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AN ECOLOGICAL ECONOMIC ANALYSIS OF SWINE WASTES IN A PERI-URBAN AREA OF THAILAND

Inaugural-Dissertation zur Erlangung des akademischen Grades
Doktor des Agrarwissenschaften (Dr. agr.) im Fachbereich
Agrarwissenschaften, Ökotrophologie und Umweltmanagement

Vorgelegt von: **KAMPANAT VIJITSRIKAMOL**

Betreut von: **PROF. DR. ERNST-AUGUST NUPPENAU**
PROF. DR. P. MICHAEL SCHMITZ

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Forschungsergebnisse aus dem Fachbereich

"Agrarwissenschaften, Oekotrophologie und Umweltmanagement"

Title der Dissertation: An Ecological Economic Analysis of Swine Wastes in a Peri-Urban Area of Thailand

Verfasser: Mr. Kampanat Vijitsrikamol

Betreuer: Prof. Dr. Ernst-August Nuppenau

Kurzfassung:

Livestock wastes have become a growing worry especially in peri-urban areas of Thailand. The major source of livestock wastes is mainly derived from swine farms. The study was theoretically based on a welfare economic approach in which the Coase Theorem was employed. The study came in a line with investigating abatement and environmental damage costs drawn from swine wastes. It intended to identify optimal abatement levels of the pollutions in order to improve social welfare of the studied community. Moreover, a participatory approach is included in the study. The analytical framework was organized into 2 working tasks. Task 1 dealt with a mathematical linear programming model used to derive marginal abatement costs. Task 2 was associated with a hedonic pricing model applied to retrieve marginal environmental damage costs. The outcomes of the two tasks were equated in accordance with the Coase approach. The study emphasized on the farm pollutions in forms of environmental indicators such as nitrogen (N), phosphorus (P), biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and pH value.

The analytical result indicated that the actual abatement levels of phosphorus, nitrogen, and BOD were significantly lower than the calculated optimal abatement levels. It is recommended that the swine farm community should attempt to increase the abatement levels of phosphorus, nitrogen, and BOD approximately one time higher than the abatement levels on a routine basis.

The results of sensitivity analyses implied that the single approach scenarios (on either decreasing in marginal abatement costs alone or increasing in net gains from manure markets alone) were likely to be inadequate to improve the community's social welfare in terms of both monetary values and optimal abatement levels. On the contrary, the mixed approach scenarios seem to be better alternatives. This can voluntarily be done by improving abatement technology and manure market environment.

Forschungsergebnisse aus dem Fachbereich
“Agrarwissenschaften, Oekotrophologie und Umweltmanagement”

Titel der Dissertation: Eine Ökologisch-Ökonomische Analyse der Abfälle aus der Schweineproduktion in einem Peri-Urbanen Gebiet in Thailand

Verfasser: Mr. Kampanat Vijitsrikamol

Betreuer: Prof. Dr. Ernst-August Nuppenau

Kurzfassung:

Probleme mit Abfällen aus der Tierproduktion nehmen insbesondere in peri-urbanen Gebieten Thailands zu. Die Hauptursache sind Abfälle aus Schweinefarmen.

Die vorliegende Studie basiert theoretisch auf wohlfahrtsökonomischen Überlegungen unter Anwendung des Coase Theorems. Sie analysiert die Kosten der Abfallbeseitigung in der Schweineproduktion und die Kosten der durch die Abfälle entstehenden Umweltschäden. Ziel ist es die optimale Abfallmenge zu definieren um die soziale Wohlfahrt der lokalen Gemeinschaft zu verbessern. Zusätzlich kommt ein partizipativer Ansatz in der Studie zur Anwendung. Die analytischen Rahmenbedingungen gliedern sich in zwei Aufgabenbereiche. Der erste besteht aus einem mathematischen linearen Programmierungsmodel zur Berechnung der marginalen Kosten der Abfallbeseitigung. Der zweite Aufgabenbereich beinhaltet ein „hedonic pricing“ Modell zur Berechnung der marginalen Kosten der Verschmutzung. Die Resultate werden, unter Anwendung des Coase Theorems, gleichgesetzt. Die Studie bewertet die Verschmutzung durch Abfälle aus Schweinefarmen unter Verwendung vom Umwelt-Indikatoren wie dem Gehalt von Stickstoff (N), Phosphor (P), dem biologischen Sauerstoff-bedarf (BOD), dem chemischen Sauerstoffbedarf (COD), den Schwebstoffen (SS), und dem pH-Wert.

Die Resultate zeigen, dass die derzeitige Verringerung der Einträge von Phosphor, Stickstoff, und BOD signifikant unter der berechneten optimalen Verringerung liegen. Es wird deshalb empfohlen, dass die Schweinezüchter versuchen, die Einträge weiter zu verringern.

Die Resultate einer Sensitivitätsanalyse zeigen, dass einseitige Lösungsvorschläge (entweder Senkung der Beseitigungskosten oder erhöhte Gewinne durch Düngemittelvermarktung) nicht ausreichen um die soziale Wohlfahrt zu erhöhen. Dies gilt sowohl bezüglich der monetären Bewertung der Wohlfahrt wie auch hinsichtlich der optimalen Verschmutzungsmenge. Eine kombinierte Lösung liefert bessere Resultate. Die Kombination kann über verbesserte Technologien im Bereich der Abfallreduktion wie auch über ein verbessertes Marktumfeld für Düngemittel erreicht werden.

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I would like to express my special thanks to my mother and father who always warmly give me supports and encouragements for my entire life. Their unconditional love takes me to get through all the good and bad things in my life. I always feel very lucky to be their beloved son.

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List of Abbreviations

LU:	Livestock Unit (1 LU = 500 kilograms)
TKN:	Total Kjeldahl Nitrogen
N:	Nitrogen
P:	Phosphorus
BOD:	Biochemical Oxygen Demand
COD:	Chemical Oxygen Demand
SS:	Suspended Solid
ABC:	Abatement Cost
DMC:	Environmental Damage Cost
MAC:	Marginal Abatement Cost
MDC:	Marginal Environmental Damage Cost
MPC:	Marginal Private Cost
MSC:	Marginal Social Cost
MEC:	Marginal External Cost
MSB:	Marginal Social Benefit
PCD:	The Pollution Control Department
DLD:	The Department of Livestock Development
Net Ag	Net Agricultural Income
Govt:	Government
Mkt:	Market

List of Units

Baht (THB):	Thai currency (THB 48.10: 1 EURO, exchange rate on February 24, 2008).
Rai:	Thai Unit of Area (1 Rai = 1,600 m^2 = 0.16 hectare)
kg:	Kilogram
km:	Kilometer

1 INTRODUCTION

1.1 Problem Statement

There are often discussions about concerns of peri-urban areas where the transitional situations are taken part in. Peri-urban areas are defined as buffering areas between urban and rural areas. Therefore, they should absorb both, development and problems from urban areas. As a result, this absorbent can lead to transitional activities in buffering areas. Eventually buffering affects the allocation of resource uses in rural areas. This implies a fundamental change in social, environmental and economical terms for peri-urban areas. However, municipal authorities have often failed to deal with the challenges of sustainable peri-urban development in the past. Key problems are uncontrolled growth, lack of infrastructure, environmental pollution, human health impacts, social reorganization, new poverty, housing in general, and lack of legal structure (WWW.PUDSEA.NET sited from BOLAY et al., 1999). An important emerging new aspect is waste generated from agriculture. Especially in the greater Bangkok area agricultural waste plays a role, since farming is still present.

In Thailand, agricultural waste, especially the case of livestock waste, has become a growing concern for ages. Animal waste including effluent nutrients such as nitrogen and phosphorus, contained in animal manure from conducting animal feeding operations, is a potential source of air and water quality degradation. From evaporation of gases, runoff to surface and leaching to ground water, problems are significant (RIAUDO, 2004; AILLERY et al., 2005). These pollution problems occur more severely in peri-urban areas where various economic activities, such as farming, manufacturing, service, and real-estate development activities, are competing in utilizing the limited amount of land as resource.

A major source of livestock waste in Thailand is mainly derived from swine farms (DEPARTMENT OF LIVESTOCK DEVELOPMENT (DLD) & FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO), 2001). In the past, swine farms were managed in a traditional manner that emitted a moderate amount of waste to the environment. The carrying capacity was able to exceed the waste emission rate (POLLUTION CONTROL DEPARTMENT, 2000). However, the number of swine farms in Thailand has increased in recent years and the production technology has become more industrialized than they used to be. For these reasons, the emission rate of the farm waste exceeds today the maximum carrying capacity of the environment. Consequently, environmental problems have begun to appear in the forms of wastewater, odor, germ spreading and local sanitation problems (POLLUTION CONTROL DEPARTMENT, 2000). Eventually, the Thai society as a whole has to invest more on the environmental management to prevent further deterioration in their social welfare.

Nakhon Pathom Province is one of the major swine producing industry in Thailand. It is in the peri-urban area of Bangkok. It produces around 1.14 million heads of swine (in 2006), and accounts for 15.87% of the entire nation's swine production (WWW.DLD.GO.TH, 2008). Nakhon Pathom is considered as a peri-urban area that is dealing with pollution problems, mostly drawn from the excess runoffs in terms of wastewater and manure from swine farms. Most of these are small scale conventionally operated farms and they are situated inside the cities (THE STUDY'S FIELD SURVEY, 2005-2006). While there exist on-farm simple waste treatment technologies and local markets for swine manure (in terms of manure application for fertilizer, fish and water flea feed) pollution problems still persist in the Nakhon Pathom area. To promote ecologically sustainable farming, it is therefore essential that technological, economic, and marketing options are adequately made available and policy measures are identified.

In terms of policy response, there has been a discussion of two major approaches of swine waste management in Thailand: 1) a determination of the farm zoning and 2) a regulation that enforces swine farms to conform to an efficient waste treatment system. The former approach has been responded by the study of DLD and the FAO in 2001 (DLD AND FAO, 2001). However, this needs to be studied more in detail because of the relocation problems. Moreover, this approach must be related to public and/or stakeholders' concerns and legal issues. For the latter approach, even though both the DLD and Pollution Control Department (PCD) have promoted an extension programs for years in developing the different waste treatment systems, which are suited for each area' s limitations, the levels of environmental indicators in terms of total Kjedahl nitrogen (TKN), phosphorus (P), suspended solid (SS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and pH value (that are randomly inspected from the farms) often exceed the standard levels (PCD, 2001). In practice, the numbers of DLD and PCD officers are unfortunately inadequate to inspect and to enforce all the swine farms in the whole country. This total number consists of about 211,329 swine farms (WWW.DLD.CO.TH, 2008). Their excess runoffs are frequently released to the public areas causing the communities' pollution problems.

One way to address these environmental problems, originated from the swine farms, is to investigate the nature of the pollution abatement cost. In order to obtain the characteristics that convey to find a solution in reaching the least expenditures on the pollution abatement processes, costs matter (BYSTROM, 1998; MCKITRICK, 1998; COWELL AND APSIMON, 1998). Abatement cost curves are powerful management tools and can play a vital role in the efficient reduction of waste discharges. It can also improve awareness of abatement technologies and encourage communications among regulators, polluters, and abatement technology developers (BEAUMONT AND TINCH, 2004). Beside the knowledge on the abatement costs, the assessment of the environmental damage costs is also crucial to measure the environmental effects caused by the pollutions. Both of these abatement and environmental damage costs can be used to evaluate the optimal pollution abatement levels so that the social welfare of the affected community can be improved (ANCEV et al., 2003). In addition, when nitrogen is recovered in some form from livestock slurry, nitrogen applications in the agricultural sector may be considered, e.g. as a fertilizer. A most obvious option is a direct use on the farm, that produces waste related products and/or use on neighboring farms. Then, little or no effort has to be put into marketing and distribution of this solution. Such treatment systems should aim at the recovery of valuable products and energy from waste with minimal energy consumption and no emission to the environment (RULKENS et al., 1998). However, the problem seems to be more complicated.

In alleviating the environmental problems, a multi-disciplinary approach to environmental economic analysis is required with collaboration between researchers from different disciplines instead of either economic or technical studies, performed in isolation (WOSSINK AND BENSON, 1999). The analysis should start at farm level where the technical and the economic disciplines meet, moreover, where the decisions regarding nutrient management are taken and implemented (WOSSINK AND BENSON, 1999). Furthermore, a participatory and transparent approach also plays an important role in the policy formulation process. Here stakeholders are to be actively engaged in decision making (SANTOS et al., 2006).

According to the knowledge of the author about swine waste problems, occurring in peri-urban areas of Thailand such as in Nakhon Pathom Province, as stated above, there has not been any ecological economic analysis to evaluate the environmental damage costs derived from swine wastes yet. Furthermore, identifying an optimal amount of pollution abatement for each community has not been reached by any scientific study. This study, therefore, mainly focuses on obtaining an ecological economic optimal abatement level of swine wastes. The objective is to maximize social welfare or at least to improve the community's social welfare as a whole as a result of abatement.

1.2 Research Questions

There are three major research questions in this study on which we tackle:

1) What are the damage cost and its magnitude caused by the runoffs from swine farms?
2) What are the socially optimal amounts of pollution abatement? and
3) What are the optimal policy implications regarding social welfare maximization?

1.3 Objectives of the Study

Generally speaking, since there have been rarely studies of the swine waste management in terms of ecological economic analysis in Thailand, this study aims to be beneficial for policy makers and planners. For them, it is necessary to acquire information and policy implications on swine waste management, especially in peri-urban areas of Thailand. This study will also provide stakeholders the information they need to make decisions on what they would rather do concerning best activities and benefits. Therefore, the specific objectives of the study are:

1) To obtain and describe the general characteristics of the local swine waste management practices in the study area,
2) To investigate the damage cost caused by the waste runoffs from swine farms in the study area,
3) To analyze and identify the economic optimal level of pollution abatement in the study area using environmental economic arguments, and
4) To retrieve optimal policy implications and recommendations for a better swine waste management under social welfare maximization and participatory approaches.

1.4 Hypotheses of the Study

According to the objectives of the study, there are 4 major hypotheses to be examined:

1) The damage costs are at least associated with the land prices,
2) The social welfare of the community yields a large positive value that farms abate due to small proportions of the abatement cost and the small net gain from manure market,
3) The optimal amounts of pollution abatement exceed the existing abatement amounts that farmers routinely practice, and
4) There might be some mechanisms to attract farmers for voluntarily participating in waste management rather than regulations and enforcement.

1.5 Scope of the Study

In general, the content of the study can be classified into 5 major aspects in terms of the following categories:

1) A description of the study area – The study was conducted in Sam Khwai Phueak Subdistrict, Nakhon Pathom Province, Thailand,
2) Type of swine wastes – The wastes were quantifiably inspected in the forms of environmental indicators such as total Kjeldahl nitrogen (TKN), phosphorus (P),

biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), and pH value,

3) Stakeholders – The stakeholders in the study are swine farmers, manure traders or middle men, manure end-users, and government agents,
4) Data collection – The study shows both field surveyed data in 2005/06 and the related secondary data obtained from various sources, and
5) Study focus – The study focuses on obtaining the optimal abatement level of swine waste under welfare maximization and recommendations retrieved from stakeholder participatory meeting.

1.6 Organization of the Study

The presentation of the study is organized in terms of nine chapters in which the general information about the study area, the descriptions of the field survey findings, the analytical results, and the recommendations are provided, notably, corresponding to the objectives of the study. As such, the organization of the study can be summarized as follows:

Chapter 1 delivers an introduction to the problem statement, the objectives, and the other related structure of the study. It provides a general view of how the study can be conducted in both empirical and theoretical themes.

Chapter 2 gives a general view on the research design in which the study area selection, data collection, sampling process, and stakeholder brainstorming are provided. Moreover, this chapter also gives an overview on geography, demography, socio-economic data of the study area as well as describing the overall picture of swine waste management and technologies in the area.

Chapter 3 summarizes some of related laws and regulations on swine production in Thailand in terms of standards, classification of farm size, farm wastewater standard and control at point of sources, and penalties.

Chapter 4 explores on and discusses about the empirical findings derived from the field survey of the total 104 swine raising farmers, 48 swine manure traders, and 37 swine manure end-users in Sam Khwai Phueak Subdistrict. Moreover, the laboratory results of the farm wastewater inspections as well as the conclusions of the stakeholder brainstorming are documented in this chapter.

Chapter 5 reviews on the related literatures that mainly focus on the analyses of nutrient runoffs and management, swine manure including other animal farm waste management, as well as their applications. Also some monitoring policies and stakeholder participation approach, and analytical methodologies related to the study are discussed.

Chapter 6 explains the analytical framework and methodology of the study. This chapter also gives some overall theoretical background on welfare theories used in the study. The analytical framework portrays the working tasks in analyzing and deriving the environmental damage and the abatement costs in order to obtain the optimal abatement solutions. The applied concept is the Coase Theorem. In addition, a sensitivity analysis is presented by setting some policy scenarios, as related to some key decision variables in the study.

Chapter 7 presents the analytical results corresponding to the analytical framework. These analytical results are compared to the actual information obtained from the empirical findings. The main topic is to go over results of the abatement and environmental damage costs that are used to derive the optimal abatement levels of the pollutions. Furthermore, the results from the sensitivity analysis of the scenario setups are also discussed in this chapter.

Chapter 8 generally concludes the problem statement, objectives, methodologies, analytical framework, empirical and analytical results of the whole study.

Chapter 9 discusses on the policy implications and recommendations related to the study.

2 RESEARCH DESIGN AND GENERAL INFORMATION ABOUT THE STUDY AREA

In this chapter, the theme is research design. The study area selection, data collection, sampling process and questionnaire design, and stakeholder brainstorming are described. In addition, the second part of the chapter presents general information on geography, demography, socio-economic data of the area as well as providing an overall picture of swine waste management and used technologies in the area.

2.1 Research Design

2.1.1 Study Area Selection

In line with its objectives, the study theoretically aims to address social welfare maximization of a swine raising community in which some environmental damages occur and the benefits from manure trading and recycling activities are taken into account. In order to obtain the optimal levels of pollution abatement for the whole community, several steps are necessary. Moreover, the community's willingness to participate in solving their problems is necessary for delivering proper recommendations to farmers in the area, policy planers, and others who are interested in. Therefore, the criteria to select the proper study components are stated as follows:

1) Swine raising community – The majority of the community in the study area should be full-time swine raising farmers who have been working on their farms for a certain period of time. In addition, the location of the community should not be far from the laboratory where all the waste samples from swine farms have to be conveniently examined from time to time in order to retrieve a consistent record on nutrient contents and environmental indicators,

2) Access to swine farms – In order to receive farm data on revenues and production costs, it is necessary to properly obtain a permission from the farm owners or farm authorities to get access to these internal data. Moreover, appointments need to be made in advance including that the interviewers and their vehicles need to be physically inspected and disinfected before entering to the farms due to the farm hygienic regulation,

3) Environmental damage – One of the study objectives is to evaluate the damage costs caused by the excess runoffs from swine farms, therefore, some of environmental damages should visibly occur in the study area,

4) Manure trading and recycling activities – The study area agents should be dealing with swine manure trading and recycling activities more or less so as to deliver some picture of how these can affect the community's welfare, and

5) Cooperation from farmers and stakeholders – It is very important to the success of the study to receive friendly cooperation from farmers and other stakeholders such as the province's governor, local administrative office, local livestock and environmental offices, provincial veterinarian, and experts. Furthermore, it is always beneficial if the study area has some of active stakeholders who are willing to participate in solving problems and developing their community, especially, in order to conduct brainstorming meetings and future extension programs.

Upon requirements to fulfill the criteria described above, "Sam Khwai Phueak Subdistrict" in Nakhon Pathom Province (Thailand) was purposively selected as the study area and a source of primary data collection.

2.1.2 Data Collection

The data base for the study mainly consists of 2 sources. They are the primary data retrieved from the field survey in the study area and the secondary data obtained from various institutional sources. The following categories explain the procedures of data collection in the study.

2.1.2.1 Primary Data Collection

Sampling Process – The sampling process was divided into 3 parts. The first part was associated with a field survey interviewing swine farm owners or managers. The second part was carried out as interviews obtained from swine manure traders or middle men and manure end-users. The third part was designed to get farm waste samples at point sources, which were then tested in a laboratory. For the first part, there were totally 104 interviews drawn from the "entire population" of the swine raising farmers in the study area. Most of the interviews targeted at the head, comprised a husband or a wife, and/or the manager of the farm.

The interviews in the second part were conducted with 85 manure traders and end-users in the study area and also areas nearby. In this part, some swine farm owners, manure traders, and end-users were the same. The connection and the addresses of the manure traders and end-users were usually received from swine farm owners who were dealing with them. Note that these first two parts of the sampling process were performed twice. The first time interviewing was derived from some interviewees in order to test and improve the drafted questionnaires and at the second time the actual survey was derived from all the interviewees.

Finally, in the third part of the sampling process we went for a waste sample collection of all swine farms in the study area. This process was carried out monthly during the survey period of six months by collecting swine waste and wastewater samples, notably, at the point of source at each farm. Samples had then been analyzed in the laboratories of Soil Science and Animal Science Departments, Kasetsart University, Nakhon Pathom Campus.

Questionnaire Design – In terms of questionnaire design, 3 types of questionnaires for 3 types of agents were employed: swine raising farmers, swine manure traders or middle men, and manure end-users, respectively. Firstly, the questionnaire for swine raising farmers contained 5 sections of various questions: 1) general background of the farm owner or manager, 2) farm characteristics and production process, 3) farm waste management, 4) farm production costs and revenue, and 5) farm owner's or manager's opinion and recommendation on participating in managing farm wastes.

Secondly, the questionnaire for manure traders comprised 3 sections that were 1) general background of the traders or middle men, 2) process of buying and selling manure, and 3) costs and revenue of manure trading, respectively. Lastly, the questionnaire for end-users consisted of 4 sections: 1) general background of the end-user, 2) reasons for using swine manure, 3) process and costs of buying manure, and 4) substitution rates between manure and fertilizer (in case of orchard/agronomic farmers) or fish feed (in case of fish farmers), respectively.

All questionnaires were designed in both closed and open-ended forms. They contained various quantitative and qualitative questions and allowed the interviewees to feel free to answer especially the open-ended questions. In order to collect interesting ideas and recommendations for the study, open-ended discussions were very fruitful.

2.1.2.2 Secondary Data Collection

The secondary data of the study were obtained from various reliable institutional sources such as the Department of Livestock Development (DLD), Pollution Control Department (PCD), and Kasetsart University, Nakhon Pathom Campus. These were the major sources of primarily technical data. The general data about the study area were kindly received from Sam Khwai Phueak Subdistrict Administration Organization. Moreover, additional data were accessed from FAO and corresponding internet websites.

2.1.3 Stakeholder Brainstorming

In order to obtain realistic policy scenarios, implications, and recommendations for a study on waste management, normally a stakeholder brainstorming should be conducted. In this study, a stakeholder meeting was organized on December 20th, 2006 in Muang District, Nakhon Pathom Province under the topic of "Swine Waste Management under Community Participation". It was aimed to be a round-table meeting which focused on 4 main issues to be discussed as follows:

1) Past and current farm waste management situation and problems in the study area,
2) Optimal waste treatment system (s). How should it be applied in the study area?,
3) Community participation in farm waste management, and
4) Supports from the public and environmentally related private sectors.

Overall, there were 47 participants in the stakeholder meeting classified into the 5 following groups:

1) Swine Raising Farmers – This group contained 10 representatives of the swine raising community in the study area. For instance, farm owners, contract farmers, and farmers with/without waste treatment system were participating,
2) Manure traders and end-users – There were 3 manure traders and 2 manure end-users in the meeting,
3) Government Officers – Ten officers from the top to the bottom hierarchy were invited to the meeting. This group consisted of the Governor of Nakhon Pathom Province, the Major of Sam Khwai Phueak Subdistrict (study area), the district sheriff dealing with complaints about the farm waste management, the provincial/district livestock officers, the regional/provincial environment officers, the provincial veterinarian, and the Small-Medium-Enterprise Promotion officers,
4) Private Sector – There were 2 executive persons from the bio-electrical generating company who were interested in investment in establishing local bio-power plants in the study area. In addition, there was another commercial banker associated to this group to observe the meeting and gave suggestions on sources of financial funds for farm waste management technologies, and
5) Experts and Research Staffs – This group comprised 19 people who were animal, environmental and soil scientists, agricultural extensionists, and economists.

2.1.4 Data Analysis

The procedure of data analysis started with the process of error correction and data editing in each individual questionnaire and traced back to the original sources if necessary. Microsoft Excel was the used computer software for the data entry in order to perform in the part of descriptive analysis. Furthermore, the numerical data base used for the software, was namely the General Algebraic Modeling System (GAMS) in the optimization part of the study. In addition, all qualitative data and the results from stakeholder brainstorming were deducted and summarized to take part in the analysis and policy recommendations.

2.2 General Information about the Study Area

2.2.1 General Information about Nakhon Pathom Province

2.2.1.1 Historical Background and Geography

The name Nakhon Pathom means "first city". It is often referred as the oldest city of Thailand. Some historians speculate it dates back to the 3rd century BC, when Buddhist missionaries from India visited the region. Nakhon Pathom Province is located in the alluvial plain of central Thailand, 56 kilometers from the west of Bangkok (Figure 2.1). It is situated approximately from 13°55′N to 100°7′E, drained by the Tha Chin River also called Nakhon Chaisi River, a distributary of the Chao Phraya River (HTTP://EN.WIKIPEDIA.ORG, 2008). The area of Nakhon Pathom covers 2,168.33 square kilometer (0.4% of the nation's land), ranked 62th among 76 provinces of Thailand. Its altitude varies from 2 to 10 meters above the sea level. The climate in Nakhon Pathom Province is influenced by tropical monsoons. Thus, it rains heavily during the rainy season ranging from 700 to 1,300 millimeters (70-120 rainy days on average) annually. The average temperature takes up around 28.5^{o}C with the maximum and minimum of 39.0 and 12.6 Celsius degrees, respectively. The average relative humidity is approximately 74% (WWW.NAKHONPATHOM.GO.TH, 2008).

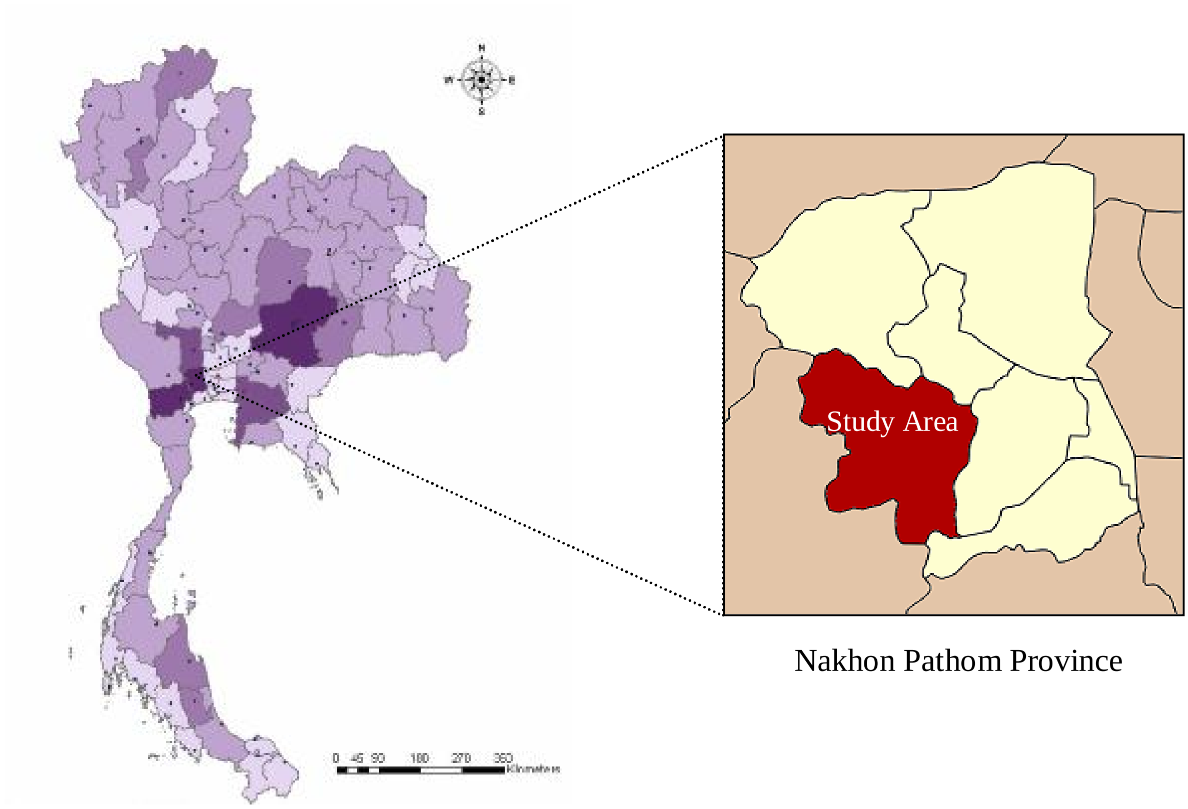

Figure 2.1: Map of Nakhon Pathom Province and

Sam Khwai Phueak Subdistrict (Study Area), Thailand

Source: WWW.DLD.GO.TH, 2008 and HTTP://EN.WIKIPEDIA.ORG, 2008.

2.2.1.2 Governance and Demography

Nakhon Pathom Province comprises 7 districts, 106 subdistricts, and 930 townships. The Muang District is its capital city. Nakhon Pathom Province is governed by a Governor who is appointed by the Minister of Interior. Its population size in 2008 was 828,846 people (male 400,597 people and female 428,249 people) stemmed from 290,714 households. Consequently, the population density is 382 people per square kilometer. In terms of labor force, Nakhon Pathom has the labor force of 589,566 people accounted for 60.61% of its total population. This labor force consists of 52.76 % male and 47.24% female labors. In addition, the employed and unemployed persons yield the numbers of 582,517 (98.8% of the labor force) and 7,049 (1.20% of the labor force) people, respectively (WWW.NAKHONPATHOM.GO.TH, 2008). Currently Nakhon Pathom is attracting migration from other parts of Thailand, notably from Bangkok and the Northeastern provinces. Thai and Burmese migrant workers are prevalent. The urban area of Bangkok has already grown until the provincial borders to Nakhon Pathom (WWW.NAKHONPATHOM.GO.TH, 2008). In addition, all levels of education are provided in Nakhon Pathom, offering from elementary schools to several leading universities in the nation (WWW.NAKHONPATHOM.GO.TH, 2008).

2.1.2.3 Overall Economy

In 2005, the gross provincial product (GPP) at current price of Nakhon Pathom was 121,010 million baht (2,470 million euros at 49 baht per euro) generated from agricultural sector by 10,700 million baht (8.84% of GPP) and non-agricultural sector 110,311 million baht (91.16% of GPP). The GPP per capita is 147,573 baht (3,011 euros at 49 baht per euro) (WWW.NESDB.GO.TH, 2008). This GPP was ranked 13rd among all provinces of the whole country and 6th among the provinces of the central plain. Top three prominent industries in the area are the food & drink, textile, and chemical industries, respectively. The total investment in the industry sector is approximately 221,204 million baht in 2006. Additionally, the total number of business units in 2006 of Nakhon Pathom Province is 5,607 units generated from Muang District alone 43.07% associated with the employment of 20.25% of the province (WWW.NAKHONPATHOM.GO.TH, 2008). It is important to notice from this information that agriculture is becoming marginal and that is an industrialized province.

For agriculture, the agricultural land takes up around 62.35% of the total provincial land engaging in 32.09% of the total provincial population. The dominant plantation crops of Nakhon Pathom Province are rice (28.37% of the total provincial land accounted for 3,635 million baht in total value in 2006), fruits (7.92% of the total provincial land accounted for 1,889 million baht in total value in 2006), and sugarcane (6.62% of the total provincial land accounted for 808 million baht in total value in 2006), respectively (WWW.NAKHONPATHOM.GO.TH, 2008). Agricultural employment is still a major income source.

In terms of livestock, there are various types of livestock such as cattle, poultry, and swine. However, swine is the major livestock in the area. Figure 2.1, the left-hand-side map, demonstrates the density of swine population by different degrees of the shading (the darker, the more populated) for each province of Thailand in 2007. Hence, it is noticeably that Nakhon Pathom Province is one of the highly populated swine raising provinces in the nation. According to the statistics in 2007 reported by the DLD, there were 1.14 million heads of swine (15.87% of the swine population in Thailand) raised by 3,436 farms (1.63% of the total swine farms in Thailand) in Nakhon Pathom Province (WWW.DLD.GO.TH, 2008). However, according to the DLD report, the numbers of swine and farms show flucuating changes during 1999 – 2006 for both cases of Nakhon Pathom Province and the whole country, as seen in Table 2.1 and Table 2.2, repectively. It reported that the farms going in and out of their businesses during the period were usually drawn from small scale farms. They were unable to face higher production costs and swine price fluctuations (instability of demand and supply for pork, including frequent market interventions by the Department of Internal Trade).

Table 2.1: Number of Swine in Nakhon Pathom Province and in Thailand, 1999 – 2006

Year	Country		Nakhon Pathom	
	Heads	% Change	Country	% Change
1999	7,423,101	-	999,744	-
2000	7,761,056	4.55	1,115,271	11.56
2001	8,203,270	5.70	857,428	-23.12
2002	6,989,464	-14.80	666,346	-22.29
2003	7,815,534	11.82	677,311	1.65
2004	6,285,603	-19.58	539,691	-20.32
2005	8,174,526	30.05	730,982	35.44
2006	7,153,784	-12.49	3,436	-99.53

Source: WWW.DLD.GO.TH, 2008.

Table 2.2: Number of Swine Farms in Nakhon Pathom Province and in Thailand, 1999 – 2006

Year	Country		Nakhon Pathom	
	Farms	% Change	Farms	% Change
1999	306,421	-	5,442	-
2000	367,272	19.86	4,770	-12.35
2001	326,198	-11.18	2,122	-55.52
2002	289,983	-11.10	3,113	46.72
2003	317,564	9.51	2,011	-35.40
2004	225,592	-28.96	829	-58.78
2005	251,569	11.52	1,656	99.76
2006	211,329	-16.00	3,436	107.49

Source: WWW.DLD.GO.TH, 2008.

2.1.2.4 Infrastructures

Nakhon Pathom is a compact city with a fairly complete infrastructure. The length of all the roads in Nakhon Pathom area is roughly 625 kilometers. A tab water supply is available covering the major municipal areas whereas the non-municipal areas are supplied by 724 natural minor canals and irrigation systems (76.49% of the total provincial land). In terms of power supply, all areas in Nakhon Pathom are completely provided by 7 power plants throughout the province. In addition, most households have fixed lines of telephone connection and many of them associate to the mobile phones.

2.2.2 General Information about Sam Khwai Phueak Subdistrict

The Sam Khwai Phueak Subdistrict, the researched area, is situated in the heart of Muang District (only 4 kilometers from Muang District), Nakhon Pathom Province. It lies between 13°49′N and 100°3′E. The total area takes up 14.77 square kilometer that contributes to 10.62 square kilometer (71.90% of the total area) of agricultural land and 4.15 square kilometer (28.10% of the total area) of non-agricultural land. There are 2,330 households living in 7 villages accommodated by one major road and one canal namely the “Chedi Bucha” canal. Sam Khwai Phueak Subdistrict is administered by its Subdistrict Administration Organization authorized by Ministry of Interior. (WWW.THAITAMBON.COM, 2008). In 2008, the population size yields 8,675 people with the numbers of 4,159 (47.94%) and 4,516 (52.06%) male and female populations, respectively (WWW.DOPA.GO.TH, 2008). Generally, the climate in Sam Khwai Phueak Subdistrict is also similar to that of Nakhon Pathom Province as a whole.

In terms of the local economy, the subdistrict mainly depends on income derived from agriculture mostly from swine, rice, orchard, and fish farming. The majority of swine farms in this subdistrict are small farms located close to each other. Combining into residential and commercial areas of the town, the area of investigation is a mixed area. Several swine farms are located along both sides of the Chedi Bucha canal which is polluted by swine manure all year round. As such, the water pollution in the canal is most observable during the summer season due to shallowness and strong odor (THE STUDY'S FIELD SURVEY, 2005-2006). Other specific information about Sam Khwai Phueak Subdistrict are provided in the chapter of field survey and empirical findings in more detail.

2.2.3 Overall Picture of Swine Farm Waste Management and Technologies in Nakhon Pathom Province

Basically, swine farm waste management and technologies in Nakhon Pathom Province as a whole are more advanced than that of Sam Khwai Phueak Subdistrict (the specific picture of farm waste management and technologies in Sam Khwai Phueak Subdistrict will be presented in chapter 4). Overall, the farm waste management in Nakhon Pathom can be viewed as 3 general aspects: waste reduction, waste treatment, and waste utilization. These aspects are portrayed in the following categories (Pollution Control Department, 1999).

2.2.3.1 Waste Reduction

Several swine farms in different areas of Nakhon Pathom Province apply various technologies to reduce waste beforehand. The technologies begin with the breed selection (Large White and Landrace breeds are famous breeds in the areas). The barn preparation and cleaning practice are also important in the process of waste reduction. For instance, many farms have installed an automatic food and water feeding machine in order to give proper amounts and formula of feed to each type of swine. They try to reduce excessive feed which later leads to cause in farms' overloaded waste (in the forms of nitrogen and phosphorus nutrients). Some swine farms try to minimize their waste odor by adding probiotics or effective microorganisms (EM) into the feed and water. Furthermore, the Pollution Control Department reports that more than 60% of the swine farms collect swine manure before washing the barn floor. The rest of the farms still wash and drain the sludge into the waste collecting system (canal) directly.

2.2.3.2 Waste Treatment

Due to a PCD study in 1999, the majority of swine farms especially small (47% of the total farms surveyed) and medium (44% of the total farms surveyed) scale farms either did not have any waste treatment system or had only one single waste collecting pond. However, it was found that farms with treatment systems mainly applied “open-type anaerobic ponds”. The system is built by installing a linear set of 2 – 7 open (small) ponds connected to each other. This system is also widely used throughout the country because of the advantages of low construction costs and low maintenance. However, there are several disadvantages in terms of limited treatment efficiency, odor problem, excessive suspended solid and sludge, incapability to process for biogas, etc. In addition, the rest of the farms, mostly large-scale farms, applied various types of treatment systems depending on the farms’ budget. These systems were available in the forms of both closed-type anaerobic and open-type aerobic systems. The first system is generally known as biogas digester system which has the advantages of high treatment capacity, i.e. of biogas recycling capability and of less odor problem. In contrast, the system is costly in terms of installing costs and high maintenance costs with the requirement of highly skilled operator. For the open-type aerobic system, the popular treatment systems used in the area are facultative ponds (1.5 – 2.5 meters in depth), oxidation ponds (1.0 – 1.5 meters in depth), and aerated lagoons. The first two depends on oxygen fixation derived from algae and plants inside the ponds. The differences among the three types are that the facultative ponds leave less amount of residue than the oxidation ponds and the aerated lagoons apply a machine (rather than natural agents) to fill oxygen into the lagoons. In addition, swine waste is used to generate power used on the farms that have the biogas digester system. However, a digester is rare in this case due to its costly technology and high maintenance requests.

2.2.3.3 Animal Waste Utilization

As mentioned previously, Nakhon Pathom Province engages in plenty of agricultural activities in terms of plantation and livestock. Therefore, swine waste, especially in the form of manure, could be an important source of waste recycling in the area. Swine manure is usually used as bio-fertilizer and soil conditioner for rice, orchard, and other farms. Moreover, many fish farmers in the area desire to apply swine manure; i.e. to either directly feed their fish or use it to boom planktons in their fish ponds. Also recently, there have been new water flea farms occurring in the Nakhon Pathom Province because of availability of the local swine manure. Manure is used as a major source of inputs.

According to the general information on swine waste management and technologies discussed above, it is not surprising that Nakhon Pathom Province has been facing pollution problems mainly drawn from the excessive runoffs from swine farms. One evidence examined by the PCD in 2002 showed that swine farms in the central region (Nakhon Pathom Province was included) were the important source of water pollution. In the major canals and rivers of Thailand as indicated by the BOD contents in Table 2.3, large amounts of pollutants occur (WWW.PCD.GO.TH, 2008).

Table 2.3: The Amount of Biochemical Oxygen Demand (BOD) Produced by Swine Farms Classified by Regions and Farm Sizes, 2002

Region	BOD (kilograms/day)			
	Small Farm	Medium Farm	Large Farm	Total
North	4,247	1,941	11,338	17,526
Northeast	4,386	2,004	11,708	18,097
Central	9,707	4,437	25,914	40,059
East	5,571	2,546	14,871	22,988
South	2,928	1,338	7,815	12,080
Total	26,838	12,266	71,646	110,750

Source: WWW.PCD.GO.TH, 2008.

2.3 Summary

In this chapter we mainly discussed the topics of both research design and general information about the study area. The major conclusion of the research design was to choose Sam Khwai Phueak Subdistrict as the study area. By means of convincing reasons behind, it seems the right location. The data of the study were mostly drawn from the field survey and brainstorming among swine raising farmers and related stakeholders. Furthermore, the study also engaged in collecting and laboratorial analyzing the samples of swine waste and wastewater from the farms to specify the magnitude of environmental indicators. For the last part of the chapter, it provided the general ideas that Nakhnon Pathom Province (including the study area) is one of the prime cities of Thailand with animal waste problems. Consequently, it has been partially facing pollution problems derived from (small and medium) conventional swine farms due to limitations on farm location and setting as well as inadequate and inefficient waste treatment systems.

3 RELATED LAWS AND REGULATIONS ON SWINE FARMS

This chapter presents the summary of related laws and regulations on swine production and farms in Thailand. It discusses laws in terms of farm standards, farm wastewater control at point source, and penalties. These laws and regulations were summarized from 2 main sources: the Department of Livestock Development (DLD) under the Ministry of Agriculture and Cooperatives and the Pollution Control Department (PCD) under the Ministry of Science, Technology, and Environment.

3.1 Swine Farm Standards

3.1.1 Classification of Farm Sizes

According to the Notification of the Ministry of Agriculture and Cooperatives, dated November 3, B.E. 2542 (1999), the classification of the farm sizes is calculated in terms of livestock unit (LU) shown in Table 3.1.

Table 3.1: Classification of Swine Farm Sizes

Farm Size	Livestock Units (LU)	Heads of Swine (heads)
Small	6 – less than 60	50 – less than 500
Medium	60 – 600	500 – 5,000
Large	higher than 600	higher than 5,000

Notes: 1) 1 LU = 500 kilograms.
2) Weight of breeding swine = 170 kilograms/head.
3) Weight of fattened swine = 60 kilograms/head.
4) Weight of nursling swine = 12 kilograms/head.

Source: WWW.DLD.GO.TH, 2008.

3.1.2 Farm Standards

The DLD is directly responsible for inspecting swine farms through out the country to check whether they follow the farm standards indicated in the Notification of the Ministry of Agriculture and Cooperatives dated November 3, B.E. 2542 (1999). In accordance with these standards, the DLD has a duty to inspect and certify those swine farms which are willing to apply for being entitled “the standard swine farm”. This means that it is not a mandatory to be a standard farm. However, being a standard farm has more privileges in terms of commercial aspects. The standard farms always receive priority in signing farm contracts with the major livestock processing companies due to their higher product quality and often get better deals. Not to mention, they also get better access to governmental supports such as financial funds, technical supports, animal disease outbreak control (BUREAU OF LIVESTOCK STANDARDS AND CERTIFICATION, 2003), etc. The general criteria that the swine farm owners have to fulfill to become a standard swine farms are mentioned as follows:

1) The farm has to install a disease-free system at the farm's entrance and exit,
2) The farm is operating in accordance with the hygienic regulations,
3) The farm's barns have proper characteristics and size to suitably fit the number of swine,
4) The farm's human resource management (in terms of labors, animal technicians, and veterinarians) has to be consistent to the number of swine, and
5) The farm must have the proper vaccination programs.

If a farm is qualified upon the 5 primary criteria stated above, the farm owner or operator will go through a training program on farm management and later receive the certificate of standard farm after completing the training program. The certificate lasts for 2 years and is renewable upon request. However, besides the 5 general criteria, there are more details in the farm standards. For instance, the farm location, farm and barn types, farm practice, human resource management, farm recording, feed and water management, animal health management and vaccination, and farm environmental management are clearly clarified in the standard requirements under the Notification of the Ministry of Agriculture and Cooperatives in 1999.

The certificate will be revoked for 3 years with the blacklist record reported to the DLD if the farm is operated inconsistent with the primary criteria and the proper farm management (BUREAU OF LIVESTOCK STANDARDS AND CERTIFICATION, 2003).

3.2 Wastewater Standard for Swine Farms

Under the Notification of the Ministry of Science, Technology, and Environment (issued under the Enactment and Conservation of the National Environmental Quality Act, B.E. 2535, published in the Royal Government Gazette, Vol. 118, Special Part 8, page 11-18, dated February 23, B.E. 2544 (2001)), swine farms are specified to be sources of pollution and have to be regulated on their wastewater. Water released to the public areas or the environment is controlled. Consequently, the PCD has the legal responsibility to inspect and enforce swine farms throughout the country to follow the effluent standard which is presented in the following Table 3.2. Though the wastewater standard for swine farms is regulated, violations still persist (WWW.PCD.GO.TH, 2008).

Table 3.2: Effluent Standard for Swine Farm

Parameter	Unit	Maximum Permitted Value		Examination Method
		Standard A	Standard B	
pH value	-	5.5 - 9	5.5 - 9	pH Meter
BOD (Biochemical Oxygen Demand)	mg/l	60	100	Azide Modification or Membrane Electrode
COD (Chemical Oxygen Demand)	mg/l	300	400	Potassium Dichromate Digestion
SS (Suspended Solid)	mg/l	150	200	Glass Fiber Filter Disc
TKN (Total Kjeldahl Nitrogen)	mg/l	120	200	Colorimetric or Ammonia Selective Electrode

Notes: Standard A is applied for large swine farms.
Standard B is applied for small and medium swine farms.
Source: WWW.PCD.GO.TH, 2008.

3.3 Penalties

In general, the specific penalties on swine farm operators, who violate the law under the Notification of the Ministry of Science, Technology, and Environment notified previously, are inexplicitly written. Thus, the PCD's Legal Office has to interpret the farm's violation into the general contexts of the law. In practice, it takes a long period of time to file a lawsuit and penalize a swine farm operator if the guilt is found. However, the general penalty for the one, who violates the law, is either serving less than a 1-year-prison time or paying 100,000 baht or both (WWW.PCD.GO.TH, 2008). Additionally, according to the study's field survey in 2006, most violation cases only receive the warning from the PCD officers and most farms need to improve their wastewater treatment system. In case of complaint from the neighbors on farm pollution, such as the farm odor, some of the farm operators, who were found guilty by the police officer, had to pay only a small amount of fine at each time of the complaint. This small magnitude of the fine is not derived from the specific penalties (inexplicitly written) indicated in the environmental law. It actually comes from the fine of disturbing or violating the rights of others.

3.4 Summary

The laws and regulations on swine farms are available and clarified by 2 major sources: the Notification of the Ministry of Agriculture and Cooperatives (dated November 3, B.E. 2542 (1999)), and the Notification of the Ministry of Science, Technology, and Environment (dated February 23, B.E. 2544 (2001)). There are 2 significant government agencies: the DLD and the PCD, responsible for the law implementation under these two notifications. The DLD is responsible for controlling the swine farm standard under the former Notification and the PCD is responsible for inspecting and enforcing swine farms on their wastewater treatment. In practice, it was often found that the two departments work separately. However, the specific penalties for the swine farm operators violating the law are inexplicitly clarified.

4 FIELD SURVEY AND EMPIRICAL FINDINGS

As said the field survey of the study took place in Sam Khwai Phueak Subdistrict, Nakhon Pathom Province, Thailand. It approximately lasted for 6 months, starting November 2005 and ending April 2006. The survey was initially led by the veterinarian from the Provincial Livestock Office of Nakhon Pathom Province. Thankfully, the survey team also received very warm welcome and cooperation from Sam Khwai Phueak Subdistrict Administration Organization, farmers, and other stakeholders in the study area.

This chapter illustrates the results from the field survey drawn from answers of 104 swine raising farmers (the whole population of the swine raising farmers in the study area), 48 swine manure traders, and 37 swine manure end-users. In addition, the results of the farm wastewater examined in the laboratory are shown in this chapter. Finally, the conclusions of the stakeholder brainstorming are presented in the last part of the chapter.

4.1 Empirical Findings on the Swine Farms and Farmers

This section expresses several aspects of the swine raising farmers and their farm practices such as their general background, farm characteristics and production processes, waste management, production costs and revenue, and farm owner's or manager's opinion and recommendation on participating in waste management of their community.

4.1.1 General Background of the Farmers

All interviews were conducted through either the family head or the manager. Table 4.1 shows that more than a half of the farm owners are male, 72 persons (69.23%), the farm owner's age ranges from 25 to 80 years old with the average of 51 years, and most (81 persons or 77.88%) of the farmers have their educational background below high school level. Only few farmers engaged in bachelor degrees. Additionally, each farm contains 5 family members on average with the maximum and minimum numbers of 14 and 1 members, respectively.

Table 4.1: General Background of the Swine Farm Owners

Categories	Units	Number	Share (%)
Gender:			
Male	persons	72	69.23
Female	persons	32	30.77
Total Samples (N)	persons	104	100.00
Age:			
Mean	years	51	-
Maximum	years	80	-
Minimum	years	25	-
Total Samples (N)	persons	104	-
Education Levels:			
Below High School	persons	81	77.88
High School	persons	14	13.46
Above High School	persons	9	8.66
Total Samples (N)	persons	104	100.00
Family Members:			
Mean	persons	5	-
Maximum	persons	14	-
Minimum	persons	1	-
Total Samples (N)	persons	104	-

Source: Survey Data, 2005-2006.

Interestingly, Figure 4.1 demonstrates that the majority of the farmers in the study area do not belong to any agricultural institution such as swine raising farmer cooperatives, swine raising farmer association, agricultural cooperatives, agricultural bank, and village fund, etc. This means that it is difficult to reach them with extension or programs to reduce waste. According to the interviews, there are 28 (26.92%) and 76 (73.08%) swine raising farmers who are members and non-members of the agricultural institutions, respectively. On one side, top three of the institutions that the farmers belong to are agricultural banks (15 persons, 53.57%), the village fund (11 persons, 39.29%), and the agricultural cooperatives (4 persons, 14.28%), respectively (Figure 4.2). In this group, they gave the reasons of joining the institutions that they can access to the sources of financial funds in terms of quicker loan approval and higher amount of loans from the village fund and the agricultural bank. Moreover, some of them can buy farm inputs at lower prices from the agricultural cooperatives. On the other side, the farmers who are non-members of any institution mostly reveal that it is unnecessary to be a member because they are contract small-scale farmers and desired to be independent.

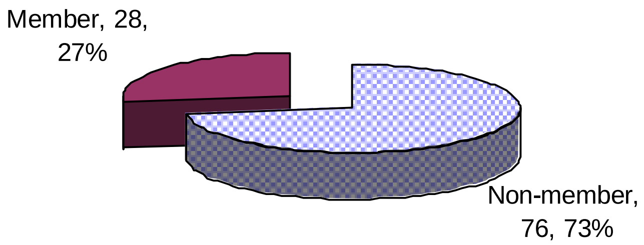

Figure 4.1: Member Status of the Swine Raising Farmers on Agricultural Institutions

Source: Survey Data, 2005-2006.

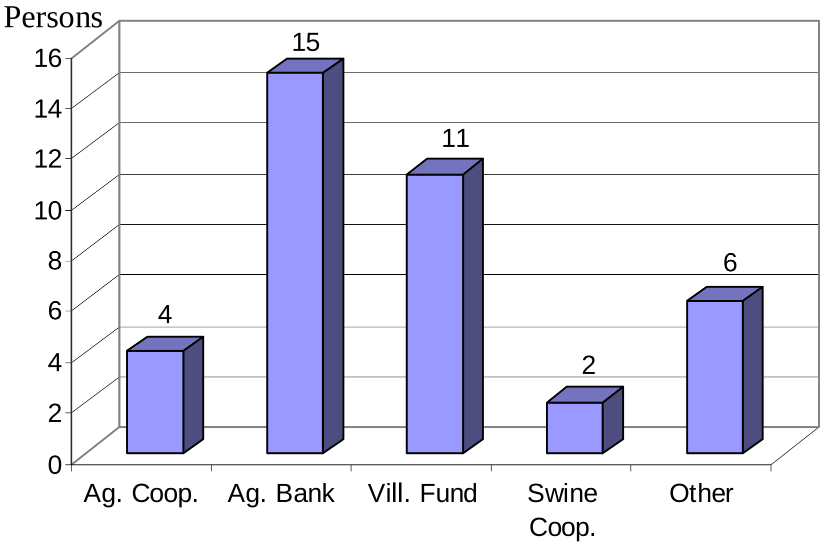

Figure 4.2: Agricultural Institutions That the Swine Raising Farmers Belong to

Notes: 1) Ag. Coop. means the Agricultural Cooperatives.

2) Ag. Bank means the Agricultural Bank.

3) Vill. Fund means the Village Fund.

4) Swine Coop. means the Swine Raising Farmer Cooperatives.

Source: Survey Data, 2005-2006.

In addition, 72 farmers (69.23%) disclose that they also hold a second occupation besides swine farming. Figure 4.3 depicts the popular additional occupations in the study area are widely drawn from vegetable growing (27 persons, 25.96%), aquarium fish farming (23 persons, 22.12%), water flea farming (7 persons, 6.73%), and others (15 persons, 14.42%), respectively. This would mean that they could use swine waste as manure.

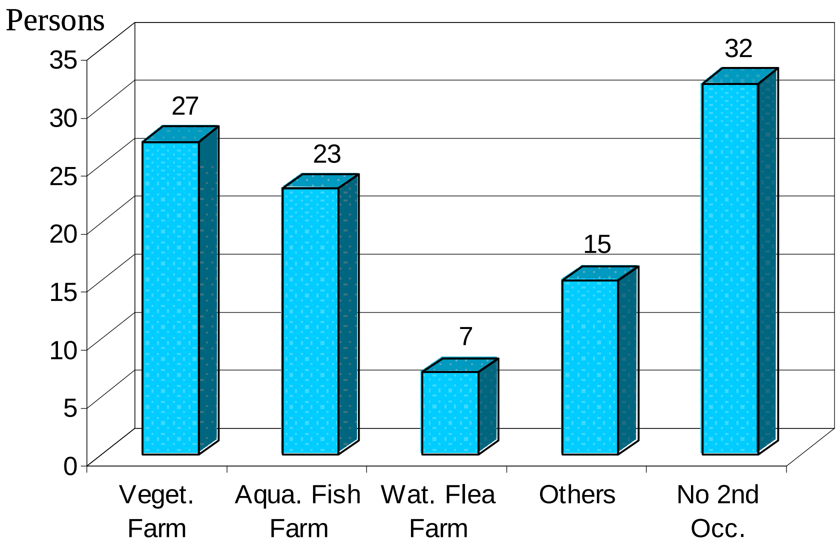

Figure 4.3: Second Occupations Held by the Swine Raising Farmers

Notes: 1) Veget. Farm means vegetable farming.

2) Aqua. Fish Farm means aquarium fish farming.

3) Wat. Flea Farm means water flea farming.

4) Others means other second occupations.

5) No 2nd Occ. means do not hold any 2nd occupations.

Source: Survey Data, 2005-2006.

4.1.2 Farm Characteristics and Production Process

According to the size classification in chapter 3, Sam Khwai Phueak comprises only small and medium scale swine farms. There are 77 (74.04%) and 27 (25.96%) small and medium farms, respectively as seen in Figure 4.4.

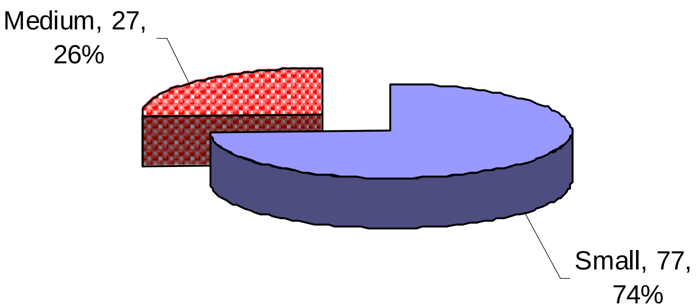

Figure 4.4: Number and Share of the Swine Farms Classified by Farm Sizes

Source: Survey Data, 2005-2006.

Approximately half of the swine farms in the study area are usually situated together with the farmers' houses along the line of village road or public canal. The rests of the farms are located next to their farmers' houses or scattered inside the community area (Figure 4.5).

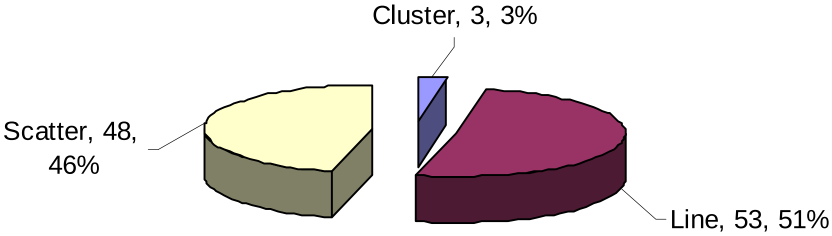

Figure 4.5: Characteristics of the Farm Location

Notes: 1) Line means number of the swine farms situated with the farmers' houses along the line of village road or canal.

2) Scatter means number of the swine farms situated with the farmers' houses and scattered inside the community area.

3) Cluster means number of the swine farms separately situated from the farmers' houses.

Source: Survey Data, 2005-2006.

Table 4.2 shows the range of land holdings ranging from 0.21 rai or 0.03 hectare to 80.00 rai or 12.80 hectare. Likewise, each swine farm attains about 3.41 rai or 0.55 hectare on average. For the land ownership, almost all of the farm lands are owned by the swine farmers themselves and only few have to rent the land (Figure 4.6).

Table 4.2: Land Holdings of the Swine Raising Farmers

Categories	Land Holding		
	rai	hectare	square meter
Mean	3.41	0.55	5,460.00
Maximum	80.00	12.80	128,000.00
Minimum	0.21	0.03	328.00
Total Samples (N)	104	104	104

Notes: Rai is the Thai unit used to measure the land size (1 rai = 1,600 square meter).

Source: Survey Data, 2005-2006.

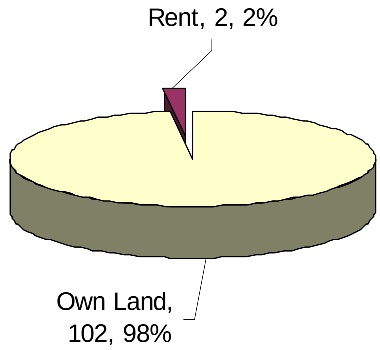

Figure 4.6: Land Tenure of the Swine Farms Classified by Farm Sizes

Source: Survey Data, 2005-2006.

Mentioned partially in chapter 2, swine raising farmers in Sam Khwai Phueak Subdistrict prefer to operate their farms in terms of contract farming (75 farms, 72.12%) rather than independent farms (29 farms, 27.88%). This would mean that contracts could have a stake in waste control, if the government accesses them. Consequently, it is not surprising that fattening swine is popular for the farmers in the study area. These can be observed from Figure 4.7. Contract farming in this area means that all contract farmers receive piglets from the local swine companies accompanied with feed, growing techniques and farm check-up programs provided by the companies.

However, some farmers pay their own feed costs for some cases. The decisions on the gate prices and the weight of swine are made in advance indicated in the contract. Hence, only costs that the farmers pay are the labor costs and the other operating costs. There are some small differences of the contract farming in the area depending on how the contract is made between the farmer and the company. For instance, some contract farmers have their own expenses on feed, vaccine, and antibiotic. On the other hand for some other cases, some of these expenses are provided by the companies. In addition, all the swine barns of the farms in the area have the characteristics of an open-type barn that is associated with low construction costs. Some of these open-type barns can cause the problems of farm odor in the area as opposed to better barns.

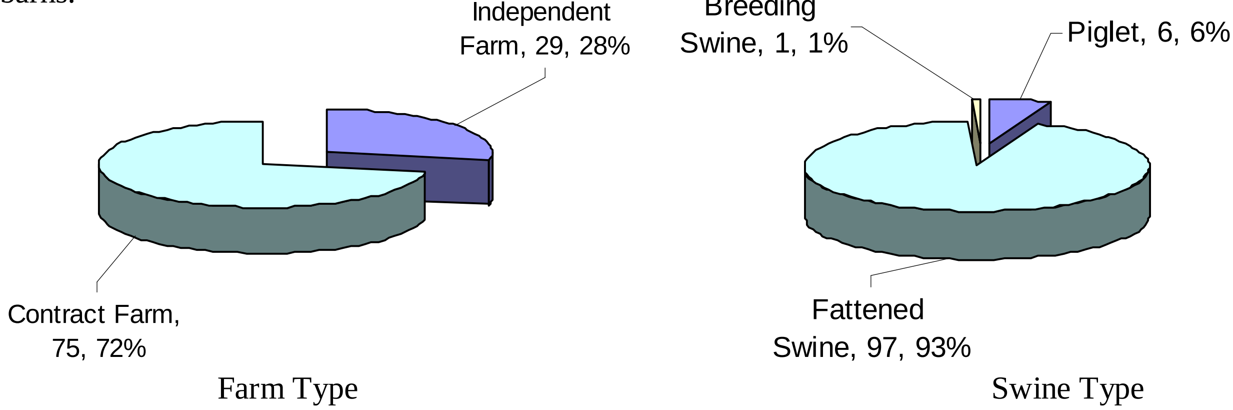

Figure 4.7: Types of Swine Farms and Swine Raised in the Study Area
Source: Survey Data, 2005-2006.

In terms of labor used in the area, Table 4.3 indicates that an average, individual swine farmer employs 4 workers on his farm. This can be either family or hired labor or even both. According to the interviews, the fulltime family workers are normally the head of the farm and his spouse. The rest of the farm workers are mainly hired labors. The wage rate in the area ranges from 70 to 233 baht per day depending on the skills and experiences of the workers. The average wage is about 155.84 baht per day while the minimum wage rate in Nakhon Pathom area is 194 baht per day (WWW.MOL.GO.TH, 2008). However, the current situation of the labor market in Nakhon Pathom area is somehow difficult. Farmers are facing labor shortages; particularly local Thai workers in the agricultural sector are scarce. Similarly, livestock (swine) farms have been dealing with worse situation because local Thais are unwilling to work in the farms surrounded by unhealthy and risky conditions with low payments. Thus, it is common to see that several swine farms in the area employ migrant workers who mostly are Burmese and who are willing to accept the hard working conditions with low payments (the Study's Field Survey, 2005-2006).

The financial sources or funds for the swine farms in the area are derived from various institutions. Besides the farmers' own funds, the most popular source is from the agricultural bank which usually charges lower interest rates for loans with flexible payback periods of time. However, being the loan customers of the bank, the farmers must acquire good records on payment and farm performance. Other sources of funds come from local private loans, local commercial banks, and cooperative, etc (Figure 4.8).

Table 4.3: Wage Rates and Number of Labors Employed by the Swine Farms

Categories	Wage Rates (baht/day)	Numbers of Farm Workers (persons)		
		Whole Workers	Family Workers	Hired Workers
Mean	155.84	4	2	3
Maximum	233.00	22	7	20
Minimum	70.00	1	1	0
Total Sample (N)	104	104	104	104

Source: Survey Data, 2005-2006.

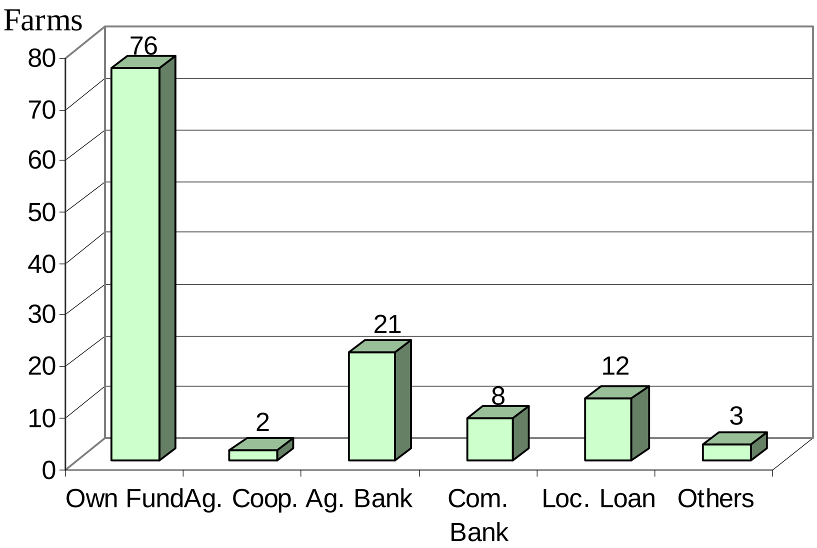

Figure 4.8: Sources of Funds for the Swine Farms

Notes: 1) Each farm can engage in more than one source of funds.

2) The numbers in the figure indicate numbers of the farms by sources of funds.

3) Own Fund means the farmers' own funds.

4) Ag. Coop. means the funds come from the Agricultural Cooperatives.

5) Ag. Bank means the funds come from the Agricultural Bank.

6) Com. Bank means the funds come from commercial banks.

7) Loc. Loan means the funds come from local loans.

8) Others means the fund come from other sources.

Source: Survey Data, 2005-2006**.**

As mentioned earlier, almost all livestock farms in the study area are fattening swine farms. In general, the production process mainly begins at preparing the swine barns properly in terms of the farm hygiene requirements. The later procedure continues on either buying or receiving 7-9 week-old piglets which weigh between 16-20 kilograms from the local breeding farms or swine companies. Overall, the process of raising and fattening swine can be explained in the following aspects:

Feeding Process – The swine feed in the area comes in different forms. For examples one finds human food, broken-milled rice, readymade feed (pellets or powder), and concentrate feed. Moreover, some farmers make feed on their own by mixing broken-milled rice, corn, pounded fish, soybean, vitamins and minerals in different formulas. Among different individual farms, different recipes exist. The sources of the feed are usually drawn from both local swine companies in case of contract farming and local markets in case of buying. A farmer normally feeds his swine 2-3 times a day by two ways: manually feeding by putting the feed in the feed rail or automatically feed by using the automatic feeding machine.

Disease Prevention – Diseases and parasites are important factors for the farms' survival and benefits. Foot and mouth disease, acute diarrhea, pneumonia, and skin infectious diseases are frequently found in swine. Therefore, for a fattening swine, the farmers apply a vaccination program starting one week after having the new piglets at his farm. Additionally, diarrhea and foot-and-mouth disease vaccinations are applied in the second and the third week, respectively.

Barn Cleaning – Farmers in the area regularly clean their barns. This is done daily by 2 ways in general: the first way is to collect swine manure before spraying water to the barn floor. The second way is that the farmers spray water to the barn floor directly without collecting manure. The farms applying the former way usually have some space to dry manure in order to sell or reuse it. In contrast, the farms without the manure drying space either drain all the sludge to waste collecting and treatment systems or remove the sludge from the drainage and keep it in plastic containers to sell manure in a wet form. The labor requirements, hence, are differing.

Selling Process – After raising the fattened swine for about 4-6 months, i.e. with the weight of 100 kilograms, the farmers sell them. There are 2 ways of selling swine: the farmers transport and deliver their swine to the buyers themselves or the buyers come to buy swine at the farms directly. The contract farmers receive the contract prices if the quality of swine matches that indicated in the contract. In case of the independent farmers, they obtain a price determined in the market.

4.1.3 Farm Waste Management

As mentioned in chapter 2, the waste treatment systems in Sam Khwai Phueak Subdistrict are rather simple as compared to that of other areas in Nakhon Pathom Province. Based on the field survey, every farmer claims that he has at least one waste treatment system in accordance with the regulations of the PCD. However, these waste treatment systems, as applied in the area, are not sufficient and efficient in abating all the daily farm waste. According to the interviews from the provincial DLD and PCD, farmers still pollute on a large scale. As said already, the waste treatment systems in the study area exist in 2 types that are "the open-type anaerobic pond" and "the septic tank". The former system is designed by the DLD for being a standard waste treatment system for small and medium farms. It is the most widely used (71 farms, 68.27%) because of the low investment and maintenance costs including its simplicity to install. This waste treatment system looks similar to a line of 2-7 uncovered rounded ponds connected to each other. The wastewater in the last pond is finally released out from the farm. The other waste treatment system, the septic tank, is a closed anaerobic reactor systems buried underneath the ground. This system is applied on few farms (20 farms, 19.23%) due to its higher costs. Its abatement capacity is higher than the former one of open-type ponds. However, some swine farms (13 farms, 12.50%) applied both waste treatment systems, as documented in Figure 4.9.

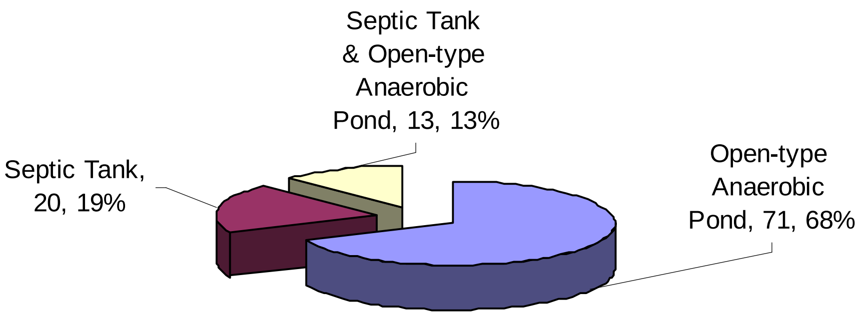

Figure 4.9: Swine Waste Treatment Systems in the Study Area
Source: Survey Data, 2005-2006.

Figure 4.10 reveals that the farmers do not load all amounts of the farm wastewater into the waste treatment systems. Several farms keep some amount for other recycling purposes. A large number of the farms (60 farms, 62.50%) tend to load more than 80% of the total farm wastewater into private waste treatment systems (open-type anaerobic ponds). This implies that the rest of wastewater remains untreated and reaches outside the treatment systems. Untreated wastewater on farm is capable to be recycled in several ways as fertilizer, water flea starter, fish feed, and so on. But, there are some swine farms (21 farms, 34.42%) loading this untreated wastewater directly into the public drainage systems and other public areas (Figure 4.11).

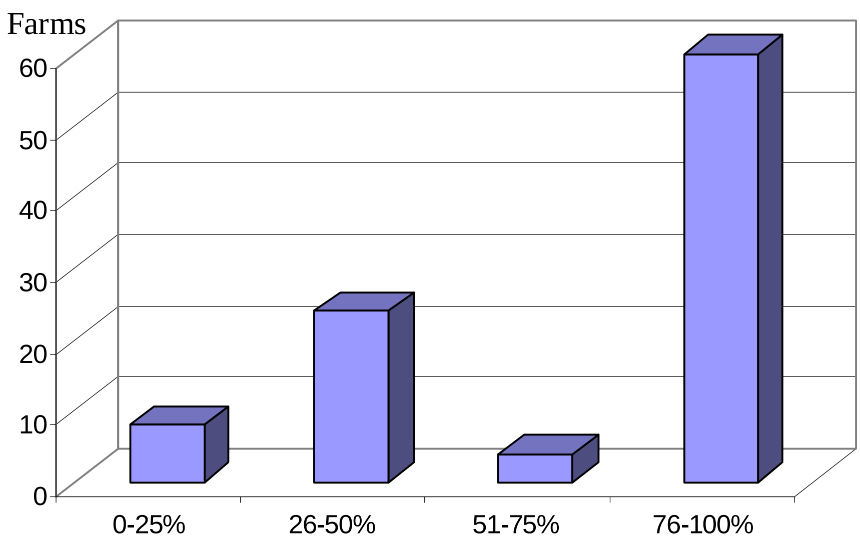

Figure 4.10: Percentage of Farm Wastewater Loaded into the Waste Treatment Systems

Notes: The horizontal axe stand for percentage of wastewater loaded into the treatment systems.

Source: Survey Data, 2005-2006

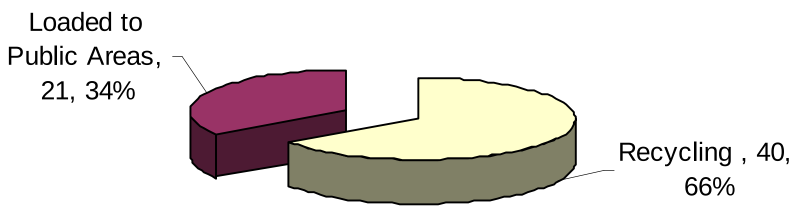

Figure 4.11: Untreated Farm Wastewater Management in the Study area

Source: Survey Data, 2005-2006.

Swine manure and wastewater in the study area are managed in different channels as seen in Table 4.4. For the manure, it is applied in both forms of dried and wet manure. The drying of manure is usually done at farms that have extra spaces available for manure drying in the sun. The dried manure is operated by both, the farm owners themselves and the farm workers. Workers are allowed to collect farm manure and sell it for their own revenue. More than half of the farmers sell dried manure to manure middle men and the rests of the farmers keep it for their own uses. This manure on the farms is mostly applied as fertilizer. On the other side, the wet manure is much less popular in terms of both selling and recycling purposes. Due to its heavy weight and difficulties to handle, it creates problems. In addition, wet manure is unable to be kept in longer storage periods of time. It has to be sold daily or every other day.

The wastewater in the area is partially recycled by using the wastewater removing service provided by the Sam Khwai Phueak Subdistrict Administration Organization. Unfortunately, this service has several limitations, such as inadequate wastewater removing trucks and workers. Hence, the service cannot be provided daily for each individual farm. By using this service, farmers have to pay a fee of 70 baht each time of calling the service in order to reduce the waste loads in their waste treatment systems. Each truck load contains about 4,000 cubic meter of the wastewater. Most of the wastewater carried out this way is sold to the water flea farmers who also have to pay the same amount of 70 baht fee to the Sam Khwai Phueak Subdistrict Administration Organization. The subdistrict claims that this activity is a good way of waste management in the area, provided by the government agency. However, according to the interviews from several stakeholders in the area, this activity is dealing with several problems in terms of high cost burdens to the subdistrict (the fees colleted are insufficient to cover all the costs). Insufficient staff and trucks to serve all farms in the area and insufficient number of water flea farms to be the buyers, are encountered.

Table 4.4: Manure and Wastewater Management in the Study Area

Types of Farm Waste	Number of Farms Classified by Manure Recycling Activities						
	SKPS Service	Sell	Waste Utilization in the Farms/Households				Total
			Fertilizer	Fish Feed	Water Flea Starter	Others	
Dried Manure	0 (0.00)	52 (66.67)	20 (25.64)	1 (1.28)	1 (1.28)	4 (5.13)	78 (100.00)
Wet Manure	0 (0.00)	6 (30.00)	2 (10.00)	6 (30.00)	3 (15.00)	3 (15.00)	20 (100.00)
Wastewater	17 (42.50)	2 (5.00)	1 (2.50)	0 (0.00)	15 (37.50)	5 (12.50)	40 (100.00)

Notes: 1) The numbers in parentheses are in percent (%) of the total samples.

2) SKPS Service is the wastewater removing service provided by Sam Khwai Phueak Subdistrict Administration Organization.

Source: Survey Data, 2005-2006.

Other problems in the farm waste management are odor and fly problems. The farmers poorly manage these problems, though they frequently clean their barns and apply effective microorganism (EM) to clean the barn floor and the treatment ponds. Unluckily, the majority of the farmers in the area ignore small problems without taking any action to that (Figure 4.12).

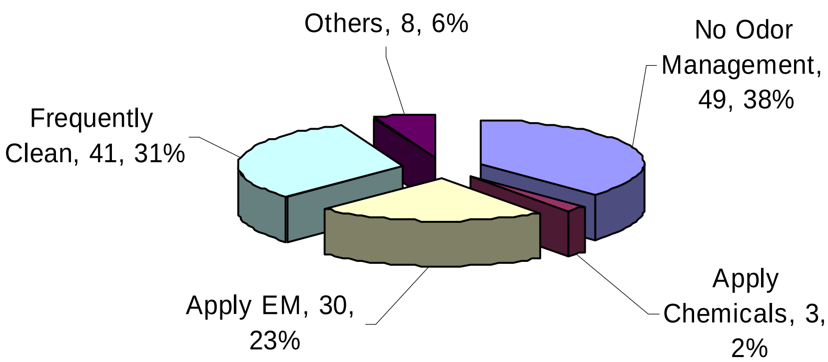

Figure 4.12: Farm Odor and Fly Management in the Study area

Source: Survey Data, 2005-2006.

Even though there are lots of waste management problems existing in the study area, the law and order regulations including the enforcement in practice are inefficient. Regulations are not enough to prosecute the violators. According to the interviews, only 3 farmers (2.88%) have experienced in paying small amount of fines (500 baht each time when found guilty) to the police officers. They were prosecuted because neighbors complained about the farm odor and wastewater leaked out to the public areas (Figure 4.13). These fines are just the fines that cause irritation to the neighbors. However, the real rates of the fines to pollute the environment in the case of swine farms have not been defined yet. These have remained unclear and disputable in the legislation procedure for a long period of time.

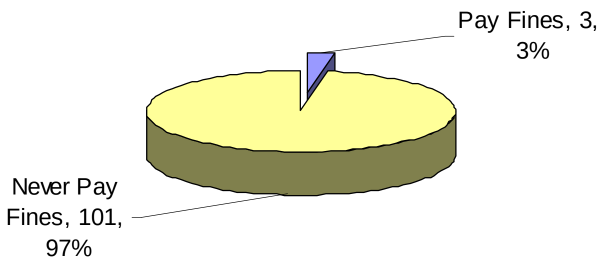

Figure 4.13: The Swine Farm Owners' Experiences of Paying Fines

Source: Survey Data, 2005-2006.

As explored earlier on the farm waste treatment technologies in the area, waste treatment systems are fairly simple. The DLD has designed different waste treatment systems suitable for different limitations in various swine farm areas through out the country. Nevertheless, in practice, the acceptance has to deal with the farmers' perceptions and attitudes on both changing their routines and farm budgets. Moreover, the inelasticity of removal the existing waste treatment to a new one is an important factor that farmers have to consider. A trust in efficiency of the new system has to be built on before making the decision. However, the governmental agencies such as the DLD and the PCD have been trying to tackle down these obstacles by financially support the farmers in helping them to install more efficient waste treatment systems. Yet, this cannot be done extensively due to the budget constraints as observed in Figure 4.14.

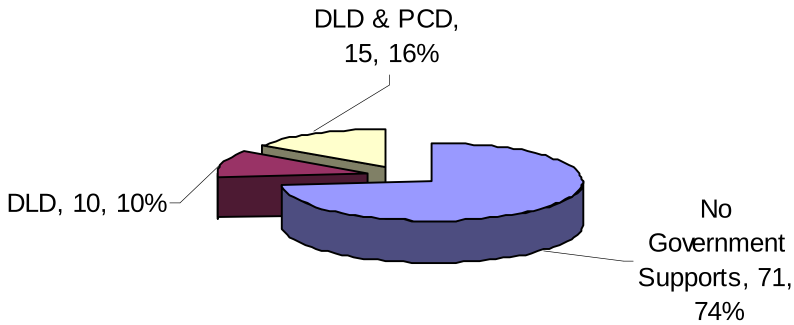

Figure 4.14: The Swine Farm Owners' Experiences of Receiving Governmental Supports

Source: Survey Data, 2005-2006.

4.1.4 Farm Wastewater Examination

Information on examination is crucial. It is a database for the analytical model. The study in this section endeavors to examine the contents of the environmental indicators such as total Kjeldahl nitrogen (TKN), phosphorus (P), suspended solid (SS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and pH value of the farm wastewater in the area. These environmental indicators had been inspected for 2 times a year or every 3 months (in November 2005 and in February 2006) during the survey period of 6 months from 104 swine farms. The process of wastewater sampling is called "grab sampling" by means of grabbing wastewater samples at the times of going in and out of the farm treatment systems. The wastewater samples were sent and examined in laboratories of the Department of Animal Science and the Department of Soil Science, Kasetsart University, Nakhon Pathom Campus. The results of the farm wastewater examination are presented in the following Table 4.5.

Table 4.5: The Results of the Farm Wastewater Examination

Types of Indicator	Environmental Indicator Contents (mg/l)									Total Samples (N)
	First Inspection			Second Inspection			Average			
	In	Out	%Diff	In	Out	%Diff	In	Out	%Diff	
TKN	908	517	-43.06	1,380	725	-47.46	1,144	621	-45.72	104
P	13.63	9.11	-33.16	16.87	10.59	-37.23	15.25	9.85	-35.41	104
SS	1,248	708	-43.27	2,034	1,027	-49.51	1,641	868	-47.11	104
BOD	1,368	659	-51.83	3,618	1,186	-67.22	2,493	923	-62.98	104
COD	2,400	1,600	-33.33	8,040	2,080	-74.13	5,220	1,840	-64.75	104
pH	7.41	7.03	-5.13	8.26	7.99	-3.27	7.84	7.51	-4.21	104

Notes: 1) Each number of the indicator contents is calculated from the average of 104 farms.
2) The unit of the indicator contents is measured in milligram per liter (mg/l) except for the pH value.
3) "In" and "Out" mean that the wastewater samples are inspected (grabbed) at the times of going in and out of the farm treatment systems, respectively.
4) "Average" is calculated from the average of the 2-time sample inspections.
5) "%Diff" is calculated from the percentage difference between going-in and going-out wastewater sampling contents.

Source: Survey Data, 2005-2006.

Even though Table 4.5 shows that the farm treatment systems in the study area can reduce some environmental indicator contents, contained in the farm wastewater, the treated wastewater remains excessively filthy (except for the pH values that are in the acceptable ranges). Compared to the benchmarks legally indicated by the law (as seen in chapter 3), farms still pollute. On average, a farm treatment system has a low capacity in wastewater abating, i.e. less than 65.00% of the total waste contents. For instance, the BOD and COD contents have been reduced by 62.98% and 64.75% of the total contents, respectively. In terms of TKN, P, and SS, these waste contents can be decreased only by half, ranging from 35.00% – 48.00%, of the total contents on average. Unsurprisingly, this is consistent to the fact that most of the swine farms in the area apply simple and low efficient waste treatment systems on their farms notably as already explored in the previous part.

4.1.5 Farm Production Costs and Revenue

In this chapter, the key structures of farm production costs and revenues are exhibited. The topic intends to point out the overall picture of the types of farm investments that the swine raising farmers in the study area concentrate on. Besides the sale of swine, it is interesting to see how significant the revenues, drawn from swine manure, are. Thus, all costs and revenues as information can be helpful in conveying some recommendations and policy implications in the end.

Table 4.6 summarizes the structure of farm production costs in the study area. The table aims to show what kind of production costs, swine raising farmers in the area face. The table presents average values (in two different units) of production costs categorized by types of costs and sizes of swine farms. The mean values of production costs are divided into 3 column-wise parts: 1) mean values for all swine farms (104 farms); 2) mean values for small farms (77 farms); and 3) mean values for medium farms (27 farms).

Overall, it illustrates that the total production cost is 31,599 baht per livestock unit per farm (63.20 baht per kilogram per farm). The total production cost comprises total fixed costs and total variable costs. Total fixed costs take up 3,212 baht per livestock unit per farm, accounted for 10.16% of the total cost. Note that the total fixed costs, displayed in the table, have already been deducted with depreciation costs. Examples of these fixed costs are farm barns, land rent, machinery costs, maintenance costs, and other farm facilities. The value of the total fixed costs is not fairly high, as compared to the total cost.

On the contrary to total fixed costs, total variable costs yield approximately 28,387 baht per livestock unit per farm, accounted for 89.84% of the total production cost. In terms of cost items, the main part of the total variable costs goes to feeding costs (43.62%). The second largest part of the total variable costs is labor costs. In the area, the cost share of the labor primarily falls into 27.24% of the total production cost, on the average. The range of labor cost share varies from farm to farm and is moderately distributed depending on the degrees of labor intensiveness. It has to be noted that costs of family laborers have been calculated and converted into farm labor expenses, even though several of them are unpaid labors.

Other variable costs such as breeding, veterinarian and drug, infrastructure, transportation, waste management, etc. are not the major expenses for swine farms due to their low cost shares in the total production cost. Among these, the costs for waste management of the farms are rather small. On average, they count only 632 baht per livestock unit per farm. In other words, swine farms in the area spend only 2.00% of the total production cost for their farm waste management. This implies that the swine raising farmers emphasize less on waste management. These small amounts of expenses on waste management are normally allocated to costs of chemicals for eliminating odor and improving wastewater condition. Applying EM to reduce the farm odor, and adding the low protein diets into the feed, can decrease nitrogen content, and so on. Besides, costs of hiring the subdistrict officers (to remove some of the wastewater out of their treatment systems) are included in waste management expenses. Consequently, it is not surprising to see that the pollution problems, caused by the swine farms, are evident and observable in Sam Khwai Phueak Subdistrict.

In terms of farm sizes, the average value of total production cost of the small farms nearly doubles that of the medium farms. That is, an aspect of economy of scales can be applied to this occurrence. Considering cost items, it is found that average total fixed costs and average total variable costs of both small and medium farms are almost the same. However, the structures of average total variable costs are rather different. The large differences, in terms of cost shares, can be seen in the costs of labor; breeding; veterinarian service and animal drugs; and waste management. The small farms are considered as labor intensive farms (engaging in the labor cost of 29.90% of the total production cost), while the labor cost share of the medium farms reveals a half less than that of the small farms. In contrast, the medium farms invest more in breeding and veterinarian service and animal drug expenses. The cost shares of those are approximately three times greater than the cost shares of the small farms. However, it is interesting to see that the waste management cost share (0.33% of the total production cost) of the medium farms is rather low as compared to the cost share (2.29% of the total production cost) of the small farms. Therefore, environmental policy makers may pay more attention on a matter of farm sizes. In this case, policy makers and local officers should encourage larger farms to engage more in their farm waste management in order to improve the community's environment and welfare.

Table 4.6: Structure of Production Costs of the Swine Farms

Type of Costs	Overall Mean (104 farms)			Mean of Small Farms (77 farms)			Mean of Medium Farms (27 farms)		
	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%
Fixed Costs	3,212	6.42	10.16	3,740	7.48	10.30	1,705	3.41	9.73
Variable Costs:	28,387	56.78	89.84	32,560	65.12	89.70	16,489	32.98	90.63
- Feeding	13,783	27.57	43.62	15,964	31.93	43.98	7,565	15.13	41.58
- Labor	8,608	17.22	27.24	10,852	21.70	29.90	2,211	4.42	12.15
- Breeding	3,114	6.23	9.86	2,543	5.09	7.00	4,741	9.48	26.06
- Vet. & Drug	851	1.70	2.69	772	1.54	2.13	1,077	2.15	5.92
- Waste Mgt.	632	1.26	2.00	833	1.67	2.29	61	0.12	0.33
- Infrastr.	1,314	2.63	4.16	1,507	3.01	4.15	762	1.52	4.19
- Tax&Others	85	0.17	0.27	89	0.18	0.25	72	0.14	0.40
Total Cost	31,599	63.20	100.00	36,300	72.60	100.00	18,194	36.39	100.00

Notes: 1) % is percentage of total production cost (cost share).

2) Vet. & Drug, Waste Mgt., and Infrastr. are costs of veterinarian service and animal drugs, costs of waste management, and costs of infrastructure, respectively.

3) Labor cost is assessed by the same wage rate between paid and unpaid laborers.

4) Bt/LU/fm = baht/livestock unit/farm and Bt/kg/fm = baht/kilogram/farm.

5) 1 LU = 500 kilograms.

Source: Survey Data, 2005-2006.

Table 4.7 follows a similar format as Table 4.6. This table documents the main sources of farm revenue. Overall average of farm revenue is as high as 54,262 baht per livestock unit per farm (108.52 baht per kilogram per farm). Although, several farmers complain about the controlled prices of swine and their high production costs, the farm revenue is rather high as compared to the total production cost discussed previously. Consequently, the average net revenue or farm profit obtains a high value of 22,663 baht per livestock unit per farm. Hence, the net revenue reveals as high as 71.72% of the total production cost.

As explored earlier, swine farms in the study area primarily raise fattening swine, therefore, the farms receive their mainstream income (86.69% of the total revenue) from the sale of fattening swine. On average, the revenue from selling fattening swine is 47,040 baht per livestock unit per farm. The second important source of the total revenue is derived from the sale of piglets. However, this part of the revenue contributes only 6.85% to the total revenue. Besides, the sales of defect and dead swine some times contribute smaller amounts to the total farm revenue.

Another source to farm revenue comes from the sale of swine manure in both dried and wet forms. Farmers in the area sell dried manure in a form of bags which contain about 15 kilograms of dried manure. Wet manure is sold in plastic barrels and each barrel weighs around 25 kilograms. The price of manure at farm is around 0.95 baht a kilogram on average. On average, the revenues between the two forms attain large different values. That is, the revenues derived from dried and wet manure are about 364 and 41 baht per livestock unit per farm, respectively. This implies that dried manure is more widely sold in the area. However, both dried and wet manure still contribute less than 1.00% of the total farm revenue while the potential of selling more manure is available in the area according to the survey observation.

A number of farmers reveal that the prices of manure are unattractive for them and these prices have remained constant for years. Moreover, the labor costs and time available to spend on managing the farm manure for selling are too costly as compared to the revenue earned from it. Therefore, one promising possibility of reducing farm waste is to make the prices of swine manure more attractive to the farmers. In order to decrease the volume of the farm waste beforehand, incentives are needed. Accordingly, the runoffs in the wastewater form from the farms to the public drainage or other areas can later be minimized in the end. Therefore, the potential of market mechanism including its pricing for the swine manure is the interesting aspect to be studied in the further step.

For aspects of farm sizes, it is found that the medium farms are capable of making much higher profits than the small farms do. Major reasons are drawn from an immense magnitude of lower production costs and higher farm revenue incurred to the medium farms. In general, the structures of farm revenue shares between the two are slightly different. Approximately 99.00% of the total farm revenue is derived from swine selling and the rest (less than one percent) comes from manure selling. Most small farms earn mainstream revenue (95.81% of the total farm revenue) from selling fattening swine, whereas the medium farms associate with two major sources of revenue: fattening swine (86.05% of the total farm revenue) and piglet (7.04% of the total farm revenue). For manure selling, the medium farms yield higher revenue share of selling dried manure than the small farms do. As explained previously, larger farms have more available space to sundry manure, while smaller farms are facing inadequate farm space problems.

Table 4.7: Structure of Farm Revenue of the Swine Farms

Sources of Revenue	Overall Mean (104 farms)			Mean of Small Farms (77 farms)			Mean of Medium Farms (27 farms)		
	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%
Swine Selling:	53,857	107.71	99.25	41,986	83.97	99.40	65,033	130.07	99.30
- Fattened Swine	47,040	94.08	86.69	40,471	80.94	95.81	56,356	112.71	86.05
- Piglet	3,716	7.43	6.85	1,165	2.33	2.76	4,611	9.22	7.04
- Defect Swine	200	0.40	0.37	66	0.13	0.16	247	0.49	0.38
- Dead Swine & Others	2,901	5.80	5.34	284	0.57	0.67	3,819	7.64	5.83
Manure Selling:	405	0.81	0.75	253	0.51	0.60	458	0.92	0.70
- Dried Manure	364	0.73	0.67	225	0.45	0.53	413	0.83	0.63
- Wet Manure	41	0.08	0.08	28	0.06	0.07	45	0.09	0.07
Total Revenue	54,262	108.52	100.00	42,239	64.48	100.00	65,491	130.98	100.00
Net Revenue	22,663	45.33	71.72*	5,939	11.88	16.36*	47,297	94.59	259.96*

Notes: 1) % is percentage of total revenue (revenue share).

2) * is calculated as percentage of total production cost.

3) Bt/LU/fm = baht/livestock unit/farm and Bt/kg/fm = baht/kilogram/farm.

4) 1 LU = 500 kilograms.

Source: Survey Data, 2005-2006.

As presented, Table 4.6 and Table 4.7 show structures of production costs and farm revenue, respectively. However, it is clearer to see Table 4.8 summarizing production costs and farm revenue in one place. Additionally, a farmer normally sells a swine which weighs around 100 kilograms. Therefore, the net farm revenue takes up approximately 4,533 baht per swine. This profit is relatively high, as compared to other livestock productions (DLP AND FAO, 2001). There might be some suggestions can be drawn from these profit figures. The suggestions intend to encourage the swine farms (especially larger farms) to invest more on their farm waste management systems. In addition, they should participate and engage more in manure trading and applying activities in their community and areas nearby.

Table 4.8: Summary of Farm Costs and Revenues

Costs and Revenues	Overall Mean (104 farms)			Mean of Small Farms (77 farms)			Mean of Medium Farms (27 farms)		
	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%	Bt/LU/fm	Bt/kg/fm	%
Total Cost:	31,599	63.20	100.00	36,300	72.60	100.00	18,194	36.39	100.00
- Fixed Costs	3,212	6.42	10.16	3,740	7.48	10.30	1,705	3.41	9.73
- Variable Costs	28,387	56.78	89.84	32,560	65.12	89.70	16,489	32.98	90.63
Total Revenue:	54,262	108.52	100.00	42,239	64.48	100.00	65,491	130.98	100.00
- Swine Selling	53,857	107.71	99.25	41,986	83.97	99.40	65,033	130.07	99.30
- Manure Selling	405	0.81	0.75	253	0.51	0.60	458	0.92	0.70
Net Revenue	22,663	45.33	71.72	5,939	11.88	16.36	47,297	94.59	259.96

Source: Survey Data, 2005-2006.

4.1.6 Farmers' Participation in Farm Waste Management

This section aims to discuss about the opinions and recommendations of the swine raising farmers on participation in farm waste management of Sam Khwai Phueak area. Table 4.9 summarizes the major causes of the farm waste management problems. The survey surprisingly discovers that more than half of the farmers say that they do not have problems on any aspect of those causes. Eighty-nine percent of the farmers reveal that they do not have problems on the knowledge of farm waste management because they regularly attend the training programs. They say they attend meetings provided by the related government agencies and they already have their own basic knowledge. On the other hand, the farmers, associated with the lack of knowledge, give the reasons of inadequate time to join the training programs. They have small numbers of swine, and are unwilling to invest more on the farm treatment system. On the aspect of waste management funding, 66.33% of the farmers state that they have adequate financial funds (for installing a simple treatment system) derived from their own savings and partly from the supports of the local companies, they have contracts with. Some farmers with this problem express that they do not want to engage because it implies a higher debt burden from installing the more efficient waste treatment systems. In addition, 82.29% of the farmers claim that they have enough space for the waste treatment systems, while the rest has limited amounts of land holdings. Finally, 60.44% of the farmers think they get enough support from the government.

The rest of the farmers complain that the government support is given unequally throughout the area.

Table 4.9: Major Causes of the Farm Waste Management

Causes of Problems	Numbers of Farms		Total Samples (N)
	Yes	No	
Inadequate Knowledge	11 (11.00)	89 (89.00)	100
Inadequate Financial Funds	33 (33.67)	65 (66.33)	98
Inadequate Land Spaces	17 (17.71)	79 (82.29)	96
Inadequate Governmental Supports	36 (39.56)	55 (60.44)	91

Notes: The numbers in parentheses are percent (%) of the total samples (N).
Source: Survey Data, 2005-2006.

Upon the interviews, several farmers are still interested and willing to participate in new farm waste management mainly through practical training activities (78 farmers), mixed methods (53 farmers), field trips (17 farmers), case studies (5 farmers), and seminars (1 farmer), respectively (Figure 4.15). However, there are some obstacles and farmers often complain about the participation. For examples, the training is not new and uninteresting, limited amount of time (due to the farm activities) is available, it is unnecessary for small-scale farms, and most farmers are not willing to change their routine practices.

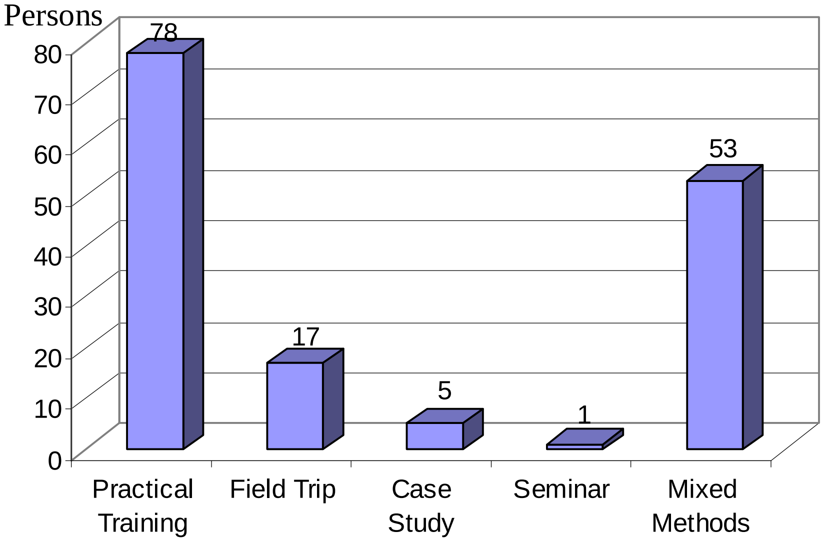

Figure 4.15: Methods of Participation in Farm Waste Management

Notes: Each farmer can engage in more than one method.

Source: Survey Data, 2005-2006.

In terms of recommendations, the swine raising farmers in the area suggest that:

1) The community should establish a farm waste management fund with the partial assistance from the government in order to be the source of low-interest loans particularly for the small-scale farms. In addition, the small-scale farms might be able to get together to access the governmental supports.
2) There should be a central farm waste treatment system for the community as a whole including the efficiency assessment of the system done by the government.
3) There should be the knock-on-farm-to-farm training programs given to the farmers in each farm.
4) Environmental awareness should be kept in mind for all members of the community.
5) Laws and regulations should be enforced to all equally. But in their opinion, strict laws and regulations are not practically useful because there will be someone trying to get out of them.
6) The government officers should make clear of the regulations to the community before implementing the laws and regulations.
7) There should be rewards and honor systems given to the farms, that continuingly follow the government farm and environmental standards.

4.2 Empirical Findings on the Swine Manure Middle Men

This chapter intends to expose the swine manure trading process in the study area including several aspects such as the general background of the swine manure middle men, manure prices, costs and revenue. They will be provided in this section. The data obtained in this part are important to be partially used in assessing the net gain from a manure market in the further analytical part of the study.

4.2.1 General Background of the Swine Manure Middle Men

In the survey, a total number of the swine manure middle men of 48 persons was interviewed. Within this number, there are 41 (85.42%) males and 7 (14.58%) females. The average age of them is 43 years. In terms of educational background, 37 (77.08%) , 9 (18.75%), and 2 (4.17%) persons associate with the degrees of lower than high school, high school, and above high school levels, respectively. Thirty persons (62.50%) have only one job as a manure middle man. The rest of them uses his manure trading business as a second career, accompanied to the major careers such as crop, swine, fish, and water flea farmers. On average, the investigated swine manure middle men have been engaged in their manure trading business for 12 years; with the maximum and the minimum numbers of 21 and 2 years, respectively. This implies that manure trading business has been going on in the area for fairly long period of time (Table 4.10).

Table 4.10: General Background of the Swine Manure Middle Men

Categories	Units	Number	Share (%)
Gender:			
Male	persons	41	85.42
Female	persons	7	14.58
Total Samples (N)	persons	48	100.00
Age:			
Mean	years	43	-
Maximum	years	69	-
Minimum	years	21	-
Total Samples (N)	persons	48	-
Education Levels:			
Below High School	persons	37	77.08
High School	persons	9	18.75
Above High School	persons	2	4.17
Total Samples (N)	persons	48	100.00

Table 4.10: Continued

Categories	Units	Number	Share (%)
Major Occupation:			
Only Manure Middle Man	persons	30	62.50
Swine Raising Farmer	persons	3	6.25
Fish Farmer	persons	5	10.42
Fruit Farmer	persons	3	6.25
Vegetable Farmer	persons	4	8.33
Rice & Other Agronomic Farmer	persons	1	2.08
Water Flea Farmer	persons	2	4.17
Total Samples (N)	persons	48	100.00
Experience in Manure Trading Business:			
Mean	years	12	-
Maximum	years	21	-
Minimum	years	2	-
Total Samples (N)	persons	48	-

Source: Survey Data, 2005-2006.

Not to mention, as seen in Figure 4.16, the interviewed manure middle men reveal that the main reason behind becoming a middle man is to earn a decent revenue out of this business. Some middle man even states that swine manure can change his life in making him a good living as if he could make money out of nothing. Several middle men also claim that their business has helped them to save their farm production costs on either costs of chemical fertilizers or costs of animal feeds as well as making some additional revenue attached to them. On the other side, some middle men express that this business has been handed down from generation to generation and they have become most skillfully in their career.

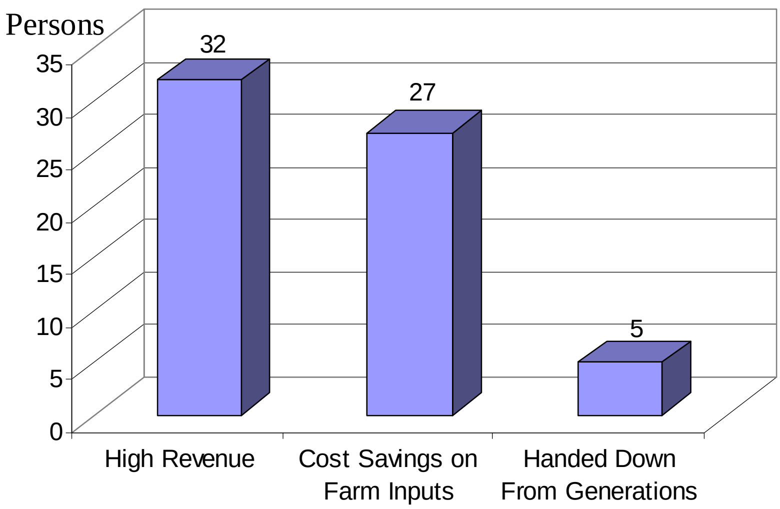

Figure 4.16: Reasons of Becoming Swine Manure Middle Men

Notes: Each manure middle man can engage in more than one reason.

Source: Survey Data, 2005-2006.

4.2.2 Swine Manure Buying Process

According to the interviews illustrated in Figure 4.17, the manure buying process is conducted in 3 channels. A first buying process is made through verbal contracts (37 persons, 77.08%) between the swine farm owner (in case of the farm owners sell manure themselves) or the farm worker (in case of the farm owners allow their workers to sell manure and keep additional money) and the middle man. In this channel, the buying process starts from a personal relationship between the swine raising farmer (owners or workers) and the middle man. A farmer allocates the quantities of his manure to different middle men according to the different levels of relationships among them. Some of them are relatives. In this case, farmers often offer good prices (lower than the market prices) and sometimes provide extra quantities without charges to a group of middle men. Furthermore, most of the middle men are the local members of the community.

Secondly, another channel of buying swine manure in the study area is the random case of buying (5 persons, 10.41%). A middle man in this case transport manure around in a swine farm community and ask farmers for willingness to sell their swine manure. The middle man buys manure not only in the study area but also in other swine community areas nearby. Many middle men, buying swine manure through this channel, come from outside of the community. Thus, the prices that the farmers offer to them follow the market prices.

The last swine manure buying channel is made through both verbal contracts and random buying. This mixed channel (6 persons, 12.51%) is usually applied by a middle man who is also located outside the community but has good relationships with some of the local farmers. The prices offered by the farmers are accordingly mixed between market and personal prices depending upon their levels of the relationships.

Generally, farmers in the study are usually responsible for providing the plastic bags/sacks (normally obtained from the feed bags/sacks) in case of selling dried manure. In case of buying wet manure, the middle men are responsible for providing the needed plastic barrels. However, both, the plastic bags/sacks and barrels, are actually exchangeable and reused among them for long time. For transport, most middle men occupy one-ton pickup trucks as their medium for transporting and carrying the manure. Some middle men also hire one or two workers to help them hauling the manure. Moreover, the frequency of buying manure in the study area varies from daily to monthly. Finally, the distance between the places of the middle men and the swine farms ranges from less than 1 up to 15 kilometers.

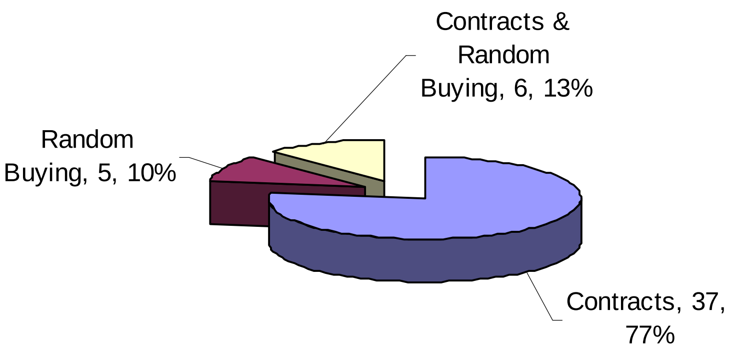

Figure 4.17: Buying Channels of Swine Manure

Source: Survey Data, 2005-2006.

4.2.3 Types of Swine Manure Customers

Normally, a swine manure middle man has his own regular customers and only few have random customers. Figure 4.18 depicts the types of manure customers. All of them are farmers in different areas. The top three customers are usually derived from fruit (pomelo, guava, mango), fish (catfish, carp fish), and agronomic (rice, sugarcane) farmers, respectively. Among these customers, croppers usually prefer to buy dried manure because it is easier to use and lasts longer than wet manure. On the other side, due to its lower prices, several fish farmers prefer to use wet manure to feed their fish as soon as they obtain it because it is unnecessary for them to keep the manure for later uses. Similar to the case between the swine farm owners/workers and the middle men, there are also price reductions given to some of the manure customers depending on the degrees of relationships among them. In addition, it is found that the distance between the middle men' and the customers' places is within the radiance of 25 kilometers.

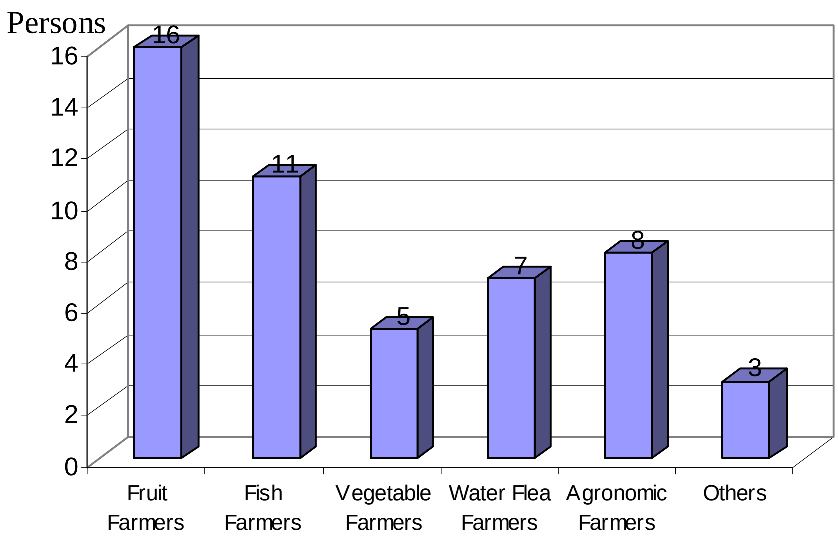

Figure 4.18: Types of Swine Manure Customers

Notes: Each manure middle man can engage in more than one type of customers.

Source: Survey Data, 2005-2006.

4.2.4 Types, Quantities, and Prices of Swine Manure Traded by the Middle Men

Table 4.11 presents the types, quantities, and prices of swine manure traded by the middle men. It shows that there are 2 types of manure: dried and wet manure. Each type engages in different number of the middle men. Most middle men (48 persons) trade dried manure while less than a half of them (16 persons) trade wet manure.

The quantity of the dried manure bought by middle men ranges from 1,525 to 11,050 kilograms a month with the average value of 6,391 kilograms a month. The average price of the dried manure bought by the middle men yields 1.15 baht per kilogram while the maximum and the minimum prices take up the values of 1.33 and 0.66 baht, respectively. On the selling aspect, the quantities sold in general are less than the quantities bought mainly because the middle men keep some manure for their own uses and some weight losses occur during transportation and storing. These quantities are decreased from 5.14 to 32.13% with the average of 10.25%. In average, each month the middle men can sell around 5,736 kilograms of the dried manure at the average price of 1.88 baht per kilogram. As a result, the percentage difference between buying and selling prices of the dried manure in average is 63.48%. It seems that this dried manure trading is a lucrative business for the middle men in general point of view.

Unlike the dried manure, the wet manure trading earns a smaller market volume due to its physical constraints in heavier weight, stronger odor, and harder to use. These largely cause the wet manure to be less popular than the dried manure. On average, the middle men monthly buy about 4,922 kilograms of the wet manure at the price of 0.75 baht per kilogram. Likewise, some amounts of the wet manure are kept for the uses of middle men. The quantity of the wet manure is then reduced by 6.17% in average, usually less than the decrease in quantity of the dried manure as mentioned earlier. In terms of selling prices, the wet manure can be sold in lower prices than the dried manure. The highest price they can obtain is 1.40 baht per kilogram while the lowest price goes down to 0.60 baht per kilogram. In average, the wet manure is sold at 0.94 baht per kilogram associated with the price margin of 25.33% which is much less that of the dried manure.

For the two cases, dried and wet manure, both buying and selling prices are usually determined by middle men themselves depending upon volumes of supply and demand for swine manure. The reason behind this is that farmers treat manure as a volatile or unused product. Therefore, they are willing to accept prices that are given by middle men. Relationships and number of the middle men in the area, rather than manure's quality, count. However, whatever reasons are, these prices have stayed quite constant (compared to the increasing prices of commercial fertilizers and animal feeds) for a long period of time in the study area and the areas nearby, according to the answers from interviewed middle men and farmers.

Table 4.11: Types, Quantities, and Prices of Swine Manure Traded by the Middle Men

Types of Manure	Buying		Selling		% Difference	
	Quantity (kg/month)	Price (baht/kg)	Quantity (kg/month)	Price (baht/kg)	Quantity (%)	Price (%)
Dried:						
Mean	6,931	1.15	5,736	1.88	-10.25	63.48
Maximum	11,050	1.33	10,482	2.00	-5.14	50.04
Minimum	1,525	0.66	1,035	1.00	-32.13	51.52
Total Samples (N)	48	48	48	48	48	48
Wet:						
Mean	4,922	0.75	4,619	0.94	-6.17	25.33
Maximum	10,400	1.00	9,873	1.40	-5.07	40.00
Minimum	2,870	0.50	2,501	0.60	-12.86	20.00
Total Samples (N)	16	16	16	16	16	16

Source: Survey Data, 2005-2006.

4.2.5 Costs and Revenue of the Manure Middle Men

Table 4.12 concludes costs and revenue of the swine manure middle men in the area. The key structure of the costs contains the fixed and the variable costs that they are normally dealing with. This covers only a couple of inputs. On average, the total cost of each middle man takes up about 2,106 baht a month. The fixed cost is chiefly derived from the truck rents including maintenance costs, manure containers such as plastic backs/sacks and barrels, and other equipment for hauling manure. The share of the fixed cost to the total cost, therefore, is mostly below 25.00% consistent to the average of 438 baht per month for each individual middle man.

For the variable costs, these comprise only a few factors that are: transportation, financial, and labor costs. In other words, the cost of transportation comes solely from the gasoline cost which usually ranges from 26.00-50.00% to the total cost of most middle men (40 persons, 83.33%). On average, the individual middle man pays around 2,472 baht a month for his transportation cost from trading manure. The other major variable cost is labor cost which includes the working hours of the middle man himself. Normally almost all middle men work alone while only few of them have to hire an additional worker due to the large volume of the manure traded each time. The labor costs only around 1,091 baht a month for each middle man in average and it usually shares less than 25.00% of the total cost. Not to mention, there are more additional costs that are usually drawn from the storage cost, such as the cost of chemicals for reducing manure odor and the cost of telephone for connecting manure suppliers and customers.

In terms of revenue and net revenue, each of the middle man can make approximately 7,973 baht a month in total revenue and around 3,899 baht monthly in net revenue. These figures imply that the swine manure trading business can make relatively decent revenue to the middle men who particularly hold it as a second job.

Table 4.12: Costs and Revenue of the Middle Men from Trading Manure

Categories	Value Range (baht/month/person)			Numbers of Farms by Ranges of Cost Shares				Total Samples (N)
	Mean	Max	Min	0-25%	26-50%	51-75%	76-100%	
Fixed Costs	438	1,300	250	47 (97.92)	1 (2.08)	- (0.00)	- (0.00)	48 (100.00)
Variable Costs:								
- Transportation	2,472	5,000	1,000	4 (8.33)	40 (83.33)	3 (6.25)	1 (2.09)	48 (100.00)
- Labor	1,091	3,500	600	43 (89.58)	5 (10.42)	- (0.00)	- (0.00)	48 (100.00)
- Others	116	800	100	48 (100.00)	- (0.00)	- (0.00)	- (0.00)	48 (100.00)
Total Cost	2,106	10,464	1,127	-	-	-	-	48
Total Revenue	7,973	18,550	1,545	-	-	-	-	48
Net Revenue	3,899	9,382	658	-	-	-	-	48

Notes: The numbers in parentheses are percent (%) of the total samples (N).

Source: Survey Data, 2005-2006.

4.3 Empirical Findings on the Swine Manure End-Users

This section aims to explore primarily how the end-users obtain swine manure and use the manure. It includes the reasons of appling swine manure. Moreover, the volume of swine manure used, its costs, and the application ratios between swine manure and commercial fertilizers or animal feeds (in case of using manure mixed with animal feeds) applied by the end-users are as well as portrayed in this section.

4.3.1 General Background of the Swine Manure End-Users

There are totally 37 end-users that apply swine manure derived from the farms in the study area. Many of the swine manure end-users are located close to the study area within the radiance of 25 kilometers and some of them are members of the community in the study area. The end-users consist of 29 (78.38%) males and 8 (21.62%) females. Their age ranges from 31 to 72 years old associated with the average of 48 years. Almost a half of them have educational degrees below high school level while 37.84% and 13.51% have the degrees of high school and above high school levels, respectively. Among these, are fruit (35.14%), fish (24.32%), and crop (21.62%) farmers. They are the top three swine manure end-users in the area. In addition, the end-users have actually been in their occupation for very long time or 23 years in average as well as the average of 9 years in using swine manure (Table 4.13).

Table 4.13: General Background of the Swine Manure End-Users

Categories	Units	Number	Share (%)
Gender:			
Male	persons	29	78.38
Female	persons	8	21.62
Total Samples (N)	persons	37	100.00
Age:			
Mean	years	48	-
Maximum	years	72	-
Minimum	years	31	-
Total Samples (N)	persons	37	-
Education Levels:			
Below High School	persons	18	48.65
High School	persons	14	37.84
Above High School	persons	5	13.51
Total Samples (N)	persons	37	100.00

Table 4.13: Continued

Categories	Units	Number	Share (%)
Major Occupation:			
Fruit Farmer	persons	13	35.14
Fish Farmer	persons	9	24.32
Rice & Other Agronomic Farmer	persons	8	21.62
Vegetable Farmer	persons	5	13.51
Water Flea Farmer	persons	2	5.41
Total Samples (N)	persons	37	100.00
Experience in Major Occupation:			
Mean	years	23	-
Maximum	years	45	-
Minimum	years	7	-
Total Samples (N)	persons	37	-
Experience in Using Swine Manure:			
Mean	years	9	-
Maximum	years	20	-
Minimum	years	1	-
Total Samples (N)	persons	37	-

Source: Survey Data, 2005-2006.

4.3.2 Reasons of Using Swine Manure

Figure 4.19 gives a picture of the reasons that the end-users answered why they use swine manure. Almost all of the end-users apply swine manure as supplementary input which is coordinately used with other major farm inputs, except for the case of water flea farmers who normally uses swine manure as one of their major farm inputs. Upon the correspondences, there are only 4 reasons that the end-users are willing to use swine manure. The top reason of using swine manure given by all the end-users is to save costs of farm inputs. The cost saving ranges from 10.00% up to 50.00% associated with the average of 18.92% of the total cost. As second of the fourth reasons comes from “soil condition improving”; the third comes from “higher growth rates of the farm outputs”; and the fourth comes from “environmental awareness”, respectively. Remarkably among these reasons is that fish farmers express that they apply swine manure with the regular feed. It makes their fish grow faster and healthier than using the feed alone. In addition, the end-users, mostly crop farmers, give the reason of environmental awareness; this additionally reveals that they would like to have healthier plants by applying swine manure in their farms instead of using excessive amounts of chemicals.

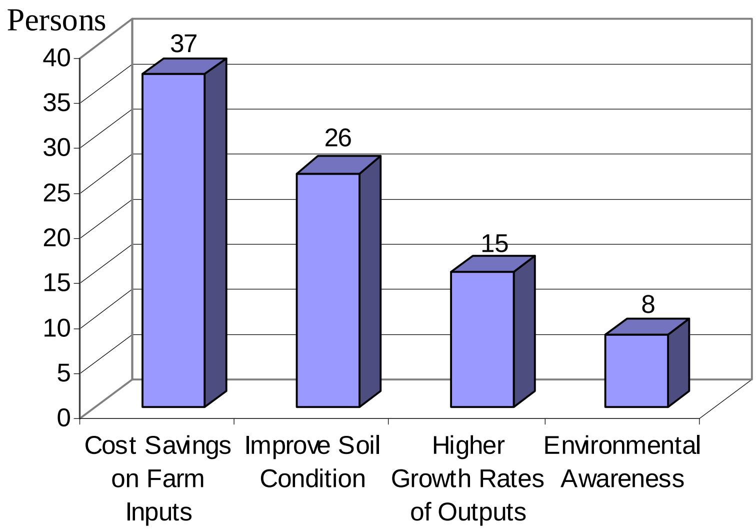

Figure 4.19: Reasons of Using Swine Manure

Notes: Each end-user can engage in more than one reason.

Source: Survey Data, 2005-2006.

4.3.3 Application Ratios as Compared between Swine Manure and Commercial Fertilizers or Animal Feeds

Noticeably the application ratios or doses of application are derived from the actual practices (trials and errors) of the end-users in using swine manure coordinately with commercial fertilizers or animal feeds. Positive results are not necessarily significant in terms of scientific bases. Observed application ratios are later used to calculate the substitution rates in the analytical part of the study. Commercial fertilizers as presented here, in terms of the general fertilizer originates from the most popular formula widely used by the end-users such as 16-16-16, 16-16-20, and 20-20-0. On the other side, fish farmers in the area vastly use the commercial pellet feed available in the local markets. However, for water flea farms, farmers normally use swine manure as one of the major inputs. It is a plankton starter essentially used to feed the water flea. In other words, a fixed ratio between swine manure and the other input in case of water flea farms does not exist and it is not presented in this part.

Table 4.14 summarizes findings that crop farmers usually apply much more of swine manure than expected. Accompanied with small amount of commercial fertilizer, it takes an average ratio of 82:18 or about 4 times greater than the amount of commercial fertilizer. On the other side, the fish farmers apply swine manure almost the same amount of the commercial fish feed at the ratio of 53:47 or approximately 1:1 in average.

Table 4.14: Application Ratios between Swine Manure and Commercial Fertilizer or Fish Feed

Range	Application Ratios	
	Manure : Fertilizer	Manure : Fish Feed
Mean	82 : 18	53 : 47
Maximum	96 : 4	90 : 10
Minimum	70 : 30	20 : 80
Total Samples (N)	26	9

Source: Survey Data, 2005-2006.

4.3.4 Swine Manure Obtaining Process by Customers

Figure 4.20 shows that there are 3 possible cases of obtaining swine manure in the study area: 1) through the manure middle men, 2) from own swine production, and 3) from a swine farm owner as a neighbor. In the first case, the end-users obtain swine manure by buying it from the middle men who come to deliver manure at the end-users' locations. This way is the most popular among the end-users due to its convenience and is available for various different deals through verbal contracts and random selling by the middle men. Most of the end-users in this case already know the middle men personally. Therefore, trust of the end-users on the quality and the correct weight of manure between them exists. The manure price is negotiable, depending on the degrees of personal relationships. Otherwise, manure is sold at a market price.

In a second case, the end-users themselves transport or buy manure at swine farms. Obtaining swine manure in this way usually occurs to end-users whose location is close to the swine farms and/or to end-users who inquire a lot of manure. Mostly they are not willing to pay higher prices to the middle men. However, for this second way, the end-users basically have their own one-ton pickup trucks and are primarily willing to bare the costs of transportation and labor on their own. Labor employing occurs in 2 scenarios: the end-users have their own workers transporting with them, or the end-users pay the swine farm workers to haul the manure for them. Both verbal contracts and random buying are common in this case. Getting swine manure this way, the end-users particularly inquire tremendous amounts of manure. It can save much money without paying the marketing margins to the middle men and they are able to select higher quality of manure with lower prices.

Finally, the last case of obtaining manure is drawn from the self delivery of the swine farm owners to the end-users' farms. This way rarely occurs because most swine farm owners are normally busy with their farm activities so that this way usually occurs in the case of personal contacts among them and mainly occurs with the case of water flea farms. They are normally relatives or close friends. The prices of manure in this case are normally lower than the prices given by the middle men and are also negotiable. Many times the end-users only pay the extra costs on transportation and labor to the swine farm owners.

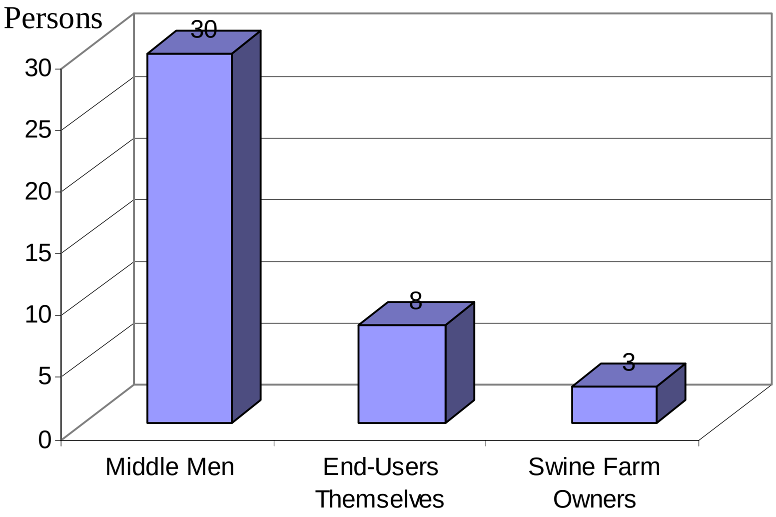

Figure 4.20: Sources of Obtaining Manure

Notes: Each end-user can engage in more than one source.

Source: Survey Data, 2005-2006.

4.3.5 Types, Quantities, and Prices of Swine Manure Used by the End-Users

According to Table 4.15, the information on manure disposal is presented in terms of manure sources that the end-users can obtain, as explained in earlier parts. Upon this information demonstrated in the table, both dried and wet manure are used by the end-users. Generally, it seems that dried manure is more popular and more expensive than the wet one. From the greater values of the quantity and price averages of swine manure, preferences can be retrieved. For instance, for dried manure, an end-user buys the highest average quantity (3,163 kilograms a month). This swine manure is transported and bought at swine farms. It is, on average, followed by obtaining manure from the delivery of the swine farm owners (2,667 kilograms a month) and by buying from the middle men (1,834 kilograms a month), respectively.

In terms of prices of dried manure, the manure sold by the middle men yield the highest price of 1.94 baht per kilogram on average, followed by 0.95 and 0.88 baht per kilogram in the case of the end-users transport of manure and the case of manure delivered by the swine farm owners themselves, respectively. This implies that the marketing margin received by the middle men is relatively high compared to the other goods or roughly 1.00 baht per kilogram of manure on average. In the case of swine farm owners' deliveries, the marketing margin is much lower on average and mainly allocated to the transportation costs as discussed previously.

Unsurprisingly, the end-users pay the lowest price of 0.88 baht per kilogram on average due to no charges as marketing margins.

With wet manure, the average quantities obtained from the middle men, the end-users themselves, and the swine farm owners are 1,059, 947, and 5,000 kilograms a month, respectively, for each individual end-user. Among these, the highest figure is 5,000 kilograms a month; it mostly belongs to the end-users of water flea farms which prefer wet manure over the dried one because of its low prices and no requirement to use the more expensive dried manure. In contrast, the end-users who go to buy manure themselves rather buy dried manure than wet manure. They think that wet manure is associated to higher transportation costs. Its physical constraints cannot last long because of strong odor. The prices of the wet manure are pretty much the same across the three sources of obtaining manure that engage in the narrow range between 0.73 and 0.77 baht per kilogram in average.

Table 4.15: Types, Quantities, and Prices of Swine Manure Used by the End-Users

Types of Manure	Sources of Obtaining Swine Manure					
	Middle Men		End-Users		Swine Farm Owners	
	Quantity (kg/month)	Price (baht/kg)	Quantity (kg/month)	Price (baht/kg)	Quantity (kg/month)	Price (baht/kg)
Dried:						
Mean	1,834	1.94	3,163	0.88	2,667	0.95
Maximum	3,200	2.00	6,000	1.25	5,000	1.10
Minimum	1,050	1.00	2,400	0.70	1,000	0.75
Total Samples (N)	30	30	8	8	3	3
Wet:						
Mean	1,059	0.75	947	0.73	5,000	0.77
Maximum	4,800	1.38	3,200	1.00	8,000	1.00
Minimum	500	0.60	800	0.50	2,000	0.50
Total Samples (N)	30	30	8	8	3	3

Source: Survey Data, 2005-2006.

4.3.6 Costs of the End-Users from Using Swine Manure

Notice the costs of the end-users from using manure are not solely the values of manure bought. Besides, other costs exist. These costs are usually drawn from transportation costs (gas and truck maintenance costs), labor costs (own labor and hired workers for hauling manure), and other costs (plastic backs/sacks and barrels). Eventually, these other costs of using manure are next to nothing; but eventually can be high.

Table 4.16 concludes that on average the total cost of using swine manure by each end-user is 2,861 baht a month associated with a maximum and minimum value of 8,028 and 986 baht per month, respectively. The table also reveals that each end-user has expenditures on buying swine manure about 2,784 baht on average per month and this mostly takes up more than three quarters of the total cost from using manure. For the transportation cost, it ranges from 0 to 2,500 baht a month per end-user particularly for whoever goes to buy swine manure at farms himself. Similarly, labor and other costs averagely yield quite small numbers of 87 and 14 baht a month per person, respectively. In addition, all the costs besides the manure buying costs take up the cost shares of lower than 25.00% of the total cost from using swine manure.

Table 4.16: Costs of the End-Users from Using Swine Manure

Categories	Cost Range (baht/month/person)			Numbers of Farms by Ranges of Cost Shares				Total Samples (N)
	Mean	Max	Min	0-25%	26-50%	51-75%	76-100%	
Manure Cost	2,784	4,399	986	- (0.00)	- (0.00)	1 (2.70)	36 (97.30)	37 (100.00)
Transportation	237	2,500	0	36 (97.30)	1 (2.70)	- (0.00)	- (0.00)	37 (100.00)
Labor	87	1,500	0	37 (100.00)	- (0.00)	- (0.00)	- (0.00)	37 (100.00)
Others	14	200	0	37 (100.00)	- (0.00)	- (0.00)	- (0.00)	37 (100.00)
Total Cost	2,861	8,028	986	-	-	-	-	37

Notes: The numbers in parentheses are percent (%) of the total samples (N).

Source: Survey Data, 2005-2006.

4.4 Results of the Stakeholder Brainstorming

The stakeholder brainstorming meeting aimed at listening to real problems occurring in the study area and attaining recommendations from key stakeholders. The meeting was organized in the form of a round-table brainstorming on December 20th, 2006 in Muang District, Nakhon Pathom Province under the topic of “Swine Waste Management under Community Participation”. Totally, there were 47 voluntary participants in the meeting present. They come from swine raising farmers, manure traders and end-users, government officers, private companies, as well as experts. The results of the brainstorming can be summarized as follows:

1) There should be better or more proper methods of managing swine waste, depending upon different beneficial factors. Also there are limitations in different areas. The existing waste treatment systems should be adjusted to improve the efficiency by partial supports of the government. Besides, the vastly discussed solutions go to market and/or economic incentive approaches, in which swine manure trading and reusing are key factors to success. In other words, there should be ways of creating value-added for swine manure. This brings us to reduce quantity of swine manure beforehand preventing the farm waste treatment systems from their overloaded capacities. Several participants suggest that there should be more people involved in developing swine manure recycling activities so that the prices of manure can be increased in the long run. In addition, there are some offers from the private sector which is interested in utilizing swine manure as input for generating bio-electrical power and NGV (natural gas for vehicle). By establishing one or two compact-size generators of the bio-power plants in the study area would help. The power from these plants could be sold to the community and the areas nearby at low prices. However, after this proposal was proposed, the project presently (2008) remains unprogressive.

2) As a key success to receive community participation in managing swine waste, the community’s environmental awareness must be created. The community should realize that the environmental problems are social, but not individual, problems. There should be close cooperation among community members and related stakeholders in controlling animal pollution. In order to have higher social welfare, cooperation is essential. Rewards and penalties should be determined by the rules of the community itself. Empirical successful cases should be honored and demonstrated to the rest of community. For participating in keeping the environment clean and increase their income, we need incentives. Moreover, the officers and related responsible persons should disseminate more information about swine waste management, technologies, costs, and benefits in recycling swine waste to the community thoroughly.

3) Supports from the government and related parties should be drawn from an efficient coordination among policy makers, central, and local officers. This would help to solve the community's actual problems. The officers should deliver proper advice in accordance with the community's potential in managing its swine waste. The roles of law enforcement and commanding should be adjusted or even changed to the roles of technical advice and supports. In finding such ways of solving the environmental problems, the community will participate. Not to mention, the private sector can also get into the picture of community waste management under the supports by low-cost financial funds from the government in order to create value-added to the swine manure and to enhance the community's welfare.

4.5 Summary

The empirical findings in this study are based on the survey data derived from 104 swine raising farmers, 48 swine manure middle men, and 37 swine manure end-users as well as the conclusions from the stakeholder brainstorming meeting in the study area. The survey reveals that most of the swine raising farmers in the study area are small-scale farmers in terms of both land holdings and number of swine raised. The majority of the farms is usually engaged in contract farming with local companies. Fattening swine is dominant in the area. Farms are primarily dealing with the low efficient waste treatment systems. It is, therefore, found out from the laboratory results that the swine farmers overload immense amounts of the farm waste to public drainage systems and areas nearby. Even though many farmers are well aware of the pollution, their improper farm waste management practices remain unchanged.

On the sides of manure middle men and end-users, the findings show that the major reasons of getting into manure trading and recycling activities come from making high revenue (high marketing margins for the middle men) and from cost savings on farm inputs (for the end-users), respectively. Both forms of dried and wet manure can be traded and recycled among middle men and end-users. However, the dried manure is more popular due to its convenient physical conditions. Transportation cost is the most important cost incurred to the middle men while the end-users mostly engage in cost of manure they inquire. In addition, crop, fish, and water flea farmers are major occupations of the end-users whereas some of the middle men hold these occupations as their second careers.

Finally, the stakeholder brainstorming meeting principally reveals that the key success of swine waste management in the area should be obtained from economic incentive scheme, which leads to create value-added to swine manure. This scheme should be associated with close cooperation and efficient participation among community's members and all other officers as well as other stakeholders.

5 LITERATURE REVIEW

One of the well known pioneers in welfare economics namely Arthur Cecil Pigou began to explain the problems of environment that were greatly derived from externalities and market failure. He has written on the environment in his remarkable book of *"Wealth and Welfare"* published in 1912 and his suggestion has later become the widely used approach of *"Pigouvian Tax"* until these days. Nevertheless, some economists have opposed this environmental taxation since pollution and its marginal effects were not clearly observable and measurable. However, this opposition was later relaxed by the innovative concepts of transaction costs and property rights which were firstly introduced by Ronald H. Coase published in the articles of *"The Nature of the Firm"* in 1937 and *"The Problem of Social Cost"* in 1960. Successively, his concepts became the well known in the environmental economic theory as *"The Coase Theorem"*. As such, all these concepts of both Pigou and Coase have been popularly applied on solving the environmental problems till current ages (JUST et al, 1982).

Likewise, the main idea of this study applies the theoretical concepts stated above as a fundamental basis on easing the pollution problems in the area under scrutiny. As mentioned in the preceding parts, the study principally aims to tackle down on problems of pollutants caused by the agricultural sector, in particular, the livestock sector. The case of swine farms is considered to be an important source of environmental problems in Thailand especially in the study area. Agricultural nutrient runoffs particularly derived from the livestock sector have been the concerned issue among analysts and policy planners for decades. Losses of nitrogen and phosphorus in land runoff and drainage from agricultural land can impair river quality and may pose a potential health hazard (WITHERS AND LORD, 2002). Nitrogen and phosphorus commonly present a wastewater source, especially in agriculture (CARMICHAEL, 1998). Besides nitrogen and phosphorus, other organic pollutants have also been of interest for many researchers to investigate their harmful effects to the environment. Among those pollutants, biological oxygen demand (BOD), chemical oxygen demand (COD), and suspended solid (SS) have been traditionally considered as the major indicators to indicate water quality. As such, various investigations intend to analyze these pollutant runoffs in terms of abatement and damage costs. Also, optimal management (in both theoretical approaches) and policy implications have been done and discussed .

In addition, manure management is another centered topic needed to be included in the study since the optimal manure management (either reusing or recycling aspect) can significantly result in reducing large amount of farm wastes beforehand at point sources. In order to attain a higher opportunity in success of the solutions, most of these investigations currently tend to incorporate studies in stakeholder participatory and policy monitoring approaches. This chapter, therefore, delivers reviews on the literatures relevant to this study which can be presented into 4 primary aspects: 1) analyses of nutrient runoffs and management, 2) manure management and applications, 3) monitoring policies and stakeholder participation, and 4) analytical methodologies.

5.1 Analyses of Nutrient Runoffs and Management

5.1.1 Assessment of Abatement and Disposal Costs

For the nutrient runoffs from agriculture, many of the literature primarily focus on the cost of pollution abatement. It is the key instrument to impose on both the polluters and the related agencies that are responsible for it. A number of studies attempt to explore on estimating the abatement costs of the agricultural nutrients, leaked from point and non-point sources. A majority of the studies tend to investigate nutrient leakages from plantation crops rather than from livestock farms. However, they have conceptual themes in common that can be applied to each other properly.

In the aspect of cleaning environments, abatement costs, especially, marginal abatement cost (MAC) plays an important role for both polluters and policy planers. They are necessary to make decisions and to negotiate on what sizes of pollution can be reduced. MAC is defined as an additional unit of costs if pollution decreases by investing in the abatement. MAC curves can be kinked and a kinked MAC curve may lead to the policy implication that output restrictions are as efficient as emission restrictions (MCKITRICK, 1998). Denitrificaton function can be linked to total costs of abatement. Marginal abatement costs are eventually obtained by a non-linear function of land size and nitrogen load on the land. Including nitrogen load, as a parameter of abatement, costs affect the expected abatement costs drastically. As a result, neglecting the impact of physical parameters on abatement costs might cause the incorrect estimation of abatement costs (BYSTROM, 1998). Particularly, it was found that ammonia abatement, rather than other nitrogen emission forms, should play a significant part in any economically-minded strategy for reducing total nitrogen emissions. Since marginal abatement cost is the criterion used to assess cost-effectiveness, this matters very much. In other words, marginal abatement cost of ammonia is relatively low compared to the others (COWELL AND APSIMON, 1998).

Related to abatement and disposal costs, manure procurement costs are an economic incentive for structural changes and investments in abatement. Shadow prices of land and housing constraints can determine the incentive for the structural change. Incentives for new investments will dissipate when the shadow prices are below the cost of the new investments. Moreover, the abatement cost in manure separation technology draws crucial interests from both farmers and policy makers in terms of the potential value of the technology (LAUWERS et al., 1997). Abatement cost curves are powerful management tools and can play a vital role in the efficient reduction of waste discharges. The process of deriving and estimating an abatement cost curve is important since it improves awareness of abatement technologies, and encourages communications among regulators, polluters, and abatement technology developers (BEAUMONT AND TINCH, 2004).

As an example, the reduction in nitrogen fertilizer under an abating farm management can lead to higher commodity prices and higher producer's surplus while the consumer's surplus is decreased through large changes in price and quantity facing an inelastic demand. Therefore, on-site fertilizer restrictions for reducing nitrogen loads should depend on the level of nutrient reduction that is desired and one has to look more a cost-effective solution (RIBAUDO et al., 2001).

Costs of abatement are measured as losses in producer profits for achieving an abatement standard. It is argued that transfer to farmers could be interpreted as compensation for provision of public goods and should be included as social opportunity costs of abatement (JOHNSEN, 1993). The relationships between nitrogen scheme and agricultural policy seem to interact to each other whereas the least-abatement cost changes no matter what it associates with the agricultural policy or not (BRADY, 2003).

5.1.2 Optimal Abatement and Management of the Nutrient Runoffs

In the previous topic, the literature pays attention on analyzing the costs of pollution abatement as a vital tool to reduce amounts of pollution. Pollutions are emitted from point and non-point sources. In this part we present literatures in a broader range of nutrient management in terms of optimization. Optimization is derived from both abatement and external or damage costs in order to seek an ultimate goal of optimal pollution abatement.

Non-spatially differentiated Pigouvian taxes on emissions are able to establish a socially optimal solution. However, spatially differentiated tax on inputs or outputs are not able to reach the optimal outcome and need to be complemented by land-zoning and land-use taxes. The environmental policies should comprise intertemporal and spatial approaches together. Furthermore, a socially optimal allocation over space is determined by the transportation cost and the environmental damage, resulting from pollution at a particular location. As a result, non-spatially differentiated taxes on the final emissions are recommended as a first prioritized policy instrument. In the case of unobservable final emissions, spatially differentiated input or output taxes are proposed. In addition, Pigouvian taxes on final emissions should be complemented by land-use or land zoning taxes to obtain the socially optimal outcome (GOETZ AND ZILBERMAN, 1998; 2000).

It is argued in the literature that the standard Pigouvian approach to environmental regulation, which means a taxing of marginal pollution damages, cannot be implemented since environmental outcomes cannot be directly monitored. Economic efficiency, however, can be enhanced by the regulation of livestock facility sizes and entry because producers have incentives to produce too many animals with either larger than is efficient. A question is: more numerous than is efficient; or as is most likely both since the government has imperfect information. (INNES, 2000).

Policy makers of nutrient runoff management should be able to enumerate the relative risk of the agricultural nutrient losses at the farm scale. Only then, proper advice (in terms of best management practices in nutrient losses) can be given to the farmers (WITHERS AND LORD, 2002). Likewise, biophysical models can be applied to quantify the optimal abatement levels of nutrient runoffs. Models can derive spatial optimal, least-cost allocation of agricultural management practices combined with optimal wastewater treatment activities (ANCEV et al., 2003).

The reason why conventional input or output oriented approaches (with regard to environmental efficiency) do not give satisfactory results is that the nutrient balance (such as the nutrient surplus in swine fattening; a typical balance indicator) is actually ignored (LAUWERS AND VAN HUYLENBROEK, 2003). Moreover, nutrient constraints may lead animal and crop production to be in balance. This reduces the quantity of manure nutrients leaching to the ground and surface water. Nutrient constraints cause an increase in the cost of production. Consequently, producers may seek additional cropland for manure spreading, incur higher hauling costs, and they invest in services associated with nutrient management. The price effects are partially able to compensate livestock and poultry sectors for costs of meeting nutrient standard if crop producers' substitution rates for manure nutrients remain at or nearly current levels. Consumers may encounter higher food prices under the nutrient standard constraints. Environmentally, nitrogen could increasingly leach to the ground water (KAPLAN et al., 2004).

Profit maximization in animal production can deliver the demands for N and P under 3 scenarios for fertilizer applications: commercial fertilizer only; manure only; and mixed manure and commercial fertilizers associated with regulating standards on manure spreading. Later, a welfare maximization is performed under these regulating nutrient standards. Under certain conditions, stricter environmental regulations may reduce the quantity of manure demanded at a given price (equivalently the price paid for a fixed quantity) (FEINERMAN et al., 2004).

An integrated approach of combining nutrient loading, physical processes, and decision analysis should be applied to obtain the optimal management of the nutrient contamination of the groundwater. It is not efficient to automatically reduce fertilizer application and assume this to be effective without the proper assessment via mathematical simulation models. The sustainable on-ground manure and fertilizer loadings are preliminary and should provide insight for more exhaustive and comprehensive strategy for nutrient pollution management (ALMASRI AND KALUARACHCHI, 2005).

Also agricultural abatement and investment in wastewater treatment capacities can coordinately considered to reach the optimal control of nutrient pollution loading. If investment is undertaken to establish wastewater treatment capacities, nutrient loads can be controlled. If the investment in improving wastewater treatment capacities is relatively inexpensive, the investment needed should be carried out immediately to adopt better treatment technology. On the other hand, if the fixed investment cost is relatively high, then only agricultural abatement should take place (LAUKKANEN AND HUHTALA, 2005).

5.2 Manure Management and Applications

5.2.1 Manure Management

As frequently said, animal waste from confined animal feeding operations is a potential source of air and water quality degradation, evaporation of gases, runoff to surface water, and leaching to ground water. Manure pollutions can originate at several stages of production such as animal production house, manure storage, and land where manure is applied (AILLERY et al., 2005). One way of tackling the mineral leakage problem in agriculture is by command-and-control measures. In other words, command and control is a measure to decrease the excessive nutrient runoffs from agriculture. This measure is to limit fertilization so that the farmers make their decision to dispose less amount of manure out of their farms. It includes the regulatory levies that are able to deliver some incentives to process more farm manure. This processing serves both mineralization and denitrification (LAUWERS et al., 1995). It is argued that improving manure management practices without modifying fertilizer use is likely to increase the nutrient losses whereas improve timing of manure application will increase the utilization of manure by crop. It should be done such that more excess amounts of nutrient losses can be removed (ZEBARTH et al., 1999).

ROKA AND HOAG (1996) incorporate manure value into herd management of swine production. Their study showed that the marginal value of swine liveweight is the positive value of pork and the negative value of manure. Therefore, manure value is taken into account for the decisions on livestock production in terms of herd size and market weight. It has to be noted that manure management depends much on the pork production. Manure value is dominated by the price of pork and it is quite small relative to pork price. As a result, a manure value does not impact on the decisions for producing swine. Moreover, manure value can be increased with herd size by irrigation (ROKA AND HOAG, 1996).

In terms of manure management (with respect to the farm and regional aspect), it was found that undergoing direct or indirect effects of manure legislation differ in their profitability and their strategic abilities (LAUWERS, 1992). Externalities (regional manure surpluses and an increased animal disease pressure) are hardly taken into account in the farm decision process. No manure policy plays a direct role in regional spread by imposing no exploitation constraints. Those constraints serve as instruments for regulation of location to help provincial and municipal authorities to evaluate application for building and operating licenses. The indirect role of an effective manure location policy gives rise to a differentiation of internalized environmental costs. It will be more advantageous to start up a livestock production unit or activity outside the concentration area. On the other hand, the closure of an enterprise will be relatively accelerated in those places where internalized environmental costs are the highest (LAUWERS, 1992).

Swine waste management systems in general comprised of two different methods: 1) swine waste management by using a mixed feces and urine treatment system such as anaerobic lagoon, anaerobic digester, and manure collection; and 2) the solid separation of dry matter from liquid matter of swine waste and recycling the dry matter as fertilizer or other purposes. The latter method could reduce odor after the separation. The separated dry matter has plenty of nutrients and it is mainly used as fertilizer. Normally, the use of swine waste for agricultural land as fertilizer could cause odor due to chemical reaction in the environment depending on the way it is being applied. Spraying swine waste in a field could spread much more of odor than the digging method (POLLUTION CONTROL DEPARTMENT, 2000).

When a government cannot directly regulate producers’ manure-spreading practices, producers will choose to apply more manure to surrounding croplands. As a result, the application of manure increases environmental harmful nutrient runoff from croplands. Hence, an economic efficiency may be improved by regulating observable producer choices. Producer choices affect both their manure-spreading practices and environmental effects of these practices. Furthermore, regulating on manure storage facilities, is a risk management of waste spills and leaks, can also enhance the economic efficiency (INNES, 2000). This is agreed by the study that problems of applying swine waste, stemming from the buildup of nutrients in manure, can negatively affect land quality especially soil and surrounding water areas. One way of easing this is to apply a program of chemical amendments in swine manure. (TAYLOR AND WOOD, 2001).

Besides, hauling and manure application costs can be estimated in order to find an amount of land needed to spread manure to meet manure nutrient standards. The cost of meeting nutrient standards is derived from a difference between the cost of spreading on required acreage and the net cost of spreading on the baseline acreage. A landowner’s willingness to accept manure is able to assist in decreasing costs of transporting manure off the farm in terms of shorter distance to spreadable land (RIBAUDO et al., 2004).

Likewise, impacts would be greatest where animal production is concentrated. Reliance on land application alone, as a regional manure management solution, may not be feasible. Other measures (such as increasing landowner willingness to accept manure, developing industrial applications for manure, subsidizing the long-range transport of manure out of the sources, or even reducing animal stocks) may play a role in dealing with a regional surplus of manure nutrients (AILLERY et al., 2005).

5.2.2 Manure Applications

In general, livestock wastes contain nitrogen in various nitrogen-containing compounds. The nature of compounds depends on local situations, governmental policy (with respect to emission standards), and rules regarding to use of manure products as animal feed. The most obvious option is a direct use of manure products on farm. Little or no effort has to be put into marketing and distribution of products. In this respect, on-farm slurry processing is more advantageous than a central processing (RULKENS et al., 1998). If a central processing is to be applied for technical or economic reasons, a close cooperation among users of the manure products is important. An advantage of central processing is that products can more easily be adjusted to demands of manure users. Successful and cost-effective implementation of nitrogen recovery from livestock manure requires an integrated waste handling and treatment system. These treatment systems should aim at recovery of valuable products and energy from the waste with minimal energy consumption and no emission to the environment (RULKENS et al., 1998). For applicable crops or cropping systems, manure incorporation can reduce total phosphorus losses from small to moderate costs to producers. A practice of manure incorporation on crop fields makes it possible to obtain enhanced phosphorus loss reductions when phosphorus-based application rates are used. Moreover, manure incorporation would be a useful best management practice (BMP) that provides significant reductions in phosphorus losses in costs when compared to other practices (OSEI et al. 2003).

In particular, there are studies on manure applications in Thailand. However swine manure application is a focus in this study. DEPARTMENT OF AGRICULTURE (1996) and DEPARTMENT OF LAND DEVELOPMENT (2000) found that swine manure fertilizer has higher contents of necessary nutrients (nitrogen: N, phosphorus: P_2O_5, and potassium: K_2O) required for cropping than other types of animal manure. In addition, manure fertilizer is normally applied in greater amounts than chemical fertilizer for crops. The use of manure or compost fertilizer can help to reduce amounts of chemical fertilizer used in a field while increasing farm yields. It has to be noted that a mix of compost and chemical fertilizer can be able to provide favorable yields and revenue.

There are three factors that influence swine raising farmers in adopting farm manure management: needs of farm management; promptness; and capability potentials. It is found that farmers with higher education (especially above secondary education) are able to manage their farms better than others. Several farmers have a background of wastewater and manure management by adding effective microorganism (EM) into their treatment ponds. Some farmers apply swine manure as fish feed and fertilizer. Moreover, different household sizes indicate different potential levels in farm environmental management (TARNCHALANUKIT, 1997).

For the energy point of view, it reveals that it is beneficial in terms of both economic and financial aspects to invest in a bio-gas system rather than electricity or liquid petroleum gas (LPG) systems on swine farms (TOKHEM, 1998). There are several factors affecting decisions of a farmer to invest in a bio-gas system. These factors include location, farm experience, financial burden, maintenance ability, and benefits from the environmental improvement. Quantitatively, a study of financial and economic feasibility shows that medium-size farms yield highest returns on investment (JINDAWONG, 2001).

In features of animal feed, swine manure can be applied as feed into fish ponds in order to build up planktons that are natural food for fish. Swine manure is a source of mineral nutrients and growth promoting organic substances resulting from bacterial and fungal decomposition. It is found that manure from one pig can be converted into 31-56 kilograms of fish weight and farmers gain higher profits. Furthermore, this waste recycling method can also help to eliminate serious air and water pollution problems (TARNCHALANUKIJ, 1978). For other animal feeds, swine feces for sheep feeding are possible. It found that the sheep gain higher weight and have higher digesting performance when they are fed with a mix of regular feed and swine manure (WISUTIUTAIKUL, 1988).

5.3 Monitoring Policies and Stakeholder Participation

Currently, monitoring policy design, embraced with stakeholder participation, is likely to be one of key items for successes in solving environmental problems. The goal of environmental sustainability can be reached if negotiations between polluters and pollution takers are made; this occurs normally through authorization and cooperation among stakeholders (such as government agencies, problem coordinators, and other related public and private sectors). Therefore, it is necessary to include participatory approaches as a part of the study.

5.3.1 Monitoring Policies of Nutrient Runoffs and Manure Surplus

Monitoring policies and their impacts on stakeholders, particularly on farmers who have to follow policy enforcements, are an interesting aspect to observe and analyze. Literature supports some policies; while others argue whether those policies serve on only specific purposes or coincidentally neglect on some of the other side effects. The following literature shows some pros and cons of such environmental policies designed to address agricultural pollutions.

While the issue of regionalization in service provision goes beyond economics, economists can play a role in demonstrating to communities what they have to gain or lose by adopting home rule management strategies versus regional approaches to solve environmental problems. At least a local public choice should include opportunity costs, marginal analysis of costs and benefits, and roles of economic incentives. The challenges, that rural communities are facing today, have created a more receptive atmosphere than ever for guidance along these lines (HALSTEAD AND PARK, 1996).

Limiting leaching of nitrogen per unit area results in changes in product mix and water sources used. Farmers' profits decrease as they confront tighter restrictions. Marginal costs of decreasing permitted nitrogen leaching can be regarded as public costs of groundwater pollution. However, limiting applied nitrogen is easier in practice, but results in decreasing cultivated areas without any direct control on the quantity of nitrogen leached. Similarly, a quota on nitrogen leached can decrease crop production, while a quota on fertilizer use can decrease loads of crops. These can be explained since fertilizer is used in high levels to achieve good yields. For taxing aspects, taxes on applied nitrogen may result in increasing nitrogen leached, while taxes on leached amounts of nitrogen are more beneficial in achieving goals but more difficult to apply (HARUVY et al., 1997).

The size of swine operations appears to affect costs of waste management. A current conjecture is that large operations meet environmental standards at a lower cost than small traditional operations. That is, capital costs and environmental expertise expenditures are spread over a larger output. This conjecture is consistent with a massive relocation of production. It has been occurring geographically towards large operations. Environmental regulations and limited absorptive capacity appear to affect competitiveness in some countries. However, it is premature to consider them as central determinants of competitiveness in the other countries. The sanitary status of herds is a more important determinant of comparative advantage although it is dichotomous. Traditional sources of competitiveness (such as feed, labor costs, and costs of processing) remain pivotal. Farm size and associated economies are new determinants of competitiveness at a national level (BEGHIN, 1998). However, Beghin's findings seem to contradict to what we have found in terms of farm size effects on costs of waste management. That is, large farms in the study area associate with smaller cost share for waste management than small farms.

Since an existing independent contract farmer structure is not conducive to an establishment of on-farm waste management, an alternative off-farm waste management may arise from a third party. As an example, a third party enterprise, dealing with the U.S. broiler industry, is able to address deployment of off-farm litter management options (GOODWIN et al., 2000). Likewise, this argument is consistent to the case in the study area. The sub-district organization performs as an off-farm third party to deliver manure from swine farms to water flea farmers. This is an alternative given to swine farmers for managing their farm waste (FIELD STUDY SURVEY, 2006). The organization should be a nonprofit corporation acting as a little wholesaler, in which waste ownership and associated liability are transferred from meat producers to the third party. Market interventions are necessary for deployment these alternative waste management enterprises. A nonprofit little bank enterprise could readily access and utilize public funds (either for operational support or for market intervention, or both) (GOODWIN et al., 2000).

A cost-effectiveness comparison of a nitrogen fertilizer tax and a combined feed-fertilizer nitrogen tax yields a result that total nitrate leaching abatement costs are lower for fertilizer tax instrument. However, none of the measures seem to lead to economically efficient nitrate leaching reductions, as the marginal abatement costs vary significantly by farm types. This implies that nitrate regulating mechanisms are indirect, as a tax is levied on a level of nitrogen input and not on a level of nitrate leaching or nitrate loads to ecosystems. Efficient regulation of nitrate pollution (non-point pollution) should be addressed by means of more differentiated policy schemes, e.g. differentiated between farm types and soil types, rather than uniform input tax schemes (SCHOU et al., 2000).

Major pork companies must help their contract growers cover the costs of switching to superior alternatives of swine waste management technologies. Note that social costs of waste management are not paid by major pork companies but they are paid by the companies' contract growers. The pork companies are able to pass on all the burdens to their contract growers. However, superior alternative technologies for swine waste management are available and affordable. Since pork producers have benefited some of lowest production costs with profits for several years, switching to superior environmental technologies will not hurt their competitive ground tremendously. In addition, their contract grower cannot afford all the clean up costs due to lower earnings (COCHRAN et al., 2000).

Even if agri-environmental policy can be modeled as a social welfare maximization problem, the problem is not solved. It recognizes a potential trade-off between increased environmental benefit and increased cost of monitoring compliance. Moral hazard arises because monitoring does not depend on detect all those who fail to comply with contractual obligations. Thus, the first-best (perfect information or monitoring) solution can not exist. If monitoring costs are negligible or fixed, or farmers are highly risk averse, the moral hazard problem can be eliminated. However, if monitoring costs depend on monitoring effort and a degree of risk aversion is low, only a second-best solution can be obtained. It is found that optimal monitoring efforts decline with increasing farmer risk aversion (OZANNE et al., 2001).

Animal waste-related environmental problems can be caused by an organizational structure of a livestock industry. Generally, high degrees of vertical integration via production contracts with independent farmers are the causes. Potential linkages between contracting and animal waste depend on scale, specialization, and concentration of animal units, as well as on division of inputs and contract settlement rules. Long-run apportioning of an increase in costs of environmental compliance depends on the integrator's market power of grower services (VUKINA, 2003). According to the interviews, this literature is likely to be the case in Thailand. Small-scale swine raising farmers usually depend on companies which they have contracts with. These companies run their business in terms of vertical integration. They are associated with high market power that can affect on costs of waste management incurred to swine farmers (FIELD STUDY SURVEY, 2006).

First-best policy instruments require that resource managers as well as farmers know everything about a farm and its links to water quality and environmental damages. Given such knowledge is not possible except at great cost. Policies that encourage farmers to reveal their private knowledge are likely to perform better than policies that do not. Policy instruments should encourage farmers to use their own private information in deciding how much pollution abatement to provide (RIBAUDO, 2004).

In case of externalities, a major role of a government is to provide a basis, i.e. defining and assigning property rights for a bargaining solution. A degree of rights can improve efficiency of transactions because agents can contract on the necessary rights only. Consequently, they make the Coasean bargaining process more efficient. A Coasean bargaining may be designed and implemented successfully if transaction costs are sufficiently low. The role played by public authorities is decisive and can obviously reduce overall transaction costs (DEPRES, 2005).

Public policy interventions are often focused on observable effects, rather than on important environmental losses. There is still a lack of understanding the relationships between types of policy instrument (– behavior of farmers – agronomical) and environmental effects (WORLD BANK, 2005). Responses of farmers (to an implementation of manure policy and measures) appear to be more varied and complex than expected. A move to a more targeted approach has a number of benefits because it gives farmers a freedom to select the most cost-effective approach to achieve the target practices and outcomes on their farms. However, on the enforcement side, the major disadvantage is the difficulty in measuring the target (WORLD BANK, 2005).

5.3.2 Participatory Approach and Multi-Disciplinary Policies

Working on research to solve or relieve complex problems of the real world nowadays requires not only on one specific expertise, but also on multi-disciplinary work and expertise from diverse branches of knowledge. Therefore, policies, derived from studies and designs of the varied planners and researchers, should be taken into account various aspects. Policies can impact on different groups of stakeholders in both general and specific purposes. Hence, stakeholder participations should be included into a process of policy design in order to be more effective on right targets and capture a variety of needs efficiently.

Participation can be categorized into 3 major steps: 1) participation in decision making, 2) participation in implementation, and 3) cost and benefit sharing among participants (COHEN AND UPHOFF, 1980). Besides these three steps, participation in monitoring and evaluation is also an important successful factor in mitigating social problems (PINTHONG, 1983).

Though an analysis of the livestock waste issue should be based on science of the mineral cycle, i.e. on biological and eco-physiological processes that govern agricultural production, it needs also social aspects. A multi-disciplinary approach to environmental economic analysis is required with collaboration between researchers from different disciplines instead of either economic or technical studies performed in isolation. An analysis should start at farm level where the technical and the economic disciplines meet. Also, it should be done in line with decisions regarding nutrient management are taken and implemented. There are 2 major instruments for achieving environmental goals: "command and control" and "economic incentives". The latter has been identified and preferred by numbers of economists as efficient means to achieve environmental objectives. However, it has several limitations as follows:

- Asymmetric information between regulators and farmers,
- Stochastic processes in pollution effects,
- Ecosystem complexity and localized damages,
- Low price elasticity of inputs containing nutrients, and
- High transaction costs.

Thus, the most efficient policy measures may be a system of locally specified policy instruments. Rather than first best solutions through economic instruments (such as ambient taxes or tradable permits), the most effective way of dealing with diffuse sources of pollution (such as nitrates and phosphates in agriculture) may occur through technological developments and business-led initiatives. This aims at meeting nutrient standard bet by command and control policies. In addition, a standardization of voluntary private codes related to environmental practices is the next generation of environmental policies (WOSSINK AND BENSON, 1999).

The distinctive policy instrument should lie on its formulation as a policy mix, comprising economic and decentralized policy instruments as complement to existing regulations. It should also emphasize on participatory and transparent approaches in policy formulation processes. The processes include stakeholders who are actively engaged in decision making. These two aspects can contribute to higher acceptance and adhesion of stakeholders to proposed policies. Given complexity and practical difficulties, a gradual implementation strategy should be adopted (SANTOS et al., 2006).

5.4 Analytical Methodologies

According to the objectives of the study, the core of the study's analytical part is to determine abatement and environmental damage costs caused by the agricultural pollutions. This serves to obtain the optimal abatement level. Literature has already demonstrated numbers of remarkable economic modeling of interests. They have attempted to both quantify and qualify agricultural pollutions in terms of theoretical approaches and empirical analyses. Economic methodologies, performed in the literatures, are available in various approaches such as static, dynamic, spatial, and temporal approaches. Additionally, a welfare optimization in forms of linear and nonlinear programming seems to be broadly used among these researches. In this section, there are interesting reviews of relevant literatures that can be categorized into 4 parts: 1) estimation of nutrient and manure abatement costs, 2) estimation of environmental damage costs, 3) economic modeling on optimal pollution management, and 4) economic modeling on policy impacts.

5.4.1 Estimation of Nutrient and Manure Abatement Costs

Estimations of nutrient and manure abatement costs have been done by numerous of researchers in various remarkable aspects. Several studies attempt to derive on the abatement cost curves in order to characterize the nature of abatement costs. Thus a cost minimization, as the general objective of the study, can be reached. Moreover, knowing the nature of abatement costs can help policy planners to design proper policies on the right targets that they want to tackle on.

A study written by BYSTROM (1998) estimated abatement costs of agricultural nitrogen pollution in wetlands by linking costs for construction of wetlands to denitrification capacity of wetlands. In other words, a relationship between abatement costs and the nitrogen loads on wetlands is investigated in this paper. In the analysis, denitrification is a non-linear (Cobb-Douglas) function of the annual nitrogen load on wetland and the area of the wetland. Consequently, denitrificaton function can be linked to total costs of abatement. Hence, marginal abatement cost is obtained by a non-linear function of wetland size and nitrogen load on the wetland. It has to be noted that marginal abatement costs estimated in this paper are private costs and do not consider potential social benefits created with wetland.

Similarly, BRADY (2003) evaluated the relative cost-efficiency of a nitrogen abatement scheme and analyzed implications of agricultural policies for a least-cost solution. A spatially distributed, nonlinear mathematical programming model was developed for the empirical analysis. Costs of abatement are measured as losses in producer profits for achieving an abatement standard. The analysis is based on 2 alternative cost-efficiency benchmarks: (1) the standard benchmark (2nd best solution) takes the current structure of agricultural support to be given, hence abatement costs reflect farmer's private opportunity costs only; (2) the coordinated benchmark (1st best solution) assumes that agricultural and environmental policy can be coordinated (e.g., reduction in agricultural subsidies are replaced with direct of production neutral income transfers) and is taken to be more reflective of the costs of abatement.

RIBAUDO et al. **(**2004) intended to examine costs of swine and crop farmers in properly managing animal waste to meet manure nutrient standards. The simulated Fleming model is used to estimate the net cost of meeting a nutrient standard. The model applies several factors (such as costs of hauling and applying manure, fertilizer prices, numbers of heads, types of manure storage system, crop mix of receiving land, local land use, and willingness to accept manure) to estimate the net hauling and application costs of meeting a nutrient standard. Given a nutrient application rate, the model estimates an amount of land needed for spreading manure and distance required to reach this land.

5.4.2 Estimation of Environmental Damage Costs

One objective of the current study is to evaluate environmental damage costs derived from the agricultural nutrient runoffs into surrounding environment. Environmental damage costs are mostly embraced into a social welfare optimization analysis. The costs occur in both tangible and intangible values; they endeavor to reflex damages in terms of measurable monetary values. The following literatures present some analytical methodologies to assess such damages. More specifically, hedonic price modeling has been applied by researchers to capture values of environmental degradation caused by the agricultural pollutions. As such, this study also employs a hedonic price modeling to evaluate damage costs. It will be explained in detail in the following chapter.

BONTEMPS et al., (2005) present a relationship between agricultural pollution and property values. An alternative semiparametric hedonic price model is employed to see impacts of the pollution derived from livestock nitrogen emissions on values of housing. It is found that a nonparametric additive form is the most appropriate specification to explain the nonlinear relationships between pollution and property values.

CONCU (2006) describes a choice modeling experiment set up to investigate the relationship between distance and willingness to pay for environmental quality changes. It allows testing distance effects on parameters of environmental attributes that imply different trade-offs between use and non-use values.

5.4.3 Economic Modeling of Optimal Pollution Management

Generally, analyses of optimal pollution management appear to deal with a social welfare optimization. Different analytical aspects have been shown, for instances, in forms static analyses, optimal control analyses in regarding of dynamic approach, spatial, and temporal analyses. All of these aim at finding out the optimal quantities of pollution abatement in order to maximize social welfare with respect to specific constraints for each specific problem and circumstance.

In the study of CARMICHAEL (1998), a presentation of simulation/optimization model with a multiple organic pollutant (nitrogen: N, phosphorus: P, and biological oxygen demand: BOD) approach is shown to determine the optimal percentage of pollution abatement. It is also to obtain a least cost wastewater management. In other words, the model performs to choose treatment levels for the three organic pollutants. It aims at minimizing a combined wastewater treatment cost to meet ambient standards. The model can calculate the marginal effect of increasing a pollutant load on downstream dissolved oxygen (DO) levels.

The study done by CACHO (1999) focuses on a sustainability of agricultural practices at microeconomic levels in order to link an individual producer behavior to a regulatory environment. The study also mentions about two important approaches that should be taken into account. They are economic/biological criteria and a dynamic of production system including the environment. In this study, an optimal control formulation is employed to propose alternative ways in which externalities are included.

GOETZ AND ZILBERMAN (2000) take into account intertemporal and spatial aspects of a phosphorus runoff problem. A land classification system is brought to address an optimal management of mineral fertilizer and manure. The study is also based on zonal taxes, zonal permits, and zonal standards which vary over time. The conceptual framework is to maximize present net benefits from agricultural production within a watershed. It takes into account economic losses resulting from the accumulation of phosphorus in the watershed. There are 2 aspects of the study implementation. The first aspect is a case of full information on production costs. It captures a socially optimal outcome by engaging a tax scheme of different sources of phosphorus runoff. The second aspect is a case dealing with no information on production costs, the study introduces a zonal system of tradable permits on phosphorus among inner and inter zones.

INNES (2000) presents a model of spatial and waste management derived from the decision of private livestock producers: how they affect the environment, how they are affected by market forces, and the implications they have for the efficient design of government regulatory policies. Three types of environmental effects are considered: (a) spills form animal waste stores, (b) nutrient leaching or runoff that can be attributed to the application of manure to croplands, and (c) direct ambient pollution from livestock operations including odors, pests, and ammonia gases. The study also takes the effects of rainfall into account of the analysis of waste spills and leaks (when it rains then the lagoon containing animal waste exceeds its maximum capacity level, there will be spills and leaks to the ground surface). The study states that a Pigouvian tax on marginal damage does not work because of practically unobservable damages.

RIBAUDO et al. (2001) make use of a mathematical programming model to compare 2 alternatives in nitrogen reduction between (1) reduction in fertilizer application rate and (2) filtration of nutrient loadings coming off cropland. In the model, commodity prices are analyzed as endogenously. Changes in production costs, due to nutrient management policies, are expected to impact commodity prices. The model also estimates nitrogen loss from cropland. Moreover, the other approach of nitrogen reduction is to install wetlands for buffering nitrogen runoff from agricultural land. In this study, the analysis focuses on fertilizer restrictions rather than restrictions on nitrogen runoff because of unobservable nature of runoff in practice.

ANCEV et al. (2003) shows a method of deriving socially optimal level of phosphorus loading by equating marginal abatement costs to the marginal environmental damage costs. The objective is to obtain a maximal amount of social welfare. Abatement costs are obtained by using technical and engineering data on wastewater treatment costs. Damage costs are estimated from additional costs on drinking water treatment and costs of recreational losses caused by phosphorus contamination. In addition, a social optimization is performed by using a linear mathematical programming to maximize the total net income. The model takes into account abatement and waste transportation costs with respect to the model constraints.

AILLERY et al., (2005) apply a positive mathematical programming to formulate a farm-level model. In the model, input-output data sets are used to perform rather than cost database. A cost database is more difficult to obtain. There are 3 steps in the calibration. Firstly, a constrained linear programming model is used to derive dual values associated with calibration constraints. Secondly, the dual values (from the first step) are used to parameterize a calibrated quadratic objective function. Finally, the calibrated model (from the second step) is used for economic analysis by imposing environmental policy constraints. For manure management modeling, it is designed to minimize regional costs of applied manure subject to total manure produced and the land available for manure applications. Total regional costs of applied manure include: transportation costs; manure application costs; nutrient management costs; and ammonia-reducing technical costs. The model allocates manure flows between source and destination counties to minimize these total regional costs.

ALMASRI AND KALUARACHCHI (2005) illustrate an integrated method for an optimal management of nitrate contamination of groundwater. It combines environmental assessment and economic cost evaluation through a multi-criteria decision analysis. The model is accounted for surface nitrogen loading and losses, soil nitrogen dynamics, fate, and transport of nitrate in groundwater. It aims at calibrating a sustainable surface nitrogen loading. In addition, protection alternatives are assessed by using a decision analysis that employs an importance order of criteria approach for ranking the protection alternatives.

LAUKKANEN AND HUHTALA (2005) use a dynamic approach to derive the optimal control of nutrient pollution in an ecosystem in which policy planers want to minimize environmental damages from nutrient accumulation through reducing nutrient loads.

5.4.4 Economic Modeling of Policy Impacts

Designing an environmental policy and/or regulation in agricultural sector is a considerable deal. It consequently has an effect on a large number of people, especially farmers whose income rely on low market prices of agricultural products and natural uncertainties. This is even worse for developing countries. A careful attention on the policy impacts must be paid in a process of policy making. A number of literatures have been working on these concerns as demonstrated in the following reviews.

LAUWERS (1992) explores on economic impacts of manure policy on intensive livestock farms. The model used in his study calculates farm level manure surpluses with respect to farm types and locations. Profitability of specialized swine farms is analyzed with and without simulated internalized environmental costs. A similar study also presented by LAUWERS et al. (1995) applies a system approach to examine command and control measures on internalizing eutrophication externalities. Extra costs at farm level are derived from shadow prices of local manure disposal constraints in a regional linear programming manure disposal model. Likewise, LAUWERS et al. (1998) apply a linear programming to analyze impacts of manure policy measures on structural changes and abatement costs. The model tries to capture interactions between manure disposal costs, which are an economic incentive for structural changes, and costs of abatement. A simulation of the interactions is constructed to describe a regional manure disposal coordination system.

FEINERMAN et al. (2004) present a derivation of manure demand and effects of manure spreading regulations on welfare costs and on pollution potential through reductions in nutrient applications. The analysis applies the von Liebig production function (Leontief-shaped curve). It minimizes input (N and P) costs to obtain maximum yield. Three types of total production costs are derived and compared under input price threshold and manure-commercial fertilizer spreading cost ratio schemes. In addition, regulating standards on manure spreading are imposed into this study. Hence, the welfare maximization is performed under these regulating nutrient standards.

The study of KAPLAN et al. (2004) analyze effects of land application constraints on manure nutrient use (Animal Feeding Operations: AFOs). The model used in the study demonstrates a constrained, partial equilibrium, and regional optimization. It seeks to maximize profits from livestock, poultry, and cropping enterprises subject to nutrient constraints. A linear programming is used to maximize profits from livestock, poultry, and cropping enterprises with respect to constraints of nutrient standards.

The above literatures can relate to the current study in aspects of giving policy implication and recommendation on manure management in the study area. However, policies on manure management in Thailand are inexplicitly established (DLD, 2000).

5.5 Summary

The literatures explored in the preceding parts intend to tackle down on the optimal management of agricultural pollution. Most literature focuses on the pollution derived from nutrient runoffs from livestock sector. Abatement and environmental damage costs can be derived in different ways depending on various factors that fit best to the state of problems. However, most literature generally aims at optimizing social welfare, which usually is a net income from agriculture, with respect to physical and regulatory constraints. These studies often employ an analytical tool of either linear or nonlinear mathematical programming under diverse aspects of spatial, temporal, static, and dynamic points of views. Accordingly, abatement and environmental damage costs need to be minimized in an optimization setup. Several studies suggest that animal manure can be recycled in terms of fertilizers for cropping and other forms of applications. On the other side, a number of studies argue and reveal adverse effects of nutrients and manure recycling on the environment. These have to be managed properly. Otherwise, nutrient runoffs can reach and accumulate to the groundwater and environment. Policy recommendations and implications have been widely discussed in the extents of command and control or economic incentive/penalty or mixed policies in different situations and scenario setups.

For the current study, a welfare optimization remains the major task of the research in order to obtain an optimal abatement level of agricultural pollutions drawn from a livestock sector. The study emphasizes on environmental cost derivations, environmental parameters used in the model, and participatory approach. In the study, a linear programming and a hedonic price modeling are employed to derive marginal abatement and marginal damage costs. This has been done under the Coase theorem. These will be explored explicitly in the next chapter. The theoretical background in the next chapter is based on JUST et al. 1982 and 2004 and also the reviewed papers are based on the same welfare analytics.

6 ANALYTICAL FRAMEWORK AND METHODOLOGY

This chapter portrays a structure of the study in which the analytical framework and methodology are thoroughly explained. Before exploring the structure, the chapter gives some overall theoretical background on welfare theories that are applied and are the basic concepts of the analytical component of the study. In particular, the concept of the Coase Theorem is principally explained in the analytical part. The analytical framework shows the overall picture of major tasks in analyzing and deriving environmental damage and abatement costs in order to obtain an optimal solution under the concept of the Coase Theorem. Furthermore, details of the methods (such as a mathematical linear programming for a welfare optimization, a derivation of gains drawn from swine manure markets, and a hedonic pricing analysis on the environmental damage costs) are explored in details. Lastly, a sensitivity analysis is presented by setting policy scenarios related to key decision variables in the study.

6.1 Theoretical Background

Since the study generally intends to find the optimal abatement solution to reach the goal of maximum social welfare of a community in which pork is produced, the following contexts deliver some overall background of welfare theories. These theories include the view and concept of the Pareto optimality, compensation principle, and optimal resource allocation for the existence of externalities.

6.1.1 Pareto Optimality

In early ages, the concept of social welfare was developed as a function of the utilities of all individuals in the society. The objective was to establish a complete "social ordering" of all possible states of the world. Nonetheless, the functional form of the social welfare function was disputable by a number of economists. Successively, the Pareto principle was firstly introduced by the great economist of all time, Vilfredo Pareto, to avoid such value judgments that occurred to cause the controversy in the former concept of social welfare (JUST et al., 2004).

Given a set of alternative allocations of, say, commodities or income for a set of individuals, a movement from one allocation to another that can make at least one individual better off without making any other individual worse off is called a "Pareto improvement". An allocation is "Pareto efficient" or "Pareto optimal" when no further Pareto improvements can be made. This is often called a strong Pareto optimum (SPO). A weak Pareto optimum (WPO) satisfies a less stringent requirement, in which a new allocation is only considered to be a Pareto improvement if it is strictly preferred by all individuals (i.e., all must gain with the new allocation). The set of SPO solutions is a subset of the set of WPO solutions, because an SPO satisfies the stronger requirement that there is no allocation that is strictly preferred by one individual and weakly preferred by the rest i.e., no individual loses out, and at least one individual gains (JUST et al., 1982). This implies that a Pareto-optimal state is defined as the situation in which "it is impossible to make one person better off without making another person worse off" (JUST et al., 2004). Theoretically, Pareto optimality can be obtained under the competitive market equilibrium (an example of a Pareto efficiency derivation can be seen in Appendix C). Pareto efficiency is an ultimate goal for policy makers to keep in mind while designing new policies or making policy changes in a society. However, compensations need to be addressed in reality when new policy or policy changes are initiated.

6.1.2 Compensation Principle

In reality, the Pareto optimum is hardly to attain due to gains and losses drawn from some social and economic changes. These changes are usually initiated by political, social, and economic policies. Such changes, aimed at improving economic efficiency, make some people in the society better off, while some others find themselves worse off. Hence, there should be compensations, transferred from the gainers to compensate the losers (Just et al., 1982). Consequently, the "compensation principle" was introduced firstly as a hypothetical compensation. It is a part of the "Kaldor-Hicks efficiency" (RICHTER, 1998). As such, the compensation principle is often called the "Kaldor-Hicks compensation test" (JUST et al., 2004).

Upon the compensation principle, the concept of compensating and equivalent variations (CV and EV, respectively) is settled in this frame. The CV is referred to "the amount of income which, when taken away from an individual after a change, leaves the person as well off as before" (JUST et al., 2004). For the welfare gain, CV is the maximum amount of income that a person would be willing to pay for the change. On the other hand, for the welfare loss, CV is the negative of minimum amount of income that the person would be willing to accept as compensation for the change (JUST et al., 2004).

On the other side, EV is "the amount of income paid to an individual which, if a change does not happen, leaves the individual as well off as if the change had occurred". For the welfare gain, EV is the minimum compensation that the person would be willing to accept to forgo the change. On the contrary, for the welfare loss, EV is the negative of maximum amount of income that the person would be willing to pay to avoid the change (JUST et al., 2004).

The concept of CV and EV (a graphical illustration can be seen in Appendix D) can be kept in mind for the study in terms of improving social welfare in the swine raising community. This concept is imposed successfully if property rights are clearly defined. As such, compensation must be made in order to restore a loss of the one who is affected by a social policy or measure. Therefore, swine raising farmers, who pollute the environment in their community, should be willing to pay some amounts of their income to compensate the affected community. This compensation will later initiate a social welfare improvement. This compensation might be in form of environmental fund for improving the community environment. However, property rights are unclear and disputable over related parties in reality. Hence, environmental problems are still difficult to solve.

6.1.3 Optimal Resource Allocation for the Existence of Externalities

Besides the Pareto principle and compensation concept, this study is dealing with non-market welfare measurement in terms of externalities derived from the nutrient runoffs of swine farms. Hence, an additional theoretical concept is included in the forms of social costs and benefits. The equilibrium of a socially optimal resource allocation is determined as the equality between marginal social cost (MSC), which is derived from the summation of marginal external cost (MEC) and marginal private cost (MPC), and marginal social benefit (MSB) which is equivalent to a demand curve, as depicted in Figure 6.1.

The aims behind Figure 6.1 are to present the changes in social welfare in the case of social optimality due to the existence of external costs derived from pollution emissions resulting in the environmental damages. Several times these costs are neglected by the polluters or the private producers so that the total private costs seem to be lower than they should have been in this case. According to Figure 6.1, for social optimality, the external cost is reduced by an area *h* (from area *j+h* to area *j*); the production cost is also reduced by an area *g+h* [derived from area *(i+g+j+h)* – area *(i+j)*]; the producer's revenue is decreased by an area [*(f+g+h)* – *(a+b)*] derived from area *(d+e+f+g+h+i+j)* – area *(a+b+d+e+i+j)*; the consumer surplus is decreased by an area *a+b+c*. Consequently, the net social welfare is equivalent to an area *h-c-f* yielding some positive value. This implies that the socially optimal resource allocation can deliver the net gain to the society (JUST et al., 2004).

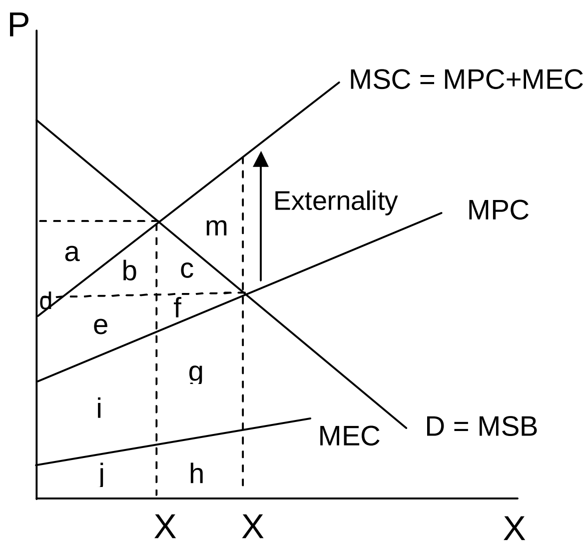

Figure 6.1: Socially Optimal Resource Allocation for Non-market External Costs

Source: Adapted from JUST et al., 2004.

In addition, the welfare economist Arthur Cecil Pigou introduced the approach of the environmental taxation incurred to the polluters who cause the externalities problems published in his extraordinary book, “Wealth and Welfare”. This approach is later known as the “Pigouvian tax” that is a unit tax used to charge polluters for each unit of pollution they emit (TIETENBERG, 2003). However, the pollution and its marginal effects are often unobservable and non-measurable in reality. Thus, the successive concepts of transaction costs and property rights were delivered by Ronald H. Coase and published in the articles of “The Nature of the Firm” in 1937 and “The Problem of Social Cost” in 1960. These concepts are also known as “The Coase Theorem”. The conclusion of the Coase Theorem reveals that as long as negotiation costs are negligible and affected, consumer can negotiate freely with each other (when the number of affected parties is small). The court could allocate the entitlement to either party and an efficient allocation would result. The only effect of the court’s decision would be to change the distribution of costs and benefits among the affected parties (TIETENBERG, 2003). This simply means that transaction costs should not be neglected when negotiations are made. As such, the property rights should be assigned clearly to each party and transaction costs should be minimized as much as possible in negotiations in order to reach the efficiency.

An other point of view is the concept of non-market external costs with respect to the Coase Theorem. It can be extended by employing the concept of damage and abatement costs in order to depict the external cost more clearly. Figure 6.4 illustrates the optimal level of pollution emission (e^*) that the society is able to accept is located where the marginal damage cost (MDC) is equivalent to the marginal abatement cost (MAC). The level of pollution emission that the affected society wishes the polluter to abate arises from zero to the maximum unit (e^{max}) along the horizontal axis. The vertical axis represents the monetary values of MDC and MAC. The MDC is minimum when the emission level attains the lowest or zero unit, vise versa. In other words, the more units of pollution are emitted (to the right hand side of the horizontal axis), the higher of damage cost will be. On the other hand, the MAC increases while an additional unit of pollution emission is reduced along the left-hand-side direction of the horizontal axis.

It is rarely observed that extreme cases of both, zero and maximum units of pollution emission, exist in the negotiation between pollution taker and polluter. This means that the pollution taker wishes the polluter to clean up the pollution emission as much as possible until reaching to the level of e^* whereas the polluter tries to minimize his abatement cost by abating the pollution emission level as minimum as possible or even wishes not to abate any emission unit at all. Each party has to insist on the negotiation until they both meet in a common point where the final outcome is satisfied and acceptable by the two parties. This yields the optimal level of pollution abatement at e^* as seen in the following Figure 6.2.

The above negotiation implies that in reality there must be some pollution emission level left. It remains accumulated in the environment even though the society wishes to diminish it until purity occurs. Note that in this case, it is assumed that there is no negotiation or transaction cost incurred to either party in the negotiation process according to the Coase Theorem. Therefore the efficient outcome is obtained at e^*. However, the outcome would be different in the case of the existence of transaction cost in the negotiation process depending upon the magnitude of the cost incurred to each party. Thus, the level of pollution emission would consequently deviate from the e^* level.

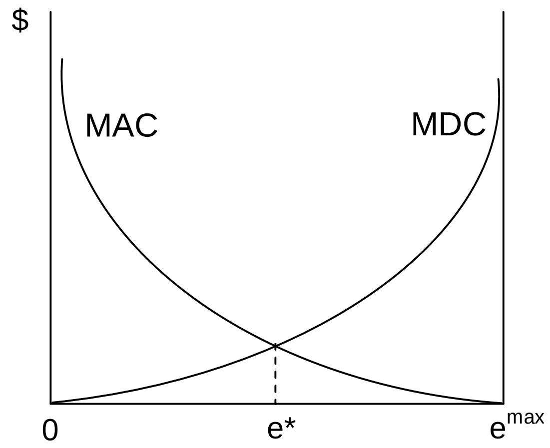

Figure 6.2: Optimal Pollution Level under MDC and MAC

Source: Adapted from PERMAN et al., 1996.

6.2 Analytical Framework

Figure 6.3 represents the broad concept of the study. The idea is to maximize the social welfare of the community in which pork is produced by taking into account both benefit and cost factors of pollution. In terms of the benefit factor, it stems from 2 sources. They are aggregated as net farm income. Net income is derived from the whole of 104-swine-farms in the community and the sum of net gains, obtained from the swine manure markets in the area. For the side of cost factors, it comprise 5 major sources: 1) aggregated abatement cost, 2) aggregated environmental damage cost, 3) aggregated labor and hauling cost, 4) aggregated transportation cost, and 5) aggregated grants form the government.

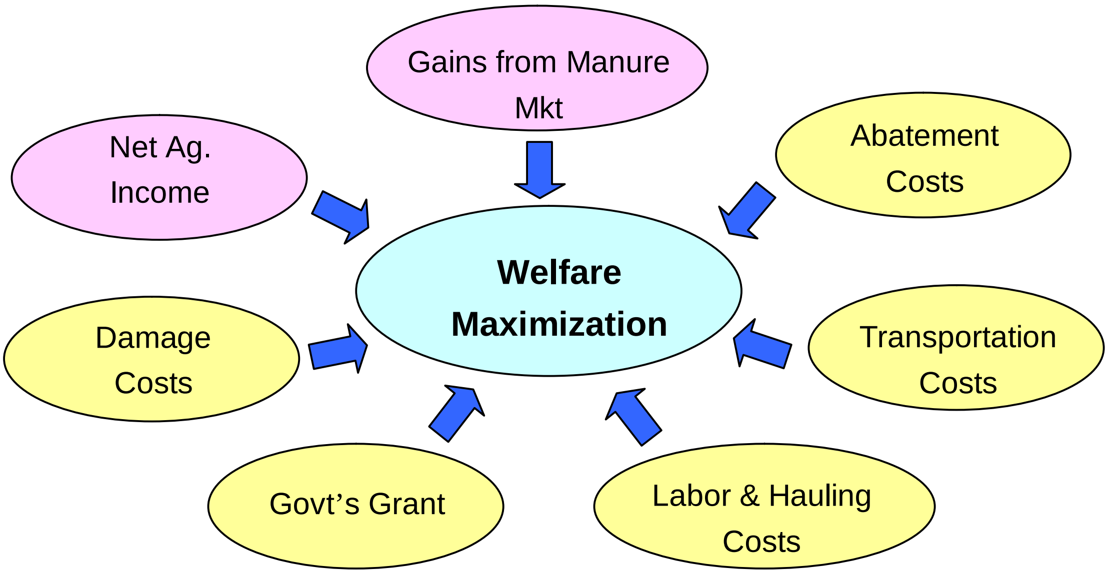

Figure 6.3: General Concept of the Study

Source: Own source.

In general, the analytical framework of the study can be divided into 2 major tasks. Task 1 aims at obtaining the marginal abatement costs by social welfare optimization. On the other side, Task 2 intends to retrieve the marginal damage costs by employing a hedonic pricing model. Regarding the Coase Theorem, the marginal abatement and the marginal damage cost solutions from the two tasks generate the optimal level of pollution abatement. It is the overall goal of the study, to find the intersection of these two curves.

In detail, Figure 6.4 illustrates the analytical framework of the study in the form of a diagram. The study has been inspired by the social welfare maximization approach that has to deal with the nutrient runoff problems from the swine farm community in the study area. The study determines to find the optimal abatement level of such pollution so that the community can reach their maximum social welfare. The analytical work of the study contains 2 principal working tasks. Task 1 deals with the social welfare maximization problem in which a mathematical linear programming is constructed. The objective function is set by subtraction all abatement costs from the sum of net farm incomes and net gains from the swine manure markets. It is noted that other farm production costs (such as transportation, labor and hauling costs including the grants from government considered as a type of social costs) have already been taken into account in the net farm incomes. Both costs and benefits are calibrated in terms of the aggregated values, derived from the total 104 swine farms, 48 swine manure middle men, and 37 swine manure end-users. The GAMS software is employed to calculate the social welfare by optimization. The outcome from the mathematical calibration process contains the shadow prices of the pollutants in the model. Each shadow price is considered as the marginal abatement cost of each pollution type. Task 1 is finished at this point where its shadow price can be used for intersection.

Task 2 attempts to evaluate the environmental damage costs by applying a hedonic price modeling. Actually, there are several methods available for researchers to value the damage cost. Many of them are more abstract in terms of monetary values and have to deal with the problems of personal perceptions and value judgments. The hedonic price modeling is employed in the study because the effects of pollutants appear more noticeably on the values of land than any other effects. Moreover, environmental effects are more understandable in terms of monetary measures and tangible damages than appeals. It is to be noted that the effects are considered as partial effects, occurring only on land values. However, there are more environmental damages that are mainly intangible and difficult to measure in practices, especially, in field surveys associated with time and resource limitations. However, at least these effects are held to be the most prominent representative of the damage cost in the study.

In our hedonic price modeling, land prices are established being a function of land attributes. For instances land size, distance from the land to the major road in the community, and distance from the land to the polluted canal, shall determine prices. The last attribute represents the factor that affects the values of the lands because swine farm pollutions have accumulated and polluted the canal. This implies that the longer distance to the polluted canal, the higher the value to the land price. After a functional form of the hedonic price modeling is selected, the econometric enumeration process begins to derive the coefficients of all contributing factors. Consequently, the coefficient of the last attribute, stated above, is then used to represent willingness to pay of the locals to buy land affected the swine farm pollutions. This willingness to pay, in other words, is the damage cost that the study tries to obtain.

A next step is to find the optimal relationship between the damage cost and all types of the pollutions by selecting the significant functional form. Once the functional form is selected, then other econometric enumeration process can start again, in order to retrieve the coefficients of all the pollutions setup in the model. The last step in this Task 2 yields the process of obtaining the marginal damage cost for each type of pollution by taking partial derivative on the enumerated equation. Finishing Task 2 enters into intersection of marginal curves.

Lastly, the outcomes of both marginal abatement and the marginal environmental damage costs for each type of the pollution are pair wise equated under the approach of the Coase Theorem such that the optimal level of pollution loaded for each type of the swine farm pollutions is obtained. Then, the optimal abatement level of pollution can be retrieved from the difference between actual and optimal levels of pollution loaded.

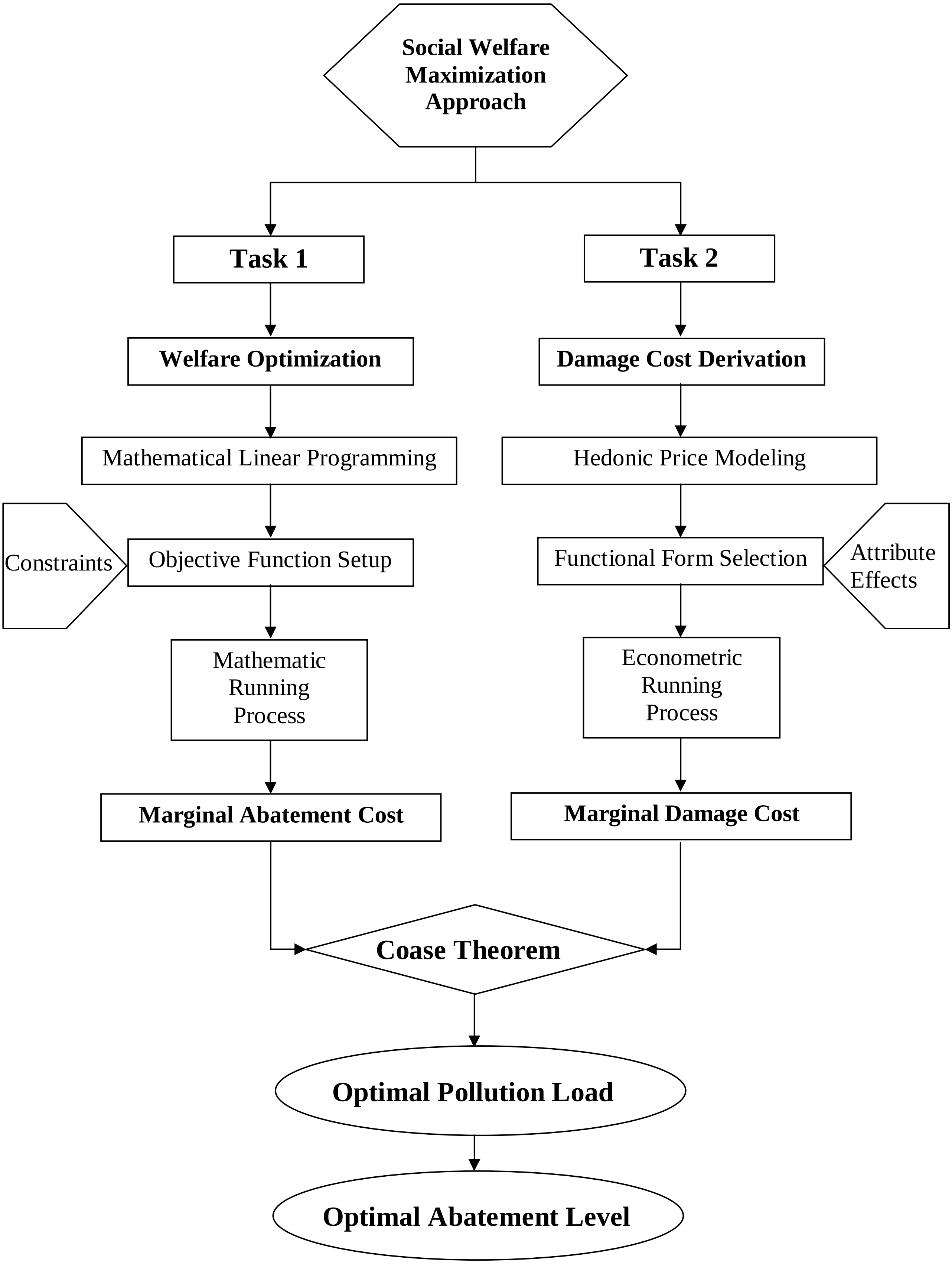

Figure 6.4: Analytical Framework of the Study

Source: Own source.

6.3 Derivation of Marginal Abatement Cost

In this part, the process of retrieving the marginal abatement costs of Task 1 is presented in the format of a mathematical linear programming setup. The objective is to maximize social welfare of farmers in a swine community in the study area. The optimization is similar to the work by Ancev et al., 2003; but the study presented here has involved more of the key environmental variables and is significantly different in the common backgrounds of the problems. The welfare maximization of Task 1 does not include the environmental damage cost because that is evaluated separately in Task 2. The general aspect has been explained earlier.

6.3.1 Overview of the Key Variables in the Welfare Optimization Analysis

The key variables in the welfare optimization consist of: net farm incomes, net gains from swine manure markets, and abatement costs for each type of the pollutants. The net farm income is calculated by subtracting the farm production costs from the farm total revenues. The total farm production costs comprise 2 parts: fixed and variable costs. Fixed costs mainly consist of land rents, costs of farm equipments and facilities. Maintenance expenditures are included and they have already been deducted by the depreciation costs. Variable costs are drawn from the costs of feeding, labor and hauling expenditures, breeding, veterinarian visits, animal drugs, farm infrastructures, waste (manure) management, taxes and other expenditures. On the side of benefits, the total farm revenues mostly come from the sales of fattened swine, piglets, defect and dead swine, and swine manure as explained in details in chapter 4.

In terms of net gains from swine manure markets, they are calculated from the summation of the net gains derived from 8 cases of the net benefits gained by the swine farm owners, the manure middle men, and the manure end-users due to manure trading and applying in the markets. These 8 cases are later explored in both contextual and mathematical details in the following part of the chapter.

As stated in the preceding chapters, the key environmental indicators to measure the swine farm wastewater pollutions are mainly derived from nitrogen (TKN or N), phosphorus (P), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), and pH value. However, COD, SS, and pH value are not included in the objective function setup because they are only scientifically relevant to each other and to the rest of the variables, causing the econometric problem in terms of multicollinearity. Therefore, for the rest of the paper, the key indicators, representing the swine farm pollutions, are only N, P, and BOD.

The variables of abatement costs for each of pollutants are entered into the model in forms of the annual costs (baht per year) which are systematically functions of the loads or the flow rates of each type of the pollutants released to the farm waste treatment system. The formula for calculating abatement costs can be seen in Appendix B. These abatement costs vary from farm to farm depending upon the differences in types, specs, and capabilities of the waste treatment systems employed by each farm to absorb different types of the pollutants (N, P, and BOD). Abatement costs are carefully collected by experts in the Department of Livestock Development in Nakhon Pathom Province. Waste treatment expenses of each farm were recorded monthly. The general classifications, specs, capabilities, and construction costs of farm waste treatment systems are availably demonstrated in Appendix B.

The objective function in the mathematical linear programming is maximized with respect to the constraints of the environmental standard on the wastewater originated from swine farms. This standard is set by the national environmental law and partly enforced by the Pollution Control Department as described previously in chapter 3.

6.3.2 Mathematical Linear Programming Model of the Study

The mathematical linear programming model for the maximization problem, aiming to obtain the marginal abatement costs of the pollutions originated from swine farms in the study area, is shown as the following setup:

$$\max_{P,N,BOD} \sum_{i=1}^{I} NetInc_i - \left[\sum_{i=1}^{I} ABC_{Pi}(PLoad_i) \cdot P_i^{'} + \sum_{i=1}^{I} ABC_{Ni}(NLoad_i) \cdot N_i^{'} + \sum_{i=1}^{I} ABC_{Bi}(BLoad_i) \cdot BOD_i^{'} \right] + NetGain_{Manure} \quad (6.1a)$$

subject to the constraints of:

$$\sum_{i=1}^{I} PLoad_i \leq P_{Max} \quad (6.1b)$$

$$\sum_{i=1}^{I} NLoad_i \leq N_{Max} \quad (6.1c)$$

$$\sum_{i=1}^{I} BLoad_i \leq BOD_{Max} \quad (6.1d)$$

$$\sum_{i=1}^{I} NetInc_{Abate_i} + \sum_{i=1}^{I} Grant_i \geq \sum_{i=1}^{I} NetInc_{Without_i} \quad (6.1e)$$

$$P^{'}, N^{'}, BOD^{'} \geq 0 \quad (6.1f)$$

The objective function illustrated in (6.1a) is based on the aggregated values derived from 104 swine farms (i = 1, 2,…, 104). In addition, the variable of $NetGain_{Manure}$ is derived from different samples that consist of 104 swine farms, 48 manure middle men (m = 1, 2,…, 48), and

37 swine manure end-users (*u* = 1, 2,…, 37) and this variable is explained later in the next part. The explanations of the variables in the above linear programming model are presented as follows:

$NetInc_i$ represents the net farm income (excluding the abatement cost) of the *i*th swine farm (baht/year),

ABC_{Pi} represents the abatement cost of phosphorus (baht/kg) that is a function of phosphorus loaded ($PLoad_i$) into the farm waste treatment system and has a unit of kg/year of the *i*th swine farm,

ABC_{Ni} represents the abatement cost of nitrogen (baht/kg) that is a function of nitrogen loaded ($NLoad_i$) into the farm waste treatment system and has a unit of kg/year of the *i*th swine farm,

ABC_{Bi} represents the abatement cost of BOD (baht/kg) that is a function of BOD loaded ($BLoad_i$) into the farm waste treatment system and has a unit of kg/year of the *i*th swine farm,

$P_i^{'}$, $N_i^{'}$, and $BOD_i^{'}$ represents the annual quantities (kg/year) of phosphorus, nitrogen, and BOD abated by the *i*th swine farm, respectively, and

$NetGain_{Manure}$ represents the annual net gains (baht/year) derived from the swine markets and is discussed in details in the following part.

In terms of the problem constraints presented from (6.1b) to (6.1f) are defined as follows:

1) Wastewater Standard Constraints – These constraints represented in (6.1b), (6.1c) and (6.4d) indicate that the loaded quantities of phosphorus ($PLoad_i$), nitrogen ($NLoad_i$), and BOD ($BLoad_i$) must not exceed the maximum levels of (P_{Max}), (N_{Max}), and (BOD_{Max}), respectively, allowed by the national environmental law.

2) Participation Constraint – This constraint shown in (6.1e) determines that the sum of the net farm income ($NetInc_{Abate_i}$) derived from the farm that associates with the waste abatement practices and the grant ($Grant_i$) from the government given to the farm that applies the waste abatement practices must be at least greater than the net farm income ($NetInc_{Without_i}$) originated from the farm that does not comply with the waste abatement practices. This constraint is determined to ensure that the farm with

the waste abatement practices has more advantages in terms of the abatement subsidies from the government than the farm without the waste abatement practices.

3) Non-negativity Constraint – The constraint in (6.1f) ensures that the abated quantities of phosphorus ($P_i^{'}$), nitrogen ($N_i^{'}$), and BOD ($BOD_i^{'}$), have the non-negative values to be entered and enumerated in the calibration process.

After calibrating this mathematically, linear programming is performed by applying the computer software, GAMS. The final outcome is reached in terms of the shadow prices of the pollutions abated or the marginal abatement costs of phosphorus (MAC_P^*), nitrogen (MAC_N^*), and BOD (MAC_{BOD}^*), respectively. In addition, a summary list of all the variables, parameters, and scalars in this linear programming model is presented in the following table 6.1.

Table 6.1: Summary List of Variables, Parameters, and Scalars used in the Linear Programming Model

Categories	Units	Definitions
Variables:		
$NetInc_i$	baht/year	annual net farm income of the *i*th farm
ABC_{Pi}	baht/kg	abatement cost of phosphorus incurred to the *i*th farm
ABC_{Ni}	baht/kg	abatement cost of nitrogen incurred to the *i*th farm
ABC_{Bi}	baht/kg	abatement cost of BOD incurred to the *i*th farm
$PLoad_i$	kg/year	annual load of phosphorus of the *i*th farm
$NLoad_i$	kg/year	annual load of nitrogen of the *i*th farm
$BLoad_i$	kg/year	annual load of BOD of the *i*th farm
$NetGain_{Manure}$	baht/year	aggregated net gains from the swine manure markets
$NetInc_{Abate_i}$	baht/year	annual net farm income of the *i*th farm associated with abatement activities
$NetInc_{Without_i}$	baht/year	annual net farm income of the *i*th farm without abatement activities
$Grant_i$	baht/year	annual grants from the government given to the *i*th farm
Parameters:		
$P_i^{'}$	kg/year	annual abated level of phosphorus of the *i*th farm
$N_i^{'}$	kg/year	annual abated level of nitrogen of the *i*th farm
$BOD_i^{'}$	kg/year	annual abated level of BOD of the *i*th farm
MAC_P^*	baht/kg	marginal abatement cost of phosphorus
MAC_N^*	baht/kg	marginal abatement cost of nitrogen
MAC_{BOD}^*	baht/kg	marginal abatement cost of BOD
Scalars:		
P_{Max}	kg/year	maximum amount of phosphorus allowed to be loaded
N_{Max}	kg/year	maximum amount of nitrogen allowed to be loaded
BOD_{Max}	kg/year	maximum amount of BOD allowed to be loaded

Source: Own source.

6.3.3 Derivation of the Net Gains from the Swine Manure Markets

This part presents the derivation of net gains originated from the swine manure markets in the study area. The net gains from the swine manure markets as represented by the variable $NetGain_{Manure}$ can be calculated by a summation of the net gains in accordance with 8 cases of the swine manure trading and using activities among related different agents as explored in the following explanations:

Case1: In this case the net gain belongs to the swine farm owner. The swine farm owner sells all the quantity of manure to the middle men and there is no expenditure incurred to the farm owner. The middle man bears the transportation and hauling costs. Hence, the net gain yields the sale revenue originated from the multiplication between manure farm price represented by P_{F_i} (baht/kg) and the quantity of manure sold represented by Q_i (kg), aggregated for the whole samples of the swine farms as presented in the following (6.2a):

$$\sum_{i=1}^{I} P_{F_i} Q_i \tag{6.2a}$$

Case 2: In this case the middle man obtains the net gain by means of transporting bought swine manure. Therefore, the transportation, labor, and hauling costs are incurred solely to the middle man. As a result, the net gain is derived from the revenue selling manure minus transportation, labor, hauling, and buying costs. The mathematical expression is calculated by the multiplication between the product of the price difference, manure retail price represented by P_{R_m} (baht/kg) and manure wholesale price represented by P_{F_m} (baht/kg). The quantity of manure sold represented by Q_m (kg) and subtraction of the transportation cost $(Dist_m TC_m)$ and the labor and hauling cost $(Hr_m LC_m)$. $Dist_m$ represents the distance (km) from the middle man place to the swine farms. TC_m, Hr_m, and LC_m represent unit transportation cost (baht/km), labor hours (hours) and wage rate (baht/hour), respectively. The aggregation term of the net gains for all the 48 middle men is expressed by the following (6.2b):

$$\sum_{m=1}^{M} \left[\left(P_{R_m} - P_{F_m} \right) Q_m - Dist_m TC_m - Hr_m LC_m \right] \tag{6.2b}$$

Case 3: In this case the net gain occurs solely to the swine manure end-users. The net gain is considered as the cost savings that the end-user retrieves from using manure to substitute partial amounts of chemical fertilizer and/or commercial animal (fish) feed. The net gain is obtained from the difference between the cost-saving benefit ($P_{C_u} r_u Q_u$) and the cost of the manure used ($P_{R_u} Q_u$). P_{C_u}, r_u, Q_u and P_{R_u} represent the retail price of chemical fertilizer or commercial animal feed (baht/kg), substitution rate between swine manure and chemical fertilizer or commercial animal feed, quantity (kg), and retail price (baht/kg) of the swine manure, respectively. The aggregated term of the net gains obtained only by the whole 38 manure end-users can be shown in the following (6.2c):

$$\sum_{u=1}^{U}\left[P_{C_u} r_u Q_u - P_{R_u} Q_u\right] \qquad (6.2c)$$

Case 4: This case is similar to case 2 but it differs in that the swine farmer transports and sells all the manure. He has to deliver to the middle men at their places. The net gain, the farmer received, is therefore the sale revenue ($P_{R_i} Q_i$) deducted by his own transportation cost ($Dist_i TC_i$) and the labor and hauling cost ($Hr_i LC_i$). P_{R_i} and Q_i represent the retail price (baht/kg) and the quantity (kg) sold, respectively. $Dist_i, TC_i, Hr_i$, and LC_i are distance between the swine farm and the middle men's places (km), unit cost of transportation (baht/km), labor hours (hours) and wage rate (baht/hour), respectively. Hence, the aggregation term can be presented by the following (6.2d):

$$\sum_{i=1}^{I}\left[P_{R_i} Q_i - Dist_i TC_i - Hr_i LC_i\right] \qquad (6.2d)$$

Case 5: Case 3 is similar; but the swine farm owner performs as a manure end-user himself. All the manure is rather used by the farm owner and there is no manure for sale. The net gain becomes the cost savings for the farm owner, who performs as an end-user. The net gain is the difference between the cost-saving benefit ($P_{C_i} r_i Q_i$) given to the farm owner and the cost of the manure used ($P_{R_i} Q_i$). In other words, the foregone sale as revenue count if the farm owner would have sold the manure. P_{C_i}, r_i, Q_i and P_{R_i} represent the retail price of chemical fertilizer or animal feed (baht/kg), substitution rate between swine manure and chemical fertilizer or animal feed, quantity (kg), and retail price (baht/kg) of the swine manure, respectively. The aggregated term is expressed in the following (6.2e):

$$\sum_{i=1}^{I}\left[P_{C_i} r_i Q_i - P_{F_i} Q_i\right] \qquad (6.2e)$$

Case 6: In this case the end-user transports bought swine manure to his farm himself. The net gain is thus drawn from the cost savings ($P_{C_u} r_u Q_u - P_{F_u} Q_u$). Using manure to partially substitute chemical fertilizer or commercial animal feed, he has to subtract the transportation ($Dist_u TC_u$) and the labor and hauling ($Hr_u LC_u$) costs from the cost savings. P_{C_u}, r_u, Q_u, and P_{F_u} are the retail price of chemical fertilizer or commercial animal feed (baht/kg), substitution rate between swine manure and chemical fertilizer or commercial animal feed, quantity (kg) and farm price (baht/kg) of the swine manure, respectively. In addition, $Dist_u, TC_u$, Hr_u, and

LC_u represent distance (km) transported by the end-user, unit transportation cost (baht/km), labor hours (hours), and wage rate (baht/hour) respectively. Therefore, the aggregated term can be calculated by the presentation in (6.2f):

$$\sum_{u=1}^{U}\left[P_{C_u} r_u Q_u - P_{F_u} Q_u - Dist_u TC_u - Hr_u LC_u\right] \tag{6.2f}$$

Case 7: In this case, the swine farm owner performs to be both manure end-user and manure seller. Some of manure is used by the farm owner and the remaining manure is sold at farm to the middle men. Hence, there are no transportation and labor costs incurred to the farm owner. Consequently, the net gain is a combination of cost savings ($P_{C_i} r_i Q_{f_i} - P_{F_u} Q_{f_i}$) from using manure and the revenue ($P_{F_i} Q_{r_i}$) received from selling manure. $P_{C_i}, r_i, Q_{f_i}, P_{F_i}$, and Q_{r_i} represent the retail price of chemical fertilizer or commercial animal feed (baht/kg), substitution rate between swine manure and chemical fertilizer or commercial animal feed, quantity (kg) and farm price (baht/kg) of the swine manure used on farm, and the quantity of manure sold (kg) at farm, respectively. The aggregated expression is presented in the following (6.2g):

$$\sum_{i=1}^{I}\left\{\left[P_{C_i} r_i Q_{f_i} - P_{F_i} Q_{f_i}\right] + \left[P_{F_i} Q_{r_i}\right]\right\} \tag{6.2g}$$

Case 8: The middle man performs to be both manure end-user and seller. However, the net gain in this case is the summation of cost savings ($P_{C_m} r_m Q_{s_m} - P_{F_m} Q_{s_m}$) from using manure (or the foregone revenue from selling manure) and the profit ($(P_{R_m} - P_{F_m})Q_{t_m}$) from selling manure deducted by his transportation ($Dist_m TC_m$) and labor ($Hr_m LC_m$) costs. $P_{C_m}, r_m, Q_{s_m}, P_{F_m}$, P_{R_m} and $, Q_{t_m}$ represent the retail price of chemical fertilizer or commercial animal feed (baht/kg), substitution rate between swine manure and chemical fertilizer or commercial animal feed, quantity (kg) and farm price (baht/kg) of the swine manure used by the middle man, the retail price (baht/kg) and the quantity of manure sold (kg), respectively. Moreover, $Dist_m$, TC_m, Hr_m, and LC_m stand for distance (km), unit transportation cost (baht/km), labor hours (hours), and wage rate (baht/hour), respectively. Thus, the expression of the aggregated term is shown in the following (6.2h):

$$\sum_{m=1}^{m}\left\{\left[P_{C_m} r_m Q_{s_m} - P_{F_m} Q_{s_m}\right] + \left[(P_{R_m} - P_{F_m})Q_{t_m}\right] - Dist_m TC_m - Hr_m LC_m\right\} \tag{6.2h}$$

Nevertheless, it is assumed that there is no weight loss of the swine manure for all the cases of manure trading and using activities in the markets, such that,

$$\sum_{i=1}^{I} Q_i = \sum_{i=1}^{I}\left[Q_{f_i} + Q_{r_i}\right] = \sum_{m=1}^{M} Q_m = \sum_{m=1}^{M}\left[Q_{s_m} + Q_{t_m}\right] = \sum_{u=1}^{U} Q_u \tag{6.2i}$$

The identity expressed in (6.5i) indicates that the total quantity of manure sold by all the farm owners ($\sum_{i=1}^{I} Q_i$), the total quantity of manure partially used and sold by the all the farm owners ($\sum_{i=1}^{I} \left[Q_{f_i} + Q_{r_i} \right]$), the total quantity of manure sold by all the middle men ($\sum_{m=1}^{M} Q_m$), the total quantity of manure partially used and sold by all the middle men ($\sum_{m=1}^{M} \left[Q_{s_m} + Q_{t_m} \right]$), and the quantity of manure used by all the end-users ($\sum_{u=1}^{U} Q_u$), are equivalent.

Table 6.2: Summary List of Variables used in the Derivation of Net Gains from the Swine Manure Markets

Categories	Units	Definitions
P_{F_i}, P_{F_m}, P_{F_u}	baht/kg	manure farm prices faced by swine farm owner, middle man, and manure end-user, respectively
P_{R_i}, P_{R_m}, P_{R_u}	baht/kg	manure retail prices faced by swine farm owner, middle man, and manure end-user, respectively
P_{C_i}, P_{C_m}, P_{C_u}	baht/kg	commercial fertilizer or animal feed prices faced by swine farm owner, middle man, and manure end-user, respectively
Q_i, Q_m, Q_u	kg	quantities of manure totally traded and/or used by swine farm owner, middle man, and manure end-user, respectively
Q_{f_i}, Q_{r_i}	kg	quantities of manure partially used on farm by swine farm owner and quantities of manure partially sold at farm to a middle man, respectively
Q_{s_m}, Q_{t_m}	kg	quantities of manure partially used by middle man and quantities of manure partially sold to an end-user, respectively
$Dist_i$, $Dist_m$, $Dist_u$	km	distances associated with the transportations of swine farm owner, middle man, and manure end-user, respectively
TC_i, TC_m, TC_u	baht/km	unit transportation costs incurred to swine farm owner, middle man, and manure end-user, respectively
Hr_i, Hr_m, Hr_u	hours	hours of labor used in hauling manure by swine farm owner, middle man, and manure end-user, respectively
LC_i, LC_m, LC_u	baht/hour	wage rates corresponded to hours used by swine farm owner, middle man, and manure end-user, respectively
r_i, r_m, r_u	-	substitution rates between swine manure and commercial fertilizer or animal feed corresponded to the cases of swine farm owner, middle man, and manure end-user, respectively

Source: Own source.

6.4 Derivation of Marginal Environmental Damage Cost

This section focuses on deriving the marginal environmental damage costs. As said, damages occur from the effects of agricultural pollutions originated from the swine farm community in the study area. The analytical tool, used to derive these marginal damage costs, is a hedonic price modeling. Hedonic price models have been popularly employed to value the commodities, where some specific properties can not be measured. Hedonic models fall under the rubric of non-market valuation because goods and services occasionally have the qualities that are not provided by the market (HAAB AND MCCONNELL, 2002). Several studies have applied hedonic price models to value housing properties and other commodities that are associated with the qualities of environment (more reviews in details on hedonic price modeling can be seen in PALMQUIST (1984; 1991; 1992)). These environmental qualities and/or the specific characteristics of the goods and services are often reviewed in terms of the attributes.

In terms of welfare measurement, hedonic price modeling can play an interesting role to measure willingness to pay (WTP) of consumers. For example, if there is an improvement of public amenities nearby the private real estates, the welfare of the households in those real estates should increase by,

$$WTP = f(a') - f(a) \tag{6.3}$$

where a' represents an improved vector of attributes, and a is the initial vector of attributes. The expression (6.3) implies that the household is willing to pay for the improved attributes by the different value, originated from the price functions of the improved ($f(a')$) and the initial ($f(a)$) attributes. The price function is usually called the hedonic price functions. WTP is the maximum amount of household's income given up to attain the improved vector of attributes (HAAB AND MCCONNELL, 2002). The most simple method, to estimate the hedonic price function, is ordinary least squares (OLS). However, a careful attention should be paid on the multicollinearity problem that often occurs in the calibration process. Because some attributes are econometrically related to each other, multicollinearity is typical. Consequently, this leads to biased and imprecise parameter estimates.

6.4.1 Hedonic Price Modeling of the Study

The hedonic pricing model, used in the study, aims to estimate willingness to pay for land in the swine farm community that is hypothetically considered to be affected by the agricultural pollutions. Leached out of the swine farms, pollutants contaminate and are accumulated in the community's major canal, Chedi Bucha. The quality condition of the canal is rather low especially in the dry season. The water is associated with dark color and odor problems. This consequently causes a price reduction, in particular for land that is located along the two sides of the canal. The closer to the canal, the lower the land prices, vise versa.

The price of the land in the swine farm community is supposed to be a function of land attributes. It consists of the land size, the closest distance of the land to the major road in the community, and the closest distance of the land to the polluted Chedi Bucha canal. The last attribute is assumed to be the environmental indicator. In this case, the environmental damage is going to be estimated in terms of the marginal environmental damage costs.

It was the next step to collect data. The total number of samples, used to estimate the land price, was 104 samples which are actually derived from land of the swine farms in the study area. As such, the price function and the estimated equation of land can be illustrated in the following (6.4a) and (6.4b), respectively:

$$P_{Land} = f(a_i) = f(Land\ Attributes : Size,\ Dist\_Rd,\ Dist\_PCanal) \quad (6.4a)$$

$$P_{Land_r} = a_0 + a_1 Size_r + a_2 Dist\_Rd_r + a_3 Dist\_PCanal_r + e_r \quad (6.4b)$$

where: P_{Land_r} represents the price of land (baht/rai) obtained from the correspondent *r*,

a_i represents land attribute *i*,

$Size_r$ represents the size of land (rai) obtained from the correspondent *r*,

$Dist\_Rd_r$ represents the closest distance from the land to the major road in the community (km) obtained from the correspondent *r*,

$Dist\_PCanal_r$ represents the closest distance from the land to the polluted canal (km) derived from the correspondent *r*,

$a_0, a_1, a_2,$ and a_3 represent the coefficients of the model,

e_r represents the error term of the estimate,

$i = 0,...,3$

$r = 1,...,104$.

Note that the land prices used in the model are assessed in terms of annual prices. The cumulative value of land price is transformed to an annual price by using the formula: $\left(\frac{P_1 - P_0}{k}\right)$. P_0 and P_1 represent land prices of year 0 and year 1, respectively, while *k* is the real interest rate of year 1.

6.4.2 Hedonic Prices and Willingness to Pay

Recall equation (6.4a), $P_{Land} = f(a_i)$. The competitive market equilibrium appears when a buyer maximizes his utility subject to budget constraint. Assuming that a buyer would like to buy a piece of land with his utility function, $U(Land\ Attributes : a_i)$ under his budget constraint, $m = P_{Land} * Land\ Quantity = f(a_i) * 1$. According to utility maximization, the optimal solution is given by:

$$\frac{\partial U(a_i)}{\partial a_i} = l\,\frac{\partial f(a_i)}{\partial a_i}, \tag{6.4c}$$

where l is a marginal utility of income (HAAB AND MCCONNELL, 2002). In the equilibrium, the equation (6.4c) delivers a connection between a hedonic price and a marginal willingness to pay, which is $l^{-1}\frac{\partial U(a_i)}{\partial a_i}$, (HAAB AND MCCONNELL, 2002). For simplicity, we generally assume that $l = 1$ i.e. marginal utility of income is 1. Therefore, the expression in equation (6.4c) implies an equivalence of marginal utility (marginal willingness to pay) and marginal hedonic price. That is, $\frac{\partial U(a_i)}{\partial a_i} = WTP$. In this case, the estimated coefficients (a_i) in equation (6.4b) will become marginal hedonic prices which are equivalent to marginal willingness to pay for the land attributes.

The estimation in (6.4b) applies a multiple linear regression in which the estimated coefficient $\hat{a}_3$ is a (marginal) willingness to pay (baht/km) of a person in order to avoid having his land located close to the polluted canal. The estimated coefficient is supposed to have a positive sign implying that the farther to the canal, the higher the land prices, vise versa.

6.4.3 Estimation of the Marginal Environmental Damage Cost

Next step, the study assumes that the willingness to pay (WTP) or $\hat{a}_3$ obtained from (6.4e) is influenced by the specifics of agricultural pollutants (P, N, BOD, COD, SS, and pH) that contaminate and are accumulated in the canal. Hence, the prices of lands shall be a function of the quantities of P, N, BOD, SS, and pH being the a_i's; as the explanatory variables, they are written as follows:

$$WTP = g(P, N, BOD, COD, SS, pH) \tag{6.4d}$$

However, in the study a multiple, quadratic regression is employed to estimate the price function in (6.4d), as seen in the following (6.4e):

$$WTP_s = b_0 + b_1 P_s + b_2 P_s^2 + b_3 N_s + b_4 N_s^2 + b_5 BOD_s + b_6 BOD_s^2 + b_7 P_s N_s + b_8 P_s BOD_s + b_9 N_s BOD_s + m_s \quad (6.4e)$$

where: WTP_s represents a willingness to pay (baht/km) of a person situated in farm land *s* to avoid to have a land being located close to the polluted canal,

P_s, N_s, BOD_s represent the quantities of phosphorus, nitrogen, and BOD loaded from farm *s*,

m_s represents an error term of the estimate,

$b_0, b_1,..., b_9$ represent coefficients of the model, and

$s = 1,...,104$.

It must be noted that COD, SS, and pH are dropped out of the price estimation because they cause the problem of multicollinearity econometrically.

In addition, the $\hat{WTP}$, estimated in (6.4e), is equivalent to an environmental damage cost ($\hat{DMC}$). It means that a person is willing to pay (or to give up) some amount of his money or income to have a land located apart from the canal. Damage is affected by the pollutions or the explanatory variables indicated above. The results of the estimation in (6.4e), thus, imply a welfare change caused by the pollution contaminated in the canal.

A change in $\hat{WTP}$ or in $\hat{DMC}$ for each additional unit (kg) of the pollutions, loaded, is considered as a marginal environmental damage cost (MDC^*). In other words, the community is affected by the pollutants in terms of environmental damages (polluted canal and decreases in land prices). The costs in the community are equivalent to the monetary value of MDC^* when an additional unit of the pollutions arises. Therefore, the change with respect to each type of the pollutions can be mathematically retrieved by taking the first-order partial derivative on the equation in (6.7e). With respect to *P*, *N*, and *BOD*, it is illustrated in the following functions (6.4f), (6.4g), and (6.4h), respectively:

for phosphorus:

$$MDC_P^* = \frac{\partial \hat{DMC}}{\partial P} = \hat{b}_1 + 2\hat{b}_2 P + \hat{b}_7 N + \hat{b}_8 BOD \quad (6.4f)$$

for nitrogen:

$$MDC_N^* = \frac{\partial \hat{DMC}}{\partial N} = \hat{b}_3 + 2\hat{b}_4 N + \hat{b}_7 P + \hat{b}_9 BOD \tag{6.4g}$$

for BOD:

$$MDC_{BOD}^* = \frac{\partial \hat{DMC}}{\partial BOD} = \hat{b}_5 + 2\hat{b}_6 BOD + \hat{b}_8 P + \hat{b}_9 N \tag{6.4h}$$

Here MDC_P^*, MDC_N^* and MDC_{BOD}^* are the marginal environmental damage costs of phosphorus, nitrogen, and BOD, respectively. These marginal damage costs are then the ultimate objective of working Task 2 (minimizing) and will be used together with the marginal abatement costs obtained from working Task 1 to compute the optimal levels of the pollution abatement in the next step. Accordingly, the missions in Task 2 are accomplished at this point.

Table 6.3: Summary List of Variables and Parameters used in the Hedonic Pricing Model of the Study

Categories	Units	Definitions
Variables:		
P_{Land_r}	baht/rai	price of land obtained from the correspondent *r*
$Size_r$	rai	size of land obtained from the correspondent *r*
$Dist\_Rd_r$	km	closest distance from the land to the major road in the community obtained from the correspondent *r*
$Dist\_PCanal_r$	km	closest distance from the land to the polluted canal derived from the correspondent *r*
WTP_s	baht	a willingness to pay of a person situated in farm land *s* to avoid to have a land being located close to the polluted canal
DMC_s	baht	amount of money that a person situated in farm land *s* would be willing to pay to avoid to have a land being located close to the polluted canal or a damage cost
$MAC_P^*, MAC_N^*, MAC_{BOD}^*$	baht/kg	marginal environmental damage costs of phosphorus, nitrogen, and BOD, respectively
$P_s, N_s, BOD_s, COD, SS, pH$	kg	quantities of phosphorus, nitrogen, and BOD loaded from farm *s*
Parameters:		
a_0, a_1, a_2, a_3	baht/km	coefficients to be estimated in the price equation
$b_0, b_1, ..., b_9$	baht/kg	coefficients to be estimated in the *WTP* equation
e_r	-	error term of the price equation
m_s	-	error term of the *WTP* equation

Source: Own source.

6.5 Derivation of the Optimal Abatement Level

A derivation of the optimal abatement can be obtained by 2 ways. On one hand, the environmental damage cost (*DMC*) can be embraced into the objective function of a mathematic linear programming. To do this in (6.1a), a single calibration runs simultaneously with the abatement cost (ABC) in order to obtain the shadow prices or the marginal values of the two costs. Then the final solution of the optimal abatement level can be retrieved later. On the other hand, the marginal abatement and the marginal environmental damage costs are estimated separately and are equated in a later step. Then the optimal abatement level can be reached. However, this study applies the latter method because it is more convenient to analyze and observe the marginal abatement and the marginal environmental damage costs separately. To combine them in a linear programming model, the objective function has to be readjusted in order to address a proper format of the *DMC*. The mode of doing this is more difficult, especially to manage changes in the objective function in the linear programming model.

In accordance with the derivation method explained above, the marginal abatement costs (MAC_P^*, MAC_N^*, and MAC_{BOD}^*) obtained from the mathematical linear programming model and the marginal environmental damage costs (MDC_P^*, MDC_N^*, and MDC_{BOD}^*) derived from the hedonic pricing model are equated under the approach of the Coase Theorem. In order to retrieve the optimal pollution level, each type of the pollutants is determined as mathematically illustrated in the following (6.5a), (6.5b), and (6.5c):

$$MAC_P^* = MDC_P^* = \hat{b}_1 + 2\hat{b}_2 P + \hat{b}_7 N + \hat{b}_8 BOD \tag{6.5a}$$

$$MAC_N^* = MDC_N^* = \hat{b}_3 + 2\hat{b}_4 N + \hat{b}_7 P + \hat{b}_9 BOD \tag{6.5b}$$

$$MAC_{BOD}^* = MDC_{BOD}^* = \hat{b}_5 + 2\hat{b}_6 BOD + \hat{b}_8 P + \hat{b}_9 N \tag{6.5c}$$

The outcomes drawn from solving equations (6.5a), (6.5b), and (6.5c) yield the optimal pollution levels of phosphorus "P", nitrogen "N", and biochemical oxygen demand "BOD", respectively. Then the optimal abatement levels of P, N, and BOD can be obtained by taking a difference between the actual and the optimal levels for each pollutant. Thus the ultimate goal of the study is fulfilled as a whole.

6.6 Policy Scenarios for a Sensitivity Analysis

According to the derivation of the marginal abatement costs, explored in the preceding part, a possibility of doing a sensitivity analysis exists. In practice we can perform the task by means of adding some adjustment factors to the variables, either on abatement cost changes or on net gains from swine manure markets or both. The reasons of selecting these two decision variables are that if a farmer wishes to decrease his marginal abatement cost, he may increase an overall investments on a farm waste abatement system. This improvement can come in terms of a better waste management technology. Alternatively a better farm waste management practice can reduce a significant amount of the farm pollutions more efficiently. Moreover, an increase in manure trading and using manure in crops is one of the efficient ways to decrease tremendous quantities of farm wastes beforehand. If economic incentives are high enough to attract all the relevant agents to efficiently perform making more benefits out of the farm wastes, such as manure and liquid waste, would be a solution.

Recall the mathematical linear programming model in (6.1a) – (6.1f), and let d and q be the adjustment factor (in percentage unit) of the abatement costs for all types of the farm pollutions (ABC_P, ABC_N and ABC_B), the adjustment factor of the net gains from manure markets is $NetGain_{Manure}$, respectively. Therefore, the objective function in (6.1a) changes to a new format of,

$$\max_{P,N,BOD} \sum_{i=1}^{I} NetInc_i - (1-d)\cdot\left[\sum_{i=1}^{I} ABC_{P\,i}(PLoad_i)\cdot P_i^{'} + \sum_{i=1}^{I} ABC_{N\,i}(NLoad_i)\cdot N_i^{'} + \sum_{i=1}^{I} ABC_{B\,i}(BLoad_i)\cdot BOD_i^{'}\right] \quad (6.6)$$
$$+ (1+q)\cdot NetGain_{Manure}$$

The d is assumed to cover all types of the pollutions in (6.6) for simplicity. It represents a decrease in marginal abatement cost that lead to yield a higher optimal abatement level. Since the marginal abatement costs are also supposed to decrease by d consequently, this may help. It can be seen by a downward shift of MAC_1 to MAC_2. d corresponds to a decrease in pollution emission levels from e_1^* to e_2^* as depicted in Figure 6.5 as follows:

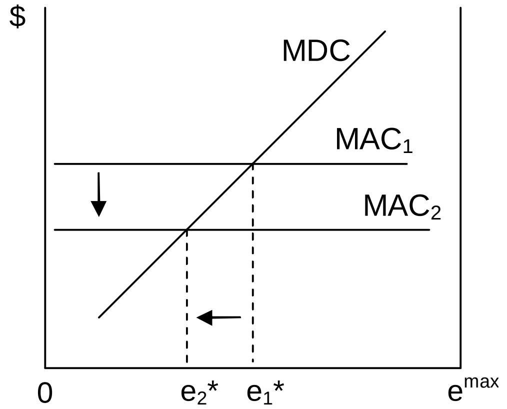

Figure 6.5: Optimal Abatement Levels with a Shift of MAC Curve
Source: Adjusted from PERMAN et al., 1996.

It has to be noted that adjustments on other variables and constraints are more complicated to manipulate. Particularly a change in the pollution standard is almost impossible to do because the legislation procedure depends immensely on politics. It takes such a long period of time to pass a new law or even a new proposition. In addition, a change in the environmental damage cost is assumed to remain constant since the environmental effects need some periods of time to reveal the outcomes of the change. Thus it is difficult to analyze under the time constraint.

Upon the adjustment approach explained above, there are 3 policy scenarios to capture and observe the effects from such adjustments. They are considered as pair-wise scenarios between a change in the abatement cost and a change in the net gains from manure market while everything else is assumed to remain constant, *ceteris paribus*, as the following demonstrations:

Scenario 1: Marginal abatement costs are decreased by d and the net gains from manure market are held constant ($q = 0$):

Case 1: $d = 0.1$,
Case 2: $d = 0.3$, and
Case 3: $d = 0.5$.

Scenario 2: Marginal abatement costs are held constant ($d = 0$) and the net gains from manure market are increased by q :

Case 1: $q = 0.1$,
Case 2: $q = 0.3$, and
Case 3: $q = 0.5$.

Scenario 3: Marginal abatement costs are decreased by d and the net gains from manure market are increased by q :

Case 1: $d = 0.1$ and $q = 0.1$,
Case 2: $d = 0.3$ and $q = 0.3$,
Case 3: $d = 0.5$ and $q = 0.5$,
Case 4: $d = 0.1$ and $q = 0.3$,
Case 5: $d = 0.1$ and $q = 0.5$,
Case 6: $d = 0.3$ and $q = 0.5$,
Case 7: $d = 0.3$ and $q = 0.1$,
Case 8: $d = 0.5$ and $q = 0.1$, and
Case 9: $d = 0.5$ and $q = 0.3$.

Scenarios 1 and 2 show the effects of a change in each individual marginal abatement costs and net gains from manure markets, respectively. Each scenario of the first two comprises 3 cases that are determined by 3 different levels (0.1, 0.3, and 0.5) of the adjustment factors. These levels are designed to capture the magnitudes of the changes from the lowest (0.1), medium (0.3), and the highest levels that are assumed to be acceptable by the community in the study area. For scenario 3, marginal abatement costs and net gains from manure markets for the first three cases of scenario 3 are assumed to change by identical magnitudes. Cases 4, 5, and 6 present the cases in which marginal abatement costs are decreased less than the increases in net gains from manure markets (or $d < q$) whereas the opposite aspect (or $d > q$) is applied to cases 7, 8, and 9.

6.7 Summary

This chapter mainly explained how the study is based on a theory of welfare economics and corresponding approaches in which the Coase Theorem is employed. We derive the optimal abatement level of the farm pollutions in the study area from this theoretical background. In the analytical framework, there are 2 working tasks to be conducted in order to obtain the marginal abatement and the marginal environmental damage costs. Task 1 deals with a mathematical linear programming model while Task 2 associates with the hedonic pricing model. The outcomes of the two tasks are put together. We equated them in accordance with the Coase approach. So the optimal abatement level of the pollutions can be reached as the ultimate goal of the study. In addition, policy scenarios for a sensitivity analysis are provided by adding some adjustment factors imposed on the marginal abatement costs. We also received the net gains from manure markets in the objective function of the mathematical linear programming model such that the changing effects on optimal abatement level and social welfare can be observed.

7 ANALYTICAL RESULTS AND DISCUSSIONS

The study results, shown here, are the combination of results between the empirical findings obtained from the field survey study (explored in chapter 4) and the numerical calibration results in accordance with the analytical procedure (explained in chapter 6). Some significant things occur. They can be interestingly compared and contrasted so as to reveal different points of view in finding optional solutions for policy implications. Note that relieving the environmental problems in the study area seems to be a matter of discourse.

The analytical results presented in this chapter are divided into 5 parts corresponding to the analytical framework demonstrated in the last chapter. Firstly, some comparisons of the key values and information are displayed. For examples, the values of net gains from manure markets, values of abatement and environmental damage costs, and grants from government are compared. The focus is on the net farm income of the community in the study area. In addition, different prices of swine manure and prices of commercial fertilizer or animal feed are contrasted to see a potential to develop the swine manure markets in the area, more intensively. Secondly, the results, obtained from the mathematical linear programming model, reveal the social welfare value including the values of marginal abatement of the agricultural pollutions. Thirdly, in this section, we explain the results from the hedonic land price estimation including the results of the environmental damage cost estimation. The intention is to retrieve the values of the marginal environmental damage costs. Fourthly, the optimal abatement levels of pollution are reached according to the results from the third and the fourth part. Finally, the results from the sensitivity analysis in running the policy scenarios are discussed in various aspects. This serves to find some possible options to ease the problems for the swine farm community and the related stakeholders in the study area in case of compliance with regulations.

7.1 Comparison of the Key Values in the Analysis

This section aims at contrasting the aggregated net farm income of the swine farm community from the other related key variables in order to see how large value differences can be. Table 7.1 reveals that the swine farm community as a whole, earned a net farm income of around 71.98 million per year baht or 692,079 baht per farm on average per year in 2006. These figures are considerably high relative to other agricultural occupations in Thailand and it is not surprising when other key values are compared to them. The value of the abatement cost, accounted from all the swine farms in the study area, was low. It yielded only 1.20 million baht per year. On average each individual swine farm invested in abating the farm pollutions just spends 11,558 baht per year. Thus, this aggregated abatement cost took up only 1.67% of the value of the community's aggregated net farm income.

Low abatement is also documented by the fact that grants[1] from the government (in subsidizing the farms' abatement costs) were actually near to the ground or only 0.46% of the aggregated net farm income. Only few swine farms received those grants. It has to be noted that a small number of farms received these grants and it does not necessarily imply that the government pays less attention on the pollution abatement problems. Rather, in practice, many times grants depend on the farmer's participations and perceptions in converting or adjusting their original inefficient abatement systems. Only few of the farmers are willing to comply with grant conditions. This is no wonder since grants given to the farmers are rare.

In contrast, the consequence of the low value in the community's abatement cost has led to rather high environmental damage costs which took the value of 4.58 million baht. They accounted for 6.36% of the value of the community's aggregated net farm income in 2006. It is clearly to see that there is a 4-time difference in values between the abatement and the environmental damage costs. Further notice is that the environmental damage cost, estimated in the study, is evaluated on a ground base of a decreasing trend in the land prices of the study area. If some other environmental effects such as community health risks and ground water contamination were assessed, the environmental damage cost would be even higher as compared to the pure land value effect.

On the other side (Table 7.1), the net gains from swine manure markets account for 2.81 million baht or 3.90% compared to the community's aggregated net farm income. It is interesting to observe that there is a promising potential for the development of a swine manure market. A considerable volume of farm wastes could be reduced beforehand. The farm pollutions would leach out below the maximum carrying capacity of the environment. Moreover, the community's members would be able to attain higher benefits from engaging more in the swine manure trading. However, the development in the swine manure markets need to be studied more in terms of feasibility, market structure, and other details in future works.

[1] The grants provided by the government, mostly by the Department of Livestock Development (DLD), are given to assist farmers in building standard waste treatment ponds designed by the DLD (around 70,000 baht a unit in total construction cost). The ratio of the grant and the farmer's private investment is 40:60 of the total investment cost.

Table 7.1: Comparison of the Key Values in the Analysis

Categories	Net Farm Income	Net Gains from Manure Markets	Total Abatement Cost	Total Environmental Damage Cost	Government's Grants
Total Value (baht/year)	71,976,237	2,806,145	1,202,080	4,578,203	330,000
Comparison to Net Farm Income (%)	100.00	3.90	1.67	6.36	0.46
LU Mean Value (baht/LU/year)	15,896	620	265	1,011	73
Farm Mean Value (baht/farm/year)	692,079	33,013	11,558	44,021	33,000
Total Samples (N)	104	85	104	104	10

Notes: Net gains from manure markets, total abatement cost, total environmental damage cost, and grants are not parts of the net farm income.

Source: Own data and calculations.

The information in Table 7.2 displays a large difference between the farm and retail prices of the swine manure in the markets. The farm prices range from o.50 to 1.10 baht per kilogram while the retail prices are much higher ranging from 0.60 to 2.00 baht per kilogram. As a result, the marketing margins vary from 20.00% to 81.82%. In other words, the highest value or difference between farm and retail prices can reach the value of 0.90 baht a kilogram with a remarkable marketing margin of 81.82%. On average, swine manure is sold at 0.86 baht per kilogram while the retail price is 1.35 baht per kilogram, making up a marketing margin up to 56.98% for the middle men. In general, these should attract more new agents to step in the markets and earn the market shares. As stated previously in chapter 4, however, the prices of swine manure have been rather constant for a long period of time even though the prices of live swine and pork have been increasing. It is interesting for future works to investigate how the swine manure markets work, and what would be the market structure and factors to determine the prices of manure. Hence, the potential to develop the swine manure markets can be assessed and this would be an indirect way of making the environment cleaner associated with making added value to the swine manure as fringe benefits to the farmers in the community.

It has been pointed out that there are very large magnitudes or differences between the prices of swine manure and commercial fertilizer or animal feed. The prices of swine manure are approximately ten times lower than the prices of commercial fertilizer or feed. In such case, if the amount of mineral contents contained in the swine manure were exactly known and/or a content guaranteed system were made to the manure, the manure markets could be more developed in terms of an increasing number of the end-users. Consequently, the substitution rates between the swine manure and commercial fertilizer or animal feed would adjust understanding the manure validation of end-users. In addition, the prices of swine manure may increase due to higher standard of the mineral content, it then is guarantee. However, doing a guaranteed system or certified product of the swine manure standard needs more of stakeholder involvements, not only the swine farmers' participations, but also a cooperation or contribution from experts, private sectors, and government agents.

Table 7.2: Comparison of the Prices related to the Manure Markets

Categories	Manure Prices			Commercial Fertilizer/Feed Prices (baht/kg)	Farm Prices of Live-swine (baht/kg)
	Farm Price (baht/kg)	Retail Price (baht/kg)	Difference (%)		
Mean	0.86	1.35	56.98	12.35	94.84
Maximum	1.10	2.00	81.82	15.00	130.00
Minimum	0.50	0.60	20.00	6.00	47.00
Total Samples (N)	85	85	85	50	104

Notes: Manure prices are in average of dried and wet manure prices.

Source: Own data and calculations.

7.2 Results of the Mathematical Linear Programming Model

Our calibration results obtained from the mathematical linear programming model show that the value of the objective function can become 53,338,977 baht per year (or 512,875 baht per individual farm). In this optimization, the abatement costs are already deducted from the objective function. In other words, the social welfare of the swine farm community is rather high compared to the low expenditures on the pollution abatement costs, explained in the preceding section. It implies that the community could have done better in making the environment less contaminated, if there is a willingness to invest more in farm abatement and to participate more in the manure trading as well as using activities in the swine manure utilization.

The results concerning pollutants reveal that the marginal abatement costs of phosphorus (MAC_P^*), nitrogen (MAC_N^*), and BOD (MAC_{BOD}^*) take up the values of 29, 1,059, and 607 baht per kilogram, respectively. These values, particularly MAC_N^* and MAC_{BOD}^*, seem rather high relative to the fact that the investments in the abatement system of the farmers in the study area are quite low. However, the figures are actually calculated based on a larger unit of kilogram instead of milligram per liter and are accumulated on an average basis. Therefore, these marginal abatement costs are reasonable to observe. It is interesting that MAC_N^* ranks the highest followed by MAC_{BOD}^* and MAC_P^*, respectively. This implies that the farmers in the community primarily emphasize more on abating nitrogen and BOD compared to phosphorus. The reason given to this occurrence is that the environmental standard for the wastewater, originated from the swine farms, is stricter on the nitrogen and BOD contents than on phosphorus contents. In practice, it implies that farmers try to employ the abatement technologies that can correspond to given standards.

Table 7.3: Results of the Mathematical Linear Programming Model

Categories	Value
Value of the Objective Function (baht/year)	53,338,977.42
Marginal Abatement Cost of Phosphorus: MAC_P^* (baht/kg)	29.29
Marginal Abatement Cost of Nitrogen: MAC_N^* (baht/kg)	1,059.19
Marginal Abatement Cost of BOD: MAC_{BOD}^* (baht/kg)	607.06

Source: Own data and calculations.

7.3 Results of the Hedonic Price Modeling

This section provides empirical results displayed in three relative parts. The first part explains the results drawn from the land price estimation, which is based on the hedonic price approach. The second part shows the results that utilize the first part's output by employing the environmental coefficient to estimate the willingness to pay (WTP) or the damage cost (DMC). It serves to avoid local closes to the damaged site. The third part delivers the values of the marginal environmental damage cost (MAC^*) which can be obtained from taking the first-order partial derivatives to the DMC.

For the first part, the linear regression results of the land price estimation, based on the hedonic price modeling, turn out to be as expected. The distance from the land to the main road and the distance from the land to the environmental damaged site significantly influence the land price; except for the size of the land that is only slightly significant (*p*-value = 0.069) (see Table 7.4). However, it is statistically acceptable. Overall, these explanatory variables can fairly good explain the dependent variable (*Land Price*) measured as R^2 value of 0.6145. The figure is considerably reasonable in terms of the regression on the cross sectional data.

All estimated coefficients of the explanatory variables have the correct signs corresponding to the analytical expectations. The variables $Size$ and $Dist\_Rd$ yield positive and negative signs, respectively. These signs point out that the larger the land size, the higher the land price whereas the shorter the distance from the land to the major road, the higher the land price, vise versa. However, the environmental damage coefficient of the $Dist\_PCanal$ variable has a positive sign as hypothetically expected. It shows the land prices vary directly in the same direction to the distance of the land from the environmental damaged site or the polluted canal. That is the farther the distance to the polluted canal, the higher of the land price, vise versa (Figure 7.1). The overall results discussed in this part can be observed in the following Table 7.4.

Table 7.4: Results of the Land Price Estimation by Hedonic Price Modeling

Categories	Coefficients	*t*-values	*S.E.*	*p*-values
Constant	596,473.029	24.525	24,321.485	0.000
Size	1,553.582	1.836	846.077	0.069
Dist_Rd	-39,892.893	-10.165	3,924.698	0.000
Dist_PCanal	28,258.097	7.989	3,537.081	0.000
Dependent Variable = *Land Price*, R^2 = 0.6145, N = 104.				

Note: Land prices are adjusted with a real interest rate in 2006 (MLR = 7.65% and inflation rate = 4.70% (Bank of Thailand: WWW.BOT.OR.TH, 2008).

Source: Own data and calculations.

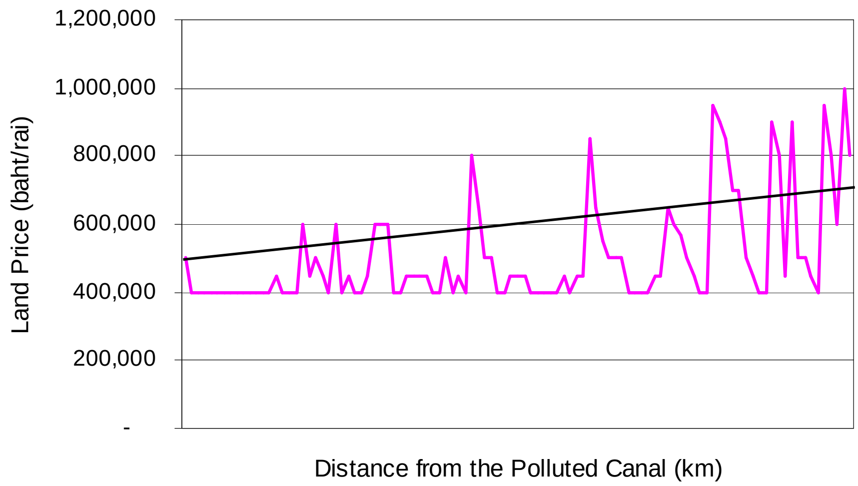

Figure 7.1: Environmental Damage in Form of Decreasing Land Prices

Source: Own data and calculations.

Table 7.5 illustrates the results of the OLS quadratic regression. This analysis is an intermediate analytical step, arranged to derive the marginal environmental damage costs. The analytical procedure is done by regressing *WTP* or *DMC* as a dependent variable, which is obtained from the estimated coefficient of the variable *Dist_PCanal* in the first part. Next explanatory variables are phosphorus, nitrogen, and BOD. It has to be noted that the interrelated terms of the explanatory variables (shown in 6.4e: clarified in chapter 6) are dropped out of the estimation because of their statistically insignificant levels. Therefore, the remaining explanatory variables for this estimation are simply in the forms of P, P^2, N, N^2, BOD, and

BOD^2. Likewise, on the whole, the explanatory variables can moderately explain the dependent variable indicated by a value of the R^2, 0.5300; that is statistically acceptable with regards to the regression of the cross sectional data.

Every estimated coefficient of the explanatory variables is statistically significant and associated with the correct signs as hypothetically expected. The estimated coefficients of the power-of-one explanatory variables yield the negative signs meaning that a person is willing to pay higher if additional units of the pollutants are managed to reduce, vise versa. In general, the monetary amount of the willingness to pay, i.e. to avoid an increase in the pollutions, in fact implies equivalent monetary values of the environmental damage costs. It means that each additional unit of the pollutant costs a person to pay the amount of his willingness. The willingness is equal to the cost of the environmental damage in his perceptional thinking. In terms of the magnitude of these coefficients, it is found that the coefficient of BOD earns the highest absolute value of 100.468 followed by the coefficients of nitrogen (60.453) and phosphorus (6.462), respectively. This practically implies that the respondents in the study area pay more attentions to the BOD accumulation rather than nitrogen and phosphorus accumulations at his damaged site. Nevertheless, this occurrence is slightly different from what the swine raising farmers focus on. Farmers give the first priority to the abatement of nitrogen pollutant rather than the others (as already explained in the previous section). For the squared terms of the explanatory variables, the estimation delivers the positive signs to their estimated coefficients indicating that the willingness to pay or the environmental damage cost is actually a nonlinear increasing function of the pollutions.

Table 7.5: Results of the Environmental Damage Cost Estimation

Categories	Coefficients	*t*-values	*S.E.*	*p*-values
Constant	37,778.351	3.274	11,537.855	0.001
P	-6.462	-7.515	8.630	0.000
P^2	0.039	5.125	0.008	0.004
N	-60.453	-13.377	4.520	0.000
N^2	0.075	19.748	0.004	0.000
BOD	-100.468	-8.365	12.008	0.001
BOD^2	0.043	4.347	0.010	0.010
Dependent Variable = $WTP(\cong DMC)$, R^2 = 0.5300, N = 104.				

Source: Own data and calculations.

The OLS results described above can be rewritten in a form of the mathematical equation as follows:

$$WTP \cong DMC = 37{,}778.351 - 6.462P + 0.039P^2 - 60.453N + 0.075N^2 - 100.468BOD + 0.043BOD^2 \quad (7.1a)$$

The marginal environmental damage costs can be retrieved by taking the first order partial derivatives of the equation expressed in (7.1a). Derivatives are taken with respect to each type of the pollutants yielding the marginal environmental damage costs of phosphorus, nitrogen, and BOD presented in the following (7.1b), (7.1c), and (7.1d),

$$MDC_P^* = -6.462 + 0.078P \quad (7.1b)$$

$$MDC_N^* = -60.453 + 0.150N \quad (7.1c)$$

$$MDC_{BOD}^* = -100.468 + 0.086BOD \quad (7.1d)$$

Consequently, the MDC_P^*, MDC_N^*, and MDC_{BOD}^* received in this part are linear equations for each type of the pollutants. They will be used to equate to the corresponding marginal abatement costs in order to obtain the optimal abatement levels of the pollutions in the next analytical part.

7.4 Optimal Abatement Levels

According to the Coase Theorem approach, the marginal abatement costs drawn from the outcome of the mathematical linear programming model can be equated to the marginal environmental damage costs derived from the hedonic price modeling so that the ultimate outcome of the study arises in terms of the optimal abatement levels of the swine farm pollutions. These can be seen in the following (7.2a), (7.2b) and (7.2c) equations:

$$MAC_P^* = 29.29 = MDC_P^* = -6.462 + 0.078P \quad (7.2a)$$

$$MAC_N^* = 1{,}059.29 = MDC_N^* = -60.453 + 0.150N \quad (7.2b)$$

$$MAC_{BOD}^* = 607.06 = MDC_{BOD}^* = -100.468 + 0.086BOD \quad (7.2c)$$

Solving all three equations above yields the optimal pollution levels of phosphorus, nitrogen, and BOD as shown in (7.2d), (7.2e) and (7.2f), respectively:

$$P^* = 455.64 \quad \text{kg/year} \quad (7.2d)$$

$$N^* = 7{,}463.02 \ \text{kg/year} \quad (7.2e)$$

$$BOD^* = 8{,}226.37 \ \text{kg/year} \quad (7.2f)$$

Thus, the optimal abatement levels of the pollutions can be retrieved by taking a difference between the actual pollution load and the optimal pollution level for each pollutant as follows:

$$P_{Abate}^* = 1{,}645 - 455.64 = 1{,}189.36 \ \text{kg/year} \quad (7.2g)$$

$$N_{Abate}^* = 22{,}108 - 7{,}463.02 = 14{,}644.98 \ \text{kg/year} \quad (7.2h)$$

$$BOD_{Abate}^* = 19{,}157 - 8{,}226.37 = 10{,}930.63 \ \text{kg/year} \quad (7.2i)$$

Upon the final outcome of the optimal abatement levels, it indicates that the swine farm community in Sam Khwai Phueak Subdistrict should altogether abate their farm pollutions in terms of phosphorus, nitrogen, and BOD contents in the quantities of P^*:1,189.36, N^*:14,644.98, and BOD^*:10,930.63 kilograms annually, respectively. The nitrogen and BOD contents are more emphasized in abating than the phosphorus content. Because they are considered as the major causes, originated from the swine farms in contaminating the public water areas rather than the phosphorus, they may actually come from the other pollution sources besides the swine farms. Other sources are wastewater from households and industries. In addition, the farm wastewater inspections by the PCD, as usually performed, examine nitrogen, BOD, COD, SS, and pH rather than phosphorus in practice. Though the phosphorus abatement is not the first priority for the swine farm abatement purpose, the community should not neglect to abate it, since phosphorus as well as contaminates the community reducing the amenities as a whole.

By contrasting the optimal abatement and the actual abatement levels as presented in Table 7.6, it is found that the actual abatement levels of phosphorus, nitrogen, and BOD are significantly lower than the optimal abatement levels. In particular, it happens in the cases of nitrogen and BOD abatement levels. In practice, the swine farm community in the study area abates more nitrogen (7,009 kg/year) than BOD (5,006 kg/year) and phosphorus (724 kg/year). As a result, it is recommended that the swine farm community should attempt to increase the abatement levels of phosphorus, nitrogen, and BOD by 64.23%, 108.95%, and 118.36%, respectively. In order to increase the community's welfare, this additional abatement would help. Roughly to say, swine raising farmers in the community should abate their farm pollutants approximately about one time higher than the amount of the pollution that they routinely practice in the abatement processes.

Table 7.6: Comparison of the Actual and the Optimal Abatement Levels

Categories	Abatement Levels		Difference	
	Actual (kg/year)	Optimal (kg/year)	Amount (kg/year)	%
P	724	1,189	465	64.23
N	7,009	14,645	7,636	108.95
BOD	5,006	10,931	5,925	118.36

Notes: Difference is calculated by subtracting the actual from the optimal abatements.

Source: Own data and calculations.

However, in reality the optimal abatement levels in terms of the mineral contents seem to be unpractical to the farmers. Unless they have proper technologies and equipments to measure these pollution contents, a realistic reduction is questionable (if marginal abatement and marginal damage costs are held constant).

Abatements of this category are nearly implausible in the swine community of the study area. For simplicity to deal with this problem, the mineral contents can be converted into a form of swine manure weights as presented in Table 7.7. This table is an example to illustrate some rough numbers or proxies of the optimal abatement levels in the form of dried swine manure. It indicates that the community as a whole should manage their farms to eliminate or reuse also to trade out their dried manure. At least 377,000 kilograms annually are required. This can be seen better in terms of the farm level that each farm should proceed. Their dried manure should be around 3,625 kilograms a year or 10 kilograms a day on the average. These figures, especially the case of the farm levels, seem to be small numbers of the dried manure but in reality most of the swine raising farmers in the study area do not practice to process their manure, as already discussed in chapter 4. Therefore, if each of them could manage to attain at least 11 kilograms of dried manure a day, the community would be better off in gaining higher social welfare in the future.

Table 7.7: Optimal Abatement Levels in terms of Swine Manure

Categories	units	Optimal Abatement
Dried Manure calculated by the Sum of P and N Contents:		
- Community Level	kg/year	377,000
- Farm Level (Yearly Basis)	kg/farm/year	3,625
- Farm Level (Daily Basis)	kg/farm/day	10

Notes: 1) In average, dried manure contains phosphorus 1.4% and nitrogen 2.8% of the total weight (DEPARTMENT OF LAND DEVELOPMENT, 2000).
2) Farm level is based on the number of 104 swine farms in the study area.
3) Daily basis is based on 365 days/year.

Source: Own data and calculations.

7.5 Results of Sensitivity Analysis

Recall the policy scenarios setup for a sensitivity analysis in chapter 6. We suggest 3 scenarios to observe the effects of the decreases in the marginal abatement costs and the net gains from manure markets. Decreases in the marginal abatement costs can be derived from various factors. For examples, government regulations and enforcements draw farmers' attention to improve on farm waste abatement and management technology; community's pressure requires farmers clean up additional units of pollution; and some incentives, such as government subsidies, may encourage farmers to reduce their marginal abatement costs, apparently it is voluntary done and so on. If farmers are willing to accept these conditions, the abatement level would be expected to increase since costs reflect activities. Furthermore, increases in net gains from manure markets can come from trading and reusing manure activities. These activities should be able to create value added to manure, which several farmers treat so far as unwanted or volatile product. As a result, additional units of farm waste are expected to be abated.

In this analysis, Scenario 1 allows decreases in the marginal abatement costs while the net gains from the manure markets are held constant; Scenario 2 is opposite to the first scenario in that the net gains from the manure markets are increased while the marginal abatement costs are fixed; Scenario 3 is the case of an opposite change i.e. changes in both the marginal abatement costs and the net gains from the manure markets.

Table 7.8 shows the results of the scenario 1 analysis that decreases marginal abatement costs alone, ranging from 10% ($d = 0.1$), 30% ($d = 0.3$), and 50% ($d = 0.5$), respectively. The decreases cause the objective value or the social welfare to increase. As an example, if the marginal abatement costs are solely managed to decrease by 50%, the social welfare rises up to 21.04%. It implies that an additional unit of pollution becomes cheaper to get abated. In terms of the optimal abatement levels, it is found that all reliments increase. Among the three cases, case 3 is considered to reveal the best solution due to its highest abatement levels of the pollutants. In this case 3, the optimal abatement of BOD gains the highest increase of 32.23%, followed by nitrogen (24.08%), and phosphorus (16.16%), respectively.

Table 7.8: Scenario 1: Decreases in Marginal Abatement Costs

Categories	Based Case	Case 1 $d = 0.1, q = 0.0$		Case 2 $d = 0.3, q = 0.0$		Case 3 $d = 0.5, q = 0.0$	
	Value	Value	% Chg.	Value	% Chg.	Value	% Chg.
Obj. Value (baht/year)	53,338,977	56,383,318	5.71	60,471,999	13.37	64,560,679	21.04
Optimal Abatement	(kg/year)	(kg/year)		(kg/year)		(kg/year)	
P^*_{Abate}	1,190	1,229	3.23	1,306	9.69	1,383	16.16
N^*_{Abate}	14,645	15,352	4.83	16,765	14.48	18,172	24.08
BOD^*_{Abate}	10,931	11,640	6.49	13,047	19.36	14,454	32.23

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

For the results from scenario 2, Table 7.9 reveals that if the net gains from the manure markets are made to increase, the social welfare of the community also increases (but in smaller proportions than in scenario 1, ranging from 2.40% to 4.51%). However, case 3 conveys the highest value of the social welfare. In addition, increases in the net gains from the manure markets impact the optimal abatement levels of the pollutions to increase less than 14% for the best case.

Table 7.9: Scenario 2: Increases in Net Gains from the Manure Markets

Categories	Based Case	Case 1 $d = 0.0, q = 0.1$		Case 2 $d = 0.0, q = 0.3$		Case 3 $d = 0.0, q = 0.5$	
	Value	Value	% Chg.	Value	% Chg.	Value	% Chg.
Obj. Value (baht/year)	53,338,977	54,619,592	2.40	55,180,821	3.45	55,742,050	4.51
Optimal Abatement	(kg/year)	(kg/year)		(kg/year)		(kg/year)	
P^*_{Abate}	1,190	1,203	1.08	1,229	3.23	1,267	6.46
N^*_{Abate}	14,645	14,918	1.87	15,625	6.69	16,238	10.88
BOD^*_{Abate}	10,931	11,152	2.02	11,710	7.13	12,419	13.62

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

In terms of the mixed scenario represented in scenario 3, changes in both the marginal abatement costs and the net gains from the manure markets can be categorized into 3 sub-scenarios as follows: Scenario 3a is associated with the case of $d = q$ presented in Table 7.10; Scenario 3b is associated with the case of $d < q$ presented in Table 7.11; and Scenario 3a is associated with the case of $d > q$ presented in Table 7.12, respectively.

Scenario 3a (shown in Table 7.10) demonstrates that the objective value increases for all 3 cases (ranging from 6.23% to 23.67%). The optimal abatement levels of the pollutions significantly increase in general. The highest increase in the optimal abatement levels occurs in case 3.

Table 7.10: Scenario 3a: Decreases in Marginal Abatement Costs and Increases in Net Gains from the Manure Markets where $d = q$

Categories	Based Case	Case 1 $d = 0.1, q = 0.1$		Case 2 $d = 0.3, q = 0.3$		Case 3 $d = 0.5, q = 0.5$	
	Value	Value	% Chg.	Value	% Chg.	Value	% Chg.
Obj. Value (baht/year)	53,338,977	56,663,932	6.23	61,313,842	14.95	65,963,752	23.67
Optimal Abatement	(kg/year)	(kg/year)		(kg/year)		(kg/year)	
P^*_{Abate}	1,190	1,242	4.31	1,344	12.92	1,447	21.54
N^*_{Abate}	14,645	15,638	6.78	17,685	20.76	19,672	34.32
BOD^*_{Abate}	10,931	11,896	8.83	13,826	26.49	15,686	43.51

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

Table 7.11 illustrates scenario 3b. The scenario deals with the cases in which the marginal abatement costs are managed to decrease less than the increases in the net gains from the manure markets. Overall, the results reveal that the objective value increases in all cases. Likewise, the optimal abatement levels of all cases increase ranging from 6.46% to 32.98%. As a result, the best results in this scenario fall to case 6 in which the optimal abatement levels attain the highest growth.

Table 7.11: Scenario 3b: Decreases in Marginal Abatement Costs and Increases in Net Gains from the Manure Markets where $d < q$

Categories	Based Case	Case 4 $d = 0.1, q = 0.3$		Case 5 $d = 0.1, q = 0.5$		Case 6 $d = 0.3, q = 0.5$	
	Value	Value	% Chg.	Value	% Chg.	Value	% Chg.
Obj. Value (baht/year)	53,338,977	57,225,161	7.29	57,786,390	8.34	61,875,071	16.00
Optimal Abatement	(kg/year)	(kg/year)		(kg/year)		(kg/year)	
P^*_{Abate}	1,190	1,267	6.46	1,306	9.69	1,370	15.08
N^*_{Abate}	14,645	16,338	11.56	16,905	15.43	18,318	25.08
BOD^*_{Abate}	10,931	12,419	13.62	13,128	20.11	14,535	32.98

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

The last scenario 3c (shown in Table 7.12) show that the marginal abatement costs are allowed to decrease higher than the increases in the net gains from the manure markets. For this scenario, the objective values increase up to 21.56% in case 9. Similarly, the optimal abatement levels attain the highest increases in case 9.

Table 7.12: Scenario 3c: Increases in both Abatement Costs and Net Gains from the Manure Markets where $d > q$

Categories	Based Case	Case 7 $d = 0.3, q = 0.1$		Case 8 $d = 0.5, q = 0.1$		Case 9 $d = 0.5, q = 0.3$	
	Value	Value	% Chg.	Value	% Chg.	Value	% Chg.
Obj. Value (baht/year)	53,338,977	60,752,613	13.90	64,402,523	20.74	64,841,294	21.56
Optimal Abatement	(kg/year)	(kg/year)		(kg/year)		(kg/year)	
P^*_{Abate}	1,190	1,319	10.77	1,383	16.16	1,421	19.39
N^*_{Abate}	14,645	17,192	17.39	18,458	26.04	19,112	30.50
BOD^*_{Abate}	10,931	13,268	21.38	14,559	33.19	15,245	39.47

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

According to all the results, delivered from the 3 scenarios presented above, it seems that a single scenario approach on either decreasing the marginal abatement costs alone (scenario 1) or increasing the net gains from the manure markets alone (scenario 2), is inadequate to improve the social welfare in terms of both the monetary values and the optimal abatement levels as a whole. Policy wise, the DLD currently subsidizes 40% of the total installing cost for swine raising farmers who are willing to install standard waste treatment systems designed by the DLD (www.dld.go.th, 2008). Also, the local PCD office in Nakhon Pathom Province sometimes provides effective organism (EM) for swine farmers in problematic areas to manage their farm pollutions (the Study Field Survey, 2005-2006). These may help farmers to reduce their marginal abatement costs. In addition, it is found that policies on manure reusing activities remain unclear (DLD and FAO, 2001). Most programs about manure reusing activities have been done by educational and research institutes (the Study Field Survey, 2005-2006). However, if a policy maker wishes to choose between the two options, the policy associated with the increases in the abatement costs can be more reasonable. Because it gains higher levels of the pollution abatement and the social welfare, policy maker will prefer it.

On the other hand, the mixed approach policies (represented by the results shown in scenarios 3a, 3b, and 3c) can be better options relative to the first 2 single approach policies. Because all of them deliver greater improved social welfare and increases in the optimal abatement levels of the pollutions, they might be even preferred by policy makers.

Table 7.13 summarizes the best results obtained from each individual scenario. It is found that the scenarios promoting changes in both the marginal abatement costs and the net gains from the manure markets in scenario 3a, appear to fit best for the purposes of the social welfare and the optimal abatement improvements. That is the magnitudes of the changes between the two attain the highest setup values. In other words, it is okay to say that the policies and/or the measures promoting farm waste management improvements by reducing the marginal abatement costs together with the increases in the swine manure trading and reusing activities can be a proper alternative to alleviate the environmental problems originated from the swine farms. By that the social welfare of the community can eventually be improved as a whole.

Table 7.13: Comparison of the Three Scenarios' Best Results

Categories	Scenario 1 Case 3	Scenario 2 Case 3	Scenario 3a Case 3	Scenario 3b Case 6	Scenario 3c Case 9
% Chg. in Obj. Value	21.04	4.51	23.67	16.00	21.56
% Chg. in Optimal Abatement Levels:					
P^*_{Abate}	16.16	6.46	21.54	15.08	19.39
N^*_{Abate}	24.08	10.88	34.32	25.08	30.50
BOD^*_{Abate}	32.23	13.62	43.51	32.98	39.47

Notes: % Chg. represents percentage change from the based case.

Source: Own data and calculations.

7.6 Summary

This chapter has delivered the analytical results derived from the three calibrating parts. The first result is that marginal abatement costs, obtained from the mathematical linear programming model, have an impact. It revealed that the swine community in the study area emphasizes abating the nitrogen and BOD contents rather than phosphorus content. This can be observed from the higher value of the marginal abatement costs of nitrogen and BOD relative to the marginal abatement cost of phosphorus. Besides, the objective value or the value of the net social welfare, we reached considerably high values compared to the net farm incomes from other agricultural occupations in Thailand. The second result came from the hedonic price modeling. It estimated the land price and willingness to pay of avoiding the environmental damaged. Results imply that persons are willing to pay higher for land to be located farther away from the damaged sites. In addition, the marginal environmental damage cost appears to be linear with respect to the quantity of each loaded pollutant. The final outcome of the optimal abatement levels of the pollution is retrieved by equating the marginal abatement costs and the marginal environmental costs in accordance with the Coase Theorem. The outcome showed that the optimal abatement of nitrogen gains the highest value, followed by those of BOD and phosphorus, respectively. These optimal abatement levels significantly exceed the current abatement levels swine raising farmers practice in the community routinely. In addition, the study also set up some policy scenarios for a sensitivity analysis. The analysis found that the policies and/or measures associated with promoting the decreases in marginal abatement costs altogether with the increases in the swine manure trading and reusing activities can be a decent alternative for relieving the community's environmental problems as well as improving the social welfare of the whole community.

8 CONCLUSIONS

The concerns about fundamental change in social, environmental, and economic aspects of peri-urban areas have been widely discussed recently. Peri-urban areas absorb both, development and problems from urban areas that lead to cause several problems in rural areas, in particular, environmental problems. In Thailand, agricultural wastes, especially the case of livestock wastes, have become a growing worry. These problems of livestock waste pollution occur most severely in peri-urban areas where various economic activities are competing in utilizing limited amounts of land and other natural resources. The major source of livestock waste in Thailand is mainly derived from swine farms. Emission rates of farm pollutions usually exceed a maximum carrying capacity of the environment. As a result, environmental problems have appeared in forms of wastewater, odor, germ spreading and local sanitation problems.

Nakhon Pathom Province, situated in the western edge of Bangkok, is one of the major swine producing areas in Thailand. It is considered as a peri-urban area that is facing pollution problems derived mostly from the swine farm pollutions. Most of the farms are small scale, conventionally operated farms and they are situated inside cities. While there exist on-farm simple waste treatment technologies and local markets for swine manure, pollution problems still persist in Nakhon Pathom area. In addition, numbers of government officers are inadequate to inspect and to enforce all the swine farms in the entire nation.

Due to the swine farm pollution problems, existing in peri-urban areas of Thailand (such as in Nakhon Pathom Province), the study comes in a line with an aspect of environmental economic analysis. It aims at investigating abatement and environmental damage costs drawn from swine wastes. It intends to identify optimal abatement levels of the pollutions in order to improve social welfare of the studied community. Moreover, a participatory approach is included in the study.

8.1 Summary of the Research Methodologies and Analytical Framework

The study selected “Sam Khwai Phueak Subdistrict”, Nakhon Pathom Province, as the study area. It consisted of the total 104 swine farms that mainly were small-scale and conventional farms. The sampling process was divided into 3 parts. The first part associated with a field survey of interviews on swine farm owners or managers. The second part carried out interviews obtained from swine manure traders or middle men and manure end-users. The third part was to get farm waste samples at point sources examined in a laboratory. It had to be noted that the study emphasized on the farm pollutions in forms of environmental indicators such as nitrogen (Total Kjeldahl Nitrogen: TKN or N), phosphorus (P), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), and pH value. Furthermore, the study also embraced a stakeholder brainstorming. The brainstorming meeting was organized in a form of a round-table meeting among related stakeholders. In terms of data analyses, Microsoft Excel was a computer software used for data entering, while the GAMS software was used in the optimization part of the study.

A broad concept of the study was to maximize a social welfare of the swine community by taking into account both benefit and cost factors. The study was theoretically based on a welfare economic approach in which the Coase Theorem was employed. The objective was to derive optimal abatement level of the farm pollutions in the study area. The analytical framework was organized into 2 working tasks corresponding to obtain marginal abatement and marginal environmental damage costs. Task 1 dealt with a mathematical linear programming model used to derive marginal abatement costs. In this task, an objective function was formulated with respect to constraints mainly drawn from the environmental standard. The objective function comprised: (1) aggregated net farm income; (2) aggregated net gains from manure markets; and (3) aggregated abatement costs of the pollutions. The solutions of Task 1 were retrieved in forms of shadow prices of the pollutions. In other words, they were marginal abatement costs of the pollution. On the other working task, Task 2 was associated with a hedonic pricing model. It was applied to retrieve marginal environmental damage costs. In this task, land prices were hypothetically assumed to get affected by the damaged environmental site, which was the Chedi Bucha canal (the major canal in the swine farm community). Consequently, a willingness to pay (or an environmental damage cost) for avoiding effects at damaged sites was estimated by means of an OLS estimation.

The marginal environmental costs were obtained by taking a first order partial derivative to damage cost function with respect to each type of pollutions. The outcomes of the two tasks were equated in accordance with the Coase approach. Therefore, the optimal abatement levels of the pollutions could be reached as the ultimate goal of the study. Besides, policy scenarios for a sensitivity analysis were provided in terms of incremental adjustments on the abatement costs and on the net gains from manure markets.

8.2 Summary of the Empirical Findings

The field survey of the study was conducted from November 2005 to April 2006. The empirical data are obtained from 5 major sources as follows:

1) 104 swine raising farmers (the whole population of the swine raising farmers in the study area),
2) 48 swine manure traders,
3) 37 swine manure end-users,
4) results of the farm wastewater samples examined in the laboratory, and
5) conclusions of the stakeholder brainstorming meeting.

The survey revealed that most of the swine raising farmers in the study area were small-scale farmers (74.04%) in terms of both land holdings and numbers of swine raised. The majority (72.12%) of the farms usually engaged in contract farming with local companies. It meant that the contract farmers received piglets from local swine companies accompanied with growing techniques and farm check-up programs provided by the companies. Decisions on farm gate prices and weights of swine were made in advance indicated in the contract. Hence, only costs, the farmers paid, were feeding costs, labor costs, and other operating costs. In addition, fattening swine were dominant in the area.

Farms were primarily dealing with low efficient waste treatment systems. The most popular farm waste treatment system was open-type anaerobic ponds. The system consisted of open rounded and connected ponds. On the average, this farm treatment system had the highest capacity of wastewater, abating less than 65.00% of the total waste contents. For instance, the BOD and COD contents had been reduced by 62.98% and 64.75% of the total contents, respectively. In terms of TKN, P, and SS, these waste contents could be decreased only by half of the total contents on average, ranging from 35.00 – 48.00%. Therefore, it was not surprising to experience that swine raising farmers overloaded immense amounts of their farm wastes to public drainage systems and areas. Even though many farmers were well aware of the pollutions, their improper farm waste management practices remained unchanged.

However, swine manure and wastewater could be managed in different channels. Both dried and wet manure were applied as fertilizer and fish feed. However, the dried manure was more popular in the area due to its lighter weight. It was convenient to handle and proceed for continuing applications. In addition, the wet manure was unable to be kept in a longer period of time. On the other side, farm wastewater was normally recycled by using the wastewater removing service provided by the Sam Khwai Phueak Subdistrict Administration Organization. Most of the wastewater was later sold to water flea farmers. This wastewater recycling process were dealing with several problems in terms of (1) high cost burdens to the subdistrict, (2) insufficient staffs, and (3) insufficient trucks to serve all the farms in the area. Also, there were insufficient water flea farms to be the buyers.

Nevertheless, there were lots of farm waste management problems existing in the study area as well as the other areas throughout the country. The law enforcement in practice was inefficient to prosecute violators. Instead, governmental agencies, such as the DLD and the PCD, were trying to tackle down obstacles by financially supporting farmers and helping them to install more efficient waste treatment systems. Yet, this could not be done extensively due to budget constraints and farmers' perceptions.

In terms of farm cost aspects, the survey results showed that, for overall, the main part of variable costs came from feeding costs (43.62% of the total production cost). The second largest part of the total variable costs was labor costs. In the area, the cost share of the labor took up 27.24% of the total production cost, on the average. However, it was interesting to notice that the costs for waste management of the farms were small. On average, they counted only 632 baht per livestock unit per farm. In other words, swine farms in the area spent only 2.00% of the total production cost for their farm waste management. This implied that the swine raising farmers emphasized less on waste management. Considering farm size aspects, the average value of total production cost of the small farms nearly doubled that of the medium farms. That was, an aspect of economy of scales came to explain this situation. Medium farms appeared to have higher cost shares of breeding and veterinarian service–animal drug expenses than small farms. On the contrary, the waste management cost share (0.33% of the total production cost) of the medium farms was rather low as compared to the cost share (2.29% of the total production cost) of the small farms. It implies that environmental policy makers may have to consider farm these size effects. In this case, policy makers and local officers should encourage larger farms to engage more in their farm waste management in order to improve the community's environment and welfare.

For the farm revenue, the overall means of total farm revenue and net farm revenue were 54,262 and 22,663 baht per livestock unit per farm, respectively. The net farm revenue revealed as high as 71.72% of the total production cost. The mainstream revenue came from selling fattening swine (86.69% of the total revenue). The second important source of the total revenue was derived from the sale of piglets. Another source of farm revenues was derived from a sale of swine manure in both dried and wet forms. However, both dried and wet manure still contributed less than 1.00% of the total farm revenue while the potential of selling more manure was available in the area according to the survey observation. Furthermore, it was found that medium farms were capable of making much higher profits than small farms did. Major reasons could be explained by the fact that medium farms had advantages of having much lower production costs and higher farm revenue as compared to small farms.

For the empirical findings on manure middle men, the results documented that the major reasons of getting into manure trading and recycling activities came from making high revenue due to high marketing margins. The manure buying process was often made through verbal contracts (77.08%). The farm owners allocated quantities of their manure to different middle men according to different levels of their relationships among them. The distance between the places of the middle men and the swine farms ranged from less than 1 to 15 kilometers. Prices of the dried manure (bought by the middle men) ranged from 0.66 to 1.33 baht per kilogram. Prices of wet manure started from 0.60 and gained up to 1.40 baht per kilogram. Several middle men also kept some manure for their own uses. It seemed that the dried manure trading was generally more beneficial than the wet manure trading for the middle men. Usually, both buying and selling prices were determined by the middle men. Swine farm owners were willing to accept prices that were given by middle men because they treated manure as an unused product.

Not to mention, transportation and labor costs tended to be expenditures incurred to the middle men. On the side of manure end-users, it was discovered that the top reason of using swine manure (given by all the end-users) was to save costs of farm inputs. The cost saving ranged from 10.00% to 50.00% of the total cost. In addition, major occupations of the end-users were cropping, fish, and water flea farmers.

Lastly, as concluding results retrieved from a stakeholder brainstorming meeting, it was revealed that a significant success of the swine waste management, in the area, should be derived from economic incentive schemes on creating value-added to swine manure. This should be done under close cooperation and efficient participation among community's members and all other officers as well as other stakeholders.

8.3 Summary of the Analytical Results

The analytical results at the study are derived from 4 relative calibrating parts. The first part of results for the marginal abatement costs (obtained from the mathematical linear programming model), shows that the value of the objective function was 53,338,977 baht per year or 512,875 baht per individual farm. This net social welfare value of the swine farm community is considered rather high as compared to its low expenditures. Expenditures are on: (1) the pollution abatement costs; (2) the environmental damage costs; and (3) the net gains from the manure markets. It implies that the community could have done better in making the environment less contaminated if it were willing to invest more on farm abatement systems. The community's stakeholders should have engaged more in manure trading and using activities in the manure markets. For values of marginal abatement costs of phosphorus (MAC_P^*), nitrogen (MAC_N^*), and BOD (MAC_{BOD}^*) contents, they attain the values of 29, 1,059, and 607 baht per kilogram, respectively. Among these, MAC_N^* and MAC_{BOD}^* seem rather high compared to the low investments in abatement systems of the farmers in the study area. However, MAC_N^* takes up the highest value followed by MAC_{BOD}^* and MAC_P^*, respectively. It implies that the farmers in the community rather emphasize on abating nitrogen and BOD as compared to phosphorus. This can be explained by the fact that, in practice, the environmental standards for wastewater, originated from the swine farms, are stricter on the nitrogen and BOD contents than on the phosphorus content. The farmers of the study area tend to apply abatement technologies that can correspond to the given standards.

The second part of the analytical results offers outcomes derived from a hedonic price modeling. The hedonic price model is employed to estimate land price and willingness to pay in avoiding the environmental damaged sites. The results reveal that persons are willing to pay and pay higher to be located far away from the damaged site, the Chedi Bucha canal. The canal is concentrated with the pollutions originated from the swine farms. It means that land prices are increasing corresponding to the distances between lands to the polluted canal. In addition, the estimated marginal environmental damage costs appear to be linearly with respect to the quantities of the pollutions.

The third part is designated to retrieve the ultimate outcome: the optimal abatement levels. The outcome can be reached by equating marginal abatement costs and marginal environmental costs in accordance with the Coase Theorem. The result indicates that the community should abate their farm pollutions in terms of phosphorus, nitrogen, and BOD contents in the quantities of 1,156, 15,754, and 12,373 kilograms a year, respectively. The nitrogen and BOD contents are more emphasized in abating than the phosphorus content. They are considered as the major causes originated from the swine farms in contaminating the public water areas rather than phosphorus. One reason is that phosphorus may actually come from other pollution sources (such as wastewater from households and industries) besides the swine farms. By contrasting the optimal abatement and the actual abatement levels, it is found that the actual abatement levels of phosphorus, nitrogen, and BOD are significantly lower than the calculated optimal abatement levels.

It is recommended that the swine farm community should attempt to increase the abatement levels of phosphorus, nitrogen, and BOD by 64%, 109%, and 118%, respectively. These abatement levels are approximately one time higher than the amounts of the pollution abatement levels on a routine basis. This helps to increase the community’s welfare. For simplicity, the nutrient figures of the optimal abatement levels can be converted into a form of swine manure weights. According to the conversion, it indicates that the community as a whole should manage their farms to eliminate or to reuse or to trade out their dried manure at least 377,000 kilograms annually or around 3,625 kilograms per farm per year or only 10 kilograms per farm per day on the average. These figures, especially the case of the farm levels, seem to be small numbers of the dried manure but in reality most of the swine raising farmers in the study area do not practice to proceed their manure.

In a last part of the result chapter, we discussed the outcomes from a sensitivity analysis of 3 scenarios. The results imply that the single approach policy scenarios (on either decreasing in marginal abatement costs alone or increasing in net gains from manure markets alone) are likely to be inadequate to improve the community’s social welfare in terms of both monetary values and optimal abatement levels as a whole. On the contrary, the mixed approach policy scenarios seem to be better alternatives than the single ones. It is found that the policy scenarios promoting changes in both marginal abatement costs and net gains from manure markets appear to fit best for the purposes of improving in social welfare and optimal abatement levels. In other words, it is roughly to say that the policies and/or the measures promoting decreases in marginal abatement costs (through technology improvements) associated with increases in swine manure trading and reusing activities can be the proper alternative. Consequently, this alternative may alleviate the environmental problems originated from swine farms so that the social welfare of the community can eventually be improved as a whole.

9 RECOMMENDATIONS AND FUTURE WORKS

According to the empirical findings, the analytical results, and the stakeholder brainstorming meeting, the study enables us to deliver a number of possible policy implications and recommendations. These policy implications and recommendations are likely to steer clear of dealing with changes and adjustments in legislation and law enforcement processes. In practice the legislation processes take a long period of time in passing through the parliament. Moreover, oppositions drawn from related stakeholders can be sufficiently strong to affect degrees of success or failure of those laws. The policy implications recommended in this study are made via the basis of the study's results. They are dealing with economic incentives and compromising institutional arrangements notably among related stakeholders. In addition, the related future works are also provided in the chapter.

9.1 Policy Implications and Recommendations

For the community like "Sam Khwai Phueak Subdistrict", where the swine farms are dominant and conventionally operated in a small-scale type, the policy implications to improve the community's welfare (by means of mitigating the environmental problems originated from the swine farm pollutions) can be made through the following recommendations:

1) The analytical part of the study revealed that the actual levels of farm pollution abatement of the swine community in the study area were approximately one time less than the optimal abatement levels. Such that, the community as a whole should be responsible for the extra amount of their farm pollutions by improving farm abatement technologies. It is suggested that investments in the farm waste treatment systems should be increased in terms of technological aspects to best fit local limitations and needs. This can impact marginal abatement costs to decrease. Then the abatement levels of pollution will be reduced. Currently, the DLD subsidizes 40% of the total installing cost for swine raising farmers who are willing to install standard waste treatment systems designed by the DLD. This investment is voluntarily done by farmers.

   However, this is not extensively adopted by the farmers in the short run due to their perceptions and some of farms' physical limitations. One way of alleviating this problem is that the related government agencies should disseminate information about choices and efficiency of abatement types and abatement levels to the farmers. Then, the farmers can successively adjust themselves to the new changes of farm waste treatment systems in the long run. To give higher level of confidence among the farmers, demonstration plots should be made empirically in the focus area as well as some economic incentives (such as feeding and other farm cost subsidies). The incentives should be rewarded to progressive farmers who associate with high levels of new improvements in farm waste treatment systems. In addition, payments subsidized to the farmers (based on farms' environmental performances) could encourage other farmers to practice more environmentally to meet environmental standards. Also, policy makers and regulators should pay more attention on farm size effects since the cost shares of farm waste management between smaller and larger farms are quite different.

2) According to the empirical findings, several farmers do not separate their farm wastes before loading them into their farm treatment systems. This inappropriate habit can lessen abatement capacities of their waste treatment systems. As a result, the end-of-pipe farm wastewater is still concentrated with mineral nutrients and high levels of filthiness. This significantly causes public drainage systems and other public areas to get contaminated in terms of polluted water and unpleasant odor. Therefore, on-farm alternatives that involve technologies for separating swine wastes into manure and wastewater, should be developed and disseminated to the farms associated with limited spaces for drying manure and low waste treatment technologies. These technical alternatives may help to reduce waste volumes loaded into the farm treatment systems. However, costs of investment in these technologies have to be taken into farmers' consideration.

3) Many swine farm owners treat their swine manure as an unwanted farm by-product. They usually ignore swine manure in further stages because of its low value. Not to mention, prices of swine manure, especially in the study area, have been rather constant for a long time. The swine manure is less attractive to the farmers for involving in further value-added activities. Hence, it is recommended that there should be a mechanism to develop swine manure markets and manure utilization in order to gain higher added value and make more uses of manure. Development of swine manure can be an alternative answer to the environmental problems. It is an economic incentive for related stakeholders in both making their fringe benefits and keeping the environment cleaner. Policies that promote or boost up prices and to ensure the qualities of swine manure (for further uses) would be desired. Price incentives are able to attract more of participants in manure trading activities. Consequently, pollutions from swine farms can be reduced considerably. It has to be noted that several studies reveal adverse effects of mineral nutrients from applying manure (LAUWERS, 1992; INNES, 2000; TAYLOR AND WOOD, 2001; AILLERY et al. 2005). The nutrients can leach to underground water and to the environment. Therefore, manure utilization should be accompanied by the policies that monitor and to give proper advices on the manure application for end-users. In addition, based on the sensitivity analysis of the policy scenarios, it is suggested that policies promoting swine manure market activities should be designed and imposed. These policies should be introduced altogether with the above policies aiming at improving investments in farm waste abatement technologies.

4) Sometimes technical information originated from government sources is available only upon requests. It is also known only among farmers who are involved the formal associations. Unfortunately, several small-scale farmers cannot access through this kind of information. These farmers just follow what they have been told by neighboring farmers about appropriate practices and actions on regulations. Thus, information about farm standards, environmental regulations, and waste abatement technologies should be equally disseminated to all levels of farmers. It can lead to better communicate and make clearer understanding between swine raising farmers and policy regulators. In addition, information of farm pollutions, examined by government officers or experts, should be made available for farmers regularly to be aware of their farm abatement capacities.

5) Due to the empirical findings, violation punishments in terms of monetary charges and legal prosecutions are rather minor worries to the farmers because of several reasons. For examples, the fine that the farmers pay is not derived from environmental laws but it, in practice, is the fine of irritating the neighbor. Files of lawsuit against the farmers are coming from neighbors. The fine is usually low compared to environmental damages. The other major reason is drawn from an insufficiency of officers. Officers should be responsible to enforce the laws and regulations on tremendous numbers of swine farms throughout the country. Only minor things happen. Therefore, it is recommended that, instead of emphasizing on laws and enforcements, the government officers should provide practical and proper advices to the farmers in compromising ways to better operate and manage their farms more environmentally friendly.

6) Participations among related stakeholders are still essential for policy makers to take into account for designing environmental policies and regulations. Participatory approach is needed to make such policies less disputable and to be more acceptable to affected parties. Prior to enforce some policies and regulations, public hearing and criticizing should be made in order to retrieve effective outcomes afterwards.

9.2 Related Future Works

The related future works to this study can deal with the following issues:

1) Consumer welfare aspects and linkages between pork prices and farm waste management should be embraced into the current study in order to reflect the complete sense of social welfare analysis.

2) An economic study in potential of investments on farm waste abatement technologies is an interesting theme. A specific attention should be paid on the small-scale conventional operated swine farms because they seem to be hardly to adjust themselves to modern technologies and environmental standard. In addition, a multidisciplinary research from other related environmental sciences and agricultural extensions should be accompanied to this study.

3) It is worthwhile to study a swine manure market structure and its mechanism in order to come across strategies to develop the local swine manure markets more attractive to the stakeholders in the area. Active manure markets seem to have a high potential as an economic incentive instrument in mitigating the local environmental problems and it is more flexible than the other command and control policy instruments. Consequently, swine manure can be more valuable than it is used to be.

4) An analysis of social welfare effects on establishments of a local bio-energy plant can be put into a research agenda in making such alternative energy project more practically feasible in terms of net benefits delivered to both a society as a whole and a private investor.

5) Feasibility study of a local manure collecting center is another interesting research area to conduct on. The manure collecting center or a manure bank can be a local organization to assure private investments in terms of certain quantity and quality of manure supplies fed to be a major input of the bio-energy plants established in the local area.

6) Participatory and extension approaches should be neglected to further study in what extents can be made to attain decent cooperation from related stakeholders in alleviating the farm environmental problems more efficiently.

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APPENDIX A: GAMS SYNTAX COMMANDS

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$Title Welfare Maximization of Swine Waste Management

$ontext
Welfare maximization due to the leakage of nutrients (P, N) and
some environmental indicator such as BOD. The model is trying to obtain
the optimal quantities of P, N, and BOD abatement at point source
under the linear programming in order to find the marginal abatement cost
or the shadow price of each pollution. The marginal abatement cost
obtained from this linear programming will be separately equated to
the marginal damage cost derived from the outside hedonic model.
After all, the optimal abatement levels of the pollutions will be reached
under the Coase's Theorem.
$offtext

Sets
      i       Farmer cases                                   /i1*i104/
      inc     Net farm income                                /inc/
      p       Abatement cost of P                            /p/
      n       Abatement cost of N                            /n/
      b       Abatement cost of BOD                          /b/
      m       Net gain (loss) from manure mkt                /m/
      g       Grant from Department of Livestock Dept.(DLD)  /g/
;
Parameters
      Net(i, inc)         Net income for case i
      ABC_P(i, p)         Abatement cost of P at point source for case i
      ABC_N(i, n)         Abatement cost of N at point source for case i
      ABC_BOD(i, b)       Abatement cost of BOD at point source for case i
      Manure(i, m)        Net gain (loss) from manure mkt for case i
      Grant (i, g)        Grant from DLD for case i
      Pload (i, p)        Phosphorus load for case i
      Nload (i, n)        Nitrogen load for case i
      BODload (i, b)      BOD load for case i
;
$libinclude xlimport Net  Run_Data.xls Rev!A1:B105;
$libinclude xlimport ABC_P  Run_Data.xls ABC-P!A1:B105;
$libinclude xlimport ABC_N  Run_Data.xls ABC-N!A1:B105;
$libinclude xlimport ABC_BOD  Run_Data.xls ABC-B!A1:B105;
$libinclude xlimport Manure  Run_Data.xls Manu!A1:B105;
$libinclude xlimport Grant  Run_Data.xls Grnt!A1:B105;
```

```
$libinclude xlimport Pload  Run_Data.xls P-Load!A1:B105
$libinclude xlimport Nload  Run_Data.xls N-Load!A1:B105
$libinclude xlimport BODload  Run_Data.xls BOD-Load!A1:B105
Variables
        Opt_P(i, p)       Optimal level of P abatement
        Opt_N(i, n)       Optimal level of N abatement
        Opt_BOD(i, b)  Optimal level of BOD abatement
        SW                     Social welfare maximum value
;
Positive Variable
        Opt_P, Opt_N, Opt_BOD
;
Scalar   Pmax            Maximum level of P permitted    /   /
;
Scalar   Nmax            Maximum level of N permitted    /   /
;
Scalar   BODmax       Maximum level of N permitted    /   /
;
Equations
        OBJ     Objective function
        Cont1   Constraint1 on maximum level of P permitted
        Cont2   Constraint2 on maximum level of N permitted
        Cont3   Constraint3 on maximum level of BOD permitted
        Cont4   Constraint6 for participation constraint
        Eq1      Level of P abatement at point source
        Eq2      Level of N abatement at point source
        Eq3      Level of BOD abatement at point source
;
OBJ.. SW =E= sum((i,inc), Net(i,inc))   - sum((i,p), ABC_P(i,p)*Opt_P(i,p))
                                                         - sum((i,n), ABC_N(i,n)*Opt_N(i,n))
                                                         - sum((i,b), ABC_BOD(i,b)*Opt_BOD(i,b))
                                                         + sum((i,m), Manure(i,m))
;
Cont1..  sum((i,p), Opt_P(i,p)) =L= Pmax;
Cont2..  sum((i,n), Opt_N(i,n)) =L= Nmax;
Cont3..  sum((i,b), Opt_BOD(i,b)) =L= BODmax;
Cont4..  sum((i,inc), Net(i,inc)) - sum((i,p), ABC_P(i,p)*Opt_P(i,p))
                         - sum((i,n), ABC_N(i,n)*Opt_N(i,n))
                         - sum((i,b), ABC_BOD(i,b)*Opt_BOD(i,b))
                         + sum((i,g), Grant(i,g))
                         =L= sum((i,inc), Net(i,inc));
Eq4..    sum((i,p), Opt_P(i,p)) =E= sum((i,p), ABC_P(i,p)/Pload(i,p));
```

```
Eq5..   sum((i,n), Opt_N(i,n)) =E= sum((i,n), ABC_N(i,n)/Nload(i,n));
Eq6..   sum((i,b), Opt_BOD(i,b)) =E= sum((i,b), ABC_BOD(i,b)/BODload(i,b));

Model Model1 /all/;
Solve Model1 using LP maximizing SW;

Display Opt_P.l, Opt_P.m;
Display Opt_N.l, Opt_N.m;
Display Opt_BOD.l, Opt_BOD.m;

$Title Sensitivity Analysis of Welfare Maximization of Swine Waste Management

$ontext
This sensitivity analysis is designed to observe changes in optimal abatement levels
of the farm pollutions. The marginal abatement costs and the net gains in manure markets
are assumed to change by various magnitudes ranging from 10% to 50%.
$offtext

Sets
      i       Farmer cases                                   /i1*i104/
      inc     Net farm income                                /inc/
      p       Abatement cost of P                            /p/
      n       Abatement cost of N                            /n/
      b       Abatement cost of BOD                          /b/
      m       Net gain (loss) from manure mkt                /m/
      g       Grant from Department of Livestock Dept.(DLD)  /g/
;
Parameters
      Net(i, inc)          Net income for case i
      ABC_P(i, p)          Abatement cost of P at point source for case i
      ABC_N(i, n)          Abatement cost of N at point source for case i
      ABC_BOD(i, b)        Abatement cost of BOD at point source for case i
      Manure(i, m)         Net gain (loss) from manure mkt for case i
      Grant (i, g)         Grant from DLD for case i
      Pload (i, p)         Phosphorus load for case i
      Nload (i, n)         Nitrogen load for case i
      BODload (i, b)       BOD load for case i
;
$libinclude xlimport Net  Run_Data.xls Rev!A1:B105;
$libinclude xlimport ABC_P  Run_Data.xls ABC-P!A1:B105;
$libinclude xlimport ABC_N  Run_Data.xls ABC-N!A1:B105;
$libinclude xlimport ABC_BOD  Run_Data.xls ABC-B!A1:B105;
```

```
$libinclude xlimport Manure  Run_Data.xls Manu!A1:B105;
$libinclude xlimport Grant  Run_Data.xls Grnt!A1:B105;
$libinclude xlimport Pload  Run_Data.xls P-Load!A1:B105
$libinclude xlimport Nload  Run_Data.xls N-Load!A1:B105
$libinclude xlimport BODload  Run_Data.xls BOD-Load!A1:B105
Variables
        Opt_P(i, p)       Optimal level of P abatement
        Opt_N(i, n)       Optimal level of N abatement
        Opt_BOD(i, b)   Optimal level of BOD abatement
        SW                    Social welfare maximum value
;
Positive Variable
        Opt_P, Opt_N, Opt_BOD
;
Scalar   Pmax            Maximum level of P permitted    /   /
;
Scalar   Nmax            Maximum level of N permitted    /   /
;
Scalar   BODmax        Maximum level of N permitted    /   /
;
Scalar   d                  delta                    /0.1/
;
Scalar   t                   theta                    /0.1/
;
Equations
        OBJ    Objective function
        Cont1   Constraint1 on maximum level of P permitted
        Cont2   Constraint2 on maximum level of N permitted
        Cont3   Constraint3 on maximum level of BOD permitted
        Cont4   Constraint6 for participation constraint
        Eq1      Level of P abatement at point source
        Eq2      Level of N abatement at point source
        Eq3      Level of BOD abatement at point source
;

OBJ.. SW =E= sum((i,inc), Net(i,inc))   - (1-d)*sum((i,p), ABC_P(i,p)*Opt_P(i,p))
                                          - (1-d)*sum((i,n), ABC_N(i,n)*Opt_N(i,n))
                                          - (1-d)*sum((i,b), ABC_BOD(i,b)*Opt_BOD(i,b))
                                          + (1+t)*sum((i,m), Manure(i,m))
;
```

```
Cont1..  sum((i,p), Opt_P(i,p)) =L= Pmax;
Cont2..  sum((i,n), Opt_N(i,n)) =L= Nmax;
Cont3..  sum((i,b), Opt_BOD(i,b)) =L= BODmax;
Cont4..  sum((i,inc), Net(i,inc)) - sum((i,p), ABC_P(i,p)*Opt_P(i,p))
                   - sum((i,n), ABC_N(i,n)*Opt_N(i,n))
                   - sum((i,b), ABC_BOD(i,b)*Opt_BOD(i,b))
                   + sum((i,g), Grant(i,g))
                   =L= sum((i,inc), Net(i,inc));
Eq4..    sum((i,p), Opt_P(i,p)) =E= sum((i,p), ABC_P(i,p)/Pload(i,p));
Eq5..    sum((i,n), Opt_N(i,n)) =E= sum((i,n), ABC_N(i,n)/Nload(i,n));
Eq6..    sum((i,b), Opt_BOD(i,b)) =E= sum((i,b), ABC_BOD(i,b)/BODload(i,b));

Model Model1 /all/;
Solve Model1 using LP maximizing SW;

Display Opt_P.l, Opt_P.m;
Display Opt_N.l, Opt_N.m;
Display Opt_BOD.l, Opt_BOD.m;
```

APPENDIX B: TECHNICAL INFORMATION ON WASTE TREATMENT SYSTEMS OF THE SWINE FARMS AND ABATEMENT COST CALCULATION

It is noted that the following information is obtained from the Department of Livestock Development – Nakhon Pathom Branch.

1. Treatment System for 100 Swine

Flow rate	4.5	m^3/day
pH	7.0-8.0	
BOD	9,000	mg/l
COD	18,000	mg/l
SS	16,000	mg/l
TKN	600	mg/l

Open-Type Anaerobic Pond

CODin	=	1,800	mg/l
BODin	=	900	mg/l
Flow rate	=	4.5	m^3/d

Fermenting Period	=	80			days
Pond Volume	=	80 x 4.5	=	360	m^3
Pond Dimension	=	15 x 15 x 3.5			
Side Slope	=	1 : 1			
Free Board	=	0.5			m.
Effective Depth	=	3.0			m.
Water Surface Area	=	(15-1) (15-1)	=	196	m^2
Bottom Area	=	(15-7) (15-7)	=	64	m^2
Mid. Depth Area	=	(196+64)/2	=	130	m^2
Effective Volume	=	130 x 3.0	=	390	m^3
<u>Check</u>					
BOD Loading Rate	=	900 x 4.5 / (1,000 x 390)	=	0.01	kg/ m^3-day
HRT	=	390/4.5	=	87	days
Treatment Efficiency for BOD	=	60%			
Hence, BODout	=	900 x 0.4	=	360	mg/l

Sediment Drying Space

Drying Period	=	4	days
Space Dimension	=	2.0 x 1.0 x 0.25 m.	per track
Tracks Needed	=	4	tracks

2. Treatment System for 250 Swine

Flow rate	11.1	m^3/day
pH	7.0-8.0	
BOD	9,000	mg/l
COD	18,000	mg/l
SS	16,000	mg/l
TKN	600	mg/l

Open-Type Anaerobic Pond

CODin	=	1,800	mg/l
BODin	=	900	mg/l
Flow rate	=	11.1	m^3/day

Fermenting Period	=	20			days
Pond Volume	=	20 x 11.1	=	222	m^3
Pond Dimension	=	15 x 15 x 3.5			
Side Slope	=	1 : 1			
Free Board	=	0.5			m.
Effective Depth	=	3.0			m.
Water Surface Area	=	(15-1) (15-1)	=	196	m^2
Bottom Area	=	(15-7) (15-7)	=	64	m^2
Mid. Depth Area	=	(196+64)/2	=	130	m^2
Effective Volume	=	130 x 3.0	=	390	m^3
<u>Check</u>					
BOD Loading Rate	=	900 x 11.1 / (1,000 x 390)	=	0.03	kg/ m^3-day
HRT	=	390/11.1	=	35	days
Treatment Efficiency for BOD	=	60%			
Hence, BODout	=	900 x 0.4	=	360	mg/l

Sediment Drying Space

Drying Period	=	4	days
Space Dimension	=	4.0 x 1.0 x 0.25 m.	per track
Tracks Needed	=	4	tracks

3. Treatment System for 500 Swine

Flow rate	22.2	m^3/day
pH	7.0-8.0	
BOD	9,000	mg/l
COD	18,000	mg/l
SS	16,000	mg/l
TKN	600	mg/l

Open-Type Anaerobic Pond

CODin	=	1,800	mg/l
BODin	=	900	mg/l
Flow rate	=	22.2	m^3/day

Fermenting Period	=	20			days
Pond Volume	=	20 x 22.2	=	444	m^3
Pond Dimension	=	15 x 20 x 3.5			
Side Slope	=	1 : 1			
Free Board	=	0.5			m.
Effective Depth	=	3.0			m.
Water Surface Area	=	(15-1) (20-1)	=	266	m^2
Bottom Area	=	(15-7) (20-7)	=	104	m^2
Mid. Depth Area	=	(266+104)/2	=	185	m^2
Effective Volume	=	185 x 3.0	=	555	m^3
<u>Check</u>					
BOD Loading Rate	=	900 x 22.2 / (1,000 x 555)	=	0.04	kg/ m^3-day
Treatment Efficiency for BOD	=	60%			
Hence, BODout	=	900 x 0.4	=	360	mg/l

Sediment Drying Space

Drying Period	=	7	days
Space Dimension	=	2.0 x 4.0 x 0.3 m.	per track
Tracks Needed	=	7	tracks

4. Treatment System for 1,000 Swine

Flow rate	44.4	m^3/day
pH	7.0-8.0	
BOD	9,000	mg/l
COD	18,000	mg/l
SS	16,000	mg/l
TKN	600	mg/l

Open-Type Anaerobic Pond

CODin = 1,800 mg/l
BODin = 900 mg/l
Flow rate = 44.4 m^3/day

Fermenting Period	=	20			days
Pond Volume	=	20 x 44.4	=	888	m^3
Pond Dimension	=	20 x 25 x 3.5			
Side Slope	=	1 : 1			
Free Board	=	0.5			m.
Effective Depth	=	3.0			m.
Water Surface Area	=	(20-1) (25-1)	=	456	m^2
Bottom Area	=	(20-7) (25-7)	=	234	m^2
Mid. Depth Area	=	(456+234)/2	=	345	m^2
Effective Volume	=	345 x 3.0	=	1,035	m^3
<u>Check</u>					
BOD Loading Rate	=	900 x 44.4/(1,000 x 1,035)	=	0.04	kg/ m^3-day
Treatment Efficiency for BOD	=	60%			
Hence, BODout	=	900 x 0.4	=	360	mg/l

Sediment Drying Space

Drying Period	=	7	days
Space Dimension	=	2.0 x 7 x 0.3 m.	per track
Tracks Needed	=	7	tracks

5. Summary of Estimated Construction Costs

Treatment Systems	Numbers of Swine for Each Treatment System			
	100	250	500	1,000
Waste Filtrating Grill	2,576	2,576	2,576	2,576
Wastewater Pond	14,493	16,663	17,263	25,580
Closed-Type Anaerobic Pond	95,862	145,016	198,386	316,154
Sediment Drying Space	16,989	24,619	58,920	82,637
Open-Type Anaerobic Pond	30,204	50,556	97,056	164,556
Total	160,124	239,431	239,431	591,503

6. Formula for Calculating Abatement Costs

Annual Abatement Cost for Pollutant *i* is:

$$(Flow_i \cdot Load_i \cdot Treat_i)\left[(\frac{d(1+d)^{t-1}}{(1+d)^{t-1}-1} \cdot Invst) + Operate\right] + Chem_i + Other_i$$

where, $Flow_i$ is the flow rate of pollutant *i*,

$Load_i$ is the loading rate of pollutant *i*,

$Treat_i$ is the treatment efficient rate of pollutant *i*,

$Invst$ is the investment cost for the farm abatement system,

$Operate$ is the operating (running) cost for the farm abatement system,

$Chem_i$ is the chemical or organic substance cost used to abate pollutant *i*,

$Other_i$ is the other cost for abating pollutant *i*,

i is types of pollutant, *i* = P, TKN, BOD, COD, SS, and pH,

d is a discount rate,

t is lifetime of the farm abatement system

APPENDIX C: EXAMPLE OF PARETO EFFICIENCY DERIVATION

To show a derivation of a Pareto optimality, for simplicity, let assume 2-person (A and B) economy exist with a market clearing condition and each person has his own utility level represented by U^A and U^B, and they are assumed to satisfy monotonicity, quasiconcavety, and differentiability properties. These 2 persons are willing to trade 2 commodities X_1 and X_2 associated with the prices of p_1 and p_2, respectively. However, these 2 commodities are produced by a monotonic-concave-differentiable production function using Z_1 and Z_2 as production inputs with respect to the input prices of w_1 and w_2, respectively. The two persons are assumed to be reasonable in seeking utility maximizations and cost minimization as mathematically demonstrated as follows (developed from RICHTER, 1998):

For the cost minimization problem, the objective function is,

$$Min\ C = w_1(Z_1^{X_1} + Z_1^{X_2}) + w_2(Z_2^{X_1} + Z_2^{X_2}) \quad (1a)$$

subject to

$$X_1(Z_1^{X_1}, Z_2^{X_1}) \quad (1b)$$

and

$$X_2(Z_1^{X_2}, Z_2^{X_2}) \quad (1c)$$

The above objective function indicates that the 2 inputs, Z_1 and Z_2, are allocated to produce the curtain quantities of commodities X_1 and X_2 under the existing technological level in order to reach the minimum production cost as the ultimate goal. Likewise, the Lagrangian of cost minimization is applied as follows:

$$L = w_1(Z_1^{X_1} + Z_1^{X_2}) + w_2(Z_2^{X_1} + Z_2^{X_2}) - l_1\left[X_1(Z_1^{X_1}, Z_2^{X_1})\right] - l_2\left[X_2(Z_1^{X_2}, Z_2^{X_2})\right] \quad (1d)$$

under the first order conditions, such that,

$$\frac{\partial L}{\partial Z_1^{X_1}} = w_1 - l_1 X_1^{Z_1} = 0 \quad (1e)$$

$$\frac{\partial L}{\partial Z_1^{X_2}} = w_1 - l_2 X_2^{Z_1} = 0 \quad (1f)$$

$$\frac{\partial L}{\partial Z_2^{X_1}} = w_2 - l_1 X_1^{Z_2} = 0 \quad (1g)$$

$$\frac{\partial L}{\partial Z_2^{X_2}} = w_2 - l_2 X_2^{Z_2} = 0 \quad (1h)$$

$$\frac{\partial L}{\partial l_1} = X_1(Z_1^{X_1}, Z_2^{X_1}) = 0 \quad (1i)$$

$$\frac{\partial L}{\partial l_2} = X_2(Z_1^{X_2}, Z_2^{X_2}) = 0 \tag{1j}$$

rearranging and dividing (1e) by (1g), and (1f) by (1h), satisfy,

$$\frac{X_1^{Z_1}(Z_1^{X_1}, Z_2^{X_1})}{X_1^{Z_2}(Z_1^{X_2}, Z_2^{X_2})} = \frac{w_1}{w_2} \tag{1k}$$

$$\frac{X_2^{Z_1}(Z_1^{X_1}, Z_2^{X_1})}{X_2^{Z_2}(Z_1^{X_2}, Z_2^{X_2})} = \frac{w_1}{w_2} \tag{1l}$$

The left hand sides of both equations (1k) and (1l) are the ratios of the marginal physical product (MPP) of producing the 2 commodities X_1 and X_2 by using inputs Z_1 and Z_2, respectively. Actually, these ratios identically represent the marginal rates of technical substitution ($MRTS$) often called the marginal rates of transformation between 2 factor inputs. Therefore, the Pareto efficiency for the cost minimization problem occurs when the $MRTS$ of the two inputs used to produce the two commodities and their input price ratios are equivalent as shown in the following (1m) and (1n),

$$\frac{MPP_{Z_1}^{X_1}}{MPP_{Z_2}^{X_1}} = \frac{MPP_{Z_1}^{X_2}}{MPP_{Z_2}^{X_2}} = \frac{w_1}{w_2} \tag{1m}$$

$$MRTS_{Z_1Z_2}^{X_1} = MRTS_{Z_1Z_2}^{X_2} = \frac{w_1}{w_2} \tag{1n}$$

On the other side, the welfare maximization problem yields the objective function of,

$$Max\, W = U^A(X_1^A, X_2^A) + U^B(X_1^B, X_2^B) \tag{2a}$$

subject to

$$p_1(X_1^A + X_1^B) + p_2(X_2^A + X_2^B) = M \tag{2b}$$

This means that both persons are willing to maximize their social welfare, denoted by W, by consuming and trading 2 commodities with respect to the sum of their monetary income budgets, M. To solve this problem, the Lagrangian of welfare maximization is employed as follows:

$$L = U^A(X_1^A, X_2^A) + U^B(X_1^B, X_2^B) - l\left[p_1(X_1^A + X_1^B) + p_2(X_2^A + X_2^B) - M\right] \tag{2c}$$

under the first order conditions, such that,

$$\frac{\partial L}{\partial X_1^A} = U_1^A(X_1^A, X_2^A) - l p_1 = 0 \tag{2d}$$

$$\frac{\partial L}{\partial X_1^B} = U_1^B(X_1^B, X_2^B) - l p_1 = 0 \tag{2e}$$

$$\frac{\partial L}{\partial X_2^A} = U_2^A(X_1^A, X_2^A) - l p_2 = 0 \tag{2f}$$

$$\frac{\partial L}{\partial X_2^B} = U_2^B(X_1^B, X_2^B) - l p_2 = 0 \tag{2g}$$

$$\frac{\partial L}{\partial l} = p_1(X_1^A + X_1^B) + p_2(X_2^A + X_2^B) - M = 0 \tag{2h}$$

rearranging and dividing (2d) by (2f), and (2e) by (2g), satisfy,

$$\frac{U_1^A(X_1^A, X_2^A)}{U_2^A(X_1^A, X_2^A)} = \frac{p_1}{p_2} \tag{2i}$$

and

$$\frac{U_1^B(X_1^B, X_2^B)}{U_2^B(X_1^B, X_2^B)} = \frac{p_1}{p_2} \tag{2j}$$

The left hand sides of both equations (2i) and (2j) are the ratios of the marginal utility (MU) of consuming the 2 commodities by Persons A and B, respectively. In other words, these ratios identically represent the marginal rates of substitution (MRS) between 2 commodities. As a result, the Pareto efficiency for the social welfare maximization problem occurs when the MRS of the commodities derived from the 2 persons in this case and their price ratios are equivalent as presented in the following (2k) and (2l),

$$\frac{MU_{X_1}^A}{MU_{X_2}^A} = \frac{MU_{X_1}^B}{MU_{X_2}^B} = \frac{p_1}{p_2} \tag{2k}$$

$$MRS_{X_1X_2}^A = MRS_{X_1X_2}^B = \frac{p_1}{p_2} \tag{2l}$$

Since the condition of profit maximization for the competitive market is where the marginal revenue (simply p_1 and p_2) is equal to the marginal cost (simply w_1 and w_2), such that,

$$MRTS_{Z_1Z_2}^{X_1} = MRTS_{Z_1Z_2}^{X_2} = MRS_{X_1X_2}^A = MRS_{X_1X_2}^B = \frac{p_1}{p_2} = \frac{w_1}{w_2} \tag{3a}$$

The identity of the competitive market equilibrium in (3a) implies that the Pareto efficiency exists in the competitive market in which it is impossible to make a change for making at least somebody better off without making somebody worse off in the society.

Graphically, Figure A.1 shows how the Pareto optimum can be socially obtained by following the preceding setup problems. The 2 persons are willing to trade 2 commodities (X_1 and X_2) according to the price ratio of p_1 and p_2 under the plausible production technology and resource availability represented by the production possibility frontier (*PPF*) which is associated with the input price ratio of w_1 and w_2. As such, the two will exchange the commodities to reach a Pareto optimum as long as they are on the contract curve $O^A O^B$ and this contract curve is connected to the point where PPF is adjacent to the Scitovsky or social indifferent curve represented by SIC. At this point, it implies that the Pareto optimum is attained and it is also Pareto efficient.

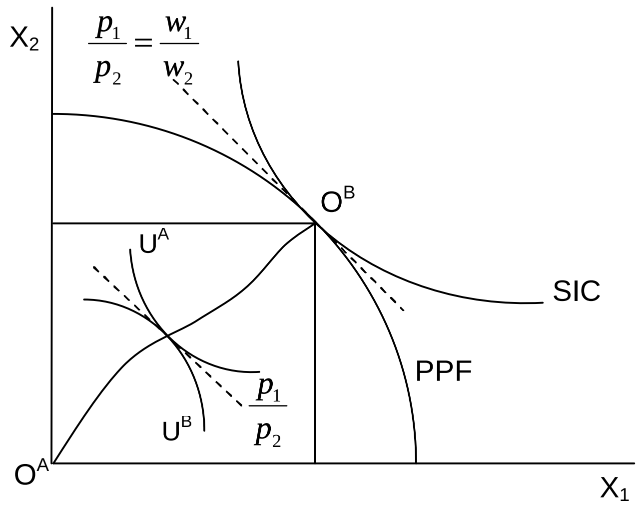

Figure A.1: Social Welfare Maximization

Source: Adapted from JUST et al., 2004.

APPENDIX D: GRAPHICAL ILLUSTRATION OF CV AND EV

Figure A.2 depicts CV and EV in a case of price decrease (welfare gain). U_1 and U_2 represent different utility levels of a person who consumes goods X_1 and X_2. Initially, this person consumes the goods at point a attaining a utility level at U_1 and change to consume at point ***b*** attaining a higher utility level at U_2 when the price of X_1 decreases. To leave this person as well off as before at U_1, income $(m_1 - m_2)$ must be taken away from this person so that he can attain the same utility level at U_1 under the new consumption combination at point ***d***. On the other hand, income $(m_3 - m_1)$ must be given to this person to make him as well off as the new utility level U_2 had occurred, therefore, the new consumption combination is located at point ***c***.

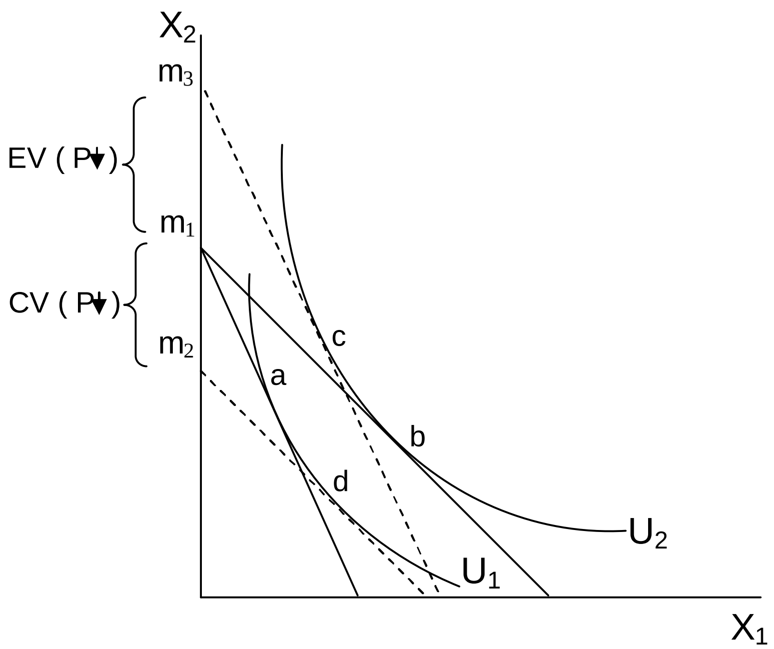

Figure A.2: Compensating and Equivalent Variations

Source: Adapted from JUST et al., 1982.

APPENDIX E: SOME PHOTOS ABOUT THE STUDY AREA

Swine Barns in the Study Area

Farm Drainage Areas

Open-Type Anaerobic Ponds (Left) and Lagoon (Right)

The Chedi Bucha Canal (Major Public Canal in the Study Area)

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