Daklak. Sixty sample households from each province were surveyed. The economic analysis showed that agroforestry systems are more profitable than the traditional cropping systems, both financially and in environmental terms for both provinces. In Thua Thien Hue, the combination of forest trees with fruit trees and annual crops was more effective than other agrosilvicultural systems. Using the discount rate of 10% for two cutting cycles of forest trees (15 years), one hectare of forest trees combined with fruit trees and annual crops can yield a net income worth 8 million dong or about 1.2 million dong annually. Meanwhile, a hectare of traditional cassava-based cropping system under the same condition could yield only 3 million dong net present value or about 450,000 dong annually.

In Daklak, benefit-cost analysis also showed a higher net present value (NPV) for the rubber-based system compared with other upland cropping systems (2,874,765.20 dong to 2,704,523.60 dong). Regression analysis showed that in both provinces, adoption was positively related to educational level and negatively related to family size. Adoption of agroforestry systems is minimal mainly because of lack of capital for investment. Hence, additional assistance from the government and other organizations in establishing a credit system or organizing the marketing system for agroforestry products are recommended.

1.0 INTRODUCTION

1.1 Problem Statement

Deforestation has become one of the most difficult problems in many developing countries. Several countries have reported shrinking hectarage on forest lands and the extent of deforestation in some countries is discouraging. The average deforestation rate was calculated to be 1.8 million ha per annum (or 5,000 ha per day) of closed forest, i.e., an annual rate of 0.06% which more or less reflects the worldwide trend of tropical deforestation (UNESCAP 1986). Despite many attempts to solve the problem, it still persists.

In Vietnam, the forest area decreased from 14.3 to 9.6 million ha from 1945 to 1993, whereas the total land area increased from 32.8 to 33.2 ha due to land reclamation. The percentage of the forest cover over the land area therefore, decreased even more from 48 percent to 29 percent. For the past half century, about one-third of

Vietnam's forest area has disappeared and has turned into barren hills, mountains, and wasteland which accounted for more than 13 million ha or 42 percent of the land area. One of the reasons for the decrease in forest area is the prevalence of shifting cultivation practices in the uplands. Shifting cultivation causes deforestation, which contributes to natural forest depletion and soil erosion in marginal land. An estimated three million people live in the uplands and practice shifting cultivation. The situation is becoming more severe because population growth makes people from the lowlands continue to encroach into forests.

Vietnam is an agricultural country where the majority of the labor force is engaged in agriculture. In 1995, the number of agricultural workers was 21.8 million or 69 percent of the labor force (Statistical Data of Agriculture, Forestry and Fishery 1985-1995). In recent years, land farming has become scarcer due to population pressure, especially in the upland. To support themselves, landless farmers appropriate land through land clearing. The over- expansion of agricultural land towards marginal and submarginal areas which should be used for forest development, is in fact doing more harm than good to farmers. This is because of high production costs, and heavy soil and nutrient loss, which make the soil infertile and lead to siltation of dams and waterways, thus, resulting to floods and reduced production.

The slash-and-burn systems of about two million shifting cultivators in upland and mountainous areas around the country further aggravate problems in deforestation and ineffective land-use systems. Deforestation has resulted in the loss of valuable plant and animal species, soil erosion, change in climatic conditions and water regime, and decreased productivity and carrying capacity of ecosystems. Shifting cultivation, therefore, worsens rural problems and leads the people to a vicious cycle of poverty because it damages the natural resource base.

How can these environmental and agricultural problems be solved? What are the relevant land-use systems for upland areas? Can people in the uplands be moved to other areas to improve the livelihood of households by helping them to adopt a land-use system that increases their income without causing significant damage to the environment? A big problem faced by upland farmers, policymakers, and government management units is how to combine these economic and environmental benefits in one feasible production unit with good economic returns and sustainable resource use.

Benefits from pure forest plantations take too long to be realized whereas the monoculture of annual crops not only puts higher pressure on forest reserves (due to lack of timber and firewood, a daily need of villagers), gradually reduces the land productivity, and results in unfavorable environmental problems. The solution to the problem for upland and hilly areas may be to develop innovative land-use systems that combine perennial tree components with annual crops so that farmers could have both food security and maintain the future productive capacity of the natural resource base. This innovative farming technology is called agroforestry (AF) which has received great attention in the last decade. The implementation of agroforestry systems (AFS) is expected to reduce deforestation; minimize environmental damage to flora, fauna, and germplasm; reduce erosion; and effect a stable and sustainable increase in productivity and farmers' income and welfare (Sugianto 1993). In many backward agricultural countries the use of agroforestry has significantly alleviated poverty.

Because of government policies, many AFS have been introduced and applied in many ecological areas of the country.

Although AFS are biologically acceptable and environmentally sound, the growth rate of these systems still falls behind the target. The implementation of agroforestry presents problems because of the ecological and economic complexity of agroforestry systems over monocropping systems. An AFS always has diversified products, which are interdependent, and at least one of which is a woody perennial so that its cycle is always more than one year. It is also locale-specific, and it has to be appropriate to the ecological and socio-economic condition in the area. For the successful development of agroforestry systems, farmers therefore, need help from specialists and researchers in technical terms, policymakers in institutional matters, and the government and other organizations in financial aspects.

To view AFS holistically so that needed measures can be launched, an economic analysis of AFS should be carried out to assess their benefits compared with the traditional cultivation practice.

This paper, therefore, concentrates on the question of what the benefits and costs of an agroforestry system are. This is one of the basic questions in which economic theory and concepts can be used to find out the best options among different land-use alternatives in the area. The study also tried to identify major factors that affected the adoption of agroforestry and the problems that farmers faced in developing their production systems to recommend appropriate policy improvements.

1.2 Objectives of the Study

General objective: To make a comparative analysis of the economic returns from agroforestry systems and traditional cropping systems in Central Vietnam.

Specific objectives:

1. To estimate and compare the benefits and costs of dominant agroforestry systems and the traditional cropping system;

2. To determine the factors affecting the adoption of an agroforestry system and constraints in its development; and

3. To recommend appropriate policies to government authorities to successfully promote agroforestry systems.

2.0 LITERATURE REVIEW

Farmers in developing countries have long practiced agroforestry (AF). A commonly agreed definition of AF is that it *"is a collective name for land use systems and technologies in which woody perennials (trees including fruit trees, shrubs, palms, bamboo, etc.) are deliberately combined on the same land management unit with herbaceous crops and/or animals either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic considerations amongst the different components"*.

AFS are very diverse production systems. AFS could be agrosilviculture (crops + trees), silvipasture (trees + pasture + animals), agrihorticulture (crops + fruit trees), agrihorti-silviculture (crops + fruit trees + MPTS), agrisilvipasture (crops + trees + pasture + animals), and homestead agroforestry (multilayer combination) (Roy, 1989). The application of an appropriate AFS is specific to an area (Sugianto 1991).

AF has many benefits through the supplementary and complementary effects of its components such as (a) biological benefits: increased space use; improvement of soil chemical, physical, and biological characteristics; potential reduction in soil erosion and reduction in microclimate extremes; and (b) economic and social benefits: increased income opportunities; variety of products and/or services; reduced establishment costs; improved labor distribution and reduced weeding requirements. AF therefore, has received considerable attention from the scientific and development communities because of its benefits to rural populations. Other advantages of AF include the fact that farmers are accustomed to practicing some forms of it, it can address a rather wide range of household needs, and it has a definite potential for smallholder farming systems from the perspective of sustainable resource management.

Although the science of AF is not yet well developed, many researchers are developing a better empirical understanding of the biophysical and socio-economic processes of AF. With this, an economic analysis will thus be a challenging research area.

Some studies on the analysis of the economics of AF system did not show the environmental effects of AFS. In India, Pathak (1991) carried out an economic analysis of a 12-year silvipasture project which applied benefit-cost analysis (BCA) and internal rate of return (IRR). The economic potential of agroforestry in hill farming, systems in India was assessed by its returns to farm income and provision of employment (Khurana and Negi 1991). The logit model was used to explore the causation of woodlot clearance of establishment in Kenya (Dewees 1993).

3.0 METHODOLOGY

3.1 Data Sources and Collection

3.1.1 Primary data

Primary data were collected through personal interviews with farmers. Household survey data and farm inventories were gathered using a questionnaire. Information on family size, age structure of the household, family work force, educational level of family members, farm size and cropping systems were also gathered. The on-site impact on soil fertility was also assessed in one of the study areas based on the results of soil sample analysis for each land-use type.

3.1.2 Secondary data

Secondary information on socio-economic aspects of households and related technical data came from local administrative authorities and scientific institutions. Specifically, some data were collected from Vietnam statistical yearbooks, and the yearbooks of the province and the chosen district. Reports of selected communes and villages were also used, plus other sources.

3.2 Sampling Procedure

3.2.1 Selection of study area

The target respondents of the study were farmers practicing AFS and the traditional farming systems. The study areas consist of Dong Hoa in Thua Thien Hue Province and two villages in Chu Sue commune, Chu M'gar district (Sut Mgru village where the AFS (rubber-based system) is predominantly practiced and M'drang village, for the traditional cultivation system). These two Ede-ethnic villages are situated in the same commune and share the same natural and socio-economic conditions.

3.2.2 Selection of sampling respondents

Sampling was implemented using both probability and nonprobability methods. First, the quota sample method was used to select a group of districts from the province, which possess natural and socio-economic characteristics of an upland area and has large potentials for agroforestry development. The quota sample was based on an initial survey and on expert comments. A district was randomly selected from the group. In this way, the commune and then the village were selected. Finally, from the village population, simple random sampling was employed to select 60 households for the survey. They consisted of adopters of both AFS and the traditional farming systems.

In Dong Hoa village, Thua Thien Hue province, 60 households were selected from 87 households (70% of the population). This figure is large enough for reliable information.

In Daklak province, 60 sample households were randomly selected: 30 for the traditional cultivation system (M'drang) and 30 for the rubber-based system (Sut Mgru).

3.3 Analytical Framework

Agroforestry is considered a solution to the problem of environmental degradation and a means of raising the living standard of rural dwellers. Because the production cycle of an AFS is always more than a year, resources are tied up which could otherwise be used differently. For smallholders to accept AF techniques, they must be convinced that expected benefits and risks associated with such techniques exceed costs. To assess the profitability of the AFS versus other cropping systems, the study applied the following analytical tools.

3.3.1 Economic analysis

Evaluation of the expected costs and returns to a project is essential in determining the allocation of limited funds and in demonstrating the viability of the project to potential investors. Benefit-cost analysis represents an appropriate analytical tool to measure the profitability of an AF to both the individual farmer and society as a whole. An attempt was made to provide a broader framework, which recognized the nature of some AF benefits and costs, which may not always be quantifiable in monetary terms. From an individual farmer's perspective, the potential benefits of an AF practice can be examined through a financial analysis of the system. If the practice's effect on society as a whole is being considered, an economic analysis is required.

In economic analysis, efficiency prices, which reflect the true value of resources to society, are used. Taxes and interest payments are not included in the analysis because they represent transfer payments between members of society rather than real resource use. Similarly, the discount rate used is inflation-free and reflects real returns. Furthermore, economic analysis considers off-site environmental effects, which do not directly affect the individual farmer but may have a social impact.

Economic analysis provides a means of evaluating the viability of AF practices. Economic evaluation can be used to answer three basic questions about the AF system: (I) What inputs should be used and in what combination to produce AF products? (2) What is the optimal or best production mix for a given AF management option?, and (3) What are the benefits and costs of an AF system?

A comparative analysis between AFS and traditional cassava-based cropping systems as well as between different models of agroforestry systems was made to define the profitability of different land-use alternatives. In this study, economic evaluation concentrates on the overall profitability of the AFS. The following steps were undertaken:

Listing of physical inputs and outputs

The first step in an economic appraisal is to list all of the expected inputs and outputs of the project on an annual basis. Table 1 shows the list and distribution of inputs and outputs over the project life.

Valuation of inputs and outputs

For the marketed inputs and outputs, we used market prices and adjusted prices or shadow prices. If the project used inputs that were imported or produced goods, which would have been imported in the absence of the project, border equivalent prices were used. The appropriate border equivalent price was the cost-insurance-freight (c.i.f.) price adjusted for domestic transportation costs.

Conversely, if the project used inputs, which would have been exported in the absence of the project or produced goods, destined for export, the appropriate price to use was the free-on-board (f.o.b.) price

Table 1. Physical inputs/outputs by year for a smallholder agroforestry system

Input Investment						
Land	Ha	+	+	+	+	+
Equipment	No.	+				
Seedlings	No.	+	+			
Tools	No.	+				+
Annual						
Seeds	Kg	+	+	+	+	+
Fertilizers	Kg	+	+	+	+	+
Labor	Workday	+	+	+	+	+
Field preparation	Workday	+	+	+	+	+
Planting	Workday	+	+	+	+	+
Fertilizer application	Workday	+	+	+	+	+
Weeding	Workday	+	+	+	+	+
Harvesting	Workday	+	+	+	+	+
Others	No.	+	+	+	+	+
Direct Output						
Crops	Kg	+	+	+	+	+
Firewood	Kg					+
Commercial wood	Stere					
Fodder	Kg	+	+	+	+	+
Fruits	No.				+	+
Animals	No.	+	+	+	+	+
Others	No.					
Indirect						
Improved vegetative cover				+	+	+
Reduced erosion				+	+	+
Reduced deforestation						+

+ Sign indicates year when input was used or an output was produced adjusted for domestic transportation costs. Non-marketed inputs such as land and family labor were valued at opportunity costs.

In addition, external costs and benefits measured by indirect valuation methods were considered in the economic analysis.

AF practices usually produce both direct and indirect outputs. Direct outputs such as firewood may not be exchanged commercially because there is no market or the farmer does not have money to purchase it. In such a situation wherein the firewood is produced by a smallholder, AF practice is valued indirectly according to labor time saved in wood collection if the wood is previously collected from the forest. The time saved is then converted into monetary terms using the same valuation as for labor inputs in the AF practice.

The AFS also provides indirect outputs. By planting trees on a portion of his land, a farmer directly benefits from reduced erosion and/or maintained soil nutrients. Much research remains to be done in quantifying the extent of soil erosion or degradation. However, together with such a research effort, there was a need to consider the economic aspects of the on-site productivity related to soil fertility. The on-site productivity effects of soil degradation arise from the loss of topsoil fertility leading to (a) loss of organic matter and nutrients and (b) reduction in water-holding capacity and degradation of soil for plant roots. Because of data limitations, only the effect of topsoil fertility loss was considered and the analysis was carried out only in the Daklak Province.

The monetary benefits of such an indirect output (on-site productivity) could be measured in increased crop yields or by the difference in value between degraded and undegraded parts of the farmer's field. The second methodology, referred to as the "replacement cost method," was used in this study. This approach estimates the value of the difference of decreased nutrients under different cropping systems in terms of how much it would cost to replace the natural soil nutrients caused by degradation using inorganic fertilizers.

The estimate of on-site cost must be interpreted cautiously. From a technical aspect, there was an underestimation as in the simplifying assumption adopted, which links the on-site impact of degradation only to loss of nutrients and which does not include effects of deterioration of soil structure and water-holding capacity linked to soil degradation. However, from an economic viewpoint, the bias was towards over-estimation. The reason was that in their current use, degraded areas were not intensively planted to agricultural crops. Thus, nutrient losses from such lands would not have the same opportunity cost as losses from lands which were continuously cultivated. The valuation technique was applied with the assumption that degraded lands are potential areas for agricultural production; thus, estimates may be regarded on the high side.

Measures of Economic Performance

Three measures of economic worthiness normally used to compare different systems are net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR).

Net present value (NPV)

Net present value gives the present worth of the net benefit (i.e., total revenue minus total cost) stream. The following formula can be used for computing NPV:

$$NPV = \sum_{t=0}^{n} \frac{(Bt - Ct)}{(1 + r)^t}$$

where: NPV = net present value
n = project cycle
t = year
Bt = benefits from the project for the t year
Ct = costs in the t year
r = discount rate

When the profitability of each land-use option was considered, the relevant NPV was annualized so that comparisons can be made and the following formula can be adopted:

$$A = \frac{NPV\ (1+r)^t}{(1 + r)^t - 1} * r$$

Benefit–cost ratio

Benefit–cost ratio (BCR) is simply the ratio of discounted benefits to discounted costs. If the ratio is greater than one, the project is yielding more benefit than costs. The ratio is computed as follows:

$$B/C = \frac{\sum_{t=0}^{n} \frac{Bt}{(1+r)^t}}{\sum_{t=0}^{n} \frac{Ct}{(1+r)^t}}$$

Internal rate of return

The internal rate of return (IRR) is the discount rate that makes the net present value equal to zero. IRR can be obtained by the solution of the equation:

$$\sum_{t=0}^{n} \frac{(Bt - Ct)}{(1 + r)^t} = 0$$

Sensitivity analysis

Farmers in upland areas pursue their livelihoods under highly variable environmental conditions. Farm risks associated with weather and price uncertainties pose a serious threat because of their impacts on outputs and household income. Sensitivity analysis is used to determine how the economic performance changes under a changing natural and economic environment. The sensitivity analysis to price, productivity, and discount rate variation is also employed to evaluate the sustainability of production systems under unstable conditions. In the study, sensitivity analysis was conducted using different discount rates, prices, and yields. This was specifically done for Thua Thien Hue Province.

To compute all these measures, a discount rate was needed. The discount rate used was inflation-free and reflected real returns, i.e., the opportunity cost of capital. The real discount rate r was calculated as:

$$r = \frac{1 + \text{nominal interest rate}}{1 + \text{inflation rate}} - 1$$

3.3.2 Determinants of adoption

The probability of a farmer adopting an agroforestry system is a function of many variables, which relate to the production decision of a farmer. The relationship was expressed in the following equation:

$$Pi = f(Xi) + e_i$$

where:
Pi = the probability of the *ith* farmer to adopt an agroforestry system
Xi = a set of variables that affect the adoption decision of the ith farmer
e_i = the discrepancy or error term

The set of variables was divided into four main groups. The first group were factors relating to the decision-maker, the head of the family who often decides what and how to produce. Such factors included age, gender, educational level, and farming experience. The more experienced and educated people may be better in planning their future. They can see the long-term profit of their projects and so they are willing to invest in them. The second group were factors relating to household economic conditions, such as labor force, land size, household size, and household income. These factors are important for the farmer to decide where to allocate limited economic resources. Farmers who have more land can devote part of it to forest development without worrying about the food security, whereas the landless must devote all of his resources to food crops. Income level was another important factor. Richer farmers can sustain the daily family needs and allocate some resources for longer production projects like agroforestry. Poorer farmers could not afford any investment.

The third group were factors relating to the out-site incentives including various kinds of assistance provided by the government and other organizations to aid the farmer in his production. These factors are important, especially in remote rural areas, where the educational and income levels of villagers were very low. The last group were factors relating to environmental characteristics, such as soil parameters, climate, and hydraulic regimes. These factors allow farmers to choose the appropriate production systems. However, they are uncontrollable variables and in this study we assumed that environmental factors equally affected the adoption decision of villagers.

Going by these characteristics we can specify the model using the logit function as follows:

$$\ln \frac{Pi}{1 - Pi} = b0 + b1\,AGE + b2\,EDU + b3\,FSIZE + b4\,LAND + b5\,INC + b6\,EXP + b7\,TECH + b8\,SEED + b9\,CRED + ei$$

or $$Pi = 1/(1+e^{-(b0 + b1\,AGE + b2\,EDU + b3\,FSIZE + b4\,LAND + b5\,INC + b6\,EXP + b7\,TECH + b8\,SEED + b9\,CRED + ei)})$$

where:

- Pi = 1 if the farmer is practicing an agroforestry system, and 0 if not
- AGE = age in years
- EDU = years of schooling
- FSIZE = number of household members
- LAND = arable land area, in hectares
- INC = income per year, in thousand dong
- EXP = farming experience, in years
- TECH (dummy) = 1 if the farmer received technical assistance, and 0 if not
- SEED (dummy) = 1 if the farmer received seedlings assistance, and 0 if not
- CRED (dummy) = 1 if the farmer received credit assistance, and 0 if not

The logit program used Statistix (Version 1.5) software package and its logistic regression routine.

4.0 SITE DESCRIPTION

4.1 Bio-physical Characterization

4.1.1 Thua Thien-Hue Province

Location and Topography

Thua Thien-Hue province is located in the central part of Vietnam, bordered by Quang Tri in the north, Da Nang in the south, Laos in the west, and the Indo-Chinese Sea in the east. It has a total land area of 500,920 ha, including 49,107 ha of agricultural land, of which 45,888 ha are planted with annual crops; perennials, 927 ha; prairies, 857 ha; water surface, 796 ha; and rehabilitated areas, 545 ha. Forested lands total 180,232 ha, of which 171,099 ha are natural forests 9,133 ha are planted forests. The total forest volume is equivalent to 18-20 million m^3 timber. Also, 23,579 ha of land and for special uses; 247,000 ha are barren land and open hills, of which 4,516 ha are wild fallow land and 191,258 ha are hilly land.

Dong Hoa village, the study area, is one of nine villages of the Binh Dien Commune and is situated near the center, 30 km southeast from the city of Hue. The Perfume River separates Binh Dien from the city. This creates many communication problems between the area and other places in the province. The soil in the village is poor in N, P, and K and has low absorbing ability *(Table 2)*. The altitude is about 30-50 m above sea level. The area is dominated by steep hills with an average steepness of about 15-30°. In the past this area was characterized by rich natural forests and valuable kinds of wood. But since the coming of the first settlers in the 18^{th} century, its resource base has been depleted.

As a result of the alarming deforestation rate and poor farming technologies, coupled with 8-10 typhoons a year, the area is suffering from soil erosion and desertification. Geographical characteristics of the region in general are not favorable to agricultural activities. However, this site can be used for developing agroforestry systems that combine forest trees with cattle and annual crops for higher productivity.

Climate

Dong Hoa village has two seasons, wet and dry, with a mean annual rainfall of about 3,000 mm. The heaviest rainfall occurs between September and November (430–740 mm/month). The dry season lasts from March to the first half of August. The rigorous weather creates many problems in agriculture, especially drought in the dry season and erosion in the rainy season.

High air humidity is also a typical climatic factor that affects agricultural activities in the area. Table 3 shows the climatic characteristics and the farming calendar of the area.

4.1.2 Daklak

Location and topography

Daklak is a province in the Central Highlands of Vietnam. Its total natural area is 19,800 km^2. The area is hilly and slightly undulated, with an altitude ranging from 500 to 800 m asl. The potential land area for AFS is 340,354 ha and the area that needs to be reforested is 619,342 ha.

Climate

The average temperature in Daklak is 24°C with the variability in temperature being about 10°C /day. There are two seasons; the rainy season from May to

Table 2. Chemico-physical characteristics of the soil, Dong Hoa village

Soil Layer (cm)	Humus (%)	Total Materials			PH (KCL)	Mechanical Composition		
		N	P_2O_5	K_2O		<0.002	0.002-0.05 mm	0.05-2 mm
0-18 (A)	1.42	0.10	0.06	0.45	4.6	12.8	12.0	75.2
18-38 (B)	0.70	0.10	0.06	0.48	4.6	20.6	8.0	71.4

Source: Survey data

Table 3. Climatic characteristics and farming calendar of Dong Hoa village

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	1	2	3	4	5	6	7	8	9	10	11	12	
Mean temperature (°C)	19.9	20.5	23.0	26.0	28.3	29.5	29.6	29.0	27.2	25.0	23.0	21.0	25.2
Max. temperature				40.0	40.0	39.9	39.8	39.2	33.2	36.1			40.0
Min. temperature	8.8	11.0	12.5	14.3							13.5	11.1	8.8
Mean rainfall (mm)	150.0	76.0	50.0	50.0	83.0	126.0	108.0	101.0	430.0	740.0	559.0	271.0	2,744
Mean humidity (%)	90.0	90.0	88.0	84.0	79.0	75.0	72.0	76.0	84.0	88.0	89.0	90.0	84.0
Mean sunny time (h)	112.0	108.0	140.0	176.0	229.0	238.0	225.0	205.0	162.0	139.0	101.0	98.0	1933.0
Cassava													
Spring rice													
Autumn rice													
Beans													
Peanuts													
Sugarcane													
Sweet potato													
Banana													
Tree crops													
Jack-fruit													
Cinnamon													
Grapefruit													
Lemon													
Sapodilla													
Pineapple													
Forest trees													
Mature trees													
Other activities													
Rattan harvesting		x	x	x	x	x	x	x					
Metal collecting		x	x	x	x	x	x	x					
Export labor									x	x	x	x	
LEGEND													
Land preparation													
Planting													
Harvesting													

Source: Yearbook of Thua Thien Hue, 1995

October, and the dry season which lasts for 5-6 months. The annual rainfall is rather high (2,000 mm) but unevenly distributed, with 70% in the rainy season. The highest rainfall (329 mm) is in August, and the lowest (2 mm) is in February. The dry season is aggravated by the fast deforestation rate and causes high evaporation rate, decreased surface flow, and reduced groundwater reserve.

4.2 Socio-economic Environment

4.2.1 Thua Thien-Hue

Thua Thien-Hue has 998,000 inhabitants, with 30 percent in the city of Hue. Its rural population of 718,365 persons has an average household size of 5.2 persons. It has a city, 8 districts, 124 communes, and 935 villages.

There is electricity in 54 of 124 communes. There is clean running water for 2.5 percent of the households, and well water for 72.2 percent. About 95 percent of the communes have access to roads. The population in all communes finished primary school, 69 percent reached middle school, whereas only 8 percent were able to continue up to secondary school. Majority (93.7%) of the communes have clinics, with four doctors per 10,000 persons (Yearbook of Vietnam 1995 and Statistical data for Agriculture, Forestry, and Fishery 1995).

Dong Hoa village is home to 87 families or 485 persons. The average family consisted of 5.5 persons and 2.3 active workers. The total area of the village is about 96.1 ha which includes 28.3 ha of agricultural lands, 10.5 ha garden, 2.2 ha homestead, and more than 50 ha of forest land. The average land size for a household was 1.1 ha, but the distribution of agricultural land among holders varied. Most of the villagers kept animals, particularly working buffaloes, oxen, and pigs.

The annual income of Binh Dien for 1996 was US$80-100 per person. About 50% of the household income was from agriculture and forestry, and 50% from carpentry, logging, and offsite activities (Village report). There was not much opportunity for export labor. Many villagers used their time mainly to harvest rattan or search for gold in the forests. Others worked in waste metal collection during the dry season from March to August.

Logging, even if illegal, is also a common activity of the villagers. A workday of logging can bring $1-1.5 to the farmer, which is just enough for the upkeep of a family for one day.

The total length of rural roads within the village is about 2.5 km, including mainly foot trails and gravel roads. There is a market in Binh Dien Center, where locals can purchase farm produce, processed food, foodstuff, and other goods, as well as inputs for agriculture and forestry like fertilizers, chemicals, and seeds. Firewood and fruits are often transported and sold in the city of Hue.

4.2.2 Daklak

Daklak increased its population about four times (363,000 to 1.3 million) from 1976 to 1995, mostly because of the resettlement and migration from other provinces in the country. The demand for agricultural land for these new settlers is quite big.

The two villages of Chu Sue commune, Chu M'gar district, Daklak are reasonably close to local markets. There is an asphalt road from Buon Ma Thuot City to Chu M'gar district town going through the commune. Within the villages earthen roads connect residential areas and farmers' fields. The road conditions are not so good especially in the rainy season.

The main income source of villagers is agricultural production. Animal raising is limited and contributes a small part to household budget. Not many fruit trees are planted because of lack of suitable markets. Cultivated area varies, but the main types of agricultural crops in the two villages change according to the topography. Table 4 shows the main characteristics of the two villages.

Upland crops such as rice, local maize, soybean, and groundnut were planted only in the rainy season. Farmers usually followed this rotation system: local maize and soybean for the first crop, and groundnut for the second crop. Two crops that need to be irrigated in the dry season are coffee and paddy rice. Because of small-scale irrigation systems, paddy fields can produce only two crops per year. Coffee consumes a lot of water in the dry season and competes with other water uses.

In the past when practicing shifting cultivation, farmers allow a 15-year fallow period before cultivating the same parcel so that soil fertility can be restored naturally. But now with population growth pressure and decrease in forested area, this practice is no longer observed by villagers. The parcel for the traditional system (TS) was cultivated continuously from year to year without any inputs. People did not use inputs for TS parcels because of lack of resources and minimal cost-effectiveness when not using inputs.

Agricultural land uses in Daklak include: paddy (37,890 ha), upland annuals (79,990 ha), rubber (26,000 ha), and coffee (130,000 ha) (Nguyen Phap, 1995).

The cultivated area for coffee has increased over time from 4,500 ha in 1976 to 130,000 ha in 1996. Coffee is a major agricultural produce for export and plays an important role in the provincial economy. However, the high price of coffee beans in the international market has pushed farmers to encroach on forests and forest land to increase coffee land. Farmers have also discarded the shelter belt of *Cassia siamea* and shade trees of *Leuceana leucocephala* to get higher yields. Thus, input investment and water consumption rates are higher. These production patterns have destroyed the environment and water resources of the province and would need to be complemented by other measures to improve the current situation.

The deforestation rate in Daklak is 8,000-10,000 ha annually. The volume of timber has decreased from 104 m^3/ha to 95 m^3/ha. The remaining forest cover is 35-40 percent whereas the safety level for the environment is 50-65 percent, which is necessary to restrict run-off and erosion on sloping land (Le duy Thuoc 1996). Daklak forests will continue to be degraded if no viable options are adopted to stop the forest destruction.

Table 4. Characteristics of the two villages [a] at Daklak

Cropping System Village	Total Pop.	No. of Households	Percentage of Area Cultivated				
			Rubber	Coffee	Paddy	Upland annuals	Total
AFS	1,010	126	28.9	47.6	6.9	5.0	100
TS	617	100	0.0	49.4	8.2	42.4	100

[a] At Sut M'gru: paddy, coffee, upland annuals, and rubber; at M'drang: paddy, coffee, and upland rice and annuals

At present, the government has launched a program to close forests and increase the forest cover to 60 percent by 2010. This is an ambitious program, because people are not acquainted with cultivating forest trees, which take a long time to give returns, and appropriate policies and measures to support villagers engaged in the program are lacking. Coffee occupies a bigger part of the perennial crop area, but is an intensive crop which needs many inputs. Moreover, the price of coffee beans fluctuates strongly and is affected by international markets. The increase in root rot disease affects coffee bushes and provides smallholders with a major challenge. When assessing the feasibility of AFS, rubber farms are considered a good alternative to degraded upland areas. This study could not only help in the planning of regreening programs in Daklak but in other provinces in the Central Highlands such as Gia lai and Kontum as well.

5.0 AGROFORESTRY SYSTEMS, PRODUCTS, AND MARKETS

5.1 Thua Thien-Hue

The agroforestry system

The climatic characteristics of Binh Dien allows many different plant species to grow (Nguyen Sinh Cuc 1995). The most common fruit trees in the area are *Artocarpus heterophyllus* (jackfruit or mit), *Citrullus lanatus* (dua hau), *Carica papaya* (papaya or du du), *Cucurbita* spp. (cucurbits or bau bi), *Musa paradisiaca* (banana or chuoi), and *Psidium gujava* (guava or oi). Root and tuber plants such as *Manihot esculenta* (cassava or san), *Ipomea batatas* (sweet potato or khoai lang), *Dioscorea alata* (yam or khoai tia), *Maranta arudinacea* (hoang tinh), and *Colocasia esculenta* (taro or khoai so) are important sources of food for humans and animals. *C. esculenta* and *M. arudinacea* are also used as medicinal plants. *Saccharum officinarum* (sugarcane or mia) is a potentially important plant that can replace part of the cassava area in the future. Other species like *Ipomea aquatica* (water convolvulos / kangkong or rau muong) and *Oryza sativa* (rice or lua nuoc) are also seen in small areas in the village.

Cassava is the most important crop for the villagers, followed by potato, green and black beans, and taro. It is grown mainly for animal food and cash, but part of it can be used for human food. Pepper used to be grown in a large area. But because of the decline in pepper price in the early 1990s, many of the pepper gardens were cut down, and new crops are being replanted in a limited area. Pepper starts fruiting at 3-4 years and continues to produce fruits until 10 years or older. However, its productivity begins to decline when the tree gets to the age of 7 or 8 years depending on the soil and tending methods. Banana is also an important fruit crop, which is seen in many household gardens. Banana fruits all year-round and is often replanted every 3 years.

The most popular fruit tree in the area is jackfruit. Jackfruit often begins fruiting when the tree is 5 years old. An average mature jackfruit tree can give 10-20 fruits, which bring to the farmer 1,500-3,000 dong per fruit. A normal tree continues to fruit until the age of 15-20 years. At this age a jackfruit tree can be sold for firewood or timber for 50,000-100,000 dong. Jackfruits not only benefit farmers economically, they also serve as an important component of the ecosystem and improve the quality of the microclimatic condition. Longan, mango, and other fruit trees have also already been introduced in the area, but none of them are in the fruit-bearing stage yet.

The most popular forest trees in the area are eucalyptus and acacia. These fast-growing trees can be harvested at 8 or 10 years and are renewable. They are an important source of firewood and building poles for villagers, and commercial wood. Eucalyptus, if grown in combination with acacia, helps maintain the soil and makes it more productive.

The cultivation systems in the village can be divided into four major systems *(Table 5)*. In AFS1, farmers combine forest trees (mainly acacia and eucalyptus) with fruit trees (pepper and jackfruit), and annual crops (cassava, beans, and banana). The system is suited for farmers who have more land and usually tend cattle and other kinds of animals. The AFS2 consist of forest trees grown in combination with annual crops using a special arrangement: the upper part of the hill is devoted to growing trees and the lower part to growing annual crops. The AFS3 has fruit trees planted in combination with annual crops. Farmers with little land use this model, with members of the households often having work other than farming, such as a small trade or handicraft making. Farmers in this group are mainly old or retired persons who want the pleasure of planting fruit trees in their gardens. The fourth system is the traditional system (TS) which often involves small land area devoted largely to the growing of food crops. Farmers in the TS category comprise 23 percent of the households in the village

Products and markets

The main AF products are firewood, jackfruits, pepper, cassava, sweet potato, and beans. Other subordinate products like tea, *M. arudinacea* roots, and forages are also normally sold in the local market.

Firewood collected by farmers from wood lots or tree gardens in excess of home consumption needs is split and bundled into 10-15 kg bundles. These are sold by the roadside to traders who collect and transport them to Hue for selling.

Wood from eucalyptus and acacia can be used as raw materials for paper and wood processing industries as well as building materials for villagers. It is usually measured by stere (1 stere is equivalent to 0.6-0.7 m^3) and sold in the market (140,000 dong/stere). Farmers also sell the wood as a stand in the garden which buyers collect themselves.

Jackfruits are often sold for 1,500-2,000 dong/ fruit at the local market, but part of them are collected by traders and

Table 5. Various farming systems used, Thua Thien-Hue

Type of Production Systems	Number of Respondents		Area		
	Frequency (n)	Percentage (%)	Amount (ha)	Percentage (%)	Average (ha)
Forest trees + Fruit trees + Annual crops	22	36.6	38.8	57.3	1.8
Forest trees + Annual crops	12	20.0	19.6	28.9	1.6
Fruit trees + Annual crops	12	20.0	4.7	6.9	0.4
Traditional cassava-based cropping systems	14	23.3	4.6	6.8	0.3
Total	60	100.0	67.7	100.0	1.1

Source: Survey data

sold in other places. An old jackfruit tree can be sold for firewood or timber for 50,000-100,000 dong, which can considerably improve the profitability of the agroforestry systems.

Pepper is an important cash crop. Its retail price is 25,000-30,000 dong/kg. However, its price closely depends on the international market.

Banana and other annual crops are also usually sold in local markets to consumers and traders who transport them to the city. A hand of banana is often sold for 2,000-5,000 dong and it may double during times of worship. An experienced farmer can control the harvest cycle of the tree and reap benefits of periodic harvests.

Harvested cassava, after cleaning, is collected by traders and sold to animal food processing mills in other locations. The prevailing price of cassava is 150-250 dong/kg but this price is unstable. The village cooperative has a price ceiling for cassava. For now it buys cassava from farmers at a cost of 200 dong/kg, which is 30-40 dong higher than in the local market. Green and black beans, on the other hand, are normally sold for 5,000 dong/kg.

The input market includes mainly fertilizers and seeds. NPK is sold at the local market for 2,200 dong/kg, whereas animal manure is sold for 90,000 dong / ton.

Production and marketing problems

As in any rural area in Central Vietnam, farmers in Thua Thien Hue face many difficulties. Although the government and other organizations have aided farmers in agricultural production, constraints remain, especially in the development of agroforestry.

The major difficulty of villagers is related to capital investment *(Table 6)*. More than 50 percent of villagers need credit for production, including buying cattle, seedlings, and food for short-term consumption. The unstable market is also a big problem to farmers. Due to price changes, farmers are not encouraged to grow long-term crops. Market limitations for agroforestry products result in losses for villagers who sometimes have to change the production system.

Traditional cultivators did not adopt agroforestry simply because of lack of capital investment and unstable market prices *(Table 7)*. Some said that they planted many fruit trees, but had to cut them down because they could not sell the fruits.

Table 6. Constraints in developing production systems

Type of Difficulties	Frequency	Percentage
Lack of capital investment and difficult access to credit	25	54.3
Lack of technical know-how	5	10.9
Lack of seedlings	5	10.9
Limited demand for current products	9	20.0
Unstable market prices	16	34.8
Other difficulties	12	26.1

Source: Survey data

Table 7. Reasons why villagers did not adopt agroforestry

Reasons	Frequency	Percentage
Lack of capital investment and difficult access to credit	9	64.3
Lack of technical know-how	3	21.4
Lack of seedlings	2	14.3
Unstable market price	5	35.7
Other reasons	5	35.7

Source: Survey data

5.2 Daklak

Agroforestry system

The agroforestry system is mostly rubber-based. Rubber *(Hevea brasiliensis)* is widespread in Southeast Asia and tropical Africa. Its main product is latex but it can provide seeds at the mature stage (250-500 kg seed/ha or 500-1,000 g/tree) and wood at the end of the production cycle. Seeds fall down in July to September. The seed weighs 3-6 g with 40 percent of the kernel and contains 30-40 percent oil. Six tons of fresh seeds usually give one ton of oil. Rubber oil is used to manufacture soap, paint, or glue. Rubber wood, with the appropriate processing methods, can be used to make furniture, crates, plywood, or paper powder. During the immature stage of rubber trees, farmers can intercrop inter-row bands with short-term staples or cash crops such as upland rice, maize, beans, etc. At the mature stage of rubber, farmers can raise bees during the flowering period.

Rubber was first planted in Daklak in 1938 during the French colonial time. The Daklak Rubber Company has planted some 13,000 ha to rubber. Since 1985-1986, the company has begun a program promoting rubber growing among farmers in fields formerly devoted to shifting cultivation so that the twin aims of generating income and regreening denuded and degraded land can be met. Rubber is favored in areas where water harvesting is difficult because it can act both as an agricultural crop and a tree crop.

In 1992, farmers in Sut Mgru, a village in Chu Sue commune in Chu M'gar district, planted rubber trees on upland fields with capital, technical assistance, and input support from Daklak Rubber Company. Farmers will repay the investment loan by selling the latex when trees yield during 10-15 years. Eighty-one farming households planted 77.4 ha of rubber trees, which represents 29 percent of the total area of the village. Other crops planted besides rubber were coffee (48% total land) and two-crop paddy rice (7% total land).

Farmers planted rubber trees because of decreased soil fertility after long periods under traditional farming systems and the high cost of watering in the dry season. This area is far from the surface water source (300-1,750 m away) and groundwater reservoir (37 m deep).

Rubber is considered a tree crop, and can protect the soil from erosion and degradation in programs of regreening bare land and denuded hills. Breeding for rubber clones has changed for two reasons: (1) rubber provides latex, and (2) it yields timber in 25-30 years. Latex is a major raw material for many industries, which produce capital equipment and commodities. Latex yield ranges from 1 t/ha to 2 t/ha in 20-30 years. It is estimated that 1 ha of old rubber trees can provide 150 m^3 of timber and 40-50 m^3 of firewood. With the shortage in hardwood from natural forests, rubber wood can help provide additional raw material for the wood industry.

Rubber trees were planted at a density of 6 x 3 m. Wider bands between rows enabled farmers to intercrop other short-term crops in the first 3 years until the canopy closed. The width of the band decreased from 4 m in the first year to 3 m in the second year, and to 2 m in the third year. Coffee trees were planted at 3 x 3 m on areas close to water resources such as water bodies or shallow wells.

There are large rubber plantations or about 10,000 ha all over the world but there are also smallholdings under 1 ha *(Table 8)*. In general smallholdings represent 80-90 percent of all rubber areas, with an average hectarage of 2 ha.

Table 8. Percentage of rubber smallholdings in some countries

Country	1985	1993
Thailand	95	96
Indonesia	81	83
Malaysia	74	80
Sri Lanka	46	56
Brazil	51	65
Cote d'Ivoire	-	31

Source: International Rubber Statistical Bulletin cited by Nguyen Khoa Chi, 1996

One advantage of smallholdings is that they need inexpensive infrastructure facilities and provide livelihood to farming families. According to their size, smallholdings are divided into three groups: Group A: <2 ha; Group B: 2-4 ha; Group C: 4-100 ha.

On sloping land steeper than 8°, rubber trees are planted along the contour lines or on terraces. The soil must be deep enough for root penetration. Rubber is suitable for climatic conditions such as 1,800-2,000 mm rainfall per year, 1,800-2,000 hours of sunshine per year, and temperatures above 10-12 °C.

The common stand density is 500-550 trees/ha at a spacing of 6 x 3 m, 7 x 2.5 m, or 7 x 2.8 m. Rubber is planted by seedlings or buddings in a nursery before transplanting in the field. Farmers choose the right clone with a good root system and good budding material (for latex and/or wood) for grafting the upper part. After 5-6 years, rubber can be tapped when the girth reaches 40-50 cm at 1 m above the soil surface. In the first year of tapping, the yield is still low (< 500 kg/ha) but this increases steadily to the 10th-13th then decreases on the 20th-25thyear. At this time latex yield is not economical and trees are cut down for timber. The tapping systems used are as follows: + S/2 d/2, + S d/3 d/4, and + S/ 2 d/3 d/4, ET 5%.

Products and markets

Latex production fluctuates from 4-14 percent over the year. In the Southeastern and Central Highlands areas, there are two distinct seasons. The rainy season starts in May and finishes by the end of October. During this period, about 50 percent of the yield is realized in February. In the middle of the dry season, rubber trees lose leaves and the yield is lowest (4%). Between the end of July and the beginning of August there is a short drought, which causes yield to decrease. Yields are highest in November and December (13-14%).

Existing domestic and international markets of perennial crops are for coffee beans and latex; markets for fast-growing tree products such as timber are still limited and unstable. Besides rice and local maize which are mainly used for home consumption, other cash crops such as coffee, beans (mungbean, groundnut, and soybean) are sold to middlemen who go to villages; farmers also bring their products directly to Buon ma thuot market. For rubber, farmers will repay the investment by selling latex to Daklak Rubber Company based on the current price from the seventh year.

Production and marketing problems

Agricultural inputs and government extension services are absent in the two villages except for the investment of Daklak Rubber Company in rubber farms in Sut M'gru village. Farmers buy main inputs such as fertilizers, pesticides, agricultural tools, and fuel from private shops in Buon Ma Thuot, Chu M'gar district or some small shops in the villages.

Daklak Rubber Company provides fertilizers to farmers for their rubber farms, but farmers buy fertilizers and agrochemicals for coffee from the middlemen at the marketplace. Farmers use little or no inputs for upland annuals in the traditional system and only some fertilizers for paddy fields.

6.0 RESULTS AND DISCUSSION

6.1 Socio-economic and Land Use Characteristics

Thua Thien Hue

From the three models of agroforestry systems observed, two (AFS1 and AFS2) systems were considered for economic analysis, these being the most dominant systems in the area. These systems were compared with the traditional cassava-based cropping systems. Table 9 shows some major socio-economic characteristics of respondents from the four major groups according to cultivation system.

The land-use systems of villagers are also shown in Table 10. Farmers adopting the traditional system devote most of their land to growing food crops (98%) and only a small area (2%) is allotted for growing trees. On the contrary, agroforesters devote the larger portion of their land to growing trees.

Table 9. Major socio-economic characteristics of respondents, by production systems, Dong Hoa village

Indicators	Total	AFS1	AFS2	AFS3	TS
Age of the family head (years)	42.2	43.1	39.6	46.9	38.8
Education level (years)	5.3	5.5	5.3	5.8	4.7
Size of the family (no.)	5.2	5.5	4.5	5.6	4.8
Land size (m^2)	11,287.0	17,646.0	16,337.0	3,942.0	3,263.0
Income per head (000 D)	1,195.0	1,442.0	1,365.0	1,034.0	840.0

Source: Survey data

Table 10. Land use structure of respondents, Dong Hoa

Land Use	Total	AFS1	AFS2	TS
Crops	25.9	16.1	15.9	97.9
Forest trees	70.2	79.4	83.8	3.1
Fruit trees	3.9	4.5	0.3	-

Source: Survey data

Daklak

Table 11 presents the general characteristics of respondents from the two villages of Daklak. Sut Mgru village represented the AFS (rubber-based system) whereas M'drang village is characterized by the predominance of the traditional system.

Sut Mgru had a bigger household size whereas M'drang household heads generally had a higher educational level. However, the household head was generally older at Sut Mgru, where the number of main labours was also greater. The number of years of work experience and average farm sizes at Sut Mgru were also higher than at M'drang village.

The likelihood of villagers adopting or rejecting AFS was closely linked with particular features of the household. The household size and the age of the household head at Sut Mgru village were higher than at M'drang village, hence, the number of labourers and years on the job were also proportionately higher. Farm sizes were also much bigger in Sut Mgru *(Table 11)*.

The land use characteristics of the two villages at Daklak are given in Table 12. The main product that farmers sold to middlemen was coffee beans. Different bean varieties are sold in small amounts because of limited cultivable areas. Rice is for home consumption.

These characteristics were also related to the respondents' adoption rate. Farmers with bigger farms adopt AFS. Table 12 shows that coffee and rubber farms predominated (58%) at Sut Mgru whereas traditional upland crops were more common (71%) at M'drang.

Table 11. General characteristics of sample farmers in two villages in Daklak

Village	Household Size (no.)	Education Level of Household Head (yr.)	Age of Household Head (yr.)	No. of Main Labor	Job Experience (yr.)	Average Farm Size (m^2)
Sut Mgru (AFS)	7.0	1.6	43.00	3.9	27.8	21,296.03
M'drang (TS)	5.2	1.7	38.27	2.3	22.9	11,337.17

Table 12. Land-use characteristics of sample farmers in two villages in Daklak

Village		No. of Parcels	Coffee (m^2)	Rubber (m^2)	Paddy Rice (m^2)	Upland Crops (m^2)
Sut Mgru (AFS)	Average	7.0	7,677.6	10,224.0	1,510.7	1,623.2
	Percentage	-	36.5	48.6	7.2	7.7
M'drang (TS)	Average	2.4	2,229.7	0.0	1,015.2	8,093.3
	Percentage	-	19.7	0.0	9.0	71.4

Table 13. Results from the economic analysis based on a one-ha farm using a discount rate of 10% and a production cycle of 15 years (see Appendix A)

Indicators	AFS1	AFS2	TS
NPV (thousand dong)	8,036.9	5,524.2	3,051.9
IRR (%)	48.5	45.6	-
B/C	2.0	1.7	1.2
Annualized benefit (thousand dong)	1,180.0	811.1	448.1

NPV = net present value, IRR = internal rate of return, B/C = benefit cost

6.2 Economic Analysis and Environmental Considerations

The BCA is a well developed technique of economic appraisal, which is designed to identify projects or policy reforms to improve social welfare. It involves a broad analysis of key traded and nontraded goods and services within a well-defined region. The results of the economic analysis are shown in Tables 13 and 18, for the Hue Province and the Daklak Province, respectively.

Thua Thien Hue

Table 13 shows that AFS1 (forest trees + fruit trees + annual crops) is the most profitable system with a net present value (NPV) of 8.037 million dong and an annualized income of 1.180 million dong. The latter figure shows how much the NPV translates to in terms of yearly income. The AFS2 ranks second in terms of profitability with an NPV of 5.524 million dong and an annualized income of 0.811 million dong. The TS is the least profitable but is still capable of earning positive returns to the farmers with an NPV of 3.051 million dong and an annualized income of 0.448 million dong. The economic analysis showed that: (1) the agroforestry systems are more profitable than traditional cropping systems and (2) the combination of a forest with fruit trees and annual crops is more profitable than the combination of forest trees with annual crops.

The sensitivity of the viability of the system to changes in discount rate *(Table 14)*, prices *(Table 15)*, and productivity of the soils for annual crops *(Table 16)* was done for the Hue Province.

Results show that an increase in discount rate from 10 percent to 15 percent will not change the attractiveness of the agroforestry and traditional farming systems but the latter is close to a breakeven position once the discount rate goes up to 15 percent. A greater than 20 percent reduction in the price of cassava will also make the system close to being unprofitable. Furthermore, if one will experience a 2 percent reduction in the productivity of the annual crops, the traditional cropping system is likely to become unprofitable.

Forest dependence of the respondents

To determine the extent of dependent of the respondents from the Hue Province on the forest, a question was asked to find out how often they go to the forest for firewood. Some of the respondents (13.6% practice AFS1 and 16.7% practiced AFS2) never go to the forest for firewood. This indicates that the AFS provides for their firewood requirements and thus lessens

Table 14. Sensitivity of the economic analysis using different discount rates

Indicators	Discount Rates				
	6%	8%	10%	12%	15%
AFS1					
NPV	12,359.6	9,944.2	8,036.9	6,518.8	4,783.0
B/CR	2.2	2.1	2.0	1.9	1.7
A	1,814.7	1,460.1	1,180.0	957.1	707.4
AFS2					
NPV	8,716.2	6,932.7	5,524.2	4,403.0	3,121.5
B/CR	1.9	1.8	1.7	1.6	1.5
A	1,279.8	1,017.9	811.1	646.5	458.3
TS					
NPV	3,974.0	3,486.3	3,051.9	2,706.0	2,289.0
B/CR	1.2	1.2	1.2	1.1	1.1
A	583.5	509.2	448.1	397.3	336.1

NPV = net present value (000 VND), B/CR = benefit cost ratio, A = annualized value (000 VND)

Table 15. Sensitivity of production systems with a 20% decrease in cassava price, 10% discount rate, and 15-year projection

Production System	NPV (000 VND)	BC (000 VND)	Annualized value (000 VND)
AFS1	7,633.3	1.9	1,120.8
AFS2	2,829.2	1.4	415.6
TS	215.4	1.0	31.6

Table 16. Sensitivity of production systems with 2% per year decrease in productivity of annual crops

Production System	NPV (000 VND)	B/C (000 VND)	Annualized value (000 VND)
AFS1	7,510.8	1.1	1,102.8
AFS2	2,810.2	1.9	412.6
TS	867.4	1.4	127.4

pressure on forest resources. Those practicing the traditional cropping system rely on the forest for firewood in the most intensive manner of daily to weekly firewood collection. Of those practicing the AFS, those with AFS 3 (fruit trees and annual crops) also relied quite heavily on the forest for their firewood requirements. In general, one can say that the adoption of the AFS, particularly those involving forest trees, helps alleviates pressure on the forest resources and thus is considered an environmentally friendly cropping practice.

Daklak

Basic Information used for the economic analysis

The economic analysis of the cropping systems in the Daklak Province also made use of the 10 percent discount rate which was obtained based on annual inflation rate of 5 percent and a nominal rate of interest in the banking systems of 15 percent.

Products that are consumed at home were valued using the prevailing prices of these commodities in the area. For rice and beans, the prices used are 1,500 dong and 5,000 dong per kg, respectively. The average wage rate in the locality of 20,000 dong/person-day was used. The prices of fertilizers, tools, latex, and other inputs were taken from the price list of Daklak Rubber Company. A 3-year planning horizon was used for the traditional system because of the projected decrease in soil fertility beyond three years of cultivation. Rubber trees have a production cycle of 32 years from the time of planting to cutting down, and coffee has a production cycle of 25 years.

In practice, farmers do not devote a large area to beans. In this case study, TS farmers planted four-fifths of the area to upland rice and one-fifth to beans. Under intercropping, bands between rubber rows decreased after 3 years from two-thirds (2/3), one-half to one-third of the total area (1 ha).

The value of fuelwood was indirectly identified by the amount of labor saved for gathering fuelwood compared with a cultivation system "without AFS" and was monetized by the same wage rate as other kinds of labor.

Results of the economic analysis

Table 18 shows that the one-ha traditional system involving the planting of annual crops is not a profitable enterprise, when all inputs are valued (a big proportion of which are labor cost) at their opportunity cost. A negative annualized income of 2.704 million dong simply means that the cost of the production system far exceeds the returns to the farmers. A one-ha coffee farm is most profitable with an annualized return of 7.50 million dong while that of the rubber-based AFS earned 2.87 million dong per hectare. Overall, the economic viability of the tree-based AFS is clearly proven in the case of the Daklak province as was also the case for the Hue Province.

Environmental consideration

The on-site productivity effects of soil degradation are due to the loss of humus and nutrients. The replacement cost method was used to estimate the value of soil degradation in terms of how much it would cost to replace the difference of natural soil nutrients taken by TS and maintained by AFS with the use of inorganic fertilizers.

To assess soil fertility under each cropping system, one composite sample was collected for each system. For each parcel, five core samples were taken at five points from the cultivation layer to 30 cm deep. Sampling of the 50 cm border of the parcel was avoided. The five core samples were mixed well into one composite sample to analyze N, P_2O_5, and K_2O.

Four soil samples were taken from each farming system: an old rubber farm, mature coffee farm, upland crops, and upland rice. From the soil analyses results, soil nutrient content affected by different cropping systems are calculated following the steps given in Appendix A.

As shown in Table 19, soils under trees like rubber and coffee contained higher nitrogen, P_2O_5, and K_2O content than soils cultivated purely under annual crops. On environmental consideration, therefore, the importance of trees over annual crops is highlighted by the above information.

Windbreak effect

The dry season in Daklak with its strong winds, high temperatures, and low air humidity, caused evaporation in plants

Table 17. Rate of logging in forests for firewood

Frequency	AFS1	AFS2	AFS3	TS
Never	13.6	16.7	-	-
Sometimes a month	36.4	50.0	8.3	-
Weekly	50.0	33.3	91.7	42.9
Daily	-	-	-	57.1

Table 18. Economic analysis of alternative cropping systems, Daklak Province

	One-ha Traditional System	One-ha Coffee Farm	One-ha AFS
PV of benefit stream (VND)	3,628,788.00	109,369,000.00	54,573,717.00
PV of cost stream (VND)	10,354,538.00	41,320,670.00	27,187,671.00
NPV (VND)	-6,725,750.00	68,048,290.00	27,386,046.00
Annualized value of NPV (n = 3 yr)	-2,704,523.60	7,496,727.60	2,874,765.20
B/C ratio	0.35	2.65	2.01

PV = present value; NPV = net present value; B/C = benefit cost

Table 19. Soil nutrient characteristics of a rubber farm and other upland cropping systems

Crop	N (%)	Avail. P_2O_5 mg/100 g soil	Avail. K_2O mg/100 g soil
Rubber	0.18	10.12	8.42
Coffee	0.20	8.40	6.60
Upland rice	0.03	7.40	3.56
Upland crop	0.11	5.95	6.20

and soil moisture. Mature rubber trees, which are 8-15 m high, had a positive effect on the microclimate and local hydrology. Mature rubber trees helped to regulate and maintain reserve surface and groundwater resources nearby during the dry season.

Control of on-farm soil erosion

At the beginning of the rainy season, soil erosion was severe in areas without a vegetative cover. This was also a drawback in the traditional cultivation system with upland rice and short-term crops. The Tay Nguyen Soil Science Research Station (1995) estimated that the difference in eroded soil between the rubber farm and pure upland rice field was about 2,756 kg/ha/year.

6.3 Determinants of Adoption

Thua Thien Hue

Using the data set from the survey and the Statistix program, function 2.2 was computed. The results of this and the regression analysis are shown in Table 20.

AGE and LAND

Age and land had positive coefficients which means that older farmers had a higher agroforestry adoption rate and that those who had more land were more likely to adopt agroforestry. The age and landholding of an average traditional cultivator were less than the age and land area of the average farmer. Traditional cultivators were mainly young farmers who migrated from lowland areas to the village recently, whereas others were new couples. Most of them lacked land to plant forest trees and they used most of the land provided by the local government to grow annual crops for food. Some young farmers often also found jobs in cities and other places. These landless farmers significantly contributed to the deforestation in the area.

EDU, EXP, and INC

These three variables, especially the educational level of farmers, strongly affected the adoption rate. Educational level is considered one of the most important factors of adoption. The effect of educational level on agroforestry adoption is shown in Table 21. Farmers with more education would tend to have a higher adoption rate. Income of the household is a very important factor that affects the adoption decision of farmers as shown in Table 22. The higher the income of the farmer, the greater the probability of adoption of the agroforestry system.

FSIZE

The negative value of this variable indicated that with limited resources, larger families had less capability to develop agroforestry. These families had to devote a large area of land for growing food crops. However, this variable had a very small coefficient of 0.004367, with a significance level of 0.04. Therefore, it did not affect the adoption rate much.

Table 20. Logistic regression results of determinants of agroforestry system adoption

Explanatory variables	Coefficients	Standard error
Constant	-5.6590	1.1093
Age of the farmer, in years (AGE)	1.0320E-02	2.0926E-02
Years of schooling (EDU)	8.5640E-01	9.3585E-02
Household members (FSIZE), number	-4.3673E-03	1.1462E-01
Total land, in hectares (LAND)	1.3872E-02	2.0214E-02
Household income (INC), in million dong	1.8534E-01	8.7446E-02
Years of farming experience (EXP)	1.8607E-02	3.8128E-02
TECH (dummy) = 1 if the farmer received technical assistance from the extentionists, and 0 if not	5.4345E-02	4.4272E-01
SEED (dummy) = 1 if the farmer received seedlings, and 0 if not	2.1522E-01	4.4070E-01
CRED (dummy) = 1 if the farmer received credit assistance, and 0 if not	1.1827E-01	3.9086E-01

Table 21. Probability of adoption of agroforestry system according to educational level when other variables are fixed

Average Educational Level (in year)	Probability of Adoption (%)
5.3	64.7[a]
5.4	65.5
5.5	66.3
5.6	67.1
5.7	67.8
5.8	68.6
5.9	69.4
6.0	70.1
7.0	77.0
8.0	82.7
9.0	87.2
10.0	90.7

[a] Probability was computed using parameters of the average household in Table 4. LAND is in hectares and INC in million dong according to the model's coefficients

Table 22. Probability of adoption of agroforestry system according to income level when other variables are fixed

Average Income (in million dong)	Probability of Adoption (%)
4	33.6
5	47.5
6[a]	64.7[a]
7	74.3
8	83.8
9	90.2
10	94.3
11	96.7
12	98.1
13	98.9
14	99.4
15	99.6

[a] Probability was computed using the parameters of the average household in Table 4

TECH, SEED, and CRED

These three factors positively affected the adoption decision of farmers differently (data not shown). While assistance with seedlings and credit had a strong effect on adoption, technical assistance almost did not affect the farmer's decision to adopt agroforestry. This indicated that technical assistance did not help much in increasing the adoption rate. However, it is still important to help farmers in developing their production systems through technical assistance because farmers have no other information source on agroforestry system.

Daklak

Tables 23 and 24 present the results of the logistic regression for the Daklak Province:

Applying the first logit model, we can calculate the probability of a sample household for its AFS adoption rate *(Table 25)*. Thus, a sample household with the characteristics shown in Table 25 has an 88 percent probability of adopting AFS.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The economic analysis has shown that agroforestry systems are more profitable than the traditional cropping systems, both financially and environmentally for both provinces. In Thua Thien Hue, the combination of forest trees with fruit trees and annual crops was more effective than other agrosilvicultural systems. Adding 18 jackfruit trees and 7 pepper trees in 1 ha can increase the net benefit by 45 percent (368,000 dong) yearly. If we use the discount rate of 10 percent, for two cutting cycles of forest trees (15 years), 1 ha of forest trees combined with fruit trees and annual crops can yield a net economic worth of 8 million dong or about 1.2 million dong annualized value. Meanwhile 1 ha of traditional cassava-based cropping system under the same condition could yield only 3 million dong net present value or about 450,000 dong annually. This is almost three times lower than the earning from an agroforestry system. If we add the value of animals and cattle, which the farmers often tend in fruit tree gardens and acacia forest,

Table 23. Logit model definitions, specifications, and coefficients

Model Specification Values of Coefficients and Standard Errors							
Model	Constant	B1	B2	B3	B4	B5	B6
AFS1	-5.711 (3.377)	-0.006 (0.178)	0.498 (0.298)	-0.127 (0.156)	0.109 (0.143)	0.0001 (0.0007)	.071 (0.757)
T-values	-1.69	-0.04	1.67	-0.81	0.76	1.39	2.74
Significance	**		**			*	***
AFS2	-5.954 (3.325)	0.026 (0.174)	0.468 (0.284)	-0.101 (0.150)	0.101 (0.140)	2.312 (0.718)	
T-values	-1.79	0.15	1.65	-0.67	0.72	3.22	
Significance	**		**			***	

* significant at 10% probability level, ** significant at 5%, *** significant at 1%

Model definitions

Model	X1	X2	X3	X4	X5	X6
AFS 1	HHMEM	EDUHE	AGEHE	JX	AREA	LAB
AFS 2	HHMEM	EDUHE	AGEHE	JX	LAB	

AFS 2 seems to suitably explain the likelihood of farmers adopting AFS.

Table 24. Logit predicting likelihood of AFS adoption, sign of coefficients

Variable	Sign of Coefficient	Rationale
HHMEM	-	Adoption rate decreases as total household members increase
EDUHE	+	Likelihood of AFS adoption increases as education level of household head increases
AGEHE	-	AFS is not adopted as age of household head increases
JX	+	Likelihood of AFS adoption increases as job experience increases
LAB	+	Likelihood of AFS adoption increases as the labor force of household increases

Table 25. Calculation of the probability of AFS adoption

Variable	Values
Household size	7
Education level of household head	2 years
Age of household head	50 years old
Job experience	35 years
Farm size	10,000 ha
Family labor force	4
Percent of adoption	88.2

the value of the farming systems could be much higher.

In Daklak, results of the BCA also showed a positive NPV/annualized value for the rubber-based system compared with other upland cropping systems (2,874,765.20 dong to -2,704,523.60 dong). Because of data limitation, the study assessed only the value of on-site soil fertility under the AFS compared with other traditional systems, but the data obtained justifies the important role of tree crops in sustaining land use. The choice of a woody perennial or rubber in Daklak was a good solution to the regreening programs of the government. Although the economic returns from growing rubber trees were higher than that from the traditional cultivation system in terms of financial, biological, environmental, and social considerations, some other factors prevent resource-poor farmers in reconciling short-term needs and long-term benefits. Farmers knew that soil degradation was occurring in their farms but constraints in budget and technical knowledge had restricted them in adopting AFS.

Regression results showed that the educational level positively affected the adoption rate. The higher the educational level of the household head, the greater the likelihood of the adoption of AFS. On the other hand, family size has a negative effect on adoption. These results are true for both provinces/study areas.

In Thua Thien Hue province, the age of the farmer positively affected the adoption rate. However, the opposite was true for Daklak, where AFS adoption and age of household head were negative correlated. Other factors that positively affected adoption rate were land, income, technical assistance, and credit. In Daklak, an additional variable that positively affected adoption was the number of the labor force of household.

Agroforestry systems benefit not only the individual farmer but also the community as a whole, and it plays an important role in reducing deforestation, preventing erosion and soil loss, and improving the quality of the surrounding environment. However, adoption of agroforestry systems is minimal. Reasons cited at Thua Thien Hue were similar with those of Daklak. Lack of capital investment to develop agroforestry systems was one of the major difficulties cited by farmers in adopting AFS. The provision of agricultural input support services is critical to smallholders who adopt AFS. Markets for tree products are also a problem in Daklak Province.

To help villagers successfully develop their production systems, additional assistance from the government and other organizations is needed to remove constraints and difficulties. Credit assistance could be established to help community members. Assistance can also be in the form of organizing the marketing system for agroforestry products throughout the region and the country. Creating a marketing system for agroforestry outputs not only increases the value of current agroforestry systems but also encourages traditional farmers to adopt them and increase the sustainability of production systems in rural areas.

REFERENCES

Abed, D.M. 1994. A Report on the Agroforestry Practices in Bangladesh and OSAD's Experience in the Field of Agro/Social Forestry. IUFRO International Symposium on Growth and Yield of Tropical Forests. pp. 258-268.

Asian Productivity Organization (APO). 1989. Forestry Resources Management. Report of the APO Symposium on FRM held in Tokyo, Japan 7-14 Nov. 1989.

Avila, M. *nd.* Economics of Agroforestry. An Ex-ante Assessment of Agroforestry Development. ICRAF, Nairobi, Kenya.

Bann, C. 1996. Economic Evaluation of Tropical Forests: A Manual for Researchers.

Deb, R.R. 1991. Agroforestry and its Impact in Economically Benefiting the Farmers. Proceedings of the Colloquium on Forestry Economics Research in Asia, March 18-20, 1991, Bangkok, (eds. Thammincha, S., L. Puangchit and H. Wood). pp.32-40

Deb, R.R. 1993. Agroforestry and its Impact in Economically Benefiting the Farmers. National Research Center for Agroforestry, Jhansi, India. *In* Forestry Economics Research in Asia, Kasetsart University, Thailand.

Dewees, P.D. 1993. Trees, Land, and Labor. World Bank Environment Paper No.4. The World Bank, Washington, D.C.

Francisco, H.A. 1993. Market Development for Forest Communities in Asia. UPLB, College, Laguna, Philippines.

Government of Vietnam. 1995. Yearbook of Vietnam, Statistical Publishing House.

Government of Vietnam. 1995. Statistical Data of Agriculture, Forestry, and Fishery. Statistical Publishing House.

Gregersen, H., S. Draper, and D. Elz (eds.). 1989. People and Trees. EDI Seminar series. The World Bank, Washington D.C.

Khurana, D.K. and Y.S. Negi. 1991. Economic Potential of Agroforestry in Hill Farming Systems – A Case of Himachal Pradesh, India. Proceedings of the Colloquium on Forestry Economics Research in Asia, March 18-20, 1991, Bangkok, (eds. Thammincha, S., L. Puangchit, and H. Wood). pp. 93-101.

Kiet, H. 1997. Erosion Management in the Slope Land Areas of Central Vietnam. Graduate Thesis. Agricultural and Forestry University of Hue, 24 Phung Hung, Hue.

Le, D. T. 1996. Some Suggestions to Develop Agroforestry Systems in Vietnam. Science, Technology and Environment Journal. Daklak Science, Technology and Environment Service. (in Vietnamese)

Nguyen, K.C. 1996. Techniques of Rubber Cultivation, Upkeeping and Processing. Agriculture Publishing House, HCMC. (in Vietnamese)

Nguyen, P. 1995. Daklak Agriculture and Forestry: 1975-1995. Agriculture Publishing House, Hanoi. (in Vietnamese)

Nguyen, S.C. 1995. Agro-ecosystem in Central Vietnam. Agricultural Publishing House. Hanoi.

Pathak, P.S. 1991. Economic Analysis of Silvipastural Systems. Proceedings of the Colloquium on Forestry Economics Research in Asia, March 18-20, 1991, Bangkok, (eds. Thammincha S., L. Puangchit, and H. Wood). pp. 41-51.

Sugianto, T. 1991. Some Considerations in Conducting Research in Agroforestry Economics. Proceedings of the Colloquium on Forestry Economics Research in Asia, March 18-20, 1991, Bangkok, (eds.Thammincha, S., L. Puangchit, and H. Wood). pp. 52-73.

Sugianto, T. 1993. Some Considerations in Conducting Research in Agroforestry Economics. Bogor University, Indonesia.

Tay Nguyen Soil Science Research Station. 1995. Annual Scientific Research Report. Tan Nguyen, Vietnam.

Tran, D.C. 1996. The Response of Daklak Forests. Environment Review. Quangnam-Danang Science, Technology and Environment Service. (in Vietnamese)

UNESCAP. 1986. Environmental Socio-economic Aspects of Tropical Deforestation in Asia and the Pacific. Proceedings of the Expert Group Meeting, 28 January - 3 February 1986, Bangkok, Thailand.

Williams, T.O. *nd.* A Framework for Economic Evaluation of Smallholder Agroforestry. International Livestock Center for Africa (ILCA), Semi-Arid Zonal Site, B.P. 12404, Niamey, Niger.

ACRONYMS

AF	Agroforestry
AFS	Agroforestry system
Asl	Above sea level
BCA	Benefit-cost analysis
IRR	Internal rate of return
Kg	Kilogram
Km	Kilometer
M	Meter
Mm	Millimeter
NPV	Net present value
TS	Traditional system

APPENDIX A.

Estimation of the fertilizer content of soils

1. To estimate the equivalent urea:

- estimate kilogram of N/ha = % total N x weight of soil layer (kg/ha)
- convert kilogram of N/ha to kg of urea/ha by the formula:

$$\frac{\text{kg N/ha}}{0.45} = \frac{\text{kg of urea}}{\text{ha}}$$

2. To estimate amount (kilogram) of P_2O_5

- compute kilogram of P_2O_5/ha = available P_2O_5 (mg/100 g soil) x weight of soil layer (kg/ha) x 10^{-2}
- convert kilogram of P_2O_5/ha to kilogram of fused phosphate by the formula:

$$\frac{\text{kg } P_2O_5\text{/ha}}{0.5} = \frac{\text{kg of fused phosphate}}{\text{ha}}$$

3. To estimate amount (kilogram) of K_2O/ ha = exchangeable K_2O (mg/100 g soil) x weight of soil layer (kg/ ha) x 10^{-2}

- convert kilogram of K_2O/ha to kilogram of muriate

$$\frac{\text{kg } K_2O\text{/ha}}{0.50} = \frac{\text{kg of muriate}}{\text{ha}}$$

The weight of the arable soil layer was computed by the formula:

Weight of soil layer (t/ha) = S x h x D

where:

S = area of 1 ha (= 10,000 m^2)
h = depth of topsoil layer (= 0.30 m)
D = average specific weight of red soil (= 1 t/m^3)
W = 10,000 x 0.3 x 1.00 = 3,000 t/ha

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AN ECONOMIC ANALYSIS OF THE CAN GIO MANGROVE SCHEME IN HO CHI MINH CITY

6

AN ECONOMIC ANALYSIS OF THE CAN GIO MANGROVE SCHEME IN HO CHI MINH CITY

To Thi Thuy Hang and Nguyen Thi Ngoc An

SUMMARY

This report presents an economic analysis of the Can Gio Mangrove Management Scheme in Ho Chi Minh City (HCMC), Vietnam. The two key features of the Can Gio management scheme were: 1) an explicit recognition of the importance of local participation in successful resource management, and 2) the provision of financial incentives to ensure that local resource users benefit directly from conservation efforts. Under this innovative scheme, local people were paid by the Government to act as guardians of the mangrove resource.

The study area covered 40,000 ha, with around 6,000 households. A total of 125 households in five of the seven villages of the district were surveyed. Their benefits from the mangrove area came from tree trimming, fuelwood collection, aquaculture and captive fishing. Of these, aquaculture (shrimp) was found to be the most profitable.

The Can Gio mangrove management scheme cost the Government $85,500 per year (or a net cost of $2 per ha). However, the scheme can be considered cost-effective because it promoted sustainable management, the net benefit of which was estimated at $14.50 per ha, based on an assessment of direct use values alone. In terms of income, households under the scheme were over $500 better off than non-participating households. The social, environmental and distributional benefits from implementing the scheme are therefore high.

The management of the area could be improved by tighter controls on aquaculture and fishing activities and the provision of technical support to improve the efficiency of these activities. The study recommends that, based on the success of the Can Gio mangrove management scheme, consideration should be given to the development of the scheme and its introduction to similar mangrove sites in other parts of Vietnam.

1.0 INTRODUCTION

Mangrove forests, an important resource in Vietnam, can be found along the country's 3,000-km coastline. They provide direct benefits such as wood for fuel and construction. They also perform a number of important ecological functions that indirectly support economic activities such as commercial fisheries. Mangroves are well known for their high biological productivity and play a significant role in the provision of nutrients to coastal fisheries. They also serve as important spawning and feeding grounds for fish and shrimp, and shelter and nursing ground for many aquatic species such as commercially important finfish and crustaceans. Furthermore, mangroves act as a natural barrier against the impact of storms, stabilise sediments, and maintain water quality since they minimise the effects of eutrophication and water pollution.

Resource use pressures have led to the destruction of mangroves throughout Southeast Asia, including Vietnam. Between 1950 and 1983, Vietnam's mangroves have been reduced by 50 percent because of the use of herbicides and defoliates during the war; over-exploitation for fuelwood and wood for construction (exacerbated by population increases); and conversion of mangrove forests to agricultural land, aquaculture ponds, and salt ponds. Studies have estimated that Vietnam has now only 154,000 ha of mangrove area (Tuan, 1996). Its distribution by geographical region is presented in Table I.

The mangrove forests between Vung Tau and Ha Tien are the largest and richest in the country due to the area's low topography, numerous rivers and canals, abundant alluvium and a favourable tropical climate. The mangrove forest of Can Gio and Minh Hai, found within this area, plays a significant role in regulating the ecosystems of South Vietnam. Both of these areas were severely damaged by chemicals during the war, but have been restored through reforestation programs.

The costs of mangrove degradation in Vietnam have been high and widespread. Estimates showed that a hectare of cleared mangrove leads to a loss of 180 kg/year of fish (World Bank 1995). In addition, mangrove loss has resulted in the intrusion of saline water into paddy fields (mainly caused by the loss of a coastal buffer zone), affecting agricultural productivity. The destruction of mangrove areas in North Vietnam has resulted in increased storm damage, including loss of human lives, property and agricultural land. Shrimp cultivation in many areas has also been unsustainable, resulting in abandoned ponds within five years of operation. Often, mangrove degradation impacts hardest on the poor families living within or close to the mangrove areas. Many of these families are dependent on the mangrove resource for their livelihood.

Table 1. Geographical distribution of mangrove areas in Vietnam

Geographical Zone	Area (ha)	No. of Species
Northeast coastline from Ngoc Cape to Do Son	39,400	16
Coastline from Do Son to Lach Truong	7,000	13
Coastline of Central Vietnam from Lach Truong to Vung Tau	14,300	28
Coastline from Vung Tau to Ha Tien	191,000	34

Source: Hang, 1997

Sustainable mangrove management has been recognized by the Government of Vietnam as important not only nationally but also globally, because of the mangroves' international significance in terms of their carbon storage function and biodiversity values. The development of effective and cost efficient mangrove management programs is therefore an important national policy issue.

2.0 CAN GIO MANGROVE MANAGEMENT SCHEME

This study analyzed an innovative mangrove management scheme implemented at Can Gio District, Ho Chi Minh City (HCMC). The scheme emphasized community involvement in the management of the mangrove resource and provided financial incentives toward this end.

An economic analysis of the Can Gio mangrove management scheme was undertaken to identify and highlight the following: value of the mangrove resource; importance of mangroves to the local people and the benefits to people under the scheme; existing pressures on the resource and actions for improved management; costs and benefits of implementing the scheme; and potential for transferring the scheme to other areas in Vietnam.

2.1 Study Area

Can Gio district is located 50 km southeast from the centre of HCMC. The district covers a total area of around 71,000 ha (one-third of HCMC's total area), 25 percent of which is covered by surface water. It has a population of around 10,000. The study area covered about 40,000 ha, with around 6,000 households living in five of the seven villages of the district: Ly Nhon, Thanh An, Long Hoa, Can Thanh and Tam Thon Hiep.

2.2 Mangrove Management in Can Gio

During the war, the rich mangrove areas of Can Gio were virtually destroyed by herbicides and defoliates, including "agent orange." After 1978, people started to resettle in Can Gio and the rehabilitation of the mangroves through reforestation programs was initiated by the Government. By 1996, nearly 35,000 ha of mangrove forest had been planted (Can Gio Mangrove Management Board 1997). The main species planted was the fast growing *Rhizophora apiriculata*; and other species such as *Nypa fruiticans*, Eucalyptus, *Avicennia*, and *Rhizophora mucronata*.

The management of mangroves in Can Gio can be broadly categorized in three stages:

- 1978-1987: The mangroves of Can Gio were directly managed by two agencies – the state-owned Duyen Hai Forest Enterprise and Duyen Hai Forest Rangers. The city government invested in reforestation in the District. In December 1983, the HCMC People's Committee issued Decision No. 441 on the assignment of land to collective farms and villages in the district, which was not enforced until 1987.

- 1987-1990: In 1987, following the HCMC People's Committee Decision No. 441, the Duyen Hai Forest Enterprise assigned land to collective farms and villages, conferring on them autonomy over these areas. By the end of 1989, however, owing to the young age of the forest, many collective farms and villages could not cover management costs, hence, they returned the land to the government. These areas were left largely unmanaged, becoming an open access resource threatened by over exploitation. During the 1980s, large areas of mangrove forest in Can Gio were converted to shrimp ponds, and over harvesting of mangrove wood was evident.

- 1990-present: In response to the threats to the mangrove resource, the Can Gio Mangrove Management Scheme was introduced in 1990. Under this scheme, the HCMC People's Committee and the Department of Agriculture and Rural Development assigned mangrove areas to the Duyen Hai Forest Enterprise and village residents. At the same time, the Can Gio mangrove forest was declared a protected area and a Management Board was established.

2.3 Main Characteristics of the Can Gio Mangrove Management Scheme

The Management Board of Can Gio Forest Protection, under the Department of Agriculture and Rural Development, is responsible for the overall management of the forest (e.g., wood processing and reforestation, and trade in wildlife and endangered species). The Board is also responsible for educating the public in reforestation and forest protection, and resolving conflicts related to forest use.

The Can Gio forest is divided into 24 sub-regions. Surveys of each sub-region had been undertaken and soil maps and land use maps are available. Forest age, forest growth (in height and diameter), forest density, forest trimming, and the annual change of the forest in terms of illegal deforestation and pesticide use is monitored for each sub-region by a Forest Protection Guard. The Forest Protection Guards work in close collaboration with households that are responsible for forest management.

Residents play a central role in the management of the mangroves. Households sign contracts with the Government to manage assigned forest areas. The contract term is 30 years and households receive a monthly salary ranging from 60,000 to 80,000 VND ($5-7) per ha for planted forest and 30,000-50,000 VND/ha ($2.50-4) for natural forest. Land is assigned based on the number of workers in each household *(Table 2)*. Households also have the right to trim the forest according to the trimming plan set by the Board. Tree trimming is carried out every 5-6 years depending on growth conditions. The volume of wood harvested through trimming is shared by the government (65%) and the households (35%). Households not benefiting from tree trimming within a given year receive the maximum salary offered. In addition to forest areas, households are assigned an area of land where they can culture fish, raise cattle, and produce agricultural crops. Reportedly, more households wanted to join the scheme but all forestlands have been assigned.

In addition, the Government also provides boats, financial assistance, loans for agro-fishery production (based on the master plan), and technical assistance on

Table 2. Forest areas assigned to households

No. of Main Workers per Household	Assigned Area	
	Planted Forest (ha)	Natural Forest (ha)
1-2	20	50
3-5	50	100
More than 5	65	100

tree trimming, reforestation, and shrimp rearing.

Other households in the area have signed contracts with the Government for the right to use surface waters for aquaculture (mainly shrimps). These households do not receive salary from the government, but pay a tax to the Government based on the income generated from fishery activities.

3.0 METHODOLOGY

The main research elements of the study were:

- an economic valuation of important direct use values of the mangrove resource;
- an economic assessment of the benefits to households under the Can Gio mangrove management scheme;
- an economic assessment of the cost and benefits to the Government resulting from implementation of the Can Gio mangrove management scheme.

Table 3 presents the total economic value (TEV) of a mangrove resource. Carried out in collaboration with the Can Gio Management Board, this study focused on the valuation of the following use values using market prices: timber, fuelwood, charcoal, fisheries, and salt.

For the purpose of this study, households were categorized into four groups:

Group A consisted of 134 households under the government's management scheme. These households have signed contracts with the government to manage assigned forest areas, received salary from the government, and can exploit non-forest areas for aquaculture and/or fishing.

Group B consisted of about 250 households with water use rights (i.e., households that have signed a contract with the government for the right to exploit surface waters for aquaculture). They do not receive salary from the government. Since these households resided in the Can Gio District before the government management scheme was introduced, this agreement over the use of surface water in effect legalized existing practices. Households in this category were not allowed to cut trees or practice any other forms of mangrove exploitation.

Group C consisted of approximately 1,000 households that were not permanent residents of Can Gio District. These households came to Can Gio mainly from the surrounding provinces such as Tien Giang, Long An, and Dong Nai. Typically, they stayed for a few months during the fishing season, practiced capture fishery, and then returned to their home province.

Group D consisted of households that did not use the mangrove resource and who worked as government employees, workers, and others. These households were not included in the survey.

The survey questionnaire was pre-tested on 25 households in September 1996. Then the survey proper was conducted in March 1997. It had 125 household respondents, which accounted for 35 percent of the overall concerned population. It covered 79 households in Group A (59% of households in Group A), 21 households in Group B (8% of households in Group B), and 25 households in Group C (2% of households in Group C). Interviewees were questioned on their use of the mangrove. The benefits to households under group A, B, and C were then estimated.

In addition to direct interviews with households, discussions and interviews were carried out with the staff of the Can Gio Management Board and the People's Committee of Can Gio District. Relevant information was also collected from the reports prepared by the above-mentioned agencies.

4.0 RESULTS

4.1 Socio-economic Information

The survey showed that the population of the study area was 54 percent male and 46 percent female. This result differed from other surveys that showed more females than males. Most household heads (86%) were male. Many of them (36%) belonged to the age bracket of 31-40 years *(Table 4)*.

Table 3. Total economic value of a mangrove resource

	Use Values		Non - use Values
Direct Value (1)	Indirect Value (2)	Option Value (3)	
Timber	Shoreline/river banks stabilization	Future use as per (1) and (2)	Cultural and aesthetic, spiritual, and religious
Fuelwood	Ground water recharge and discharge		
Charcoal	Flood and flow control		
Fisheries	Storage and recycling of human waste and pollutants		
Forest resources: food, medicine, construction materials, tools, dyes, wildlife	Maintenance of biodiversity		
Agricultural resources	Provision of migration habitat		
Water supply	Provision of nursery and breeding grounds for fish		
Water transport	Nutrient retention		
Genetic resources	Coral reef maintenance and protection		
Tourism and recreation	Prevention of saline water intrusion		
Human habitat			
Educational, historic, and scientific information			

Source: Bann, 1997

Table 4. Age of household heads

Age	Percentage (%)			
	Total	Group A	Group B	Group C
20-30	8	4	2	2
31-40	36	22	7	7
41-50	25	19	2	4
51-60	18	10	2	6
> 60	11	8	1	2
Total	98	63	14	21

Table 5. Education level of household heads

Education level	Percentage (%)			
	Total	Group A	Group B	Group C
Illiterate	6	2	2	2
Read and write only	5	2	1	2
Primary	71	44	10	17
Secondary	17	14	3	-
Tertiary	1	1	-	-
Total	100	63	16	21

The households heads have a low level of education *(Table 5)*: 71 percent with primary education (grade 1-5); 17 percent, secondary education (grade 6-9); and less than 1 percent, tertiary education (grade 10-12). There were no university graduates. The illiteracy rate was 6 percent, lower than the country average of 9 percent. The educational level of the entire population within the study area was: 52 percent had primary education; 19 percent, secondary education; and 1 percent, tertiary education. The illiteracy rate was close to the national illiteracy rate of 8.3 percent. Group A had the highest percentage of educated people, while group B had the highest illiteracy rate.

The results also showed that the majority (54%) of households have settled in Can Gio district after 1990. Around 34 percent of the households came to the area between 1975 and 1990 and 12 percent before 1995 *(Table 6)*[1]. The high level of in-migration after 1975 (88% of the current population) may be attributed to the fact that during the war, few people resided in the area because of insecurity and the effects of herbicides and defoliates. The influx of people to the area after 1975 increased the pressures on the mangrove resource, which, in turn, led to the implementation in 1990 of the current management scheme in order to avert the deterioration of the Can Gio mangrove forest. The fact that more than 50 percent of households settled in the area after 1990 points to the popularity and success of the new management scheme as a mechanism for improving the living conditions of participating households.

The households in the study area had various income-earning activities *(Table 7)*. Group A households exploited the mangroves for forest trimming and aquaculture. Group B practised aquaculture, while Group C mainly practised fish capture.

Table 6. Residency background of households

Period	Percentage (%)			
	Total	Group A	Group B	Group C
Before 1975	12	9	1	2
1975-1990	34	20	6	8
After 1990	54	34	10	10
Total	100	63	17	20

Table 7. Uses of the mangrove area

Mode of Mangrove Exploitation	Percentage %			
	Total	Group A	Group B	Group C
Forestry only	29	29	-	-
Aquaculture	17	-	17	-
Forestry and aquaculture	34	34	-	-
Fish capture	20	-	-	20

Table 8. Land use in the Can Gio area

Land Use	Total		Group A		Group B		Group C	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Forest	5,411.0	76	5,411.0	76	-	-	-	-
Shrimp	483.0	7	273.0	4	210	3	-	-
Pond	1.2	<1	0.2	<1	-	-	1	<1
Fish/crab	10.0	<1	8.0	<1	-	-	2	<1
Pond	1,198.0	17	1,186.0	17	-	-	12	<1
Residential	24.0	<1	7.0	<1	-	-	17	<1
Open space	5.0	<1	5.0	<1	-	-	-	-
Total	7,132.2	100	6,890.2	97	210	3	32	<1

In terms of land use, 76 percent of the study area was forest, 17 percent was open space, and 7 percent was used for aquaculture by households in Groups A and B *(Table 8).*

4.2 Economic Analysis of the Can Gio Mangrove Management Scheme

Households within the mangrove area benefited from tree trimming, fuelwood collection, aquaculture, and capture fishery. An economic valuation of these direct use benefits of the mangrove resource was undertaken. In addition, the economic benefits to the different categories of households within the study area from these activities were assessed to compare the benefits accruing to each group.

4.2.1 Tree trimming

Tree trimming was carried out every 5-6 years, depending on the tree quality based on the following schedule (Report of Can Gio Forest Management Board):

The first trimming is done when the tree is 6-7 years old and has reached a diameter of 3-4 cm and a height of 4-6 m. On the average, the total number of trees per ha is 7,500 and wood productivity is about 5m^3/ha. Trees not attaining these technical qualifications are cut to give space to other healthier trees.

The second trimming takes place when the tree is 9-11 years old. At this time, the average diameter of the tree is 6-9 cm and its height is 6-10 m. The total number of trees per ha is about 4,500, and wood productivity is about 14 m^3/ha.

The third trimming was done when the tree is 15-16 years old and has an average diameter of 9-12 cm and an average height of 12-16 m. The total number of trees is low (around 2,500/ha) compared to previous periods but productivity is high at 25 m^3/ha *(Table 9)*.

Only households in Group A, which were involved in mangrove protection activities, benefited from tree trimming. The volume trimmed each period was set by the Government. Households received 35 percent of the total volume trimmed, while the Government retained the remaining 65 percent. In most cases, the households sold the timber; only a very small portion was used domestically as construction material.

An estimated 1,200 ha of mangrove forest were trimmed annually between 1984 and 1996, with a productivity range of 7-10 m^3/ha. Usually during the first trimming period when productivity was low, households were allowed to keep all of the trimmings. The Government, however, claimed its share in subsequent trimming periods.

The net benefits to households from tree trimming were calculated based on the quantity of wood allocated (regardless of whether these products were sold or used domestically) multiplied by the market price for timber *(Table 10)*, less production costs. The following trimming costs were taken into account: equipment (axes or knives); transportation (boat hire and diesel at 2,500 VND/litre or $0.20) to transport wood to the market, and labour at the district wage rate of 30,000 VND/day or $2.60. Labour costs included hired labour as well as household labour.

Table 9. Tree trimming cycle in the Can Gio mangrove forest

Trimming Cycle	Age of Tree (years)	Average Diameter (cm)	Average Height (m)	No. of Trees/ha	Productivity (m^3/ha)
1st period	6-7	3-4	4-6	7,500	5
2nd period	9-11	6-9	6-10	4,500	14
3rd period	15-16	9-12	12-16	2,500	25

Table 10. Market price of mangrove wood

Type of Wood	VND/m^3	US$/m^3
Rhizophora, large size	300,000-540,000	26-47
Medium size	180,000- 200,000	16-17
Small size	60,000	5
Cajuput	42,000- 60,000	4-5

The net benefits per household were allocated over a five-year period (cycle of trimming) to derive the annual net benefits. Net benefits with and without including the opportunity cost of household labour were calculated.

Only 12 of the households interviewed were involved in tree trimming at the time of survey. The average annual net benefits per household from tree trimming, with and without accounting for opportunity cost of household labour, were estimated at 1,209,923 VND ($105) and 1,279,923 VND ($111), respectively *(Table 11)*.

4.2.2 Fuelwood collection

Woodchips and small branches were collected from *Rhizophora*, cork tree, *avicennia*, and nipa palm by households for fuelwood. Of the 125 households surveyed, only 14 (11%) households belonging to Group B used diesel rather than fuelwood. The economic value of woodchips was estimated at 60,000 VND/m^3 ($5/m^3). This was based on the market price of woodchips and a wage rate for fuelwood collection of 20,000 VND/day ($1.70)[2].

On the average, each household spent 18 days per year collecting fuelwood. The average annual net benefits per household, with and without accounting for the opportunity cost of labour, were estimated at 303,892 VND ($26) and 669,297 VND ($58), respectively. When the opportunity cost of household labour was considered, the net benefits per household became negative in some cases.

4.2.3 Aquaculture

Aquaculture was practiced by households in Groups A and B. Households in Group C mainly practiced capture fishery. Many species were cultivated including shrimp, crab, fish, snail, and squid. Species of shrimp included *Penaeus merguiensis*, *Methapenaeus ensis*, *Aphaeus* sp., and *Methapenaeus intermedius*. Fish

Table 11. Net benefits per household from tree trimming (VND/year)

Household Number	Benefit/Cycle		Benefit/Year	
	With Opportunity Cost of Labour	Without Opportunity Cost of Labour	With Opportunity Cost of Labour	Without Opportunity Cost of Labour
1	4,420,000	8,620,000	884,000	1,724,000
2	390,000	390,000	78,000	78,000
3	950,000	950,000	190,000	190,000
5	690,000	690,000	138,000	138,000
7	12,250,000	12,250,000	2,450,000	2,450,000
14	2,050,000	2,050,000	410,000	410,000
15	23,270,000	23,270,000	4,654,000	4,654,000
16	2,665,000	2,665,000	533,000	533,000
18	8,990,000	8,990,000	1,798,000	1,798,000
20	11,655,000	11,655,000	2,331,000	2,331,000
21	4,274,000	4,274,000	854,800	854,800
79	991,400	991,400	198,280	198,280
Average	6,049,617	1,209,923	6,399,617	1,279,923

species cultivated included striped mullet (*Mugil affinis*), *Boleophthalmus boddarti*, and *Lates calcarifera*.

The net benefits per harvest were estimated based on quantities harvested (i.e., quantities sold plus the small amount of products used domestically) multiplied by the market price, less harvesting costs. The market price for shrimp ranged from 10,000 to 40,000 VND ($0.90-3.50). Two species were of particularly high value: *Aphaeus* sp. at 260,000 VND/kg ($23) and *Penaeus merguiensis* at 120,000 VND/kg ($10.50). The net benefits from aquaculture production per household were calculated considering the following costs: construction costs (e.g., initial construction cost of the pond, sluice gates, and dikes), equipment (e.g., tools and fishnets), and labour (e.g., labour for pond construction, annual repair, management, and harvesting). Some households used their own labour. In such cases, the opportunity cost of labour was based on the market wage rate of 30,000 VND/day ($2.61). Initial construction costs were discounted at an interest rate of 12 percent over the lifetime of the pond (typically 8 years although in a few special cases ponds have a lifetime as long as 15 years).

The average annual benefits per household, with and without accounting for the opportunity cost of household labour, were estimated at 6,807,342 VND ($592) and 8,924,128 VND ($776), respectively. When the 4 percent tax payable to the Government was deducted, the net benefit was $568.

For 14 households (22% of households practice aquaculture), the net benefits from aquaculture were negative. If the opportunity cost of labour were excluded, there would be only nine households incurring net losses. One explanation for such financial losses was the decline in productivity reportedly due to water pollution. In two cases, households were unable to harvest shrimp because of oil spills; they were forced to stop cultivation despite the initial investment costs incurred.

4.2.4 Capture fishery

Capture fishery was practiced by almost all households in Group C, and by some households in Group A. Capture fishery required investment in a boat and fishing equipment. Fish harvested included shrimp (*Penaeus nerguiensis, Metapenaeus ensis,* and *Peneaues monodow*), fish (*Mugil affinis, Boleophthamus boddarti,* and *Peiophthalmus barbarus*), squid (*sepia*), snail (*Caritides obtusa*), and crab (*Scylla serrata*). The average annual benefits per household from capture fishery based on market prices, with and without considering the opportunity cost of labour, were estimated at 4,558,475 VND ($396) and 5,579,413 VND ($485), respectively. When the 4 percent tax payable to the Government was deducted, the net benefit to households was $380. Some households experienced losses because they harvested low value species (e.g., more snails or squid and fewer shrimp), and/or low because of production capacity (e.g., lack of facilities to fish offshore).

While fishing nets were required to have a mesh size greater than 18 mm, mesh sizes were unregulated; therefore, the types of nets actually used were unknown. Hence, it was possible that inappropriate fishing practices affected the sustainability of the resources.

4.2.5 Benefits to households

Aquaculture generated the highest (6,807,342 VND or $568) annual net benefits among the key income earning activities in the study area. It was followed by fish capture (4,558,475 VND or $380), tree trimming (1,209,923 VND or $105), and fuelwood (303,892 VND or $26).

These figures included the opportunity cost of labour.

The average annual net benefits per household under the management scheme were: 11,431,734 VND/year or $994 for Group A; 9,975,971 VND/year or $867 for Group B; and 5,363,617 VND/year or $466 for Group C. These figures likewise included the opportunity cost of labour and Government taxes for capture fisheries and aquaculture.

The benefits to Group A households were higher than in Groups B and C. This was because by joining the Government's mangrove management scheme, Group A households received a regular salary from the government, in addition to the benefits from tree trimming, capture fishery, and/or aquaculture. The average annual salary of Group A household was $415, representing 42 percent of the total net benefits. If the salary paid to households in Group A were excluded, their net benefits would be less than those in Group B (aquaculture). The results showed that aquaculture was the most profitable activity currently practiced by households in the mangrove area. Households in Group C had the lowest net benefits.

It can be concluded that households which joined the Government mangrove management scheme were better off than the other households. Participating in the Government's management scheme brought additional benefits to households and provided an incentive for sustainably managing the mangrove resource.

4.2.6 Benefits to the government

Costs incurred by the Government in the implementation of the mangrove management scheme included the salaries of the Can Gio Management Board (CGMB), households, forest rangers, and district staff involved in administration of taxes; and the reforestation costs *(Table 12)*. The reforestation costs for 1996 was based on data supplied by the Can Gio Management Board (1997).

On the whole, the cost to the Government of the Can Gio management scheme was 875,000,000 VND ($75,000) per year. Based on an area of 40,000 ha, the total cost per hectare was $3.50, while the net cost to the government was $2/ha.

Table 12. Annual costs and benefits to Government arising from the implementation of the Can Gio mangrove management scheme

Cost			Benefit		
Salary of CGMB	222,038,648 VND	$19,308	Trimming	300,495,000 VND	$26,130
Salary of households	378,141,000 VND	$32,882	Salt tax	48,000,000 VND	$4,174
Salary of forest rangers	209,000,000 VND	$18,174	Charcoal	46,189,020 VND	$4,016
Salary of district staff	400,000,000 VND	$34,783	Shrimp tax	108,928,000 VND	$9,472
Reforestation	412,141, 856 VND	$36,621	Fishery tax	189,750,000 VND	$16,500
Total	1,621,321,504 VND	$140,984	Total	693,362,020 VND	$60,292
Net Cost: 927,959,482 VND ($80,692)					

Revenues to the government were obtained from tree trimming, salt production, charcoal production, and taxes on shrimp farms.

Revenues from tree trimming. Of the harvested timber, the Government had a share of 65 percent.

Revenues from salt production. The government collected a salt tax of 150,000 VND ha/year. Salt was produced in Ly Nhon, Long Hoa (close to Hao Vo), and Thanh An (in Thieng Lieng area) villages. Records showed that salt productivity increased between the periods 1991-1995 and 1980-1990 *(Table 13).* Increases in salt prices in 1990 promoted salt production; on the other hand, increased yields were made possible through the introduction of new technologies and intensive farming. Table 14 presents the costs of salt production.

At a market price of 250,000 VND/t, income from salt production was estimated at 13,055,000 VND/ha ($1,135), and 4,700,000,000 VND ($408,696) for the total area. Taking into account the annual costs of labour and tax only (i.e., 12,150,000 VND/ha or $1,056), this resulted in a benefit to producers of $79/ha or $2,844 for the whole area. These benefits were over estimations since equipment and construction costs were not apportioned. Meaning that otherwise, the benefits may have been negative in some years. However, production had been very variable; it was reported to be as high as 120 t/ha in some years (resulting in a gross benefit of $2,608/ha or $939,130 for the whole area, and a net benefit of $901-1,552/ha), providing the incentive for continued investment. Using a rough estimate of $79/ha of benefit to producers, the benefits to the Government from taxation based on an average productivity of 52.2 tons would be 48,000,000 VND or $4,174 (150,000 VND/ha for a total of 360 ha).

Table 13. Salt production in Can Gio District

	1980-1990	1991-1995
Average total area (ha)	523	360
Average yield (t/ha/year)	34.66	52.22
Productivity (t/year)	18,120	18,800

Source: Agricultural Unit of Can Gio District, 1996

Revenue from charcoal. Charcoal was produced using the trunk and roots of *Rhizophora.* Tam Thon Hiep village had three kilns, all managed by the Government. Charcoal from the trunk was produced three times a year, while charcoal from the roots was produced six times a year. The production cycle was around one month. Kilns cost around 8,000,000 VND and lasted for 10 years. Tables 15, 16, and 17 present the net benefits from charcoal production.

Tax on shrimp farms. The Government collected a shrimp tax of 4 percent of total production. This tax may be waived in years of low productivity due to natural disasters such as storms.

Table 14. Costs of salt production (ha), VND

Description	Cost
Thatch hut accommodation for workers	1,000,000
Bank construction	3,600,000
Labour costs (VND/month for 6 months)	12,000,000 ($1,043)
Pump	2,000,000
Roller Blade	1,000,000
Tax	150,000 ($13)
Total	19,750,000 ($1,707)

Table 15. Charcoal production (trunk of *Rhizophora*)

Input	Cost (VND)	Output	Value
Rhizophora wood: 170, 000 m³ * 35 m³	5,950, 000	Charcoal blocks: 2,400 VND/kg * 4,200 kg	10,080,000
Transportation (fuelwood): 12,000 VND/m³ * 35m³	420, 000	Charcoal chunks: 1,500 VND/kg * 350 kg	525,000
Fuelwood (date-palm): 20, 000 VND/m³ *25m³	500,000	Charcoal strips: 800 VND/kg * 480 kg	384,000
Transportation (charcoal)	860,000	Dust and bark: 200 VND/kg * 480 kg	96,000
Repair of kiln	400,000	Partially burnt charcoal: 1,000 VND/kg * 300 kg	300,000
Interest payment (1.4%)	163,820		
Total	8,293, 820		11,385,000
Net benefit per production cycle/kiln: 2,797,180 VND			
Net benefit per year (2,797, 180 VND * 3 cycles * 3 kilns) = 25,174,620 VND ($2,142)			

Table 16. Charcoal production (roots of *Rhizophora*)

Input	Cost	Output	Value
Rhizophora wood: 130,000 VND/m³ *35m³	4,550,000	Charcoal blocks: 2,200 VND/kg * 3,200 kg	7,040,000
Transportation (fuelwood): 10,000 VND/m³ * 35 m³	350,000	Charcoal chunks: 1,500 VND/kg * 100 kg	150,000
Fuelwood (date palm): 20,000 VND/m³ * 25 m³	500,000	Charcoal strips: 800 VND/kg * 30 kg	24,000
Transportation (charcoal)	860,000	Dust and bark: 200 VND/kg * 500kg	100,000
Interest payment	93,240	Partially burnt charcoal: 1,000 VND/kg *300kg	300,000
Kiln repairs	400,00		
Total	6,753,200		7,614,000
Net benefit per production cycle/kiln: 1,300,800 VND			
Net benefit per year (1,300,800 VND * 6 cycles * 3 kilns) =23,414,400 VND ($2,036)			

Table 17. Summary of annual benefits from charcoal (VND)

	Cost	Revenue	Benefit
Charcoal made from trunk	74,194,380	99,369,000	25,174,620
Charcoal made from root	121,557,600	144,972,000	23,414,400
Construction cost	2,400,000	-	- 2,400,000
Total	198,151,980	244,341,000	46,189,020

4.2.7 Economic value of key mangrove resources

A summary of the economic values of key mangrove resources is presented in Table 18. The total value of the mangrove resource based on direct use benefits was estimated at $729,316 annually or $18/ha, based on an area of 40,000 ha. If the cost of $3.50/ha to manage the mangrove area were considered, the net benefit would be $14.50/ha. This can be taken as a lower bound estimate of the mangrove resource since it does not include important indirect use functions of the mangroves such as carbon storage functions, shoreline protection, and biodiversity values *(Table 3)*.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The Can Gio mangrove management scheme provided households with improved living conditions and financial incentives for sustainable mangrove management. Households that joined the scheme enjoyed increased economic stability through a regular monthly salary paid by the Government for their participation in protecting the mangrove resource, plus additional opportunities to earn income through tree trimming, aquaculture, and capture fishery. By raising the awareness of residents on the benefits of environmental management and making them the main beneficiaries of sustainable resource use,

Table 18. Summary of valuation results (VND/year)

Product	Net Benefit to Households	Benefit to Government	Total
Timber (tree trimming)[1]	161,805,000 ($14,070)	300,495,000 ($26,130)	462,300,000 ($40,200)
Fuelwood[2]	330,993,000 ($28,782)	-	330,993,000 ($28, 782)
Charcoal[3]	-	46,189,020 ($4,016)	46,189,020 ($4,016)
Salt[4]	32,706,000 ($2,844)	48,000,000 ($4,175)	80,706,000 ($7,017)
Aquaculture[5]	2,614,272,000 ($227,328)	108,928,000 ($9,472)	2,723,200,000 ($236,800)
Fish Capture[6]	4,554,000,000 ($396,000)	189,750,000 ($16,500)	4,743,750,000 ($412,500)
Total	7,693,776,000 ($669,024)	693,362,020 ($60,292)	8,387,138,000 ($729,316)

Notes:

1. Based on 134 households under the scheme with right to tree trimming and average annual benefit per household of $105
2. Based on 1,107 households (i.e., 81% of households within categories A, B, and C estimated to use fuelwood) and average value per household per year of $26
3. See Table 17
4. Based on market price of salt of 250, 000 VND/ton and annual productivity of 18,800/tons
5. Based on 384 households (from categories A and B), average annual net benefits of $592, and 4% Government tax
6. Based on 1,000 households in Group C, average annual net benefit of $396, and Government tax of 4%

the scheme represents a successful model which could be replicated at other mangrove sites with similar characteristics.

The fact that more than 50 percent of households settled in the area after 1990 when the implementation of the scheme was started and the scheme had been oversubscribed, points to the popularity and success of the new management scheme as a mechanism for improving the living conditions of the participating households. Households under the scheme were over $500 better off than households that did not participate in it.

While it costs the Government $80,500 per year (a net cost of under $2 per ha), the Can Gio mangrove management scheme can be considered cost-effective since it has promoted sustainable management of the mangrove resource, the benefits of which were estimated at $14 per ha. This estimate included only the direct use values of the mangrove resource, and, hence, the full benefits of sustainable management were greatly underestimated. The social and distributional benefits from implementing the scheme are therefore high.

Shrimp aquaculture was a profitable activity within the mangrove area. However, there were signs of decline in productivity as a result of water pollution and weak fries. Given the negative impacts of unsustainable aquaculture production throughout Southeast Asia, including Vietnam, this activity needs to be very carefully managed if the mangrove resource is not to be damaged and the high potential benefits from aquaculture sustained. Fish capture, while less profitable than aquaculture, could be improved by the introduction of new facilities and tools. The use of small size mesh nets needs to be carefully controlled so that over-exploitation of fish resources could be avoided.

The primary recommendation of this study is that the Can Gio management scheme should be strengthened and studies be undertaken to assess the potential for transferring this scheme to other mangroves in Vietnam. Possible initiatives to improve the scheme include:

a) The introduction of property right to the households to further increase the incentives for resource management.

b) The provision of technical assistance to households in aquaculture, especially shrimp rearing, to ensure sustainable production practices.

c) Development of initiatives for improving living standards of households in Groups B and C to prevent over-exploitation of mangroves.

d) Improved control and monitoring of fishing activities such as the size of nets used.

ENDNOTES

1 1975 was taken as the lower benchmark because the country was unified this year; 1990 was taken as the upper benchmark since it was the year when the management scheme was implemented

2 Since fuelwood collection was less labour intensive than the other activities, a lower wage rate was used.

LITERATURE CITED

Agricultural Unit of Can Gio District. 1996. Published Report.

Bann, C. 1997. The Economic Valuation of Mangroves: A Manual for Researchers. The Economy and Environment Program for Southeast Asia (EEPSEA).

Can Gio Mangrove Management Board. 1997. Published Report.

Hang, T. T. 1997. Economic Analysis of Mangrove Management Policy in Vietnam. Institute for Economic Research. Ho Chi Minh City, Vietnam. *Draft.*

Tuan, M. 1996. 'Building up the Strategy for Mangrove Management in Vietnam.' Proceedings of the Regional Seminar - Ecotone V: Community Participation in Conservation, Sustainable Use and Rehabilitation of Mangroves in Southeast Asia, Ho Chi Minh City, 8-12 January 1996.

World Bank. 1995. Vietnam Environmental Program and Policy Priorities for a Socialist Economy in Transition.

ACRONYMS

ha	Hectare
km	Kilometer
kg	Kilogram
HCMC	Ho Chi Minh City
TEV	Total economic value
cm	Centimeter
mm	Millimeter
t	Tons

Exchange rate:
US $1 = 11,500 VND

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ECONOMIC AND ENVIRONMENTAL IMPACTS OF RICE–SHRIMP FARMING SYSTEMS IN THE MEKONG DELTA

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ECONOMIC AND ENVIRONMENTAL IMPACTS OF RICE-SHRIMP FARMING SYSTEMS IN THE MEKONG DELTA

Tran Thanh Be and Le Canh Dung

SUMMARY

An in-depth survey of 300 households was conducted in 1996 covering two districts, Vinh Chau of Soc Trang province and Gia Rai of Bac Lieu province in the Mekong Delta to analyze the benefits and costs of three alternative systems: rice monoculture (RM), integrated rice-shrimp (RS), and shrimp monoculture (SM) in the coastal areas. The two main indirect costs studied were the cost of sedimentation and salinisation. Results showed that if rice farmers would be properly compensated for losses caused by salinisation from nearby shrimp farms, all rice systems would show positive net benefits. Many shrimp farms in the study area under the current management practices were found to be uneconomic even without internalizing the costs of salinisation. Inclusion of these external costs would mean more substantial losses in shrimp farming.

However, several cases of shrimp farming (especially RS-integrated rice-natural shrimp) exceeded the break-even production level of the system. Moreover, analysis of the best cases showed RS as the most profitable among the systems studied. Even when the opportunity cost for family labour was considered, it still gave the highest net benefit (5,989 VND/ha = US$521/ha) while the best rice monoculture ranked second (net benefit of 4,936 VND/ha = US$429/ha). Shrimp farming, despite currently poor performance, has generated more jobs (and consequently incomes) through more efficient use of family labour for local farmers in the dry season, when the rice farmers in the region usually produce nothing. This should be considered as the good social aspect of shrimp farming, which has helped make the shrimp farmers' lives better.

1.0 INTRODUCTION

The Mekong Delta (MD) represents one of the nine agroecological regions of Vietnam. It covers 4 million ha, 2.3 million ha of which are under rice cultivation (Vu 1987). It has an estimated 16.2 million inhabitants[1]. It is characterized by fertile alluvial soils deposited by the 4,500-km long Mekong River, and a temperate (non-typhoon) monsoon tropical climate. These natural advantages have made the MD Vietnam's most important region for rice production (National 60B Program 1987). The MD is well known as the "rice bowl and fish basket" of Vietnam. In recent years, rice production in the area has increased rapidly to around 50 percent of the national total rice production.

Many diverse farming systems are practiced within the delta based on farmers' understanding of the ecological and socio-economic characteristics of particular areas. This report focuses on important agricultural systems within the *coastal areas*. In coastal areas, saline water intrusion into inland areas during the dry season (5-6 months a year) has severely limited the availability of fresh water for 300,000 ha of agricultural land. Consequently, local farmers cannot practice traditional agricultural activities, particularly rice production in the dry season. In such areas, rice monoculture has improved through the introduction of high yielding varieties, chemical fertilisers, and improved irrigation systems. However, rice monoculture generally does not generate enough income to cover the living expenses of a farmer's household because of its high production cost and the low price of rice.

Local farmers in coastal areas have adapted to natural and socio-economic conditions by creating a new farming system known as the rice-shrimp integrated system. In this integrated farming system, farmers surround their rice fields with a dike, a trench-ditch system, and a water flap-gate and gap system. In the dry season, farmers take saline water containing shrimp seeds (*Metapenaeus spp.*) from local river-canal systems into their polders during spring tide. The shrimps grow on the natural feeds available in the polders and are harvested 1.5-2 months later.

At the beginning of the wet season, the farmers flush the saline water out of their polders using rain and fresh river water so that they can plant rice. Farmers also exploit natural shrimps during the wet season. Starting in the late 1980s, farmers have begun to extensively cultivate tiger shrimps (*Penaeus monodon*). They have also integrated fresh water shrimps (*Macrobrachium rosenbergii*) in their polders during the wet season (Tran 1994).

The integrated rice-shrimp system has rapidly extended to other sites throughout the brackish water areas of the MD largely because of high profits, mainly from shrimp production (Le *et al.* 1991; Nguyen *et al.* 1992; Nguyen, 1992). In the late 1980s to the early 1990s, agri-aquaculture farming systems covered tens of thousands of hectares in Bac Lieu, Soc Trang, and other coastal provinces of the MD (Vuong 1992; Le, 1993; Committee of Science and Technology of Minh Hai Province 1993; Tran 1994).

While many farmers favour this integrated farming system owing to its higher returns than rice monoculture, a number of environmental concerns have been associated with integrated rice-shrimp production. These concerns question the system's sustainability and economic viability (Tran 1994). Environmental impacts include salinisation (on-site and off-site as saline water leaks into adjacent rice fields) and sedimentation.

More recently, the high export price of shrimps has encouraged farmers to shift from the integrated rice-shrimp system to shrimp monoculture. Instead of growing rice during the rainy season, farmers keep the saline water in their fields for a longer period in order to raise a second crop of tiger shrimps. In this new semi-intensive system, stocking density ranges from one to two shrimp juveniles (post larvae) per square meter. Supplementary feeds are supplied to increase yields and, hence, profits. The sustainability and economic viability of this system are highly questionable. Pollution from shrimp feeds has become an added environmental concern.

In summary, while integrated rice-shrimp and shrimp monoculture systems are profitable for farmers because of the high value of shrimps, these systems' economic benefits to society are uncertain because of the environmental costs associated with them, which have not been accounted for by the private farmers.

2.0 METHODOLOGY

The objective of this study was to undertake an economic benefit-cost analysis of three alternative farming systems, namely: rice monoculture (RM), integrated rice-shrimp (RS), and shrimp monoculture (SM), in the coastal areas. The analysis hopes to provide information to policymakers and farmers on the most economical and socially optimal system in coastal areas over the long term. Environmental costs and benefits were included in the analysis.

Three hundred households practicing the three farming systems were surveyed to obtain information on the costs, benefits, and management practices of each system. The survey covered 12 villages belonging to six communes in the districts of Gia Rai (Bac Lieu province) and Vinh Chau (Soc Trang province). Rice monoculture was categorized further into rice fields adjacent to RS (RMA), rice fields adjacent to SM (RMB), and rice fields away from RS/SM (RMC). The number of households surveyed in each farming system was 67 SM, 66 RS, 56 RMA, 43 RMB, and 68 RMC *(Table 1)*. Of the respondents, 62 (21%) were female.

The study focused on two main indirect costs associated with shrimp farming systems: the cost of sedimentation and the cost of salinisation. The cost of sedimentation was estimated using the avertive approach, based on farmers' actual expenditures for removing sediments from their polders (trench and field surface).

Salinisation costs were estimated using two approaches: first, based on the annual cost of dike construction of rice farmers to avoid leakage/overflow of saline water from shrimp farms (the avertive behaviour approach); second, based on the cost of declines in rice production caused by the direct influences of salinity, the cost of delayed planting, and the cost of production

Table 1. Number of survey samples for each farming system

District	Commune	Village	SM	RS	RMA	RMB	RMC
Gia Rai	Long Dien	Dau La	13		3	7	3
		Thanh Hai		13	13		4
	LD Dong	Mot		24	10		10
	An Trach	Hiep Vinh	15				
		Thanh T.A	1			7	9
		Van Duc A				15	
Number	*3*	*6*	*29*	*37*	*26*	*29*	*26*
Vinh Chau	Vinh Chau	Sai Con	4	16	10		6
		Doc Rung		8	6	1	8
	Khanh Hoa	Ta Nien	6	2	2	1	2
		Chau Khanh	11	3	12	2	11
	Hoa Dong	Tra Teo	12			1	15
		Xom Moi	5			9	
Number	*3*	*6*	*38*	*29*	*30*	*14*	*42*
Total	6	12	67	66	56	43	68

SM - shrimp monoculture; RS - integrated rice-shrimp; RMA - adjacent to RS; RMB - adjacent to SM; RMC - away from RS/SM loss due to decline in area available for rice production caused by dike building (the change in the value of production approach).

The survey was conducted in such a way that the effect of salinisation on the productivity of the different systems could be isolated. The research team collaborated with the local authorities, particularly the Department of Agriculture and Rural Development of the districts, in conducting the household survey and gathering necessary data from farmers.

3.0 RESULTS

3.1 Socioeconomic Information

The age of farmers varied from 19 to 85 years, averaging 48 years. The average age of farmers was higher in Vinh Chau (50 years) than in Gia Rai district (46 years). In both districts, younger farmers more actively shifted to the rice-shrimp integrated system (RS) *(Table 2)*.

Farmers had attained a very low level of formal education. Most had studied up to the primary level only; none had a college or university education[2]. Farmers practicing SM or RS were more highly educated than RM farmers. Farmers in Vinh Chau had a lower education level than those in Gia Rai. Family members were also poorly educated. More than half (54.8%) of them studied in primary schools, only 2.5 percent and 0.8 percent were in high schools and colleges/ universities, respectively (Figure 1).

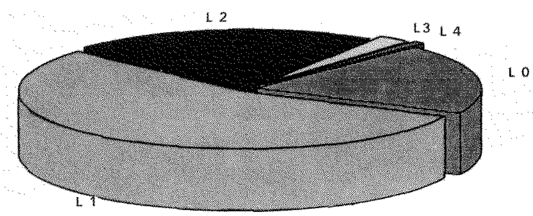


Figure 1. Educational levels of the surveyed household members in Gia Rai and Vin Chau, 1997

Table 2. Socio-economic data (averages) of the households in Gia Rai and Vin Chau, 1996

Farming System	Age in Years	Educational Level*	Years of Farming Experience			HH Size	Number of HH Labour	
			SM	RS	RM		Total	Female
Gia Rai								
SM	47.9	1.4	10.4			6.1	3.0	1.5
RS	43.8	1.2		8.8		6.4	2.9	1.4
RM	46.6	1.2			20.4	6.0	3.1	1.6
RMA	43.4	1.2			15.7	6.7	2.5	1.3
RMB	49.9	1.1			24.6	6.4	3.3	1.7
RMC	46.4	1.3			21.3	5.9	3.4	1.8
Vinh Chau								
SM	49.1	0.9	7.4	3.6	22.8	6.1	3.0	1.5
RS	50.8	1.2		4.7	23.6	6.4	2.9	1.4
RM	51.0	0.8	5.5	4.4	26.3	6.2	2.8	1.3
RMA	51.4	0.7	3.0	4.0	27.2	6.7	2.9	1.2
RMB		0.9	10.0	4.0	24.3	6.3	2.8	1.4
RMC		0.9	4.0	4.8	26.4	5.9	2.7	1.4

* *Education level*
1 = primary
2 = secondary
3 = high school
4 = college/university

The experience of farmers differed according to farming system. The average number of years of farming experience per system was RM - 20, SM - 10, and RS - 9 years in Gia Rai, and RM - 26, SM - 7, and RS - 5 years in Vinh Chau. This reflected the shift from traditional RM to SM and then RS. The farmers in Vinh Chau had more years of experience in RM, but SM and RS farming were adopted earlier in Gia Rai. In fact, shrimp and rice-shrimp integrated farming were initiated in Gia Rai and then spread to other areas of the MD.

In Vinh Chau district, farmers practiced more than one farming system at the same time (farmers in Gia Rai were not questioned on this issue). Rice was typically grown on a parcel of land for family food security. The rest of the land may be used for producing shrimps which were sold for cash. It was, therefore, sometimes difficult to clearly define the household category, whether rice or shrimp farmers. However, in this study, households were categorized into RM, SM, or RS based on the main farming system to which a household devoted a major proportion of its agricultural land.

Household size varied from 1 to 12 persons, with an average of 6 persons. Farming families had more children than the average Vietnamese family, which typically has 1-2 children. The household size in Vinh Chau was larger than in Gia Rai. About 48 percent of family members belonged to the main labour group (18-60 years old); women contributed 49 percent of the labour force[3]. In some families, however, no one belonged to the main labour group (i.e., where the family consisted only of elders over 60 years of age).

Total agricultural land owned by the households varied from 0.26 to 10.00 ha, with an average of 2.12 ha. The average land of households in Vinh Chau (2.18 ha) was bigger than in Gia Rai (2.06 ha). In both districts, households practicing SM had the biggest land area. Furthermore, the proportion of land farmers allotted to the main farming system varied greatly among systems and districts: it was smallest for SM in Vinh Chau (54%) but biggest for SM in Gia Rai (89%). Among the three main farming systems, the area used for SM was the biggest (average of 1.91 ha) followed by RS (1.57 ha) and RM (1.46 ha).

Agricultural land in Gia Rai was located at a lower elevation (as compared with the surrounding areas). It had a heavier structure (more clay), and was more acidic than that in Vinh Chau (Table 3). Among the three farming systems, RM fields were more acidic but less salty; they were in a lower elevation.

Table 3. Land area per household and land characteristics, 1996

Farming System	Agr. Land Area, ha	Main FS Area, ha	Elevation[1]	Structure[2]	Acidity[3]	Salinity[4]
Gia Rai						
SM	2.93	2.61	2.2	1.4	2.3	2.9
RS	2.26	1.61	1.8	1.8	2.3	2.4
RM	1.66	1.24	1.7	1.4	2.4	2.0
Vinh Chau						
SM	2.54	1.38	2.3	2.0	2.2	2.6
RS	1.73	1.52	1.9	2.5	2.3	2.8
RM	2.17	1.67	1.9	2.4	2.4	2.0

1/ Elevation (versus surrounding area): 1 = low 2 = medium 3 = high
2/ Structure: 1 = clay 2 = loamy clay 3 = loam 4 = sandy
3/ Acidity/Salinity: 0 = none 1 = slight 2 = medium 3 = heavy

Table 4 shows that the average gross income per household in 1996 was nearly 10 million VND (US$ 845/HH)[4]. Though there was little difference between the two districts, households practicing RS systems seemed to have higher gross incomes (9.9-11.4 million VND) than those who had adopted the SM system (8.2-9.1 million VND). Farming, the main activity of households, contributed 77.9 percent of their gross income.

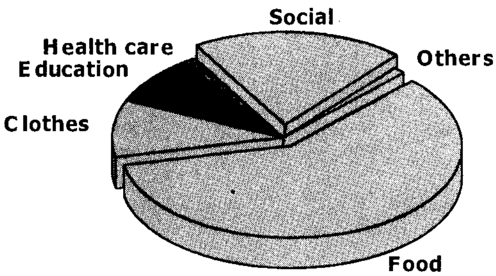
Total household expenses reached 11.8 million VND (US $103) in Gia Rai and 14.8 million VND (US$129/HH) in Vinh Chau. Farmers spent more on "living expenses" such as food, clothes, education, health care, social obligations, and others than on farming which received only 32.1 percent and 33.5 percent of the total household expenses in Gia Rai and Vin Chau, respectively. (This figure was net of operating costs such as seed, fertiliser, tax and irrigation, but excluded family labour and external costs.) Generally, food accounted for more than half of the households' living expenses, followed by social obligation[5].

The analysis showed that the average net income per household in 1996 was negative under each farming system *(Table 4)*. Losses ranged from 60,000 VND (US$5, RS in Gia Rai) to 6.6 million VND (US$574, RS in Vinh Chau). On the whole, only 69 households (23%) had a positive net income. More households in Gia Rai (27.9%) had positive net income than in Vinh Chau (18.3%). Among the three main systems, SM had the lowest (14.9%) number of households with a positive net income. There was not much difference in this aspect among the categories in Vinh Chau (16.7% for RS, 18.4% for SM, and 18.8% for RM). In Gia Rai, 40.5 percent of the RS households had positive net incomes and

Table 4. Household income and expenditure (1,000 VND)

Item	Gia Rai				Vinh Chau			
	SM	RS	RM	All	SM	RS	RM	All
Income								
Farming	5,574	10,018	7,273	7,629	6,041	8,689	7,949	7,620
Main system	4,046	6,457	5,079	5,222	2,081	6,783	5,935	5,144
Additional system	3,458	4,723	7,244	5,090	5,614	2,773	5,366	5,230
Off-farming [a]	1,979	2,456	1,349	1,702	1,841	2,243	1,451	1,656
Non-farming [b]	2,977	3,000	4,396	3,788	4,799	3,060	3,873	4,026
Total income [c]	8,192	11,365	9,632	9,784	9,123	9,906	9,751	9,625
Expenditures								
Farming	4,206	4,207	3,615	3,880	5,002	7,303	4,672	5,271
Main system	3,929	2,833	3,459	3,394	2,985	6,991	4,425	4,570
Additional system	2,674	3,087	2,523	2,917	3,318	2,341	2,097	2,870
Living	8,845	7,459	7,941	8,002	9,127	9,246	9,951	9,611
Food	4,385	4,165	4,251	4,257	4,973	5,495	5,395	5,312
Clothes	796	728	745	751	689	818	942	856
Education	2,063	720	867	1,072	630	598	782	703
Health Care	523	675	851	743	882	834	746	796
Social obligations	1,516	1,324	1,521	1,470	1,519	1,394	1,536	1,504
Others	1,288	245	909	833	1,010	486	1,239	1,069
Total	13,051	11,465	11,555	11,828	13,757	16,549	14,623	14,785
Net Income	-4,860	-60	-1,924	-2,034	-4,634	-6,643	-4,872	-5,160

[a] Activities as hired labours in farming for other farmers
[b] All activities, except on-farm and off-farm, generating incomes for households
[c] Total income was not derived by adding up the listed sources because those were averages from different samples (i.e., not all households had off-farm and non-farm activities)



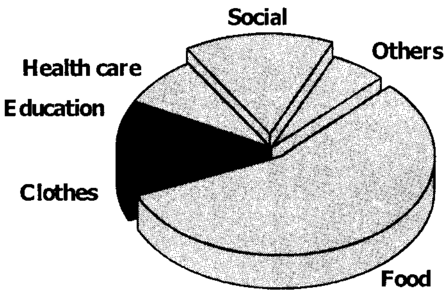


Figure 2. Components of the households' living expenses

as low as 10.3 percent in the case of SM households. Figure 2 shows the components of the household expenditures in terms of percentage share.

3.2 Rice Monoculture (RM)

3.2.1 Production and benefit-cost analysis

Farmers in Gia Rai district used only modern high-yielding rice varieties for RM, while those in Vinh Chau had adopted a wide range of rice varieties. Varieties used were traditional, glutinous, modern, combination of traditional and glutinous, and aromatic.

Rice yields in RM systems varied from close to zero to 7 t/ha, averaging 3.22 t/ha *(Table 5)*. They were higher in Gia Rai (3.63 t/ha) than in Vinh Chau (2.83 t/ha). This may be partly explained by the use of high-yielding rice varieties in Gia Rai. Average rice yields in RMB (fields adjacent to SM) were the lowest among the different types of RM systems in both districts, but more so in Gia Rai where rice yields in RMA (fields adjacent to RS) and RMC (fields not adjacent to neither RS nor SM) were higher than 4 t/ha. Average rice yields in RMC were the highest.

Almost all farmers sold their products on site. The farm gate price of rice depended on the variety and grain quality. Normally, aromatic varieties commanded the highest price, followed by glutinous, traditional, and modern rice varieties. As a result, rice price in Vinh Chau (1,297 VND/kg on the average) was higher than in Gia Rai (1,175 VND/kg). Interestingly, among different systems, rice produced in RMB had the lowest price (1,149 VND/kg for RMB compared with 1,249 and 1,253 VND/kg for RMA and RMC, respectively). This was true also in Gia Rai where farmers used only high-yielding varieties.

The above variations in yield and price indicated that the gross value of rice production varied widely, from zero to nearly 10 million VND per hectare, with an overall average of 3,961,000 VND/ha (US$ 344/ha). Because of the low yield and price of rice from RMB, the gross value of this system was lower (2,998,000 VND/ha, US$ 260/ha) than that of RMA and RMC, whose gross values were over 4 million VND/ha (US$ 350/ha).

Production costs consisted of materials (seed, fertilizer, and chemicals), machine rental, hired labour, family labour, tax, and irrigation costs. Total costs were estimated

Table 5. Benefit-cost analysis of rice monoculture (RM), 1996

District System	Rice Yield (T/ha)	Rice Price (VND/kg)	Gross Value 000VND/ha	Production Cost 000 VND/ha		Net Benefit 000 VND/ha	
				Total	Without Family Labour	Total	Without Family Labour
Vinh Chau							
RMA	2.59	1,257	3,277	2,769	2,294	508	983
RMB	2.28	1,340	2,861	2,973	2,431	-112	430
RMC	3.18	1,433	4,212	3,545	3,017	667	1,195
Average	2.83	1,358	3,670	3,186	2,674	484	997
Gia Rai							
RMA	4.04	1,225	4,982	3,514	2,650	1,469	2,333
RMB	2.76	1,111	3,065	3,662	2,809	-598	256
RMC	4.20	1,146	4,892	3,788	3,100	1,104	1,793
Average	3.63	1,159	4,267	3,655	2,851	612	1,416
Overall							
RMA	3.28	1,242	4,083	3,121	2,462	962	1,621
RMB	2.61	1,187	2,998	3,438	2,686	-440	312
RMC	3.57	1,323	4,472	3,638	3,048	834	1,423
Average	3.22	1,261	3,961	3,415	2,760	547	1,201

with and without the cost of family labour. The cost of family labour was based on the opportunity cost of labour (i.e., the wage rate of hired labour for similar activities undertaken by the family, multiplied by the time spent working). The opportunity cost of labour averaged 655,000 VND/ha (US$ 57/ha) and accounted for 19.2 percent of the total cost. This cost was the most significant in RMB among the different RM systems.

Land use tax (which included the cost of irrigation) has been set by the local government as the amount of paddy/ha based on the potential productivity of the land[6]. However, farmers paid this tax in cash based on the price of rice set annually by the government. This tax may be adjusted by a local evaluation council if events out of farmers' control had seriously damaged the production. From the survey sample, the tax cost 321,000 VND/ha (US$ 28/ha), representing 9.4 percent of total production cost or 8.1 percent of gross value. Land use taxes were similar in Gia Rai and Vinh Chau. However, in each district and consequently overall, the cost for RMC was higher than those for RMA and RMB.

Overall, the average total production cost for the three systems was 3,415,000 VND/ha (US$ 297/ha). In both districts, the production cost was highest in RMC followed by RMB, and RMA. However, it was higher in Gia Rai than in Vinh Chau.

The overall net benefit of rice production was 547,000 VND/ha (US$ 48/ ha). When the cost of family labour was excluded, the net benefit of RM was 1,201,000 VND/ha (US$ 104/ha). Rice production in Gia Rai offered farmers higher net benefits than in Vinh Chau (612,000 VND/ha vs. 484,000 VND/ha with family labour cost, and 1,416,000 VND/ha vs. 997,000 VND/ha without family labour costs). Interestingly, RMB farmers in both districts suffered losses resulting in an overall net loss of 440,000 VND/ha (US$ 38/ha).

The high net benefits of RMA in Gia Rai made this system the most profitable among the different rice monoculture systems. The BCR (ratio of net benefit to total cost) of RMA was 0.31 and that of RMC was 0.23. The BCR of RMC was -0.13.

3.2.2 The cost of salinisation

Shrimp farming using brackish water in RS or SM systems had caused adverse externalities to rice production in adjacent fields (RMA or RMB). These were the direct and indirect effects of salinisation caused by leakage and/or overflow of brackish water from shrimp polders to rice fields. Most (84%) RMA and RMB farmers reported that leakage and/or overflow of brackish water from shrimp polders in the dry season decreased rice production in certain areas of RMA and RMB fields. Because of this, rice farmers waited for rain to flush out salinity from their fields. Consequently, this delayed planting led to risks at later stages of rice growth such as damages caused by birds, rats, insects, and even lack of fresh water. However, only 22 percent of the rice farmers surveyed estimated the cost of such damages. To avoid the foreseen influences of salinisation, the majority of rice farmers (69%) built dikes around their land. Unfortunately, the leakage could not be completely prevented because the dikes were not high and large enough. This lessened the area of land available for rice culture, thereby decreasing rice production. All this unexpected cost to rice production was equivalent to the cost of salinisation.

The cost of salinisation in RMA or RMB was estimated using both the change in production approach and the avertive behaviour approach *(Table 6)*. To avoid double counts, averages were based on the whole surveyed sample for each system and district. Local costs quoted by farmers were used in the calculations. Overall, the average area of the rice field affected by direct salinisation was 3,853 m^2/ha. However, the affected area differed between the two systems (3,082 m^2 for RMA and 4,938 m^2 for RMB) and the two districts (4,493 m^2 in Vinh Chau and 3,352 m^2 in Gia Rai). In addition, salinity had different effects, depending on the location. This had

Table 6. Salinisation cost analysis of rice monoculture (RM)

District/ System	Cost of Production Decline[1]	Cost of Planting Delay[2]	Annual Cost of Dike Construction[3]	Cost of Production Loss[4]	Total Cost of Salinity
Vinh Chau					
RMA	1,014	308	64	164	1,550
RMB	708	93	67	112	908
Average	*915*	*238*	*65*	*147*	*1,365*
Gia Rai					
RMA	413	34	22	73	542
RMB	845	118	31	111	1,104
Average	*640*	*78*	*27*	*93*	*838*
Overall					
RMA	730	179	44	121	1,073
RMB	800	110	42	111	1,064
Average	*761*	*148*	*43*	*117*	*1,069*

[1] Production declines due to direct effects of salinisation from shrimp farming polders
[2] Delayed planting as a result of externalities owing to salinisation (waited for rain to flush out salinity leading to other risks)
[3] Building dikes to avoid salinisation
[4] Production loss due to the loss of land available for rice production caused by building dikes

led to varying production declines, from 349 kg/ha for RMA to 868 kg/ha for RMB both in Gia Rai. The cost of production decline, therefore, varied greatly[7]. There was a significant difference in this cost between the two districts, which was 915,000 VND/ha (US$ 80/ha) in Vinh Chau and 640,000 VND/ha (US$ 56/ha) in Gia Rai. However, the difference was not much between RMA and RMB, owing to the low price of rice produced in RMB. The cost of delayed planting varied widely between systems and districts, ranging from 34,000 VND/ha (US$ 3/ha) for RMA in Gia Rai to 304,000 VND/ha (US$ 26/h) for RMA in Vinh Chau[8]. The overall average was 148,000 VND/ha (US$ 13/ha).

The dikes in RMA fields in Gia Rai were small (154m^2), while those of the other systems and other districts were large (429-519 m^2). Hence, the annual cost of dike construction in Vinh Chau (65,000 VND/ha) was twice as high as that in Gia Rai (27,000 VND/ha)[9]. The overall average was 43,000 VND/ha (US$ 4/ha).

The cost of lost production due to area loss for dike construction was also significantly higher in Vinh Chau than in Gia Rai[10]. It was highest in RMA. Overall, this cost was estimated to average 117,000 VND/ha (US$ 10/ha). Adding the four components mentioned above, the total cost of salinisation varied between systems and districts. This cost was higher in Vinh Chau than in Gia Rai, but was the same for RMA and RMB. Overall, the average cost of salinisation was 1,069,000 VND/ha (US$93/ha).

3.3 Shrimp Monoculture (SM)

There were different aquaculture systems: natural shrimp; tiger shrimp; combined natural and tiger shrimp; and crabs or combined crab and shrimp. Among these, single shrimp species systems were the most commonly adopted in the region (75% of sample survey). However, farmers in Gia Rai preferred natural shrimps (59%), while those in Vinh Chau preferred tiger shrimps (80%).

There were three main systems of shrimp monoculture in the study sites: natural shrimp, tiger shrimp, and combination of natural and tiger shrimps. Sometimes crabs or a combination of shrimps and crabs were farmed. In Vinh Chau district, single shrimp species systems were preferred (of 38 cases surveyed, 50% were for natural shrimps and 45% were for tiger shrimps). In Gia Rai district, farmers preferred natural shrimps (76% of cases) to tiger shrimp (4%). The combination system was more commonly practiced in Gia Rai (20%) than in Vinh Chau (5%) *(Tables 7 and 8)*.

Shrimp yields in 1996 were as low as 69 kg/ha for natural shrimps and 44 kg/ha for tiger shrimps. Shrimp yields in polders combining the two shrimp types or with crabs were higher than those in polders with only one shrimp type. Overall, shrimp yields were as high as 86 kg/ha and 46 kg/ha for natural and tiger shrimps, respectively[11]. In both districts, yields of natural shrimps were higher than those of tiger shrimps.

The price of tiger shrimps (averaging 74,300 VND/kg = US$ 6.5/kg) was 4.6 times higher than that of natural shrimps (16,200 VND/kg = US$ 1.4/kg). The local price of natural shrimps was higher in Vinh Chau (due to bigger size of shrimps) than in Gia Rai.

Owing to the differences in shrimp price and yield, the gross value of different shrimp production systems varied widely, from zero to over 15 million VND/ha (US$ 0-1300/ha). The gross value of SM averaged 2,268,000 VND/ha (US$ 197/ha). The tiger shrimp system had a higher average gross value despite its lower yields than the

Table 7. Benefit-cost analysis of shrimp monoculture

Citeria	Vinh Chau			Gia Rai			Total		
	Natural	Tiger	Over*	Natural	Tiger	Over*	Natural	Tiger	Over*
No. of HH	19	17	38	22	1	29	41	18	67
Yield, kg/ha									
Natural	89	-	89	52	-	83	69	-	86
Tiger	-	46	46	-	3	44	-	44	46
Price, 000VND/kg	17	75	-	15	?	-	16	74	-
Gross Value	1,516	3,432	2,501	771	476	1,964	1,116	3,268	2,268
Prod. Cost	1,180	4,704	2,873	597	1,070	994	867	4,502	2,060
Const. Cost	348	818	550	204	215	197	271	785	397
Sedim. Cost	617	963	804	885	621	869	761	944	833
Total Cost	2,145	6,485	4,227	1,685	1,906	2,061	1,898	6,231	3,289
Net Benefit	-629	-3,053	-1,727	-914	1,430	-97	-782	-2,963	-1,021

Note: All figures represent average estimates based on survey result
* Overall figure comprised natural, tiger, and combined shrimp systems

Table 8. Main production costs of shrimp monoculture

Component	Vinh Chau			Gia Rai			Both Districts		
	Natural	Tiger	Over*	Natural	Tiger	Over*	Natural	Tiger	Over*
Seed	0.0	35.1	17.9	0.0	11.3	9.3	0.0	33.8	14.4
Feed	0.0	23.1	11.0	0.0	25.8	1.0	0.0	23.3	6.9
Derris	2.1	3.8	2.9	1.4	14.5	2.4	1.8	4.4	2.7
Labour									
Total	76.2	32.3	53.8	46.2	19.3	44.8	51.2	31.6	50.2
Hired	1.3	2.8	1.9	2.6	0.0	1.9	1.96	2.6	1.9
Family	74.9	29.5	51.9	43.6	19.3	42.9	59.3	29.0	48.3
Tax and irrigation	21.7	4.9	13.7	47.6	23.2	38.7	34.6	5.9	23.8

* Overall figure comprised natural, tiger, and combined shrimp systems

natural shrimp system (3,268,000 VND/ha = US$ 284/ha compared with 1,116,000 VND/ha = US$ 97/ha) because of the formers high price. Higher yields and prices of shrimps had made SM better in Vinh Chau than in Gia Rai in terms of the gross value of production (overall average of 2,501,000 VND/ha = US$ 217/ha compared with 1,964,000 VND/ha = US$ 170/ha).

Production cost consisted of seed, feed, fertiliser, derris[12], chemicals, machinery, labour, tax, and other costs (e.g., tools, loan interest). Overall, it averaged 2,060,000 VND/ha (US$ 179/ha). However, it was higher in Vinh Chau than in Gia Rai.

Expenditure on shrimp seed (33.8%) and feeds (23.3%) represented a significant part of the production cost of tiger shrimp farming. On the other hand, natural shrimp farming had no such expenditure. This resulted in a big difference in production costs between the tiger shrimp system (4,502,000 VND/ha = US$ 391/ha) and natural shrimp system (867,000 VND/ha = US$ 75/ha).

Shrimp farming required a lot of labour. Hence, as a result, labour cost was also a significant factor in the total production cost (50.2%), especially in the natural shrimp farming system where total production cost was low. However, farmers mainly used their own family labour, particularly in guarding farms at night. Family labour cost was estimated to account for up to 48.3 percent of total cost.

Land use tax and irrigation costs were set by the government as in the case of rice monoculture. Theoretically, this cost should not vary much. However, owing to a very low production as a result of mass mortality caused by virus diseases in shrimps in 1996, the local government set a declining tax and even granted tax exemption to many farms. Farmers usually paid land use tax of zero to 503,000 VND/ha, or an average of 208,000 VND/ha (US$ 18/ha). This cost was higher in Gia Rai (230,000 VND/ha) than in Vinh Chau (191,000 VND/ha), and in natural shrimp system (208,000 VND/ha) than in tiger shrimp system (186,000 VND/ha) because of higher rates of mortality in the latter. This cost thus accounted for 23.8 percent of the total production cost, ranging from 5.9 percent for tiger shrimp to 34.6 percent for natural shrimp systems.

Polders were constructed for long-term use, therefore farmers tended not to consider this cost in their annual assessment of costs. In this study, the annual cost of capital investment for polder construction (converted to 1996 value) was estimated based on an average interest rate of 12 percent/year. Overall, this cost was 397,000 VND/ha (US$ 35/ha), which was equal to 19.2 percent of the total production cost. It was higher in the tiger shrimp system (which had more trenches and bigger dikes) than in the natural shrimp system; it was also higher in Vinh Chau than in Gia Rai.

Sedimentation cost was estimated using the avertive behaviour approach. This was based on the annual expenditures of farmers to remove sediment deposited on the field surface (mostly once every 3-5 years) and trench system of the polder (1-3 times per year), mainly using hired labour. This was a significant cost in shrimp production, equal to 40.4 percent of total production cost. In Gia Rai district, this was 86.8 percent of the total production cost.

The total cost is the sum of production, construction, and sedimentation costs; it averaged 3,289,000 VND/ha (US$ 286/ha). This cost was significantly higher in the tiger shrimp system (6,231,000 VND/ha = US$ 542/ha) than in the natural shrimp system (1,898,000 VND/ha = US$ 165/ha). It was also higher in Vinh Chau (4,227,000 VND/ha = US$ 368/ha) than in Gia Rai district (2,061,000 VND/ha = US$ 179/ha).

Family labour was used extensively in shrimp production and in removing sediments from the fields. The cost of family labour was estimated based on the amount of time of family labour used for farming (number of days) and the average wage of hired labour for the same work. Overall, it was estimated at 1,023,000 VND/ha (US$ 89/ha), which was 31.1 percent of total cost of shrimp production. Because of their high value, tiger shrimp farms used family labour for guarding farms, particularly at night, to avoid theft. The opportunity cost of labour was therefore higher in the tiger shrimp system (1,801,000 VND/ha = US$ 156/ha) than in the natural shrimp system (696,000 VND/ha = US$ 60/ha), although the production cycle for the former was shorter than the latter.

Considering the total cost, shrimp production resulted in an annual net loss of 1,021,000 VND/ha (US$ 89/ha). Farmers in Gia Rai had smaller losses (97,000 VND/

ha = US$ 8/ha) than those in Vinh Chau district (1,727,000 VND/ha = US$ 150/ha). Tiger shrimp was less successful than natural shrimp farming; net loss of tiger shrimp farms averaged 2,963,000 VND/ha (US$ 258/ha) while that of natural shrimp farms was only 782,000 VND/ha (US$ 68/ ha).

Excluding the cost of family labour, net benefits of shrimp farming in 1996 averaged at 2,000 VND/ha only. The single shrimp species systems had average losses of 86,000 VND/ha (US$ 7/ha) for natural shrimps to 1,162,000 VND/ha (US$ 101/ha) for tiger shrimps. These meant that the combination system offered higher benefits. In this case, shrimp farmers in Vinh Chau suffered an average loss of 305,000 VND/ ha (US$ 26/ha) because of big losses among tiger shrimp farms, while those in Gia Rai obtained a net benefit of 402,000 VND/ha (US$ 35/ha).

3.4 Rice-Shrimp Integrated System (RS)

Rice yields differed between systems, from an average of only 91 kg/ha for tiger shrimp systems in Gia Rai to 2,046 kg/ha for combined shrimp systems in Vinh Chau *(Table 9)*. For the two single species systems, rice yields were higher in the natural shrimp system (1,444 kg/ha) than in the tiger shrimp system (1,252 kg/ha). In general, there was a big difference in rice yields between the two districts because of the lower rice yields in single shrimp and combined shrimp systems in Gia Rai than in Vinh Chau.

In general, natural shrimp yields (117 kg/ha) were much higher than tiger shrimp yields (34 kg/ha), particularly in Gia Rai district where the latter's average yield was 19 kg/ha while that of the former was 124 kg/ha. On the other hand, tiger shrimp yield in Vinh Chau was twice that in Gia Rai, but the natural shrimp yield was much less in Vin Chau.

Rice prices varied widely, from 890 VND/kg to 1,496 VND/kg, with an overall average of 1,295 VND/kg (US$ 0.113/kg). This, coupled with the wide difference in rice yields, resulted in a great variation in the gross value of rice production in the RS systems. High prices and rice yields in Vinh Chau led to its higher gross values for rice production (2,019,000 VND/ha = US$ 176/ha) relative to Gia Rai (1,467,000 VND/ha = US$ 128/ha). While the overall gross value of rice production was 1,714,000 VND/ha (US$ 149/ha), that for combined rice-tiger shrimp systems was 1,866,000 VND/ha (US$ 162/ha) owing to the high price of rice (1,490 VND/kg). The latter appear to be the best among different RM systems.

With the higher yields of natural shrimp and combined rice-crab production, gross aquacultural production values in Gia Rai (3,000,000 VND/ha) were a bit higher than in Vinh Chau (2,617,000 VND/ha). Overall, the gross value from aquacultural component of RS systems was 2,828,000 VND/ha (US$ 246/ha). In terms of gross value, combination systems, particularly with crabs, proved better than single species systems. Concurrently, the tiger shrimp systems offered higher gross values than natural shrimp systems, especially in Vinh Chau, on account of the high price for tiger shrimps.

Local farmers grew many kinds of crops on the dikes of their RS polders, including food crops (cassava, sweet potato, corn, tomato, chili, onion, eggplant and fruits) and industrial crops (sugar cane, coconut palm). However, only a small number of farmers (15 cases, mostly in Gia Rai district) used part of the dike for this activity. This resulted in a very low overall gross value for upland crop production of 169,000 VND/ha (US$ 15/ha). However, in

Table 9. Benefit-cost analysis of the integrated rice-shrimp system

District System	Yield (kg/ha)			Gross Value (000VND/ha)				Cost (000VND/ha)					Net Benefit (000VND/ ha)
	Rice	Tiger Shrimp	Natural Shrimp	Total	Rice	Shrimp & others	Crops on Dike	Prod. Cost	Const. Cost	Sedim. Cost	Family Cost	Total Cost	
Vinh Chau													
Natural	1,509	-	64	2,888	1,790	1,097	0	2,176	180	546	782	2,902	-14
Tiger	1,397	41	-	5,061	2,090	2,826	145	5,877	444	521	1,566	6,842	-1,781
Combined	2,046	13	88	4,265	2,214	2,052	0	4,783	180	557	2,207	5,520	-1,254
Crab	1,000	18	50	3,385	1,200	2,185	0	2,158	768	542	435	3,468	-82
Overall	*1,422*	*38*	*71*	*4,751*	*2,019*	*2,617*	*116*	*5,310*	*430*	*526*	*1,481*	*6,266*	*-1,515*
Gia Rai													
Natural	1,438	-	117	401-	1,721	2,177	121	2,134	187	935	1,013	3,256	763
Tiger	91	26	-	2,570	81	2,335	154	1,904	42	1,200	495	3,146	-576
Combined	817	13	125	5,342	918	3,970	455	2,547	423	1,386	710	4,355	987
Crab	1,435	-	146	7,190	1,658	5,177	355	3,187	145	1,007	1,534	4,399	2,851
Overall	*1,244*	*19*	*124*	*4,680*	*1,467*	*3,000*	*213*	*2,370*	*200*	*1,031*	*1,029*	*3,600*	*1,080*
Overall													
Natural	1,444	-	112	3,925	1,727	2,081	111	2,137	187	902	994	3,226	699
Tiger	1,252	39	-	4,784	1,866	2,772	146	5,436	399	596	1,447	6,431	-1,674
Combined	1,168	13	114	5,034	1,288	3,422	325	3,186	353	1,149	1,138	4,688	346
Crab	1,338	18	134	6,345	1,556	4,512	276	2,959	284	903	1,290	4,146	2,199
Overall	*1,324*	*34*	*117*	*4,712*	*1,714*	*2,828*	*169*	*3,686*	*303*	*805*	*1,231*	*4,794*	*-82*

NOTE: Prices used in calculation were based on prices stated by farmers. The average prices of main products were:
Rice: 1,290 VND/kg (US$ 0.11/kg)
Tiger shrimp: 65,420 VND/kg (US$ 5.69/kg)
Natural shrimp: 19,140 VND/kg (US$ 1.66/kg)

some cases, the gross value was higher than the gross returns from components of the main farming system (i.e., shrimp and rice). In the past, farmers showed little interest in crop production because of the high profits from shrimp farming. More attention was started to be paid to this activity, which should be further studied and encouraged as a means of generating income for farmers.

The total gross value of the RS systems is the sum of the gross values for rice, aquaculture, and upland crops. Average gross value was estimated at 4,712,000 VND/ha (US$ 410/ha). There was not much difference between the two districts; differences were large among systems. The gross value of combined systems, especially with crabs, was the highest (6,345,000 VND/ha = US$ 552/ha), while that of natural shrimp systems was the lowest (3,925,000 VND/ha = US$ 341/ha). However, in Vinh Chau district, the tiger shrimp system, which had a total gross value of 5,061 000 VND/ha (US$ 440/ha), was the best system.

In general, the aquacultural component represented the main part of total gross value (60%). This was 64 percent in Gia Rai and 55 percent in Vinh Chau. Overall, the contribution of the rice component to the total gross value overall was 36.4 percent: 31.3 percent and 42.5 percent in the two districts, respectively.

The overall average production cost, which included the cost of materials, machine rental, labour (hired and family), land use tax, and irrigation cost, was 3,686,000 VND/ha (US$ 320/ha). It was quite different between the two districts: 5,310,000 VND/ha (US$ 462/ha) in Vinh Chau and 2,370,000 VND/ha (US$ 206/ha) in Gia Rai. The production cost of natural shrimp systems was the lowest (2,137,000 VND/ha = US$ 186/ha) while that of tiger shrimp systems was the highest (5,436,000 VND/ha = US$ 473/ha). This can be explained by the high cost of shrimp juveniles in tiger shrimp systems.

To practice the integrated systems, local farmers had to construct structures in their rice fields. In this analysis, polders were assumed to last for a very long time, and construction costs were annualized (based on present values). The overall annual cost was estimated at 303,000 VND/ha (US$ 26/ha). It was higher in Vinh Chau (430,000 VND/ha = US$ 37/ha) than in Gia Rai (200,000 VND/ha = US$ 17/ha). The cost of polder construction was likewise highest in tiger shrimp systems and lowest in natural shrimp systems. In order to maintain their polders, farmers had to remove sediments deposited during shrimp production. Sediments were removed from the trench once or twice a year, and from the field surface every 3-4 years. Using the avertive behaviour approach, sedimentation cost was estimated to be as high as 805,000 VND/ha (US$ 70/ha). The various systems in Vinh Chau had similar values, with an average cost of 526,000 VND/ha (US$ 46/ha). In Gia Rai district, the average was much higher at 1,031,000 VND/ha (US$ 89/ha).

Family members participated in harvesting, guarding farms, and removing sediments. The opportunity cost of labour was estimated at 1,231,000 VND/ha. It was higher in Vinh Chau (1,481,000 VND/ha = US$ 129/ha) than in Gia Rai (1,029,000 VND/ha = US$ 89/ha). The results showed that use of family labour was lower in natural shrimp farming than in other systems, particularly in comparison with tiger shrimp systems.

The total cost of production, construction, and sedimentation of rice-shrimp systems was 4,794,000 VND/ha (US$ 417/ha). It was notably different between the two districts and among systems. Production costs were higher in Vinh Chau (6,266,000 VND/ha = US$ 545/ha) than in Gia Rai (3,600,000 VND/ ha = US$ 313/ha); they were highest in the tiger shrimp system (6,431,000 VND/ha = US$ 559/ha) and lowest in the natural shrimp system (3,226,000 VND/ha = US$ 280/ha). They contributed 76.9 percent of the total cost, while sedimentation cost accounted for 16.8 percent, and construction cost, 6.3 percent. Production costs were especially important in Vinh Chau district where they contributed up to 84.7 percent of total costs. Sedimentation costs were more important in Gia Rai (28.6%) than in Vinh Chau (8.4%). Family labour (included in production and sedimentation costs) was only 25.7 percent of total cost.

Owing to high operating costs, all systems in Vinh Chau incurred losses, from 14,000 VND/ha (US$ 1.2/ha) in the natural shrimp system to 1,781,000 VND/ha (US$ 155/ha) in the tiger shrimp system. This resulted in the district's overall loss of 1,515,000 VND/ha (US$ = 132/ha). On the other hand, the net benefit in Gia Rai was 1,080,000 VND/ha (US$ 94/ha) which resulted from the positive net benefits from all systems, with the exception of tiger shrimp systems. On the whole, however, both districts suffered an overall loss of 82,000 VND/ha (US$ 7/ha). The loss of 1,647,000 VND/ha (US$ 143/ha) in the tiger shrimp system offset the positive net benefits in the other systems, which ranged from 346,000 VND/ha (US$ 30/ha) for combined shrimp to 2,199,000 VND/ha (US$ 191/ha) for combined crab systems.

3.5 Polder Components of SM and RS Systems

SM or RS polders consisted of three main components: a surrounding dike, a trench system, and split field (Figure 3). Sedimentation caused by shrimp farming increased the dike area over time and, consequently decreased the field area available for rice production (in RS systems) or shrimp production (trench and field area in both RS and SM systems). However, farmers commonly could not give accurate information on the structure of their polders in the past (they did not pay attention to this issue). Tables 10 and 11 present results and analysis based on such less reliable information obtained from farmers.

In 1996, dike systems occupied an average of 33.30 percent of the total SM polder area. Over a period of eight years (average age of polders indicated by the farmers), this area increased by 0.44 percent per year. While the current proportion of the dike in SM systems was almost the same between the two districts, its annual change in Gia Rai was much higher than that in Vinh Chau. In 1996, the average proportions of dike and field were 27.22 percent and 51.24 percent of total area for RS polder, respectively. Over six years, the dike area increased annually by 0.28 percent while the field surface decreased by 0.51 percent. There were large differences between the area of dike and field, and their change over time in the two districts.

Further analysis using regression methods showed a close relationship between component areas and age *(Table 11)*. The correlation coefficients (r^2) relating the area of the dike to age (grouped into four groups of 5 years) in Gia Rai were 0.43 and 0.66 for SM and 0.86 and 0.40 for RS systems. These values indicated that sedimentation was a risk for both rice and shrimp production in RS and SM systems, threatening the sustainability of these systems.

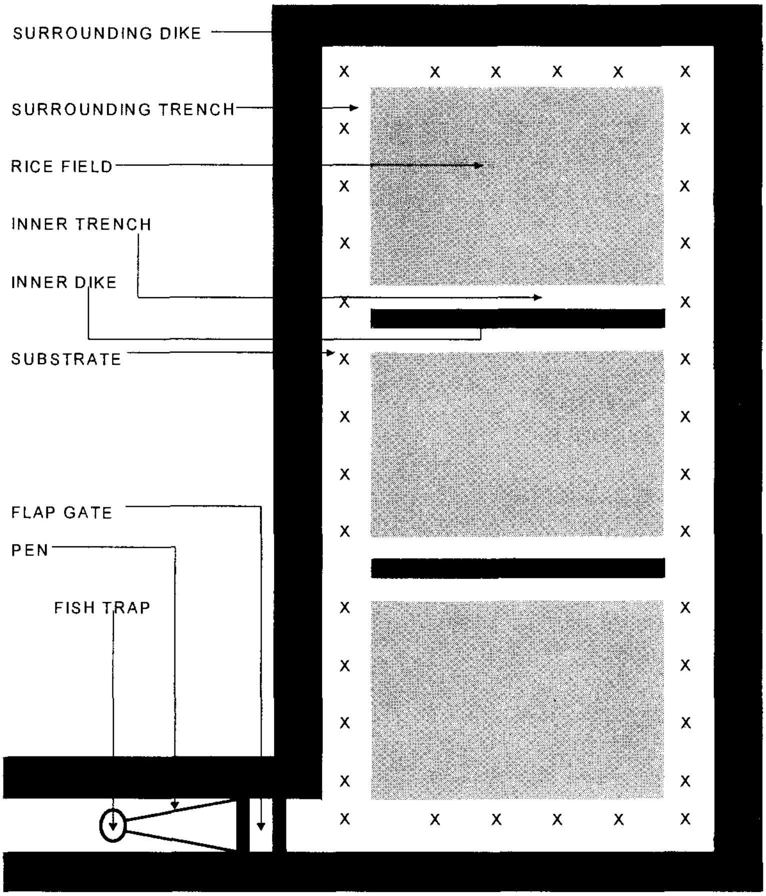


Figure 3. Typical rice-shrimp polder design

Table 10. Dike and field components of shrimp monoculture and rice-shrimp integrated system polders

System		Component in 1996		Change/year		Time Period
		Dike	Field	Dike	Field	(Year)
SM	Vinh Chau	34.35	-	0.37	-	7.13
	Gia Rai	31.93	-	0.53	-	10.14
	Overall	33.30	-	0.44	-	8.43
RS	Vinh Chau	20.57	60.52	0.07	-0.07	3.20
	Gia Rai	32.60	43.72	0.46	-0.87	8.43
	Overall	27.22	51.24	0.28	-0.51	6.09

Table 11. Relationship between dike area and farm age for monoculture and rice-shrimp integrated system in Gia Rai

Age Range (year)	Average Age (year)		Dike(%)		Dike Change(%/ year)	
	SM	RS	SM	RS	SM	RS
1 - 5	2.4	3.5	38.1	26.4	0.09	0.16
6 - 10	8.5	7.4	20.2	35.1	0.49	0.47
11 - 15	12.9	13.7	30.4	36.3	0.79	1.54
> 15	19.3	17.8	47.8	37.6	0.51	0.36
Correlation Coefficient			0.4284	0.8588	0.6655	0.4046

3.6 Comparison of the Different Systems

3.6.1 Yield and production

Analysis of yield and production

Production and yield differed for some systems *(Table 12)*. Production (kg/ha) of a system is calculated on the basis of the whole polder area, while yield (kg/ha) was based on actual area used to produce each product. Therefore, in the case of RM, yield and production were the same because farmers used the whole area for rice production (assuming the dike area was not significant). However, rice fields were just one component of the RS polder; and in some cases, farmers grew rice on only part of the rice field. For example, if the polder covered one hectare, only two-thirds of this might be used for rice production. Therefore, in RS systems, rice yield was higher than rice production. In the same way, shrimp yield was higher than shrimp production because yield was based on the sum of trench and field area (excluding dike area) while production was based on the whole polder area.

As mentioned in the RM section (section 3.2), RMC rice yields were higher than RMA's or RMB's. Overall, their average yields (and production) were 3571 kg/ha, 3277 kg/ha, and 2607 kg/ha, respectively. They were all higher than overall rice yield and production of RS, which was 2466 kg/ ha and 1324 kg/ha, respectively. Rice production levels of RMA and RMB were 91.8 percent and 73.0 percent, respectively of RMC's while that of RS is only 37.1 percent. In addition, RS rice yields in Gia Rai (2,717 kg/ha) were higher than in Vinh Chau (2,404 kg/ha) while rice production in Gia Rai (1,244 kg/ha was lower than in Vinh Chau (1,422 kg/ha). This was largely explained by the fact that the dike area in Gia Rai was larger than in Vinh Chau.

The comparison of rice yields in different systems is presented in Figure 4.

Overall, natural shrimp yields (178 kg/ ha) in RS systems were higher than in SM systems (127 kg/ha). However, in Vinh Chau district, the reverse was true: tiger shrimp yields in SM (81 kg/ha) were higher than in RS systems (45 kg/ha). This may be because of the more "intensive" methods used to grow tiger shrimps in SM (such as feeding and stocking density) than in RS systems.

Various comparisons of shrimp production have resulted in the same conclusion as those for shrimp yields *(Figure 5)*: using shrimp production in SM as "standard," that in RS was 136 percent for natural shrimps and 73.9 percent for tiger shrimps. However, production-yield

Table 12. Comparison of yield and production among systems

System	Yield (kg/ha)			Production (kg/ha)		
	Rice	Shrimp		Rice	Shrimp	
		Natural	Tiger		Natural	Tiger
RMA						
Vinh Chau	2,593	-	-	2,593	-	-
Gia Rai	4,041	-	-	4,041	-	-
Overall	3,277	-	-	3,277	-	-
RMB						
Vinh Chau	2,285	-	-	3,181	-	-
Gia Rai	2,763	-	-	4,200	-	-
Overall	2,607	-	-	3,571	-	-
RMC						
Vinh Chau	3,181	-	-	3,181	-	-
Gia Rai	4,200	-	-	4,200	-	-
Overall	3,571	-	-	3,571	-	-
SM						
Vinh Chau	-	145	84	-	89	46
Gia Rai	-	115	49	-	83	44
Overall	-	127	81	-	86	46
RS						
Vinh Chau	2,404	86	50	1,422	71	38
Gia Rai	2,517	191	30	1,244	124	19
Overall	2,466	178	45	1,324	117	34

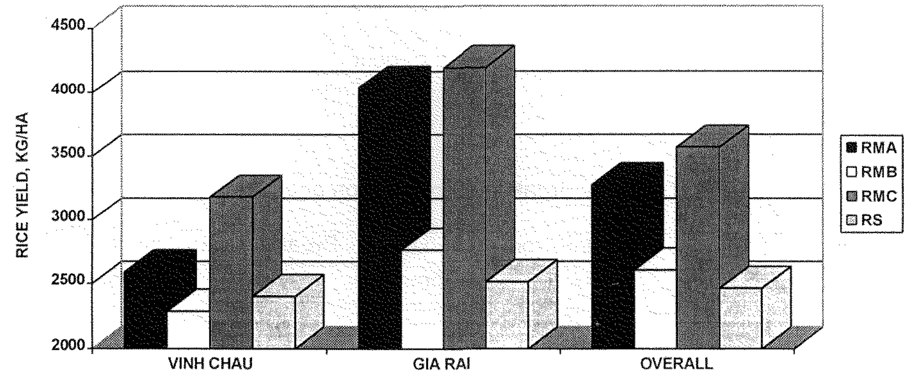


Figure 4. Rice yields of the different farming systems

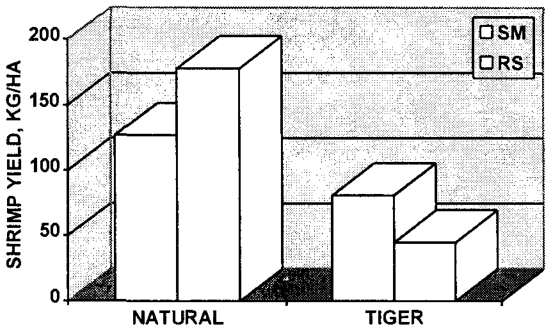


Figure 5. Shrimp yields in the different farming systems

ratios were different between pairs of districts, systems, and species. In fact, the average ratio of production to yield of natural shrimp was 67.7 percent in the case of SM and 65.7 percent in RS systems. Conversely, the ratio of tiger shrimp in SM (56.8%) was lower than in RS systems (75.5%).

Analysis of the break-even production

Table 13 presents the break-even production (i.e., production where the system's gross returns equal costs, supposing that all costs and prices were unchanged) of the systems studied[13]. The break-even production level of profitable systems (RMA, RMC, and RS-Natural) was lower than their current production. Farmers practicing other systems (RMB, both SM-Natural and Tiger, and RS-Tiger) had to improve their production (without any extra costs) to meet the break-even point.

The proportion exceeding the break-even production level of rice monoculture systems was highest in RMA (75%), followed by RMB (44%) and RMC (73%). Only seven cases of SM-Natural and three cases of SM-Tiger (17% of sample analyzed) exceeded the break-even production level. In the case of RS systems, while as high as 56 percent and 58 percent cases of RS-Natural exceeded the break-even production level of shrimp and rice, respectively, the figures of RS-Tiger were very low at 11 percent and 0 percent, respectively.

3.6.2 Economic comparison

When the cost of salinisation was excluded, RMA and RMC were the best systems with an overall positive net benefits of 962,000 VND/ha (US$ 84/ha) and 834,000 VND/ha (US$ 73/ha), respectively. Other systems showed losses ranging from 82,000 VND/ha (US$ 7/ha) for RS to 1,021,000 VND/ha (US$ 89/ha) for SM systems *(Table 14)*. All systems in Gia Rai performed better (i.e., had higher net benefits or smaller net losses) than those in Vinh Chau, except for RMB.

Table 13. Break-even production analysis

System	Current Production (kg/ha)		Break-even Production (kg/ha)	
	Rice	Shrimp	Rice	Shrimp
RMA	3,280	-	2,513	-
RMB	2,610	-	2,896	-
RMC	3,638	-	2,750	-
SM-Natural shrimp	-	69	-	119
SM-Tiger shrimp	-	44	-	84
RS-Natural shrimp[1]	1,444	112	839	71
RS-Tiger shrimp[1]	1,252	39	3,007	74

[1] In the case of RS, rice production was assumed unchanged (as current average production) to calculate the break-even production for shrimp and current shrimp production was kept stable to calculate the break-even production for rice

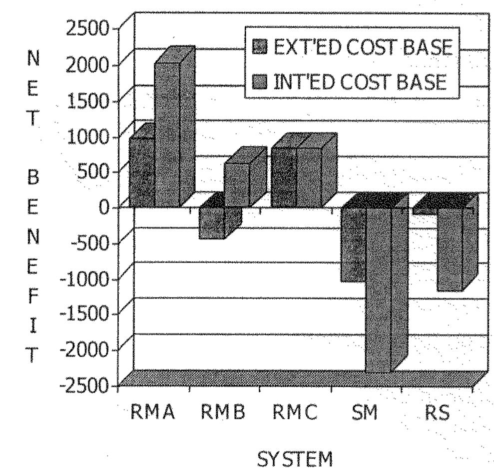


Figure 6. Net benefits of the different farming systems (000 VND/ha)

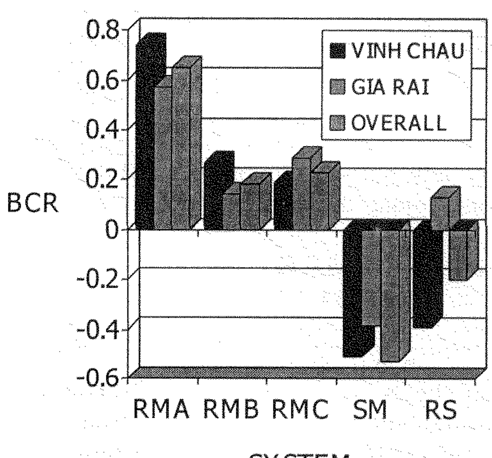


Figure 7. Benefit-cost ratio of the different farming systems (Internalized Cost Base)

The cost of salinisation in rice monoculture fields (RMA and RMB) caused by shrimp farming during the dry season can be viewed as the amount of compensation farmers practicing SM or RS should pay rice monoculture farmers to cover the costs they had imposed on them. If rice farmers were compensated for the cost of salinisation, all rice monoculture systems would have positive net benefits. In such case, RMA was economically the most viable, showing a net benefit of 2,035,000 VND/ha (US$ 177/ha) and a BCR of 0.65. It was followed by RMC.

Except for RS in Gia Rai, whose net benefit was positive at 538,000 VND/ha (US$ 47/ha), other RS and SM systems incurred higher losses and worse BCR. The worst among them was SM (BCR = -0.51) and RS (net loss = 3,065,000 VND/ha or US$ 266/ha), both in Vinh Chau.

Even without accounting for the external cost of salinisation, RMA was seen to be the most economically viable among the different farming systems studied *(Figures 6 and 7)*. It was followed by RMC and RMB. Both SM and RS systems showed negative returns. The results of this study suggested that shrimp farming as currently practiced in the study area was uneconomical. However, returns from shrimp farming were variable, and high profits had been evident in the past[14]. Most farmers therefore continued to adopt shrimp cultivation, expecting high yields and hence profitability[15]. Without careful management of the natural resource base on which shrimp production depends, such expectations of profits would be unrealistic.

Analysis of the best cases

Analysis of the three most profitable cases from each system (SM and RS split into two sub-groups, single species of natural and tiger shrimps) showed different results from the whole sample analysis *(Table 15)*.

While rice production from the best cases of RMA and RMB increased by 41 percent and 84 percent, respectively, that for RMC increased by only 4 percent in comparison with the whole sample

Table 14. Summary of net benefits of alternative farming systems

System	Net Benefit (000 VND/ha)	
	Excluding Salinisation Cost	Including Salinisation Cost
RMA	962	2035
RMB	-440	624
RMC	834	834
SM	-1021	-2293
RS	-82	-1155

Table 15. Analysis of the best performing cases[1]

System	Production (kg/ha)			Gross Value (000 VND/ha)			Net benefit	
	Rice	Shrimp	Total	Rice	Shrimp	Crops	Total	Ex. FL[2]
RMA	4,630	-	7,315	7,315	-	-	4,345	5,194
RMB	4,790	-	5,055	5,055	-	-	2,773	3,202
RMC	3,730	-	7,007	7,007	-	-	4,936	5,127
SM Natural	-	213	3,782	-	2,726	1,056	2,243	2,529
SM Tiger	-	90	6,711	-	6,711	-	1,283	2,179
RS Natural	3,048	272	9,242	3,657	5,585	-	5,989	7,169
RS Tiger	2,404	95	11,503	3,394	8,108	-	3,867	5,747

[1] Three best cases from each farming system listed; salinisation cost was excluded
[2] Excluding the opportunity cost of family labour

averages. An aromatic rice variety was used, which commanded high prices but yields made two cases of RMC as the most profitable. Rice production in RS increased by 92 percent (tiger shrimps) and 111 percent (natural shrimps). Among the best cases, shrimp production was 2-3 times higher than that of the whole sample (RS both natural and tiger shrimps – 2.4 times, SM tiger – double, SM natural – triple).

In such analysis, RS systems were found to be the best among alternative systems studied. Gross value and net benefit (excluding family labour costs) from RS exceeded those from RM systems. Even when the opportunity cost of family labour was considered, RS-Natural remained first in rank in terms of net benefit (5,989,000 VND/ha = US$ 521/ha) while the best rice monoculture, RMC, ranked second (net benefit of 4,936,000 VND/ha = US$ 429/ ha). Both SM sub-groups were still the worst among the systems.

4.0 SUMMARY OF RESULTS

An in-depth survey of 300 households was conducted in 1996 covering two districts, Vinh Chau of Soc Trang province and Gia Rai of Bac Lieu province in the Mekong Delta. The households practiced rice monoculture (RMA – adjacent to rice-shrimp integrated fields, RMB – adjacent to shrimp monoculture fields, and RMC – apart from shrimp and rice-shrimp fields), shrimp monoculture (SM), and rice-shrimp integrated (RS) systems. The main results of this study *(Tables 16 and 17)* were as follows:

1. While farmers had a long tradition in rice farming (over 20 years), they had

Table 16. Socio-economic information on the households obtained during the survey

Criterion	Value/Comparison
Farming experience	RM (> 20 yr.) > SM > RS (< 10 yr.)
Farmers education level	Most level 1 (primary school)
Household size	6.2 persons
Agricultural land/household	2.12 ha
Total income of HH in 1996	9, 625, 000 VND (USS 837)
Total expenditure of HH in 1996	14, 785, 000 VND (UDS 1, 286)
Contribution of farming to HH incomes	78%
Expense for farming/HH expenses	36%

Table 17. Main criteria of farming systems studied

Criterion	Farming System				
	RMA	RMB	RMC	SM	RS
Rice production (kg/ha)	3.28	2.61	3.57	-	1.32
Tiger shrimp production (kg/ha)	-	-	-	46	34
Natural shrimp production (kg/ha)	-	-	-	86	117
Gross value (000VND/ha)	4,083	2,998	4,472	2,268	4,712
Total cost (000VND/ha)	3,121	3,438	3,638	3,289	4,792
Family labour opportunity cost (000VND/ha)	659	752	590	1,023	1,231
Net benefit (000VND/ha)	962	-440	834	-1,021	-82
Salinisation cost (000VND/ha)	1,073	1,064	-	-1,064	1,073
Net benefit including compensation (VND/ha)	2,035	624	834	-2,293	-1,155

RS = Rice field adjacent to integrated rice-shrimp
RMB = Rice adjacent to shrimp monoculture
SM = shrimp monoculture
RMC = rice field away from RS
RS = integrated rice-shrimp
RM = rice monoculture

less experience in shrimp farming, especially in integrated rice-shrimp farming systems (under 10 years). Farmers attained low levels of education (at most primary school level only).

2. The average household size was six members, which was bigger than the normal Vietnamese family of four members. Households owned an average of 2.12 ha of agricultural land. The land was characterized by a medium elevation (compared with surrounding areas), loamy clay soils, and slight to medium levels of acidity and salinity. Local farmers commonly practiced more than one farming system. The main farming system occupied between 54 percent to 89 percent of the household's total agricultural land.

3. Farming was the main activity of households, contributing up to 78 percent of the total gross income. Farming expenses accounted for only one-third of the total household expenses. Among the living expenses, expenditure on food was the highest, followed by social obligations. Net incomes of households in 1996 were negative.

4. Rice monoculture was diversified in the sense that many varieties were used. Yields and net incomes (excluding salinisation cost) for RM in 1996 averaged 3.22 t/ha and 547,000 VND/ha (US$ 48/ha). Rice farmers in Gia Rai obtained better results than those in Vinh Chau district. Among the different rice systems, RMB was the worst in terms of yield and net income, while

RMA gave the highest net income because it had the lowest cost. On the other hand, RMC had the highest yield.

5. Yields for shrimp monoculture systems were low in 1996: 86 kg/ha for natural shrimps and 46 kg/ha for tiger shrimps. Shrimp yields of polders combining two shrimp types or with crabs were higher than of polders cultivating shrimp only. The average gross value of SM was 2,268,000 VND/ha (US$ 197/ha). However, owing to very high prices of tiger shrimps compared with natural shrimps, the gross value of tiger shrimp production (3,268,000 VND/ha = US$ 284/ha) was much higher than that of natural shrimps (1,116,000 VND/ha = US$ 97/ha).

   The cost of shrimp farming was very high, averaging 3,289,000 VND/ha (US$ 286/ha). On the average, shrimp farmers incurred losses of 1,021,000 VND/ha (US$ 89/ha). When family labour was excluded from the analysis, farmers earned a small net benefit of 2,000 VND/ha (US$ 0.17/ha). In both districts, natural shrimp farming was better than tiger shrimp farming, with and without accounting for the cost of family labour. Between the two districts, gross incomes and costs were higher in Vinh Chau than Gia Rai. Net benefits were therefore higher in Gia Rai.

6. In general, production/ha of rice and tiger shrimp in the rice-shrimp integrated systems was lower than that of RM and SM systems. However, natural shrimp production was typically higher in RS than SM. RS systems showed an average gross value of 4,712,000 VND/ha (US$ 410/ha) and total cost of 4,794,000 VND/ha (US$ 417/ha), the highest among the systems studied. RS systems therefore suffered an average loss of 82,000 VND/ha (US$ 7/ha), but generated net benefits averaging 1,149,000 VND/ha (US$ 100/ha) when the cost of family labour was excluded. These systems were therefore more productive than SM systems, but less productive than RM systems.

7. Sedimentation costs consisted of the annual cost of removing sediments deposited on the field surface and trench system of the polder. This cost was included in the total cost of SM and RS systems. Using the avertive behaviour approach, the cost of sedimentation was estimated at 833,000 VND/ha (US$ 72/ha) for SM and 805,000 VND/ha (US$ 70/ha) for RS systems. This was an important cost in shrimp production because it accounted for up to 25 percent and 17 percent of the total cost for SM and RS, respectively.

8. Leakage and/or overflow of brackish water from shrimp farms (RS and SM) in the dry season adversely effected the RM systems. The cost of salinisation was estimated in this study using the avertive behaviour and the change in the value of production approach. It was estimated at 1,069,000 VND/ha (US$ 93/ha). This cost represented an external cost to shrimp producers, since they did not have to account for this cost within their own private production costs. One way of "internalizing" this cost would be for shrimp farmers to compensate rice farmers for the damage to their fields caused by salinity from shrimp farms. That is, they would pay rice farmers 1,069,000 VND/ha (US$ 93/ha).

9. If the costs of salinisation would be internalized (i.e., a compensation equal to this cost would be paid by shrimp farmers to adjacent rice farmers), then the net benefits of RMA and RMB would increase to 2,035,000 VND/ha (US$ 177/ha) and 624,000 VND/ha (US$ 54/ha), respectively. In this case, shrimp farmers would incur bigger losses, up to 2,293,000 VND/ha (US$ 199/ha) for SM and 1,155,000 VND/ha (US$ 100/ha) for RS. The net benefit of RMC would remain at 834,000 VND/ha (US$ 72/ha).

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results of this study highlighted the need for a comprehensive economic analysis of current farming systems to provide more accurate information on the true economic value of alternative systems. If rice farmers would be properly compensated for losses caused by salinisation from nearby shrimp farms, all rice systems would show positive net benefits. Many shrimp farms in the study area under the current management practices were found to be uneconomical even without internalizing the costs of salinisation. Inclusion of these external costs would mean more substantial losses in shrimp farming.

However, several cases of shrimp farming (especially RS-Natural shrimp) exceeded the break-even production level of the system. Moreover, analysis of the best cases showed RS as the most profitable among the systems studied. Shrimp farming, despite currently poor financial performance, has generated more jobs (and consequently incomes through more efficient use of family labour as shown in Table 17 for local farmers in the dry season, when the rice farmers in the region usually produce nothing. This should be considered as the good social aspect of shrimp farming, which has helped make the shrimp farmers' lives better.

5.2 Recommendations

1. Tax on Shrimp Farm to Internalize Costs of Salinisation

In the past, shrimp farming systems had been subsidized by the government through exemptions on land use tax and irrigation fees[16]. Such exemptions distort the true economic benefit of the systems. As a first step, therefore, such *subsidies should be stopped, followed by the introduction of a tax on shrimp farms equivalent to the cost of salinisation* caused to adjacent rice fields.

2. Development of Management Strategy for Shrimp Farming

Although relatively new in the area, shrimp monoculture and integrated rice-shrimp systems spread fast to brackish water areas of the MD. Shrimp farmers had developed their production autonomously and received from the government in terms of extension. Shrimp farming has been unmanaged, with no restrictions on location, harvesting techniques, and technology used. However, SM and RS systems, despite poor performance in recent years, are considered to have the potential to be economically viable if properly managed as shown by the results of this study.

Two main initiatives are considered to be essential to ensure proper management of the farmers:

(i) Development of land zoning system

A *zoning system* needs to be developed, where shrimp farming would not be permitted in areas of high ecological importance or where damage to adjacent rice systems would be likely. Further studies are necessary in order to provide details on shrimp seed source, typography of the area, and soil characteristics (physics and chemistry).

Following the development of a zoning plan, an *appropriate dike system* will need to be constructed to separate areas of rice and shrimp culture. It is assumed that this dike will be larger than any current existing dike system. It should be large and high enough to prevent leakage and overflow of saline water from shrimp farms to rice fields. The exact dimensions of the dike need to be determined through further research on hydrology, including tidal regime and land characteristics.

Shrimp farmers would be liable for the cost of construction and maintenance of the dike. Since the costs of building the dike will be large, installment payments could be arranged, perhaps using the existing tax mechanism.

In the short term, farmers should be made to pay for the costs of salinisation of adjacent rice fields through increased taxes. Following the development of a land zoning plan, this tax may increase to cover both the costs of salinisation and of dike construction. In time, however, this tax is expected to decrease as the problem of saline leakage/ over flow is eliminated.

(ii) Technological development

Very little research has been undertaken on the optimal techniques for tiger and natural shrimp farming in the area. Greater understanding is urgently needed on *appropriate methods of shrimp farming* such as polder design, cropping season, stocking density and feeding of tiger shrimp, water management in general, treatment of diseases and algae development, and harvesting techniques. *Technologies for rice production in integrated farming systems* (variety, planting methods and density, fertiliser application, pest management) need to be further studied as well.

3. Financial Support for a Sustainable Shrimp Farming

Despite attractive profits in the 1980s and early 1990s from shrimp production, many shrimp (integrated and particularly monoculture) farmers in the area had suffered losses since 1993 because of the mass mortality of shrimp and spread of shrimp diseases. Many farmers now face serious financial difficulties[17]. Financial assistance from the government and/or other organizations, such as *easy-to-access long-term credit programs with appropriate rates of interest*, would significantly help the farmers recover and improve their shrimp farming activities. This would result in better livelihood for farmers in the area.

ENDNOTES

[1] In 1995, the national population of Vietnam was 73.6 million.

[2] The current 12-year education system of Vietnam consists of primary (5 years), secondary (4 years), and high school (3 years) levels. In addition, professional high schools (3 years) offer learning opportunities to students who have at least the graduation certificate of the secondary level. High school is followed by college (3 years) or university level (4-7 years depending on the study field).

[3] Additional labour refers to workers aged 13-18 years and over 60 years. Additional labor was not considered in this study.

[4] Exchange rate in early 1997 was US$ 1 = 11,500 VND.

[5] Social obligation includes birthdays, weddings (for both relatives and neighbors), and temple offerings.

[6] The cost of salinisation was based on production lost in the area affected multiplied by price of rice. For example, for RMA in Gia Rai, this figure was 349 kg/ha X 1,183 VND/kg = 413,000 VND/ha.

[7] The cost of delayed planting as a result of salinisation was estimated by farmers as the amount of rice lost mutiplied by the local farm gate price of rice.

[8] The annual cost of dike construction was derived based on the present value (1996) of construction cost at an interest rate of 12% per annum.

[9] The cost of production loss due to area loss for dike construction was based on the dike area as percentage of the polder area x average yield x price of rice. For RMA in Gia Rai, for example, it is 1.54% x 4.04 t/ha x 1183 VND/kg = 73,000 VND/ha.

[10] Overall figures included yields from combined systems.

[11] Derris is a plant from which rotenone is extracted (mainly from roots) and used in killing wild fish in shrimp farms in the region.

[12] Break-even production = costs / price of output.

[13] A study of the RS system at Tham Don commune (My Xuyen distric, Soc Trang province), which surveyed 43 HH, showed that the BCR of the rice-natural shrimp integrated system was 273 (Le et al. 1991). In Vinh Chau district (Soc Trang province), the productivity of RS systems was 7.2 t/ha of paddy compared with 1.5-2.5 t/ha from rice monoculture (Nguyen, et al. 1992). For the RS system in Gia Rai and Vinh Loi districts (Bac Lieu province), the average shrimp yield was 244 kg/ha/season. This led to the system's total net income of 2.1 million VND/year which was much higher than that of salt-shrimp and extensive shrimp monoculture (0.7 and 1.5 million VND/year, respectively) (Nguyen et al. 1993). A study of the farming system in Tra Cu district (Tra Vinh province) showed that the income from RS, where rice yield averaged 2.36 t/ha and shrimp yield was 67 kg/ha, was 2.7 times higher than that from RM (one crop/year) systems (Nguyen, et al., 1993). A survey of 116 HH practicing RS system in My Xuyen district (Soc Trang province) showed that the system's net benefit was 3.78 million VND/ha from rice and shrimp plus 0.34 million VND from upland crops while that of RM was only 1.57 million VND/ha (Tran, 1994). All these results, suggested that RS had been highly profitable. This fueled the fast expansion of this

integrated farming system in brackish water areas of the MD in the past (late 1980s - early 1990s).

14 Based on *pers. com.* with District Officials, shrimp yields in Gia Rai were high in the 1997 dry season.

15 Exemptions from land use tax and irrigation fees are common for all farming systems in Vietnam. They are granted when harvests are especially low on account of extreme natural conditions (e.g., flooding, drought, pest and disease epidemic).

16 Profits gained from small-scale polders in the past had been used mainly to expand the polders gradually and partly for housing needs. In almost all cases, nothing had been left as savings.

LITERATURE CITED

Committee of Science and Technology of Minh Hai Province. 1993. Rice Shrimp Farming System in Minh Hai Province. (pers. com.).

Le, H. H. 1993. The 1992 Final Report of Soc Trang Provincial Department of Fisheries, Soc Trang, Vietnam. (in Vietnamese)

Le, T. D., N. T. Duong, D. C. Nguyen et al. 1991. Survey on Rice-shrimp Farming System at Giong Co Hamlet, Tham Don Village, My Xuyen District, Hau Giang Province. *In* Results of Research on Farming Systems of Vietnam, Proceedings of the First Workshop of Vietnam FS R&E Network held in Can Tho 1990, pp.43-48. (in Vietnamese)

National 60B Program of the Mekong Delta Integrated Investigation, the 2nd Stage. 1987. The Report on Adjustment, Surveying, Supplementing and Completing the Soils Maps. Can Tho University. (in Vietnamese)

Nguyen, A. T., V. T. Nguyen, N. H. Tran, and T. B. Cao. 1992. Some Comments on Techniques and Sustainability of Rice-Brackish Water Shrimp Farming Systems at Bac Lieu-Ca Mau Area. Paper presented at the Scientific Conference of the Can Tho University, Faculty of Fisheries, Can Tho University. (in Vietnamese)

Nguyen, D.C. 1992. The Rice-Shrimp Farming System in the Long Dien Dong C Village, Gia Rai District, Minh Hai Province. Paper presented at the Joint Meeting of the ARFSN, INSURF, IPMN and CARMNAC held in Ho Chi Minh City and Can Tho City, Vietnam, 11-18 Oct. 1992.

Nguyen, T. H., et al. 1993. Results of a Survey on Rice-Fresh Water Prawn and Rice-Saline Water Shrimp Systems in Vinh Long and Tra Vinh Provinces. *In* Research on Farming Systems, Proceedings of the Third Workshop of Vietnam FS R&E Network at Thai Nguyen City in 1992, FS R & D Institute, Can Tho. pp 127-129. (in Vietnamese)

Nguyen V. L., et al. 1992. Improving Cropping Systems in Vinh Chau District, Hau Giang Province. *In* Results of Studies on Farming Systems. Proceeding of 1991 Workshop of Vietnam FS R & E Network at Hue City, FS R & D Institute, Can Tho, pp. 216-27. (in Vietnamese)

Tran, T. B. 1994. Sustainability of Rice-Shrimp Farming System in a Brackish Water Area in the Mekong Delta of Vietnam. MSc Thesis, UWSH, Australia. 199 p.

Vu, T. H. 1987. Rice Production in Vietnam. *In* International Rice Commission Newsletter. 35 (2): 9-19.

Vuong, H. 1992. Report on Aquatic Production Situation and Future Development Plan in My Xuyen District. Report to Soc Trang Provincial Department of Agriculture, My Xuyen Dept. of Agriculture, Soc Trang, Vietnam. (in Vietnamese)

ACRONYMS

BCR	Benefit-cost ratio
ha	Hectare
HH	(Farming) Household
kg	Kilogram
MD	Mekong Delta
OVR	Overall
RM	Rice monoculture
RMA	Rice monoculture fields adjacent to rice-shrimp fields
RMB	Rice monoculture fields away from rice-shrimp or shrimp farming fields
RMC	Rice monoculture fields adjacent to shrimp monoculture fields
RS	Rice-shrimp integrated farming
SM	Shrimp monoculture
t	Tons
US$	United States dollar
VND	Vietnamese Dong

Exchange rate (1997)
1 US$ = 11,500 VND

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