Final Report

Establishment of Knowledge and Network of Researchers on Environment and Climate Change in Thailand and Neighboring Countries (CLMV-T)

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Establishment of Knowledge and Network of Researchers on Environment and Climate Change in Thailand and Neighboring Countries (CLMV-T)

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ABBREVIATIONS

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
AEGE	ASEAN Expert Group on Environment
ALGAS	Least Cost Greenhouse Gas Abatement Strategy Project
ASEAN	Association of Southeast Asian Nations
ASOEN	ASEAN Senior Officials on Environment
BMP	Best Management Practices
CDM	Clean Development Mechanism
CEU	Car Equivalent Unit
CIA	Central Intelligence Agency
CITES	Convention on International Trade of Endangered Species of Wild Fauna and Flora
CLMV	Cambodia, Lao PDR, Myanmar and Vietnam
CO	Carbon Monoxide
CO_2	Carbon dioxide
COST	Committee on Science and Technology
DEQP	Department of Environmental Quality Promotion
EKC	Environmental Kuznets Curve
EU	European Union
GAP	Good Agricultural Practices
GDP	Gross Domestic Products
GEF	Global Environment Facility
GHG	Greenhouse gases
GIS	Geographical Information System
GMS	Greater Mekong Sub region
GMSARN	Greater Mekong Sub-region Academic and Research network
GPP	Gross Provincial Product
GPP	Gross Provincial Products
GRP	Gross Regional Products
IAI	Initiative for ASEAN Integration
IUCN	International Union for Conservation of Nature
LNTA	Lao National Tourism Administration

LUCF	Land use change and forestry
MOE	Ministry of Environment (Cambodia)
MONRE	Ministry of Natural Resources and Environment (Vietnam)
MRC	Mekong River Commission
NC	National Communications
NCCOP	National Climate Change and Ozone Protection Office (Vietnam)
NCEA	National Commission on Environmental Affairs (Myanmar)
NO	Nitric oxide
NO_2	Nitrogen dioxide
NTFPs	Non-timber Forest Products
PM_{10}	Particulate Matter smaller than 10 micron
PPM	Phnom Penh Municipality
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SCS	UNEP/GEF Project: Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand
SO_2	sulfur dioxide
STEA	Science Technology and Environment Agency
TRF	Thailand Research Fund
TSP	Total Suspended Particulates
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP RRCAP	UNEP Regional Resource Center for Asia and the Pacific
UNEP WCMC	UNEP World Conservation Monitoring Center
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
VEPA	Vietnam Environment Protection Agency
WCS	Wildlife Conservation Society

CHAPTER 1:INTRODUCTION

Thailand Research Fund (TRF) has initiated a project to establish research collaboration between Thailand and neighboring countries i.e. Cambodia, Laos, Myanmar and Vietnam (CLMV-T). The main objectives of this initiative are to establish academic data and information on priority areas of common interest such as food security, ecosystem, water resources and climate changes as well as to set up a research network at both individual and institutional levels to respond to the need of this region. The first phase of collaboration involved organization of consultative meetings among researchers from Laos, Vietnam and Thailand. The main objective of the meetings is to identify potential areas for initial collaborative research. After several meetings, it was agreed that "Threats to Food Security" will be one of the important emerging issues for the initial phase. It was further agreed that the research should be focus on sustainable agriculture and involve linkages between food production and economic, social, and environmental factors. In implementing the project, researchers were divided into two groups:

- Economic transition and social changes and
- Agriculture, environment and food security

1.1 OBJECTIVES

This report is the outcome from the group on agriculture, environment and food security. The main objectives were to:

- Review and synthesis existing research knowledge on environment and climate change focusing on agricultural issues;
- Identify priority areas for collaborative research; and
- Suggest a framework for establishing collaborative research and networking among researchers in the field of environment and climate change.

1.2 METHODOLOGY

The methodology used for this project was based on the evaluation and assessment of the secondary data collected from published reports of relevant organizations including international and regional organizations, government agencies, universities and research institutions. Meetings of researchers and representatives from relevant organizations were also conducted to exchange information and report the progress of their projects. Finally, outcomes of the research will be shared at the technical conference to identify areas for collaborative research in the future.

The scope of work included:

3.1. Review current status on research on environment and climate change in CLMV countries and to recommend framework for research and guideline on the establishment of network of researchers in CLMV – T countries;

3.2. Review on current status on non-point source of pollution from agriculture in Thailand;

3.3. Coordination and Synthesis Knowledge on "Agricultural Sustainability: Challenges in Environment and Climate Change" focusing on the followings:

- Economic Growth and Environmental Degradation: Linkages and Implications,

- Non-point Sources of Pollution from Agriculture,
- Climate Vulnerability and Agricultural Development,
- Implications of Climate Change Mitigation Mechanisms on Agriculture Sector,
- Capacity Building on Climate Change and Environment: Education and Training,
- Climate Change and Biodiversity.

1.2.1 Review current status on research on environment and climate change in CLMV countries

The objectives of this activity were to review current status on research on environment and climate change in four countries namely Cambodia, Lao PDR, Myanmar and Vietnam; and to recommend areas for future research and framework for collaborative research between CLMV countries and Thailand.

One research assistant was recruited for collecting information on existing research in four CLMV countries for 3 months. Most of the data were collected from the internet and was limited to data available in English language.

The first draft of the review paper was submitted to TRF on 18 May 2009. This paper was also presented at the Technical Conference on 27 May 2009 at the Grand Millennium Hotel, Bangkok. The final draft was submitted to TRF on 12 July 2009. The final version of review report is presented in Chapter 2 of this report. The outcomes of this chapter will be integrated with the outcomes from the synthesis of projects on "Agricultural Sustainability: Challenges in Environment and Climate Change" which is presented in Chapter 4.

1.2.2 Review on current status on non-point source of pollution from agriculture in Thailand

This review was carried out by Assistant Professor Dr. Anat Thapinta and Dr. Tatsanawalai Utarasakul from Faculty of Science and Technology, Suan Sunandha Rajabhat University and Ms Sunee Thabinta from Department of Pollution Control.

The objectives of this project are as follow:-

- To compile and review information in respect to state of knowledge on non-point source pollution from agriculture,
- To review current situation of existing researches and identify gaps for future works which can improve or update the knowledge on non-point source pollution from agriculture,
- To recommend areas for collaborative researches and mitigation measures that can be shared with neighboring countries in the future.

This project is based on secondary data from collected from government reports, journals and other relevant published papers. Data from the year 2000 to 2009 was used to evaluate current status on non-point source pollution from agriculture of the country. The full report of the review is presented in Chapter 3 of this report.

1.2.3 Coordination and Synthesis Knowledge on "Agricultural Sustainability: Challenges in Environment and Climate Change"

The first consultative meeting of researchers was organized at the Faculty of Economics, Nong Lam University in November 2008 to identify areas for collaborative research. The meeting was attended by researchers from Lao PDR, Vietnam and Thailand. The meeting agreed that the theme of the initial phase of collaborative research should be food security. The meeting also agreed that research should focus on linkages between agriculture and social, economic and environmental factors.

There were total of 15 projects on food security and 6 of these projects on linkages to environment and climate change, four projects in Thailand, 1 project in Vietnam and 1 project in Lao PDR. They are:

1. Economic Growth and Environmental Degradation in Thailand: Linkage and Implications;
2. Climate Change and its Mitigation Mechanisms: Implications on Agriculture and Food Security in Thailand;
3. Understanding the Linkage of Biodiversity and Agricultural Sustainability under the Current Environmental Change in Thailand;
4. Current Status on Non-point Sources of Pollution from Agriculture in Thailand;
5. Food Security and Agricultural Sustainability: Challenge and Opportunity in Vegetable Production in the Lao PDR; and
6. Food security and Environment: Case Study of Rice Production and its impacts on Environment in Go Cong Dong District, Tien Giang Province.

A follow-up meeting between researchers from Lao and Vietnam and Thailand was organized at the Faculty of Economics, Nong Lam University on 30 March 2009 to discuss the progress of the projects in Vietnam. Comments and suggestions were given in order to complete the report. In addition, three meetings of Thai researchers were organized at TRF to report the progress of the projects in Thailand and to provide comments and suggestions on the projects.

All researchers attended the Conference on Cooperation of Countries in Asian Sub-region organized by TRF on 25-30 May 2009 at Grand Millennium Hotel, Bangkok. The conference was divided into two sessions: "Agriculture, Environment, Food Security and Cooperation of Countries in Asian Sub-region" on 25-27 May 2009 and "Economic Transition and Social Changes of Countries in Asian Sub-region" on 28-30 May 2009. The outcomes of all 6 projects were presented at this conference and there was a discussion on the potential areas for full projects on the last day.

The outcomes of the technical conference and meetings were used as inputs to the synthesis which is presented in Chapter 4 of this report.

CHAPTER 2:CURRENT STATUS ON RESEARCH ON ENVIRONMENT AND CLIMATE CHANGE IN CLMV COUNTRIES

The objective of this chapter is to review current status on research on environment and climate change in Cambodia. Lao PDR, Myanmar and Vietnam (these countries will be referred to as CLMV countries). It first describes socioeconomic conditions, state of the environment, institutional and legal arrangement and existing research in each country. Based on future trends and challenges, it identifies priority areas for research and recommends framework for research collaboration and the establishment of a network of researchers in CLMV countries and Thailand.

2.1 SOCIO-ECONOMIC CONDITION

CLMV countries are situated in the Southeast Asia Region, covering the area of about 1.4 million km^2 and with population of about 155 million (CIA, n.d.). Cambodia, Lao PDR and Myanmar have borders with Thailand while Vietnam is connected to Thailand via the Gulf of Thailand (see Figure 2.1).

Figure 2.1: Map of CLMV Countries

These countries are very important to Thailand in term of economic, political and environment. According to Table 2.1, Myanmar is the largest country with a total area of 678,500 km^2, while Cambodia is the smallest with a total area of 181,040 $km^{2.}$ All CLMV countries have coastlines except Lao PDR. Vietnam has the longest coastline of 3,440 km while Cambodia has only 444 km. Although Lao PDR is a land-locked country, Lao PDR is connected to the sea via the Mekong River. Vietnam has the highest population of about 87 millions in 2008 which is about 12 times more than population of Lao PDR. Cambodia, Lao PDR and Myanmar are among the poorest countries in Asia, with more than 30% of population below the poverty line. Majority of people live in the rural area and engage in subsistence agriculture.

Table 2.1: Comparison of key indicators of CLMV countries

	Cambodia	Lao PDR	Myanmar	Vietnam
Total area (km^2)	181,040	236,800	678,500	329,560
Coastline(2008)	443 km	0 km	1,930 km	3,444 km
Population (2008)	14,241,640	6,677,534	47,758,180	86,116,560
Population growth rate (2008)[1]	1.752% (2008)	2.344% (2008)	0.8% (2008)	0.99% (2008)
Population below poverty line (%)	35 (2004)	30.7 (2005)	32.7 (2007)	14.8 (2007)
GDP (2008 est.) :Agriculture	29.00%	39.20%	40.90%	19.00%
GDP (2008 est.): Industry:	30.00%	34.30%	19.70%	42.70%
GDP (2008 est.): Services	41.00%	26.60%	39.30%	38.40%
GDP – per capita (2008 est.)	USD 2,000	USD 2,100	USD 1,200	USD 2,800
GDP – real growth rate (2008 est.)	6.8%	7.5%	0.9%	6.2%

Source: CIA World Factbook (www.cia.gov/libary/publications/the-world-factbook/)

The economy of all CLMV countries is based on agriculture. However, similar to other developing countries, the CLMV countries are experiencing a decrease in Gross Domestic Product (GDP) from agriculture and an increase in GDP from industry. For example in Lao PDR, GDP from agriculture dropped from 49.4% in 2004 to 39.2 % in 2008 while GDP from industry grew from 24.5 % in 2004 to 34.3 % in 2008 (CIA, n.d.). Industrial development in Vietnam is highest in the region. According to Table 2.1, the estimated 2008 GDP from industrial sector in Vietnam is more than double of the GDP from agriculture.

Due to the topography of the country, Lao PDR has very limited areas for agriculture as most of the land areas are mountainous. Only 4% of total land area is suitable for agriculture (CIA, n.d.). Rice is the most important crop for all countries. According to Figure 2.2, paddy rice sown areas in 2004 are more than 50% of cropland in all countries except Myanmar (Xiao et al., 2005). Vietnam has the largest area of rice with 73,000 km^2 which is more than 9 times more than Lao PDR and three times of Cambodia. Furthermore, Vietnam paddy rice area account for about 22% of the country area which is the highest among CLMV countries (Xiao et al., 2005).

According to Figure 2.2, Vietnam has the highest rice production, which is 35.5 million tons (Xiao et al., 2005). In general, rice production is mainly for consumption within the country. However, a large amount of rice production in Vietnam is also for export. In 2003 Vietnam exported 3.8 million tons of rice, making Vietnam one of the lead rice exporting countries of the world (USDA, 2003).

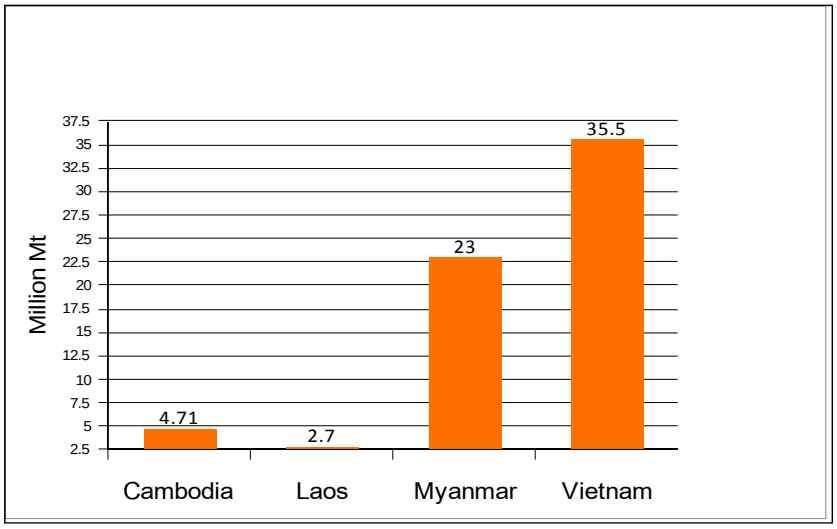

Figure 2.2: Rice Production in 2004

Developed from Xiao et al., 2005

All CLMV countries are experiencing rapid industrial development. It is estimated that industrial production growth rates vary from 7 to11 % in 2008 (CIA, n.d.). In Lao PDR, output from mining contributed to 19.5% of the industrial sector. It is expected that mining will continue to grow at a rate of approximately 11% per year during 2006-2010 (Phetsomphou, 2007). Forest products are important for Cambodia, Lao PDR and Myanmar. A lot of forest areas have been under commercial concession for wood products. Export of wood products is the major source of income in these countries.

Recently tourism development in CLMV countries has also grown more rapidly. Number of tourists visiting Lao PDR grew from 14,400 in 1990, to 1.1 million in 2005 (LNTA, 2009). It is expected that annual revenue from tourism will increase to USD 250-300 million in 2020 (LNTA, 2009).

2.1.1 Lao PDR

Lao PDR is the only landlocked country in the region and shares the borders with all CLMV countries. The landscape is mainly mountainous and most of the land areas are covered with forest. Forest cover constitutes more than 50% of the total land area (Stibig et al., 2007). About 80% of arable land is used for rice cultivation (Xiao et al., 2005). About eighty percent of the population is employed in agriculture, mainly subsistent agriculture. Lao PDR is dependent on natural resources such as water, forest and minerals. With plenty of water and suitable topography, Lao PDR can develop many hydropower projects which provide excess electricity for export to neighboring countries including Thailand. The country's economy is now developing more rapidly and is moving towards industrialization.

2.1.2 Cambodia

Cambodia is a small country with the size of almost four times smaller than Myanmar. The central plain covers about 75% of the whole country and is surrounded by mountains and plateaus. The central plain comprises the alluvial plain of the Mekong River and the Tonle Sap Basin and coastal plain in the southwest. Over 80% of population lives in rural areas, 52% of which live in the central plains (MOE, 1998). The country economy is dependent on agriculture, fisheries and forestry.

Presently, about 30 percent of Cambodia's population depends on the Tonle Sap Lake and its floodplain for their livelihood (MOE, 1998). It is the largest freshwater lake in Asia and the size of the lake is regulated by water flow from Mekong River. The lake is about 250 km long and 100 km wide during the rainy season and about 120 km long and 35 km wide during the dry season (MOE, 1998). The water surface expands from 250,000-300,000 ha during the dry season to 1.1- 1.3 million ha during the rainy season (MOE, 1998). The average depth of the Tonle Sap Lake increases from 1-2 m in the dry season to 8-10 m during the rainy season. The Tonle Sap is surrounded by a floodplain 20-40 km wide, which is dominated by inundated forests and rice fields (MOE, 1998). Tonle Sap Lake also provides an important fishing ground contributing about 53-68 % of the inland catch valued at USD 44-58 million a year which is about 5% of the country GDP (MOE, 1998). Tonle Sap Lake and Mekong River are the main sources for freshwater for irrigation and domestic uses. However, 60% of the people in the rural areas use ground water (MOE, 1998).

Garment and textile industry is one of the major contributors of the GDP from industrial sector. Revenue from tourism is also increasing as the Angkor Wat become more and more popular among international tourists. Electricity is still limited and the main source of electricity generation is diesel fuel (ADB, 2006). Alternative sources of energy such hydropower, clean coal, wind and solar is being considered (ADB, 2006).

2.1.3 Myanmar

The Union of Myanmar or formally known as Burma is the largest country in Southeast Asia. Burma changed the name to Myanmar in 1989. The country is dominated by three mountain ranges running north to south and three major river systems. Myanmar's population comprises seven major ethnic groups, 68 % of which is Burmese. Majority of people live in Ayarawadi Valley. The country is still rich with natural resources such as forest. At present, it is estimated that forest covers more than 50% of the land area.

The top three export earnings are from agricultural, petroleum and forestry sectors. Ranking third, forestry constitute 10% of the total export earnings in 2001/2002 (NCEA and UNEP RRCAP, 2006). Teak, ironwood and rosewood are the most valuable among forty-five commercial timber species (NCEA and UNEP RRCAP, 2006). Non-timber forest products included charcoal, bamboo, cane, resin, latex, honey, beeswax, edible bird nests, bat's guano, turpentine and orchids. Although Harvesting of non-wood products has been done on commercial scale it mainly supports livelihood of local people. The rate of deforestation was 2% between 1975 and 1989 and the loss was accelerated to 7% during 1989-1998 (NCEA and UNEP RRCAP, 2006).

As Myanmar is moving towards market economy, the country is likely to face many environmental problems. Rapid urbanization and industrialization since 1988 has created challenges for wastewater and solid waste management.

2.1.4 Vietnam

Vietnam has elongate shape similar to Lao PDR but with a long coastline of more than 3,200 km. Three-fourths of the land is mountainous area with an elevation mostly from 100 to 1000 meters (ADPC, 2003). There are 2,360 rivers in Vietnam but most of the rivers in Vietnam are small with less than 100 km^2 of basin area (ADPC, 2003). The nine major river basins account for 90% of total river basin in the country (World Bank, 2006). Six out of nine major river basins are transboundary (World Bank, 2006). More than two third of the population live in the two low-lying deltas: the Red River delta in the North and the Mekong delta in the south.

Vietnam population is the highest among CLMV countries. Population density is also the highest, which was about 260 people per km^2 in 2008 (CIA, n.d.). With family planning measures, Vietnam's population growth rate has gradually been reduced from 2.2 % in early 1990s to 1.7% in 1995 and 1.4% in 2000 (ADPC, 2003). The estimated population growth in 2008 is 0.99% compared to 2.34% in Lao PDR (CIA, n.d.).

In addition to the long coastline, there are about 3,000 islands in Vietnam. As a result the country economy is highly dependent on the marine resources. Vietnam has played an important role in marine transport in the region. Vietnam's sea has been used as navigational channel for commercial ships connecting the Indian Ocean and the Pacific Ocean. Vietnam also is one of two CLMV countries besides Myanmar that export oil. Oil production is based on offshore oil reserves (VEPA, 2003).

2.1.5 Regional and Sub-regional mechanisms

CLMV countries have established a close collaboration for many years. They are all the member of the Association of Southeast Asian Nations or ASEAN. Vietnam was the first countries to join ASEAN in 1995, followed by Lao PDR and Myanmar in 1997. Cambodia is the last country to become a member of ASEAN in 1999. In addition, they also jointly established several sub-regional cooperation frameworks such as the Mekong River Commission.

Mekong River Commission (MRC)

The Mekong River Commission was established in 1995 by the Governments of Cambodia, Lao PDR, Thailand and Vietnam aiming at joint management and development of the Mekong River Basin. Based on the principle of Integrated Water Resources Management, MRC's programme have been conducted in irrigation and drought management; navigation; hydropower; flood management; fisheries; watershed management; environment and tourism.

Association of Southeast Asian Nations (ASEAN)

ASEAN has established many collaborative programmes including agriculture and forestry, economics (trade), energy, environment, finance, health, information, investment, labour, law, regional haze, rural development and poverty alleviation, science and technology, social welfare, telecommunications, transnational crime, transportation, tourism, youth. ASEAN initiated an environmental cooperation programme in 1977 through the formation of the ASEAN Expert Group on Environment (AEGE) under the ASEAN Committee on Science and Technology (ASEAN COST). In 1989, the AEGE was elevated to become the ASEAN Senior Officials on Environment (ASOEN) at the same level as the (ASEAN COST). The ASOEN provides operational policy guidance on the various environmental programmes under ASEAN, which are implemented by its working groups. ASOEN submit their recommendations to the ASEAN Ministerial Meeting on Environment for endorsement. At present ASEAN focuses it cooperation based on the Vientiane Action Programme (VAP).

In November 2000, the ASEAN Leaders agreed to launch an Initiative for ASEAN Integration (IAI) programme, aiming at narrowing the development gap between ASEAN's older and newer members. Later, the ASEAN Leaders, at their Summit Meeting in Phnom Penh in November 2002 endorsed a work plan to implement 48 projects. Funding for IAI projects are provided by the six ASEAN's old member countries as well as other donors.

The programmes, activities and projects under the current six-year IAI Work Plan (July 2002 – June 2008) are directed at strengthening the CLMV countries' capacity and capability in meeting the challenges ahead such as reducing poverty, preparing them to face global competition and also assisting them to gain some competitive edge in world markets. The

current IAI Work Plan for CLMV focuses on four priority areas, namely infrastructure development, human resource development, information and communication technology and promoting regional economic integration in the CLMV countries.

Greater Mekong Sub region (GMS)

The Greater Mekong Sub-region Programme was initiated in 1992 to promote economic cooperation in six countries bordering Mekong River namely Cambodia, Yunan Province of China, Lao PDR, Myanmar, Thailand and Vietnam. Various projects in transport, energy, telecommunications, environment, human resource development, tourism, trade, private sector investment, and agriculture have been implemented with support from the Asian Development Bank (ADB) and other donors. As a major donor, ADB finance 179 technical assistance projects focusing on human resource development, tourism, environment, trade and investment.

2.2 STATE OF ENVIRONMENT

CLMV Countries are rich with natural resources. About half of the region land is still covered with forest. People are dependent on natural forest for their livelihood. In most CLMV countries, environmental problems are mainly caused by over exploitation of natural resources but the extent of the problems varies from country to country. This section describes the state of environment and natural resources. It also shows some statistical data on natural resources and environment in the past and compares the state of environment among CLMV countries. Most of data available in this report is based on published national and regional reports for the period of the past twenty years.

2.2.1 Forest Resources

In the past, the CLMV region was covered with extensive forest. In 1990 Forest covers in Cambodia, Lao PDR, Myanmar and Vietnam were 73, 75, 60 and 29 percent of the total land area respectively (see Figure 2.1). Commercial forest production has been a major contribution to the economy, mainly from export of wood products. Local people also depend on non-timber forest products (NTFPs) for both household and commercial uses. Due to the demand for agricultural land, clearing of forest for agriculture has occurred both in upland and low land areas. Commercial logging and forest encroachment by local people for NTFPs and forest clearing for agriculture have contributed to degradation and loss of forest land.

In most CLMV countries, the demand for firewood is high, the use of fuel wood in Cambodia, Lao PDR and Myanmar account about 80% of the energy consumption. Fuel wood consumption in Vietnam was less than other countries. Fuel wood share in the traditional energy supply is about 84% while traditional fuels accounted for 37.8% of the total energy consumption in 1997 (Kumar et al., 2003).

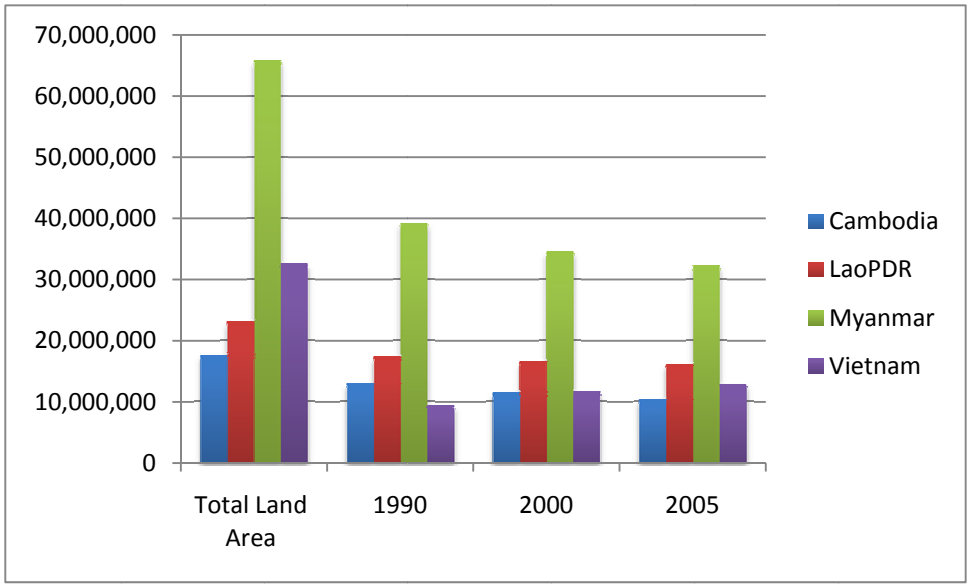

Figure 2.3: Forest and total land areas in CLMV Countries, 1990-2005 (ha.)

Developed from UNESCAP, 2008

Forest areas in the Cambodia, Lao PDR and Myanmar have continuously been decreasing since 1990. In 2005, percentages of forest in Cambodia, Lao PDR and Myanmar were 59, 69 and 49 respectively. The reverse trend was found in Vietnam, which had the least percentage of forest area among the CLMV countries. According to Figure 2.3, forest area in Vietnam has gradually been increasing from 9,363,000 ha in 1990 to 12,931,000 ha in 2005.

In Cambodia, percentage of forest decreased significantly from 73% in 1965 to 59.8% in 1993, with an average loss of about 0.4% during this period (DEQP and UNEP RRCAP, 2006). The reversing trend occurred in 1997 with an annual increase of 1.3% during 1997-2002 (MOE and UNEP RRCAP, 2006). Mangrove forests cover the southwest coastline and some coastal islands. It was estimated that mangrove forest was 72,835 ha in 1997 and the rate of loss increased from 1.1 during 1980-1990 to 1.6 during 1990-2000 (UNEP, 2004).

Deforestation rate in Lao PDR during 1982 – 1992 was 0.2%/year (Phongoudome et al., 2008). This problem increased during 1992 – 2002, rate of deforestation was 0.6%/year (Phongoudome et al., 2008). It was observed that the annual shifting cultivation area declined sharply from 0.8% of the total area in 1998 to 0.2 % of the total area in 2004 (STEA and UNEP RRCAP, 2006).

In 2005, about half of the land area in Myanmar was still covered with forests. The loss of forest cover increased from 2% of total land area during 1975 - 1989 to 7% during 1989 - 1998 (NCEA and UNEP RRCAP, 2006). Mangrove forests in the Delta Forest Reserve declined more than half from 253,018 ha in 1924 to 111,939 ha in 2001 (NCEA and UNEP RRCAP, 2006). Rice cultivation, charcoal production and shrimp farming were among the main causes of the decline. As a measure to solve this problem, the government banned wood extraction for charcoal in 1990. Loss of mangrove forest in the delta area is now mainly due to shrimp farming (NCEA and UNEP RRCAP, 2006).

Deforestation in Vietnam in the past was mainly caused by the use of chemicals during the war. It was estimated that more than 124,000 hectares of tidal mangrove (41%) and 26,000 hectares (27%) of rear mangrove forests were totally destroyed by the use of herbicides (Veilleux, 1994). The chemical spray also destroyed 44% of tropical rain forests and 60% of rubber plantations and at least 400,000 hectares of agricultural land, mostly paddy fields

(Veilleux, 1994). Ratio of roundwood production over total forest area increased from 2,273 M^3/1000 hectares in 1980 to 3,321 M^3/1000 hectares in 1990 (MONRE and UNEP RRCAP, 2006). The roundwood production is highest compared to other CLMV countries (MONRE and UNEP RRCAP, 2006). The gradual increase in forest area after 1990 is mainly due to reforestation. However, a study in three villages in the northwestern Vietnam indicated that an increase in forest areas was caused by agricultural intensification, which reduced pressure on agricultural land (Sigkor, 2001). Rapid increase in shrimp farming during 1980s was believed to be a main cause of mangrove destruction. Coastal aquaculture area increased from 356,000 ha in 1995 to 704,000 ha in 2003 (MONRE and UNEP RRCAP, 2006). Mangrove forest decreased to about 170,000 ha in 2001 (MONRE and UNEP RRCAP, 2006).

It can be concluded that common causes of deforestation are:

- Inadequate forest management of commercial forest and illegal logging;
- Shifting cultivation;
- Encroachment and land clearing caused by agriculture and urban expansion;
- Forest fire.

2.2.2 Soil Erosion and degradation

Soil erosion is common in all CLMV countries. Shifting cultivation is believed to be the main cause of soil erosion, especially in Lao PDR and Myanmar as there are many people who live in the upland areas. These people are mainly poor and depend on subsistent agriculture. The cultivated areas which are susceptible to soil erosion are located at altitudes of 1000 feet and above with the slopes of 10 degrees and above. The Myanmar Forests Department estimated that total vulnerable farming area with slopes of 10 degrees and more in these upland areas in 1998 was 4.8 million acres (NCEA and UNEP RRCAP, 2006). In Lao PDR, 70% of land area has slope more than 20 degrees (World Bank, 2005a).

Soil erosion is also caused by unregulated commercial logging and illegal logging in the upland areas. Forest logging and clearing around Tonle Sap has resulted in sedimentation load into the lake.

2.2.3 Loss of Biodiversity

The CLMV region is one of the richest biodiversity regions in the world. However, rapid economic development has threatened the region's rich biodiversity. The common causes of biodiversity loss include increased population, poverty and rapid economic development. Decreasing forest areas is one of the major threats of biodiversity. With a low rate of natural resource exploitation and a low population, the problem of biodiversity in Lao PDR is less compared to other CLMV countries. According to Table 2.2, Lao PDR had the least number of threatened species while Vietnam had highest number.

Table 2.2: Number of threatened species in each country

	Mammals	Birds	Reptiles	Amphibians	Fishes	Mollusks	Other Invertebrates	Plants	Total
Cambodia	37	23	12	3	28	0	67	31	201
Lao PDR	46	21	11	5	23	0	3	21	130
Myanmar	45	39	22	0	28	1	63	38	236
Vietnam	54	36	27	16	45	0	92	147	417

Source: IUCN, 2009 http://www.iucnredlist.org/documents/summarystatistics/2009RL_Stats_Table_5.pdf

In term of biodiversity, wetlands are considered the most important ecosystems in Cambodia. They are habitats for many animals including at least 57 species listed on the IUCN Red List of globally threatened species (World Bank, 2003). Three Ramsar Sites includes the Koh Kapik and associated islets on the coast, the Boeng Chmar and associated river system in the Tonle Sap floodplain, and the middle stretches of the Mekong River north of Stoeng Treng in the northeast (World Bank, 2003). Tonle Sap, which is the largest permanent freshwater lake in Southeast Asia, is also recognized internationally as a Biosphere Reserve under the Man and Biosphere of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The biodiversity of the Tonle Sap and Mekong River system has been threatened by overfishing, illegal fishing, an increasing use of pesticides, unsustainable hunting, deforestation, conversion of flooded forests, and water resource development projects of the Mekong. Illegal international trade of wildlife was also identified as one of the major threats to biodiversity.

Biodiversity plays an important role in economic development and well being of the people, mostly subsistence farmers, as well as environmental protection. Although Lao still rich with biological resources compared to other CLMV countries, the country have faced heavy losses in biodiversity resources during the last few decades. Loss of biodiversity was caused by poor forest management, illegal logging, unsustainable hunting and fishing practices, wildlife trade, and shifting cultivation. Many rural people, particularly in the remote areas are dependent on wildlife, both for trade and consumption. International trade in wildlife and wildlife products also exists for curios, souvenirs and decorative items, and as ingredients of traditional medicines (MAF, 2003). Wildlife trade increased during the 1980s and 1990s and most of the wildlife trade is driven by demand outside the country (MAF, 2003).

There is a lack completed an inventory of its biological resources in Myanmar and the biodiversity data therefore was expressed as the percentage of the number of threatened species at the national level over the number of threatened species at the global level which is approximately 2.4%. This figure comprises approximately 3.6% of globally threatened mammals, 4% of birds, 8.6% reptiles, and 1.3% of globally threatened fish (NCEA and UNEP RRCAP, 2006). It is certain that the greatest threat to biodiversity in Myanmar is overall decline in forest cover and forest habitats (NCEA and UNEP RRCAP, 2006). Completing for other land uses is one of the major threats to tropical rain forests and mangrove forest, which provide habitat to a wide range of threatened species. (NCEA and UNEP RRCAP, 2006).

Rapid economic development in Vietnam has created many adverse impacts on its rich biodiversity. In general, threats to terrestrial and marine ecosystems include commercial logging, rice farming, destructive fishing, aquaculture development, poaching and infrastructure development. Infrastructure development has facilitated international trade of wild life as well as an introduction of invasive species. Vietnam's international trade in 2002 was approximately 3,050 tons and was worth over $66 million (World Bank, 2005). Fire has been one of the main causes of forest loss. The annual rate of forest loss by fire during 1992-2002 was 6,000 hectares (World Bank, 2005). 80 % of coral reefs are threatened by destructive fishing (World Bank, 2005). Mangrove forests declined from 409,000 ha in 1943 to about 155,000 ha in 1999 (World Bank, 2005). The 62 % decrease was previously caused by the war and recently by rapid expansion of shrimp culture (World Bank, 2005). Although the governments have implemented reforestation programmes, the biodiversity of these forests is under threat. In Vietnam, the government has targeted for 43 % of forest cover by 2010 (World Bank, 2005b). Despite an increase in total forest area, the natural forest is fragmented and degraded and over two-third of natural forest is considered poor and regenerating (World Bank, 2005b).

2.2.4 Degradation of Water Resources and Water Pollution

Being agricultural based economy, water is an important resource of the region. In Cambodia, fundamental source of water are from natural sources such as rivers, lakes and ground water. Water use for agriculture is more than 50% while water uses for domestic and livestock are 17% and 10 % respectively (Aun, 2007). However, irrigation water is rather limited, therefore most farmers and fishermen live around Tonle Sap and tributaries of Mekong River. Both farmers and fishermen are dependent on Tonle Sap and Mekong for their livelihood.

Agriculture is a main source of water pollution in the rural areas, both in term of sediments and agricultural chemicals. Sewage and industrial effluents have caused pollution in the urban areas. Although the water quality of the Bassac, Mekong, and Tonle Sap rivers is declining due to increase in pollution loading from Phnom Penh, a water quality survey conducted by the Department of Environmental Pollution Control of the Ministry of Environment in 2001 showed that most of the pollutants were still within the standard limits (World Bank, 2003).

Despite an increasing demand, Lao will not face water shortage in the near future as the country has abundant water resources (STEA and UNEP RRCAP, 2006). Water shortage both for irrigation and consumption has been found only in some areas and during certain period of time (STEA and UNEP RRCAP, 2006). Hydropower is a main source of income through export of electricity to neighboring countries such as Thailand.

Compared to other countries in the region, water quality in Lao PDR is currently quite good and is not significantly affected by human activities. However localized degradation to some streams, rivers, and wetlands has occurred due to increased sedimentation caused by soil erosion from land clearing. The annual sedimentation from some rivers such as Xe Banghieng, Xe Done, Nam Ou, and the upper and lower stretches of the Mekong varied from 0.41 to 3.45 tons per hectare per year (World Bank, 2005a). Water quality in urban areas is declining due to wastewater discharges from domestic and industrial sources. Mining is another sector, which has potential impact on Lao's water resources. In addition to competing water use, mining may cause water pollution of surface water by waste discharge and tailings spill (World Bank, 2005a).

Similar to Lao PDR, there is adequate supply of water from natural sources in Myanmar. There are four major rivers namely Ayeyarwady, Sittaung, Thanlwin, Bago and their major tributaries. Their drainage areas are about 738,230 km² with 1,082 km³ of water volume per annum (Than, 2008). The estimated groundwater potential in Myanmar is about 495 km³ in eight principal river basins in Myanmar (Than, 2008). Irrigation projects include dams, river pumping stations and tube wells. Irrigated areas of farmland were about 1.7 million ha by dam, 188,000 ha by river pumping and 48,000 ha by tube wells (Than, 2008). The total irrigated area has increased up to 18% of the sown area in 2006-2007 (Than, 2008). Although there is no monitoring data, water quality is deteriorating due to discharging of sewage, solid wastes, industrial wastes and agrochemical wastes.

In Vietnam, there is an increasing pressure for other types of water uses beside agriculture. For example, economic expansion in the northern and southern economic focal region has resulted in a completing demand for water in agriculture, industrial and domestic uses (VEPA, 2006). The problem of inadequate supply of water in Cau River and the Nhue-Day River sub-basins in the north and the Noi Dai river basin in the south is worsen by pollution caused by rapid economic development in these areas.

Water pollution is critical in the three major rivers of Vietnam, Cau and Nhue-Day Rivers in the north and Dong Nai River in the South (VEPA, 2004). These rivers flow through major

cities such as Hanoi and Ho Chi Minh City. Many parts of these rivers suffered extremely high level of pollution, with low dissolved oxygen, high levels of COD and BOD, and high levels of coliform which exceed the standards (VEPA, 2004)

In conclusion, water pollution problems that countries are facing include sedimentation, wastes from agriculture in the rural areas and industrial and domestic wastes in the urban areas. The problem of sedimentation in rivers and other waterways has been mainly caused by deforestation and shifting cultivation in the upland areas. However, there is a lack of information on the quantity of sediment discharged into the rivers. There is also a lack of data to estimate pollutants released from agricultural activities into the rivers, lakes and streams. Domestic wastewater is another source of pollution in major cities in the region due to an increase in urban population and lack of wastewater treatment systems. Pollution from domestic and industrial sources is currently a localized problem especially in Vietnam.

2.2.5 Air Pollution

Rapid urbanization in CLMV countries has caused increasing air pollution, mainly from transportation and energy. The number of motorcycles and cars is increasing in most of the big cities such Ho Chi Minh City, Hanoi, Phnom Penh, Vientiane and Yangon. Furthermore, import of second-hand vehicles in many countries is also contributed to an increase in air pollution. Power generation is also a main contributor to air pollution in urban areas in Cambodia because power generators are often located along the road (ADB, 2006). Furthermore there is no control of import of second hand generators into Cambodia (ADB, 2006). The lack of air quality standards and emission standards has caused the problem to rise as it is difficult for authorities to implement pollution control measures. Although Cambodia has established mobile emissions standards, these standards are limited to only 3 sets, two sets for motorcycles (2-stoke and 4-stoke motorcycle) and one set for other vehicles. There is a need for emission standards for certain type and size of vehicles. Similar to other CLMV countries, monitoring data is quite limited to accurately assess the air pollution.

The number of motor vehicles has steadily rising in Yangon and Mandalay. The values of Car Equivalent Unit (CEU) per square kilometer between 1999 and 2004 increased by 13% and 39%, respectively (NCEA and UNEP RRCAP, 2006). At the same time fuel consumption per CEU has been declining.

In Ho Chi Minh City and Hanoi, the main source of air pollution is transportation, which account for 70 % of air pollution (Tung, 2004). In Hanoi, the number of car increased more than double from about 60,000 in 1995 to 130,000 in 2000 (Tung, 2004). The number of motorcycles in Hanoi increased from 600,000 to 1.2 million, which is about ten times more than cars. Other important sources of urban air pollution are industry and construction. In the rural area, air pollution is from forest fire.

There is a lack of regular monitoring system for air pollution in Cambodia, Lao PDR and Myanmar. Air quality monitoring has been carried out for the key pollutants i.e. total suspended particulate (TSP), Particulate Matter smaller than 10 micron (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Most monitoring has been carried out on a project basis with a few monitoring stations and a short monitoring period. The limited air quality data conducted in most big cities showed that air quality parameters except TSP are within the international guidelines for ambient air quality. Comprehensive and systematic monitoring programme is needed to accurately estimate the level of air pollution in all CLMV countries.

2.2.6 Solid Waste

CLMV countries share the common problems of increasing amount of solid wastes from

urban area. The amount of solid waste has been increasing due to expansion of urban areas and increasing urban population. In most countries, hospital wastes are incinerated onsite but there is no separated collection and treatment system for hazardous wastes.

The problem of solid waste in Cambodia has occurred in the capital city of Phnom Penh. The amount of waste generated in Phnom Penh Municipality (PPM) was 465 tonnes per day or about 72 % of the country. About 70% of the waste generated in PPM has been collected by private sector through franchising scheme, however, this method seemed not to be cost effective for the private sector (World Bank, 2003).

The annual waste (mainly domestic) generation in Lao PDR was 270,000 tons. The main source is from domestic wastes from urban areas with daily average of 0.75 kg per capita. There are only five landfills with small disposal areas and no leachate collection or monitoring wells in Vientiane and the four secondary towns (World Bank, 2005a).

According to the study by World Bank in 1999, the daily amount of solid waste generated was about 1,400 ton in Yangon compared to about 100 tons/day in Vientiane, Lao PDR (NCEA and UNEP RRCAP, 2006). Solid waste collection in Yangon increased from 39% in 19983 to 80 % in 2003 (NCEA and UNEP RRCAP, 2006). There was a clear improvement of solid waste collection in Yangon and Mandalay but not in the other states (NCEA and UNEP RRCAP, 2006).

Vietnam has the highest amount of solid waste generated among CLMV countries. The total annual waste generation is 12.8 million tons with average per capita of 0.4 kg. In term of collection, 71% of total waste is collected and disposed (World Bank, 2004). In conclusion, there is inadequate collection and disposal of domestic waste and no separate system for hazardous wastes in all countries.

2.2.7 Climate Change

The problem of climate change is the result of the greenhouse effect caused by emission of greenhouse gases (GHGs) into the atmosphere by human activities such as burning of fossil fuel, mining, industrial activities, land use change and forestry (LUCF). According to Table 2.3, all CLMV Countries have already been parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. All countries except Myanmar have submitted their initial NC.

Table 2.3: Status of CLMV Countries relating to UNFCCC

Country	UNFCCC (date of ratification)	Kyoto Protocol (date of ratification)	1st NC (date of submission)
Cambodia	18/12/1995	22/08/2002	2002
Lao PDR	04/01/1995	06/02/2003	2000
Myanmar	25/11/1994	13/08/2003	-
Vietnam	16/11/1994	25/9/2002	2003

The state of GHG emission in CLMV countries is determined by three main GHGs namely carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). At present emission of GHGs from CLMV countries is still low compared to other countries in ASEAN. CO_2 is mainly

GHGs emitted from energy and LUCF while CH_4 and N_2O are from agriculture activities.

Table 2.4 shows Total aggregate emissions and removals of CO_2, CH_4 and N_2O in CO_2 equivalent in CLMV countries (1990 for Lao PDR and Myanmar and 1994 for Cambodia and Vietnam). The emission data of all countries except Myanmar were GHG inventory drawn from the First NCs submitted to UNFCCC. Emission data for Myanmar was based on the GHG inventory under the Asia Least Cost Greenhouse Gas Abatement Strategy Project (ALGAS).

Table 2.4: Total aggregate emissions and removals of GHG (Gg)

Sector	Cambodia*	Lao PDR*	Myanmar**	Vietnam*
Energy	1,881.11 (14.7%)	929.85 (13.5%)	6,086.1	25,632.69 (30.4%)
Industrial process	4,985 (0.4%)	-	180.4	3,807.19 (4.5%)
Agriculture	10,559.05 (82.7%)	5,696.67 (83.0%)	39,202.0	52,444.90 (62.1%)
Land Use Change & Forestry (LUCF)	–17,907.69 (–140.3%)	–104,303.83 (–1,519.0%)	-6,655.7	19,384.78 (23%)
Waste	272.37 (2.1%)	240.03 (3.5%)	2.686.4	2,565.02 (3%)
Total without LUCF	12,762.38	6,866.55	48,154.9	84,449.80
Net emission (Total with LUCF)	-5,145.31	–97,437.28	41,499.9	103,834.58

Source: *UNFCCC, 2005 (http://unfccc.int/resource/docs/2005/sbi/eng/18a02.pdf)**NCEA,2006

According to Table 2.4, Cambodia and Lao PDR were net sink of all sectors while all countries except Vietnam were net sink of LUCF.

Percentage of total GHG emission of Cambodia from LUCF, agriculture and energy were approximately 81%, 16% and 3% respectively while percentage of total GHG emissions from industrial sector was insignificant (DEQP and UNEP RRCAP, 2006). In 1994 Cambodia sequestered about 73,000 Gg of CO_2-equivalent through land use change and forestry sector making Cambodia a net sink country (DEQP and UNEP RRCAP, 2006).

Compared to other countries Lao PDR had the highest CO_2 sequestration, which was 121,641 Gg (STEA and UNEP RRCAP, 2006). The agriculture sector contributed about 86 percent of the country's methane emissions in the late 1990s and 50 percent of the total emission was from rice cultivation (STEA and RRCAP, 2006).

In the base year 1990, the net removal of CO_2 through LUCF in Myanmar was 6,655 Gg. This is mainly because the growing of forest stocks and abandon of marginal lands (NCEA and UNEP RRCAP, 2006). The largest emitter of GHG in Myanmar was agriculture sector, mainly rice farming which contributed about 94% of overall emission in 1990 (NCEA and UNEP RRCAP, 2006). Traditional biomass burning was 2541.7 Gg, which accounted about 43 % of the energy sector, which was second largest emitter in Myanmar (NCEA and UNEP RRCAP, 2006).

In Vietnam, GHG emission of energy and industry increased during 1994 to 2002 while slight decreases in GHG emission were observed for LUCF and agriculture. Energy is the most important source of GHG emission. The percentage of total emission from energy sector grew from about 25 in 1994 to 46 in 2002 (MONRE and UNEP RRCAP, 2006). Although emission from industrial processes is small compared to energy, the 2002 emission was almost triple of that in 1994 (MONRE and UNEP RRCAP, 2006). Vietnam is now preparing a second NC to be submitted to UNFCCC secretariat.

Under current commitments, these countries need not concern about reducing GHG emission but rather how to deal with the impact of climate change. Climate change causes many negative impacts on forestry and agriculture, which are important sectors of the CLMV countries. Impacts of climate change include changes in temperature and precipitation, hydrological pattern, frequency and intensity of extreme weather such as cyclone and storm surges. The change in weather both temperature and precipitation cause adverse impact on forest productivity as well as biodiversity. Similarly, climate change has direct impact on agricultural sector.

2.2.8 Transboundary Environmental Issues

All CLMV countries share borders with other countries therefore countries are likely to experience environmental problems caused by other countries. Transboundary environmental issues include water pollution in shared inland water bodies such as Mekong River, marine pollution in shared marine water bodies such as the South China Sea and Gulf of Thailand and the Andaman Sea and air pollution such as haze and acid rain. Illegal trading of wildlife has also been an important transboundary issue which threatens the rich biodiversity of the region. Although all CLMV Countries are parties to CITES, international trade of wildlife among these countries is still going on due to high price and high demand.

The Mekong River, 4,200 km in length, is the twelfth longest river in the world, starting from the snow melts of the Himalayan Mountains in China, passing through Myanmar, Lao PDR, Thailand, Cambodia and Vietnam before discharging in the South China Sea. The transboundary issues in Mekong River include quantity and quality of water, fisheries and migratory species, loss of biodiversity and water pollution from agricultural chemicals. Construction of dams in the upper river basin has created various adverse impacts in the downstream areas. Alteration of water flow in the upstream river has resulted in saltwater intrusion and flood in the Mekong delta in Vietnam.

Water resource development is one of the major treats to migratory fish species. There are 30 migratory fish species within the Lao section of the Mekong River. Improvement of navigation channels which alters aquatic habitats, consequently affects fish and other aquatic organisms' migratory behavior and spawning, water quality, and the availability of food resources for fish. Other major threats to Mekong river include water pollution, over-harvesting, and introduction of exotic species for aquaculture. Destruction of habitats, over-fishing has threatened the endangered Mekong Giant Catfish (Pangasianodon gigas).

Fishing activities in the transboundary waters of Kampot province in Cambodia and Kien Giang Province in Vietnam has created threats to seagrass beds in these waters. Under the UNEP/GEF Project: Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand, an agreement was signed to establish collaboration in the management of the area. The agreement is aimed at biodiversity conservation and sustainable use of marine resources to improve livelihood of local communities (UNEP/GEF SCS Project, n.d.).

Transboundary haze pollution is another emerging problem in the region as open burning of agricultural wastes has commonly practiced in all countries. Forest fire is another major cause

of transboundary haze pollution as the region is still covered with extensive forest areas. Both clearing land for agriculture by open burning and forest fire also contribute to the increase in emission of GHG. At present there is no report of the acid rain incident in the region.

Based on the data in the past described in section 2.2, it can be concluded that common environment problems among CLMV countries are:

- Decrease in forest areas and loss of biodiversity caused by unregulated commercial logging, slash and burn agriculture in upland areas and forest encroachment caused by increasing population;
- Soil erosion and land degradation caused by unsustainable practices in agriculture and environmental problems caused by the use of agricultural chemicals;
- Decreasing water quantity and quality due to construction of irrigation system, hydropower projects and inappropriate agriculture practices in the rural area;
- Air pollution mainly caused by transportation in urban and industrial areas, inadequate collection and disposal of solid wastes and sewage;
- Transboundary issues including haze pollution and degradation of Mekong River.

2.3 FUTURE TRENDS AND CHALLENGES

As summarized in Section 2.2, main environmental problems were caused by forestry and agriculture and these problems were interconnected. CLMV countries will continue to be dependent on agriculture and forestry in the near future. Many environmental problems such as deforestation, soil erosion, and loss of biodiversity will continue to exist. As countries are moving toward rapid economic development, environmental problems related to urbanization and industrialization will emerge. Countries need to put more effort need to cope with ongoing problems on natural resources degradation caused by forestry and agriculture as well as emerging problems caused by urban and industrial development.

This section summarizes common environmental problems in the past in CLMV countries also discusses the trends and challenges in the future.

2.3.1 Forestry and Agriculture

Although areas of natural forest will continue to decrease, in most countries, total forest cover is increasing. This is mainly due to government policies and measures such as expanding of forest reserve and protected area and reforestation. Each government has set the target of forest cover as shown in Table 2.5 .

Table 2.5: Comparative Forest Cover in CLMV Countries: Trend and Targets

Country	Year of assessment	% Forest cover	Trend	Target
Cambodia	2002	61	Signs of leveling after 30- year decline	Maintain 60% through to 2015
Lao PDR	2002	41.5	Down from 49.1% in 1982	70 % by year 2020
Myanmar	1998	52	Down from 61% in 1975	Not less than 35%
Viet Nam	2002	36.1	Increased from 28% in mid 1990s	39% by 2005 and 44% by 2010

Source: DEQP, 2006

For example, the Vietnamese government has set a target of 44 percent forest cover in the country by 2010. The reforestation policy has resulted in an increase in forest areas (see Figure 2.1). As part of the 1995 Forest Policy, Myanmar Government has set targets of 30% and 5% of the total land area as reserve forest and protected area (NCEA, 2006). The government also aimed at an annual reforestation target of 20,000 ha to restore degraded lands (NCEA, 2006).

Despite the government effort in increasing forest areas, the loss of natural forest area will continue in the near future. The future trend in loss of natural forest will exacerbate by decrease in forest biodiversity and other environmental problems related to agriculture such as soil erosion, decreasing water quality. For example in Lao PDR, forest lands become fragmented, forest density has been decreasing, sizes of forest trees become smaller and species composition of forest has changed (Vongmany, 2008).

The CLMV region will continue to experience deforestation problem in the near future due to an increasing demand for forest products and agricultural land to meet the demand of increasing population. The 2008 population growth rate in Cambodia, Lao PDR, Myanmar and Vietnam are 1.75, 2.34, 0.8 and 0.99 % respectively (see Section 2.1). As the population grows, an increasing demand for agricultural land will continue in the future, especially in Lao PDR where population growth rate is still high and low land is limited. Therefore natural forest will continue to decline by slash and burn agriculture in the upland areas.

The need to export wood products for foreign exchange is a main challenge in dealing with further destruction of forest land in the future. There are commercial logging will continue because of high demand in importing countries. In Cambodia, Lao PDR and Myanmar, demand for fuel wood will continue to rise to meet an increasing population as fuel wood are the main source for cooking. The main challenge in solving deforestation caused by logging for fuel wood is to find alternative sources for energy to meet an increasing demand.

All countries face challenges not only in achieving the targets of forest areas set by governments but also conserving forest biodiversity. These challenges include setting up measures to increase forest reserves and other types of protected areas, establishing community forest and reforestation. Monitoring the change in forest areas is necessary to evaluate if the target is achieved. In general, detail assessment of long term change of forest cover is lacking. In addition to an increase in forest areas by these measures, it is also challenging to conserve biodiversity of forested areas. There is a need to evaluate the impacts of reforestation on biodiversity so appropriate measures can be implemented to conserve biodiversity of natural forest.

CLMV countries will continue to face the problems caused by agriculture include forest clearing, soil erosion and pollution caused by agricultural chemicals. There are several challenges in coping with a need to further increase agricultural production and at the same time reducing non-point source of pollution. Non-point source of pollution is caused by releasing agricultural chemicals into water, soil and air via natural processes such as precipitation, seepage and runoff. At present, due to limited agricultural land and need to increase agricultural production, the use of chemical fertilizers, pesticides and herbicides is increasing. The extent of non-point source pollution problem is generally not available due to a lack of data and information in term of agricultural wastes released to the environment and their fate. Lack of environmental monitoring data in water and soil is the main obstacle to effectively evaluate environmental impacts of agricultural wastes. There is also a need for research on the impact of agricultural waste on biodiversity.

Countries have to find more sustainable farming methods to increase agricultural production

without creating environmental impact. Sustainable agriculture such as organic farming is necessary to ensure the adequate supply of food to meet the need of people especially the poor at the same time prevent the impact of chemicals on the environment. Sustainable farming methods such as Good Agricultural Practices (GAP) and Best Management Practices (BMP) can be used to reduce the use of agricultural chemicals and reduce environmental impact caused by agricultural activities.

It can be summarized that challenges in forestry and agriculture are:

- Sustainable management of forest concession and forest reserve areas
- Sustainable methods for agriculture to increase production without clearing more forest areas;
- Integrated water resource management to increase supply of water both in term of quantity and quality;
- Conservation of biological diversity for poverty eradication though community forest and integrated farming;
- Application of GAP and BMP to reduce the use of chemicals and impact on the environment
- Environmental monitoring system for agricultural wastes and sediment.
- Establishment of community forest to reduce impact of forest clearing and shifting cultivation.

2.3.2 Biodiversity

All CLMV countries have established protect areas as one of the measures to combat the loss of biodiversity and to conserve and protect important ecosystems of the region. Table 2.6 summarizes the numbers and areas of protected areas in CLMV countries (as of 31st Jan 2008).

Table 2.6: Nationally Designated Protected Areas

Country	Total number of nationally designated protected areas	Total area protected (km) of all nationally designated protected areas	Total territorial area (%) protected per country/territory
Cambodia	30	43464.85	21.92
Lao PDR	25	37545.13	15.86
Myanmar	50	45789.56261	5.52
Viet Nam	117	22551.10287	3.64

Source: World Database on Protected Area: Information support to MDG Goal 7 (http://www.unep-wcmc.org/wdpa/mdgs/wdpapastata_Jan08_download.xls)

In 1984 six ASEAN member countries signed the ASEAN Declaration on Heritage Parks and Reserves to designate conserve areas of uniqueness, diversity and outstanding values that deserve the highest recognition as the ASEAN Heritage Parks Reserves so that their importance as conservation areas could be appreciated regionally and internationally. At present there are 13 Heritage Parks and Reserves in CLMV countries as listed in Table 2.7.

Table 2.7: List of ASEAN Heritage Parks in CLMV Countries.

Country	ASEAN Heritage Park/ Reserve
Cambodia	• Preah Monivong National Park
	• Virachey National Park
Lao PDR	• Nam Ha National Biodiversity Conservation Area
Myanmar	• Alaungdaw Kattapha National Park
	• Indawgy Lake Wildlife Sanctuary
	• Inlay Lake Wildlife Sanctuary
	• Khakaborazi National Park
	• Lampi Marine National Park
	• Meinmahla Kyun Wildlife Sanctuary
Vietnam	• Ba Be National Park
	• Chu Mom Ray National Park
	• Hoang Lien Sa Pa National Park
	• Kon Ka Kinh National Park

Source: ACB, n.d.

There has been a positive trend in establishment of protected areas in all CLMV Countries. In Cambodia, the proclamation of 1993 Royal Decree on Protected Area designated 3,273,200 ha or 18.08% of the total land area as protected area consisting of 23 protected areas, which are National Parks, Wildlife sanctuaries and Multiple Use Area (DEQP and UNEP RRCAP, 2006). The protected areas increased continuously during 1993 - 2002. According to Table 2.6 numbers of protected areas in Cambodia increased to 30: 7 national parks, 10 wildlife sanctuaries, 3 protected landscapes, 3 protected forests, 6 multiple use management areas and 1 crane sanctuary (UNEP-WCMC, n.d.). Additional concessional forest area of 1,332,218 ha in 2002 brought the total protected area to 32% of the total land area, the highest among all CLMV countries (DEQP and UNEP RRCAP, 2006). Protected areas in Lao PDR increased from 2,979,700 ha or 12.6% in 1993 to 3,387,370 or 14.3% in 2002 (STEA and UNEP RRCAP, 2006). The protected area in Myanmar covered 1% of the total land area when it was formally established in 1994 (NCEA and UNEP RRCAP, 2006). The protected area system has extended since then. Additional areas extended the system to 39 protected areas or approximately 4.9 million hectares equivalent to 7.2% of total land area (NCEA and UNEP RRCAP, 2006). The system of national protected areas in Viet Nam has increased from 128,675 ha or 0.39% of the total land area when it was initiated in 1992 to 2,049,992 ha or 6.18% of the total land area by year 2002 (MONRE and UNEP RRCAP, 2006).

Despite an increase in protected areas in the region, challenge still remains in term of sustainable management of these protected areas to effectively reduce biodiversity loss.

2.3.3 Urban and industrial pollution

The CLMV countries are now facing the challenge in mitigating the increasing level of pollution as the countries moving toward market economy. Although the level of air and water pollution are still within the standard limits either national or international, the level of

urban and industrial pollution is likely to increase unless mitigation measures are in place. Industrial pollution also poses a threat to all countries as the level of industrial development rises. Inadequate laws and regulation is a major constraint in dealing with industrial pollution.

Cambodia has smallest land areas among CLMV countries. An increasing population will inevitably create a lot of pressure on natural resources and environment. There is a need for increasing agricultural land and water for irrigation to ensure food security. At the same time, demand for land for urbanization and industrial development is increasing. This will create a competing demand for land and water for between agriculture, domestic and industrial uses. Furthermore, expansion of urban area and rapid industrial development has resulted in an increasing demand for energy. At present, electricity generation is mainly based on diesel fuel, which is mainly imported (ADB, 2006). There is a need for hydropower generation and other sources of energy.

Because Lao PDR has a low population density and extensive land area and plenty natural resources, the environmental problems are likely to be less than the other countries. Nevertheless, some of the constraints due to its geography and topography are likely to create a threat to the environment in the future. Lack of flat land and an increasing demand for food production will create environmental impacts from agriculture in the mountainous areas. As a land-lock country Lao PDR has to depend on inland fisheries particularly in the Mekong River. As a result inland water bodies have to be properly managed to prevent pollution from wastewater.

Myanmar has been experienced urban and industrial expansion since 1988. Urban population in Yangon and Mandalay increased from 2.5 million in 1983 to 4.1 million in 2003/2004 and from 532,949 in 1983 and to 856,264 in 2003 respectively (NCEA and UNEP RRCAP, 2006). Eighteen industrial zones were established during 1988 to 2001, mostly in these two cities (NCEA and UNEP RRCAP, 2006). Lack of monitoring data makes it difficult to evaluate air pollution in these cities. In Myanmar, there is a lack of effluent standards from industrial activities and ambient standards for air pollution (NCEA and UNEP RRCAP, 2006).

Coastal and marine environment is very important to the well being of Vietnamese people. Twenty seven provinces are located in the coastal areas covering the area of 41.3 % of the country (VEPA, 2006). Coastal population is about 51.7% (VEPA, 2006). With the rapid development, pollution from land based activities is a major threat to its rich coastal and marine resources such as coral reef, mangrove and seagrasses. Five industrial centers located on the coast of Halong, Danang, Nha Thang, Quy Nhon and Vung Tua cities are the main sources of land-based pollution. Other coastal provinces with industrial centers located near rivers such as Hai Phong and Ho Chi Minh cities also contributed greatly to land-based pollution. Industrial activities in these areas include chemical industry, food processing, shipbuilding and repairing, port, cement production and electricity generation (VEPA, 2006). Sea-based pollution is also a major problem as Vietnam seas are used for international commercial shipping. Oil pollution from spills and shipping operation will increase as oil has become important export recently. Production of crude oil rose from 40,000 tons in 1986 to 16,500,000 tons in 2000 (VEPA, 2006). There were a total of 31 oil spills during 1995-2000, the highest number of spills occurred in 1999 was 10 (VEPA, 2006).

Major challenges to mitigate pollution from expansion of urban and industrial areas include:

- Establishment of ambient standards for air and water
- Establishment of effluent standards for air pollution from mobile sources;
- Establishment of industrial effluent standards

- Establishment of monitoring system for air and water pollution
- Introduction of alternative energy
- Appropriate waste collection and treatment system (both solid waste and wastewater).

2.3.4 Climate change

Similar to other developing countries, CLMV countries will face with an increasing Green House Gas emission due to the increasing demand for fossil fuel for transport and energy consumption. In addition increase in deforestation is threatening the sink for carbon dioxide (CO_2). All countries have been moving toward net emitter of CO_2 due to trend in forest degradation. The GHG emission from agricultural sector is going to rise because the increasing demands for agricultural land, especially for rice farming.

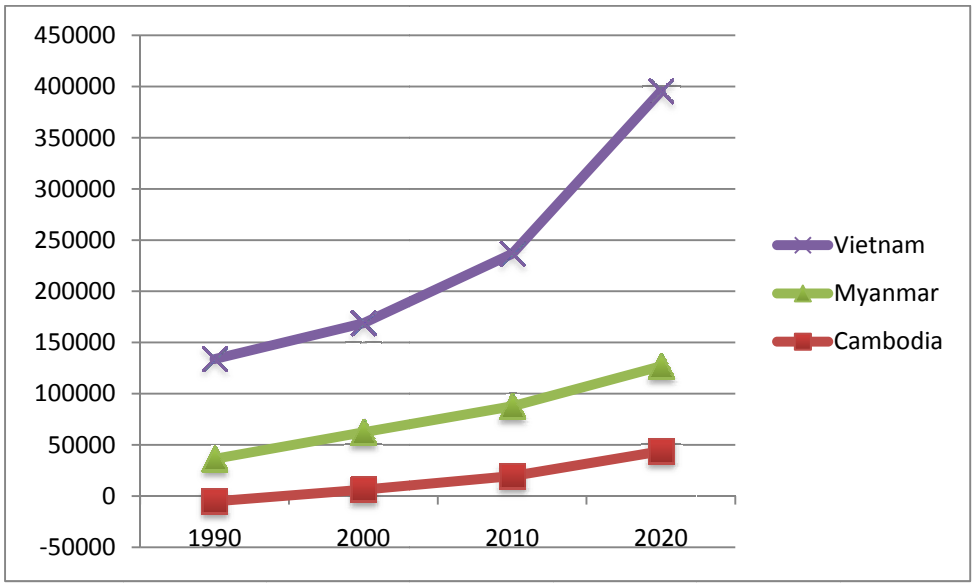

Figure 2.4: Estimated Total GHGs Emissions for 1994-2020 by Country (Gg)

Source: DEQP and UNEP RRCAP, 2006; NCEA and UNEP RRCAP; MONRE and UNEP RRCAP, 2006

Clean Development Mechanism (CDM) is a main mechanism under the Kyoto Protocol which facilitates CLMV Countries in implementing projects to mitigating GHG from LUCF and agriculture. Another initiative is REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), which provides funding to developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. At present Cambodia, Lao PDR and Vietnam are in the process of implementing the CDM projects as well as the REDD programme.

With regard to adaptation, agriculture sector is vulnerable to changes in temperature and precipitation. Countries have to develop agricultural technology to cope with the changes such as changing crop varieties and farming methods. For sea level rise, Vietnam is the most vulnerable country because of its long coastline and extensive low-lying coastal areas, high coastal population and high rapid development in coastal areas. Therefore Vietnam needs to develop adaptation measures to deal with the problems of sea level rise and extreme weather events. Poor people are the most vulnerable to natural disasters both in term of lost of lives and their livelihood.

As climate change relates to many sectors there is a need of multi-disciplinary initiatives. Various sector such as energy, transport, industry, agriculture and forestry contribute to the emission of GHGs. Therefore to solve the problems, cooperation among related sectors and among different levels very critical. Support of donor community is also very important as

the countries lack both financial and technical capacities to cope with the problems. All countries except Myanmar have developed national adaptation plans. Ongoing adaptation projects in Lao PDR include projects on agriculture forestry, water resource and health.

Challenges can be summarized as follow:

- Development of CDM and REDD projects to mitigate GHG emission and to reduce poverty;
- Development of climate change adaptation measures to reduce impact on agriculture and forestry.

2.3.5 Country Trends and Challenges

Environmental problems facing CLMV countries are greatly influenced by the status of development in each country. Cambodia, Lao PDR and Myanmar are facing quite similar problems while problems in Vietnam are more serious due to rapid economic development. Table 2.8 summarizes future trends and challenges of each country.

Table 2.8: Future Trends and Challenges in each CLMV Country

Country	Future trends	Challenges
Cambodia	Less arable land for agriculture	Increasing demined areas
	Continuation of forest destruction by illegal logging and shifting cultivation	Poverty eradication, law enforcement, forest demarcation and sustainable agriculture
	Increase reforestation	Biodiversity loss of replanting forest
	Increase in GHG emission from energy and LUCF	Alternative energy sources and increase CO_2 sequestration through LUCF
	Increase fish production due to increase in fish consumption	Prevention and mitigation of destructive fishing methods
Lao PDR	Increasing demand for agricultural land due to increasing population	Stabilize agricultural land in the upland areas and encourage settled agriculture
	Hazardous Chemicals: Increase use of POPs	Import control of banned pesticides & herbicides Introduction of organic farming, BAP and GAP Determination of baseline levels of pesticides, herbicides and heavy metals in both aquatic and terrestrial environment
	Increase in mining activities	Forest destruction caused by mining and quarry Control of medium scale mining operation
	Increase in hydro-power generation	Environmental impacts on water flow, biodiversity and fisheries resources in the Mekong rivers
Myanmar	Continuous increase in fuelwood for household consumption	Alternative sources of energy for household use
	Threats to biodiversity caused by habitat destruction	Expand protected area system
	Continue expanding upland agricultural areas	Application of BAP and GAP

Table 2.6 (continued)

Country	Future trends	Challenges
	Decline in mangrove areas although logging is banned	Continued increase in charcoal production Control of rice and shrimp farming
	Improve solid waste collection and disposal in Yangon and Mandalay	Improve solid waste collection and disposal in other states
	Increase in hazardous waste	Untreated hazardous waste
Vietnam	Increase in coastal aquaculture and intensive rice farming	Mangrove forest loss and coastal pollution, salt water intrusion, flood
	Increase pollution from urban and industrial sources	Industrial effluent standards Central treatment system for sewage and solid waste
	Increase oil spill incidents	Oil spill contingency plan and control of offshore oil and gas development and shipping
	Increase in climate related vulnerabilities and impact	Climate change adaptation measures

2.4 ENVIRONMENTAL GOVERNANCE

In response to the rising problems, all the governments have established policies, plans and strategies to mitigate and prevent the problems. Many laws and regulations related to natural resources and environment has been established and revised. New organizations responsible for environment management have been established. There is a positive trend in the development of institutional and legal arrangements but the level of development varies among the countries. The trend is similar with regard to research on the environment.

2.4.1 Cambodia

Cambodia has recognized the importance of natural resources and environmental management, the government has established the following key national policies:

- National Environmental Action Plan (NEAP) covering the period from 1998-2002;
- Second Five Year Socio-Economic Development Plan (2001-2005);
- Land and Forest Policies;

In addition to policies, the following laws have been promulgated:

- Royal Decree on the Creation and Designation of Protected Areas, 1993;
- Environmental Protection and Natural Resources Management Act 1996;
- Sub-decree on Water Pollution Control, 1999;
- Sub-decree on Solid Waste Management, 1999;
- Sub-decree on Environmental Impact Assessment, 1999;
- Sub-decree on Air Pollution and Noise Disturbance Control, 2000.
- Sub-decree on Community Forest
- Sub-decree on Forest Concession Management

There are a lot of government departments involve in the management of environment. Main government agencies and their responsibilities are described in Table 2.9:

Table 2.9: Government Agencies Responsible for Environment in Cambodia

Agency	Responsibility
Ministry of the Environment (MOE)	Environmental management
Ministry of Agriculture, Forestry and Fisheries	Agriculture, forestry and fisheries issues
Ministry of Industry, Mines and Energy	Pollution from industries and mines, energy generation
Ministry of Public Works and Transportation	Construction of roads and other related infrastructure
Council for the Development of Cambodia	Promotion of public sector investment, reconstruction of Cambodia, foreign investments
National Committee for Land Use and Urbanization	Land use and urban management issues

2.4.2 Lao PDR

The Government has passed several numbers of laws on natural resource management and protection and pollution control since 1990 as shown in Table 2.10.

Table 2.10: Existing laws related to environment and natural resources in Lao PDR

Law	Description
Environmental Protection Law (EPL) (1999)	Requires protection of natural resources and socio-economic aspects in development.
Prime Minister's Decree No. 68 (1998)	Designates the Science, Technology and Environment Agency (STEA) as the agency responsible for oversight and coordination of environmental protection.
Forest Law (1996)	Categorizes forest lands and calls for reforestation, sustained yield, and catchment protection.
Water and Water Resources Law (1996)	Sets out the necessary principles, rules, and measures for the administration, use, and development of water and water resources; classifies catchment areas for various uses; and promotes protection and rehabilitation of forests, fishing, and the environment in general.
Electricity Law (1997)	Requires environmental assessments (EA) for hydropower dams and payment of compensation for damages to the environment.
Road Law (1999),	Mandates environmental protection during road building activities and requires compensation for rights-of-way, relocation or replacement of structures, and loss of property.
Mining Law (1997),	Requires developers to utilize procedures that limit adverse effects, control toxic substances, and preserve and restore disturbed lands.

Source: Dethrasavong, 2003

In addition to the laws described in Table 2.10, Ministry of Industry and Handicraft is in the process of seeking approval from the Peoples' Assembly in issuing new law on industry. There were several action plans related to sustainable natural resources management such as the National Tropical Forestry Action Plan (1991) and the Environmental Action Plan (1993).

Science Technology and Environment Agency (STEA) is a central agency within the Prime Minister Office, in charge of environment of the whole country while cooperating with line ministries and specialized agencies such as Ministry of Communications, Post, Transport and Construction, Ministry of Energy and Mining, Ministry of Agriculture and Forestry and Ministry of Public Health in implementing government policies and projects.

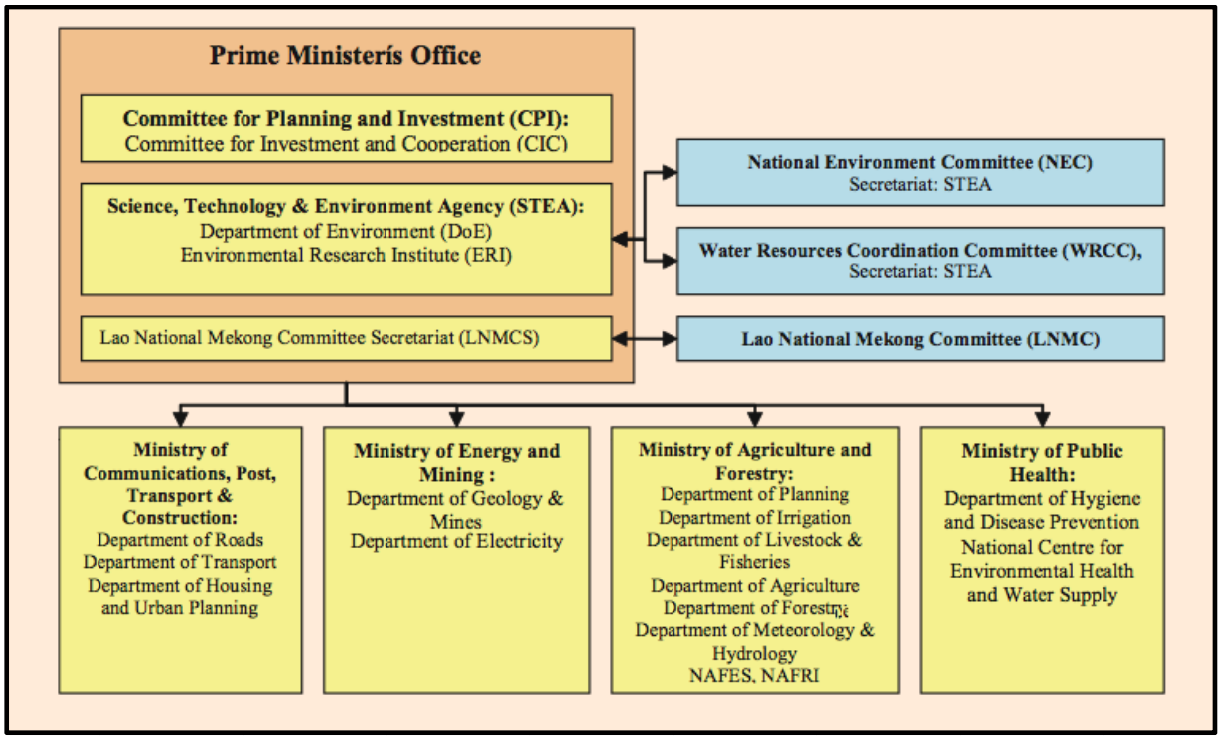

Figure 2.5: Organization Chart of Selected Government Agencies in Lao PDR
Source: World Bank, 2005a

As shown in Figure 2.5, three committees were set up under the Prime Minister Office for coordination. For example, the Water Resources Coordination Committee (WRCC) is assigned to advise the government on matters relating to water and water resources, coordinate planning and management, and coordinate the follow-up, inspection, and protection of water and water resources.

2.4.3 Myanmar

Until 1989, Myanmar has no central governmental agency responsible for environmental matters. Different government departments are responsible for their respective resources and activities as shown in Table 2.11. For example, management of forest resources is under the Ministry of Forestry. Several government departments sometimes share their responsibilities, for instance, City/township Development Committees, Government Affairs Department, Department of Human Settlement and Housing Development, Department of Health, and Directorate of Industrial Supervision, and Inspection share their responsibilities in managing urban environment.

Table 2.11: Line ministries and agencies in Myanmar

Ministry	Department
Ministry of Forestry	• Department of Forestry
Ministry of Agriculture and Irrigation	• Department of Agriculture Planning • Department of Irrigation
Ministry of Livestocks and Fisheries	• Department of Fisheries
Ministry of Transport	• Directorate of Water Resources and Improvement of River Systems • Department of Meteorology and Hydrology • Road Transport Administration Department
Ministry of Health	• Department of Health
Ministry of Mining	• Department of Mines
Ministry of Energy	• Department of Energy Planning
Ministry of Industry	• Directorate of Industry Supervision and Inspection
Ministry of National Planning and Economic Development	• Department of National Planning • Central Statistical Organization
Ministry of Construction	• Department of Human Settlement and Housing Development
Ministry of Progress of Border Areas and National Races and Development Affairs	• Department of Development Affairs

Source: NCEA and UNEP RRCAP, 2006

In 1990, the National Commission for Environmental Affairs (NCEA) was established to act as a central agency for environmental management. One of the NCEA's tasks is to develop national environmental policy for the country. Another important task is to upgrade NCEA into a statutory body. However, lack of political will and ongoing political crisis are major threats to environmental governance in Myanmar (Myint, 2003). NCEA has not yet fully recognized as a statutory body. In 2005, supervision of NCEA was transferred from the Ministry of Foreign Affairs to Ministry of Forests.

There is no environment law enacted in Myanmar. There are however many laws related to the environment. These laws include

- Factory Act (1951)
- Public Health Law (1972)
- Territorial Sea and Maritime Zone Law (1977)
- Fishing Rights of Foreign Vessels Law (1989)
- Marine Fisheries Law (1990)
- Forestry Law (1992)
- Protection of Wildlife and Wild Plants and Conservation of Natural Areas Law (1994)
- Myanmar Mines Law (1996)
- Fertilizer Law (2002)

In the absence of environmental law, National Environmental Action Plan, developed in 1994, is a main tool used to deal with environmental affairs of the country. The National

Environmental Action Plan includes drafting comprehensive environmental legislation, reviewing and drafting sectoral legislation, conducting environmental impact assessment, setting up environmental standards, collecting environmental data, promoting environmental awareness and alleviating poverty.

2.4.4 Vietnam

The Ministry of Science, Technology and Environment (MOSTE) was in charge of environmental protection since 1993. It was replaced by the Ministry of Resources and Environment (MONRE) in July 2002. MONRE has an overall mandate for resource and environmental strategy, legislation and policy formulation, resource and environmental institution building, environmental impact assessment, resource and environmental research, environmental quality standards, data collection and management. MONRE is also in charge of inspection, development of guidelines for provinces and international cooperation for resource and environmental protection.

Under MONRE, Vietnam Environment Protection Agency (VEPA) was set up in 2002 to be responsible for facilitating the Minister in state management in environmental protection in the following fields: inspecting, monitoring, preventing, remediating environmental pollution and degradation; environmental quality improvement; biodiversity conservation; environmental monitor; technology application; environmental data and information, integrated coastal zone management; environmental education and awareness raising. As a principal government agency responsible for resource and environmental policy, planning and management, MONRE cooperates with various ministries and general departments in managing natural resources and environment in relevant sectors as described in Table 2.12.

Table 2.12: Government Agencies and Areas of Responsibilities in Vietnam

Agency	Responsibility
Department of Natural Resources and Environment (DONRE)	Provincial environmental management
Ministry of Science and Technology (MST)	Cooperation with MONRE and other ministries for introducing application of advanced science, technique and technology on resources and environment, and pollution control.
Ministry of Agriculture and Rural Development (MARD)	Agriculture, forestry, water resources and rural development, terrestrial national parks and protected areas, including coastal wetlands; control and diminution of pollution sources from agriculture activities and control the use of chemical fertilizers.
Ministry of Construction (MoC)	Spatial planning and building water supply and sanitation facilities, and managing solid wastes from construction sites.
Ministry of Fisheries (MoF)	Aquaculture and aquatic processing factories, protection of aquatic resources including the coastal and marine resources.
Ministry of Education and Training (MOET)	Cooperation with MONRE in raising awareness and knowledge on environment.
Ministry of Industry (MOI)	Monitoring and control pollution from factories and assists industrial firms in solving environmental problems.
Ministry of Planning & Investments (MPI)	Overall planning projects related to environmental issues in collaboration with MONRE
Ministry of Public Health (MOPH)	Managing hospital wastes, raising awareness relating to environmental health issues.
Ministry of Transport (MOT)	Overall planning, implementation of infrastructure and control of air, land, railway and maritime transport, controlling pollution from port and shipping activities.
National Center for Natural Sciences and Technology (NCNST)	Networking with other research institutes in the line of ministries in conducting research on environmental issues, developing technology for mitigating pollution

Source: VEPA, 2004

2.4.5 Regional and sub-regional cooperation

CLMV countries are members of existing regional and sub-regional cooperation programmes, cooperation on environment and climate change. The main collaboration framework is ASEAN. The main objective of these cooperative programmes is to strengthen capacity of the member countries to effectively address environmental problems at national and regional levels. Through projects and activities CLMV countries have gain knowledge and experiences from other ASEAN countries.

ASEAN Working Group on Multilateral Environmental Agreements (MEAs)

At present ASEAN cooperation on the environment is guided by the Vientiane Action Plan 200-2010. Nine priority areas were land and forest fires and transboundary haze pollution, coastal and marine environment, sustainable management of biodiversity, freshwater resources, public awareness and environmental education, promotion of environmentally sound technologies and cleaner production, urban environmental management and

governance, and, sustainable development, monitoring and reporting/ database harmonization.

To implement these priority areas, ASEAN has established several working groups.

- ASEAN Working Group on Nature Conservation and Biodiversity (AWGNCB)
- ASEAN Working Group on Coastal and Marine Environment (AWGCME)
- ASEAN Working Group on Multilateral Environmental Agreements (AWGMEA)
- ASEAN Working Group on Environmentally Sustainable Cities (AWGESC)
- ASEAN Working Group on Water Resources Management (AWGWRM)
- ASEAN Working Group on Environmental Education

AWGMEA was established to deal with the global environmental issues including climate change.

ASEAN Center for Biological Diversity (ACB)

Established in 2005, ACB is the continuation of the ASEAN Regional Centre for Biodiversity Conservation (ARCBC) with the support from the European Union (EU). The center established a fund for research related to biological diversity. The mandate of ACB is to facilitate cooperation and coordination among the ASEAN Member States and with relevant national government, regional and international organizations, on the conservation and sustainable use of biological diversity and the fair and equitable sharing of benefits arising from the use of such biodiversity in the ASEAN region. Current thematic areas include ecosystems services and economic valuation of biodiversity, invasive alien species, protected area management, climate change and biodiversity, ecotourism and biodiversity conservation, access and fair and equitable sharing of benefits from biological and genetic resources.

ASEAN Agreement on Transboundary Haze Pollution

ASEAN adopted the ASEAN Agreement on Transboundary Haze Pollution to solve of the problem of transboundary haze pollution first occurred in 1987 as a result of forest fire in Sumatra. The impact of haze has been recognized by Singapore, Brunei, Malaysia and Thailand. The Agreement was signed by the ASEAN Environment Ministers during the 9th ASEAN Ministerial Meeting on Haze (AMMH) on 10 July 2002, in Kuala Lumpur, Malaysia. To date, eight ASEAN Member Countries has ratified the Agreement, namely, Brunei Darussalam, Cambodia, Lao PDR, Malaysia, Myanmar, Singapore, Thailand, and Viet Nam. The Agreement provide guidance on monitoring and assessment; prevention; preparedness; national emergency response; joint emergency response through provision of assistance; procedures for deployment of people, materials and equipment across border in the event of transboundary haze pollution and technical cooperation and scientific research.

The Agreement also necessitate a country to provide quick response, such as information, forest fire mitigation resources or consultation to the requesting party during critical land and forest fire incidents; facilitate the establishment of ASEAN Coordinating Centre for Transboundary Haze Pollution Control ; provide a framework for the member countries to strengthen and refine its national policy in land and forest fire mitigation; and provide a framework to develop the national standard operating procedures.

2.4.6 Future Trends and challenges in environmental governance

The trend in environmental management in the region has continuously been improved for several decades due to programmes and projects funded by many international donors. The

international assistance has provided a foundation for environmental management in CLMV countries as the governments have developed and implement policies, projects and activities to respond to environmental problems. However, government effort has not met increasing problems in most countries. At present all governments still express their need to enhance measures in combating the environmental problems in several priority areas namely deforestation, environmental impact by agriculture and urban and industrial pollution.

Law and law enforcement

There is a need for improving existing laws as well as law enforcement. In general, there are many laws related to environment. Most countries have already enacted environment law except Myanmar. Most of these laws need to be revised to respond to the emerging problems. Degradation of forest resource is also caused by unregulated commercial logging. There are still a lot of forest concessions in Lao PDR and Myanmar. Although replanting is required after logging, implementation is not so effective because of inadequate law enforcement.

Environmental Organizations

All CLMV Countries have already established environmental agencies. Myanmar has established a commission under the Ministry of Foreign Affairs and later transferred to the Ministry of Forestry. Lao PDR has established STEA under the Prime Minister Office. Cambodia and Vietnam have upgraded their environment agencies to a ministerial level. Although there are main agencies responsible for environment, management of environment and natural resources depend very much on sectoral agencies such as forestry, agriculture and industry. Coordination among various line agencies is necessary to effectively address environmental problems and degradation of natural resources.

There is a need to strengthen existing regional cooperation frameworks to effectively address transboundary environmental problems. Transboundary environmental issues in the Mekong River can be considered in future development planning under MRC. Other transboundary issues such as haze pollution and marine pollution can be addressed under ASEAN Vientiane Programme of Actions.

Financial Resources

Budget constraint is also identified as a major obstacle to environmental management. For example, although most countries have laws and regulations in protecting forest, lack of clear delineation of forest protected areas has been one of the major obstacles to combat forest encroachment. This is because demarcation of forest required considerable amount of budget. Similarly environmental monitoring programme is needed to tackle pollution problems. Environment agencies often are given low priority regarding budget allocation.

Capacity building

Another important issue regarding effective management of environment is capacity building of government officials. There is a need for both improvement in effective management of commercial forest and forest monitoring to effective management of forest in the country. At present most CLMV countries lack capacity to monitor the change in forestland. There is often a lack of up to date information to get the accurate assessment of forest cover. Therefore the capacity of countries should be further strengthen in the areas of remote sensing and Geographical Information System (GIS). At present, countries in the region receive funding for various capacity building projects from international donors. However, capacity building has to be funded by the governments in the long term when donor support is not available. Collaborative research can be used as one of the capacity building tools to provide scientific information needed to improve environmental management of the CLMV

countries.

In conclusion, challenges facing countries in environmental governance include:

- Improve existing laws and law enforcement;
- Empowerment of environment agencies and capacity building;
- Improve coordination among national government agencies;
- Strengthen regional coordination mechanisms such as MRC and ASEAN.

2.5 STATUS OF RESEARCH ON ENVIRONMENT AND CLIMATE CHANGE

In most CLMV countries, research has been focused in the field of agriculture and forestry. Most of the researches were carried out with the support from many international organizations such as UNDP, UNEP, FAO, WHO, World Bank, Asian Development Bank and other donor agencies.

2.5.1 National institutions

National institutions involve in conducting research included government departments and academic institutions. As discussed in the previous chapter, environmental issues have just been recognized by these countries recently. Table 2.13 shows the list of government departments and universities which have been involved in environmental programmes and research.

Table 2.13: Organizations involved in Research on the Environment

Country	Government agency	University/NGO
Cambodia	Cambodia Agricultural Research and Development Institute (CARDI), Ministry of Agriculture, Forestry and Fisheries Ministry of Water Resources and Meteorology Ministry of Environment	Royal University of Phnom Penh (RUPP), - Department of Environmental Science Royal University of Agriculture (RUA): Faculty of Forestry - Department of Forest Management, - Department of Forest Conservation Prek Leap National School of Agriculture (PNSA)
Lao PDR	Environmental Research Institute (ERI) National Agriculture and Forestry Research Institute (NAFRI)	National University of Lao PDR (NUOL)
Myanmar	Forest Research Institute Department of Agricultural Research	Yezin Agricultural University University of Forestry, Yezin Biodiversity and Nature Conservation Association (BANCA)
Vietnam	Ministry of Natural Resources and Environment National Academic of Science National Center for Natural Sciences and Technology (NCNST)	Can Tho University (CTU) Vietnam National University (VNU) Vietnam National University Ho Chi Minh City (VNU-HCM) Hanoi Architectural University Hue University Institute of Resources, Environment and Biotechnology (IREB) Nong Lam University of Agriculture and Forestry Environmental Technology and Management Center Hue University of Agriculture and Forestry Hanoi University of Agriculture Department of Environmental Technology

2.5.2 International organizations

There are several UN agencies involve in research and development in CLMV countries. The main one is UNDP was the main agency which provide technical and financial support to these countries as they are among the poor developing countries. Although initially the assistance was in the form of development projects, recently many UNDP projects focus more on environment and sustainable development. Another important UN organization which supports research and development on environment is UNEP. UNEP has been actively involved in the development of the state of environment reports and many development agencies such as World Bank and ADB also play an important role in the area of environment and climate change.

There have been a number of projects carried out by international NGOs including Wildlife Conservation Society (WCS), WildAid, World Wildlife Fund, Wetland International, IUCN, International Crane Foundation, Fauna and Flora International.

2.5.3 Regional University Networks

Existing regional university networks could be used as a mechanism to promote researches on environment and climate change without the establishment of a new collaborative mechanism. The two main networks are the Greater Mekong Sub-region Academic and Research network (GMSARN) and the ASEAN University Network (AUN).

The Greater Mekong Sub-region Academic and Research network (GMSARN) is a network of academic and research institution in a Greater Mekong Sub Region. The mission of the network is to carry out activities in human resources development, joint research and dissemination of information in the region emphasizing complementary linkages between technological and socioeconomic development issues. The CLMV members include Institute of Technology of Cambodia, Royal University of Phnom Penh, National University of Lao PDR, Yangon Technological University, Hanoi University of Technology, Ho Chi Minh City University of Technology.

The ASEAN University Network (AUN) was founded in 1995 with members comprising 13 universities in 7 countries. The member grew to 21 at present with the joining of Cambodia, Lao PDR and Myanmar. The main objective of AUN is to strengthen cooperation among universities in the ASEAN region by promoting collaborative studies and research programmes. It also promotes cooperation and solidarity among scientists and scholars to enhance human resources development as well as to promote and disseminate scientific knowledge and information. Participating universities provide funding for the network's activities and ASEAN "dialogue partners" such as EU, China, Korea, Japan, India and Russia also provide funding to the network. CLMV members include Royal University of Phnom Penh, National University of Lao PDR, University of Yangon, Yangon Institute of Economics, Vietnam National University, Hanoi and Vietnam University, Ho Chi Minh City.

2.5.4 Environment Research

As mention earlier that forestry and agriculture are very important to all countries in the region. In the past researches were mainly focus on exploitation of forest resources and agriculture technology to increase production. As the development increases, countries have faced environmental problems caused by forestry and agriculture. As a result, there have been a number of researches on agriculture and forestry which touch upon environmental issues. However, researches that directly deal with environment is still very limited. Many research projects have been funded by donors and international organizations. Based on limited information on existing research, Table 2.14 summarized the areas of research conducted in

each country.

Table 2.14: Existing Areas of Research in CLMV Countries

Institution	Agriculture	Forestry	Air pollution	Water Pollution	Marine Pollution	Solid waste	Hazardous waste	Bio-diversity	Climate change
Cambodia	x	x	x	x		x		x	x
Lao PDR	x	x	x			x		x	x
Myanmar	x	x				x		x	x
Vietnam	x	x	x	x	x	x	x	x	x

According to Table 2.14, countries have researches in most areas, however number of projects is very limited in some areas such as water and air pollution and hazardous wastes. Vietnam has more research areas compared to other CLMV countries. For example, there is no information on hazardous waste in most countries except Vietnam. Vietnam also has comprehensive research on coastal and marine environment.

State of the environment reporting

State of the environment reports provides valuable sources on research related to environment as they present data and information on status of natural resources and environment in the countries. It comprises statistical and scientific data that provide a useful input to the development of environmental policies and measures to policies makers.

There have been several reports on the state of the environment in the CLMV region. At national or country level, most of the reports have been developed with support from various international organizations such as UNDP, World Bank, ADB and UNEP. Furthermore, state of the environment reports have been done at a sub-regional, regional and global levels. Table 2.15 summarized various types of reports by various agencies.

Table 2.15: Published National State of Environment Reports

Country	World Bank	ADB/ UNEP Under GMS Programme	UNEP/ Norad
Cambodia	Environment Monitor 2003: General Environment	Cambodia National Environmental Performance Assessment (EPA) Report	In production
Lao PDR	Environment Monitor 2003: General Environment	Lao PDR National Environmental Performance Assessment (EPA) Report	State of Environment, Lao PDR 2001
Myanmar		Myanmar National Environmental Performance Assessment (EPA) Report	In production
Vietnam	Environment Monitor 2004: Solid waste Environment Monitor 2005: Biodiversity Environment monitor 2006: Water Quality	Vietnam National Environmental Performance Assessment (EPA) Report	State of Environment, Vietnam 2001

Environment Monitor is a series of environmental reports prepared by the World Bank. The objective of this report is to present a snapshot of environmental trends across a range of issues. Its purpose is to engage and inform interested stakeholders of key environmental changes as they occur. The format is intended to be easy to understand and accessible to a wide audience.

In addition to national state of environment reports, reports have been developed at regional and sub-regional levels. The State of the Environment in Asian and Pacific has been published every five years by UNESCAP since 1985, with the generous support of the Government of Japan, and in collaboration with partners such as the ADB and UNEP. The reports present an overview of sustainable developments issues, environmental conditions and trends and response in Asia and the Pacific. The latest report is for 2005 focusing on Green Growth.

ASEAN has published two 'State of the Environment' reports with collaborative efforts among ASEAN Member Countries, the United Nations Environment Programme (UNEP) and individual experts under the supervision and coordination of the ASEAN Secretariat.

The First ASEAN State of the Environment Report 1997 (SoER1) is the first in the series of state of the environment reporting of ASEAN. The SoER1 takes stock of environmental conditions and their impact and interrelationship with other sectoral areas in ASEAN. The SoER1 also identified challenges facing the region and highlighted what ASEAN has done to protect the environment and promote sustainable development. The SoER 1 covered the seven countries which were then member countries of ASEAN, i.e. Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam.

***The Second ASEAN State of the Environment Report 2000 (SoER2*)**: presents the status and condition of the environment and natural resources in ASEAN during 1998 – 2000. The SoER 2 coverage expanded to ten member countries as three new members - Myanmar, Lao PDR and Cambodia.

2.5.5 Climate Change Research

Recently, climate change has become a priority area for research. As non-Annex I parties, CLMV countries have no commitment in reducing emission of GHGs for the first commitment period (2008-2012). Emission of GHG from these countries is still low compared to other Non-Annex I countries and Annex I countries. As they are vulnerable to the impact of climate change, CLMV countries have been provided with a lot of funding for climate change related research projects on both mitigation and adaptation. The example of such research projects cover a wide range of topic such as alternative energy, integrated water resources management, bio fuel, wet rice plantation, agro-biodiversity, renewable energy for rural energy services, small scale hydropower potential, solar energy, climate-related health issue.

National Communications (NC)

One of the obligations of Non-Annex I parties of the UNFCCC, CLMV countries are committed to submit its NC to the convention secretariat. The NC include inventory of GHGs, GHG projection and mitigation analysis, vulnerability and adaptation assessment, government plans, policies and measures, research and systematic observation, education, training and public participation, financial resources, technology transfer and capacity building. Therefore research related to emission of GHGs as well as impacts of climate change on various sectors are necessary for countries to meet the obligations under UNFCCC and the Kyoto Protocol. As shown in Table, all CLMV Countries have developed GHG Inventory although Myanmar has not yet submitted their NC. There has not been GHG projection for Lao PDR. The GHG inventory in Vietnam is by far the most comprehensive one compared to the rest of CLMV countries. The National Climate Change and Ozone Protection Office (NCCOP) of the Ministry of Natural Resources and Environment (MONRE) is mainly responsible for the inventory. Based on the 1993 inventory undertaken under the ALGAS Project, NCCOP has developed GHG inventory for the year 1994, 1998

and 2002.

Table 2.16: Country status regarding GHG inventory and projection

Country	1st NC	GHG Inventory (year)	GHG Projection (year)
Cambodia	2002	1994	2000, 2010, 2020
Lao PDR	2000	1990	-
Myanmar	-	1990	2000, 2010, 2020
Vietnam	2003	1993,1994, 1998, 2002	2000, 2010, 2020

The development of NC requires scientific data and information on several fields such as local emission factors, activities data and local climate models. At present, countries use default emission factors in assessing the emission of GHG. Cambodia used emission factors developed by Thailand Philippines or Indonesia for its GHG emission inventory (MOE and UNEP/ RRCAP, 2006). Lack of data in forestry, agriculture and energy has also been identified as constraints in developing NC. In many cases, data were estimated from relevant data with assumptions (MOE and UNEP/ RRCAP, 2006). Local climate models were needed to accurately evaluate the impact of climate change on forestry agriculture and human health. At present, global climate model is used to estimate the impact of climate change.

Clean Development Mechanism (CDM) is one of the Kyoto Mechanism to assist developed countries to implement GHG mitigation projects in developing countries. Developed countries will get credit from CDM project while developing countries will benefit from sustainable development activities. Developing countries have to establish national guidelines and criteria for CDM projects in their countries. Most CDM projects include:

- Renewable energy (hydro, solar, wind, biomass);
- Energy efficiency (both on the demand and supply side);
- Waste management (CH_4 recovery from landfill, waste water, livestock husbandry and other sources);
- Aforestation and reforestation (carbon sink project).

The FAO-UNDP-UNEP Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (REDD) which established in July 2008 has provide a major funding to countries to mitigate GHG emission from forest sector.

Research needed for GHG Inventory and adaptation to climate change are:

- Local emission factors;
- Activity data for each GHG emission sectors;
- Development of CDM projects such as alternative energy development, farming and livestock development;
- Impact of climate change and adaptation measures.

2.6 CONCLUSIONS AND RECOMMENDATIONS

CLMV countries share a lot of similarities in term of socioeconomic circumstances. First of all, all countries are moving towards market economy, Majority of people are living in poverty and dependent on agriculture. Industrial development is becoming more and more important. Percentage of rural and urban population is increasing. All of these changes have created a lot of adverse impact on the environment and degradation of natural resources. Common environmental problems are deforestation, degradation of land, loss of biodiversity, increase in urban and industrial pollution such as air pollution, solid and hazardous wastes. Scientific data and information would be definitely necessary to cope with increasing problems.

With regard to climate change, countries are vulnerable to the impact of climate change. Adaptation measures are needed to mitigate impact on agriculture water resources disaster management and health. At present, CLMV countries are not responsible for GHG emission reduction, trend in rapid development will inevitable increase the level of GHG emission. As a consequence, mitigation measures will be needed. At present the lack of scientific information has been identified as a major constraint in both mitigation and adaptation of climate change.

2.6.1 Priority Areas for future research

The review of existing research is mainly based on the information provided in various state of environment reports (described in the previous section) shows that there is a lack of scientific knowledge in many areas which is necessary to enhance the management of environment and climate change in the country. It is noted that the reviews only included published reports in English but not in local languages.

Based on the gaps in research identified in the relevant reports, the areas for future research can be summarized below.

1. Forestry:
   - Monitoring of changes in forest covers (Remote sensing and GIS);
   - Impact of deforestation on biodiversity and forest ecosystem;
   - Monitoring of sedimentation caused by deforestation;
   - Impact of climate change on forest productivity and biodiversity.
2. Pollution:
   - Monitoring of urban pollution such as waste water, solid waste and air pollution;
   - Establishment of the ambient water and air quality standards;
   - Establishment of effluent standards for specific types of vehicles;
   - Appropriate technology for waste water treatment system;
   - Establishment of laws and regulation related to control of pollution from specific industrial sector such as mining.
3. Climate change
   - Establishment of activity data for inventory of GHG emission;
   - Alternative energy sources;

- Impact of climate change on agriculture sector.

4. Agriculture
   - Sustainable farming method including organic farming, impact on biodiversity;
   - Impact of pollution from agriculture.
5. Transboundary issues
   - Mekong River: quantity and quality of water caused by construction of dams, fisheries and migratory species, loss of biodiversity and water pollution from agricultural chemicals, salt water intrusion in the Mekong delta
   - South China Sea and the Gulf of Thailand: degradation of coastal ecosystems such as coral reef and seagrass beds between Cambodia and Vietnam, fisheries management.
   - Transboundary haze pollution: forest fire caused by slash and burn agriculture.

2.6.2 Framework for future collaborative research

All CLMV countries have an opportunity to learn from their neighbouring countries through collaborative research and a network of researchers. Exchange of data and information on research and development will facilitate and enhance capability of countries in tackling with increasing problems. Cooperation can easily be built upon existing regional and sub-regional framework such as ASEAN, MRC and GMS.

At present many research studies are carried out both by researchers from government departments, universities and NGOs. Collaboration in research related to environment and climate change can be done through identification of priority areas, organizing technical workshops, implementing joint research projects, training in monitoring programme etc. Research should be guided by the agreed policies and plans such as the Vientiane Action Programme under the ASOEN. The regular meeting of these programmes could also be used to identify gaps and needs for research and to recommend areas for collaborative research. Furthermore, the outcomes of research could be presented at the intergovernmental meeting under such cooperation frameworks such as meetings of ASEAN working groups. This would provide the opportunity for government representatives to acquire necessary data and information useful for developing relevant policies and plans.

Based on the existing network of universities in the region, a regional network of researchers should be established to build collaborative research programmes and projects as well as to provide a forum for information exchange and sharing of experiences. National focal points of researchers should be established within each country to coordinate with local researchers as well as to coordinate with other national focal points through the established network. National Focal points is very useful in collecting and synthesizing existing research within the countries, particularly research in local languages. Regular reporting of the status of research within the country provides available inputs to other countries as well as to identify research gaps and needs within the country. Recommendations on framework for future collaborative research are elaborated in Chapter 4 after integrating with the outcomes of synthesis of projects on agriculture and environment.

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CHAPTER 3: CURRENT STATUS ON NON-POINT SOURCE POLLUTION FROM AGRICULTURE IN THAILAND

3.1 INTRODUCTION

3.1.1 Background

Thailand is an agricultural-based economy which approximately 50-60% of the population is in agricultural sector. Geographically, the country is located on monsoon region in Southeast Asia which is suitable for cultivating a wide range of tropical crops throughout the year. This is the reason that Thailand can produce a variety of food for consumption in the country and for export worldwide. However, it is apparent that an increase in agricultural production is due to expansion of cultivated land rather than increasing production yield per unit area. As a result, the degradation of forest area has occurred and leads to other environmental problems especially global warming and climate change which are very serious situation all over the world.

Another environmental problem caused by an increase in agricultural production is due to bad agricultural practices of Thai farmers by heavy application of pesticides. In 1995, approximately 24% of pesticides used in Thailand were applied to fruits and vegetables. Of the remaining 76%, 18% was allocated to grains, 12% to rice, 10% to cotton, 9% to maize, 7% to soybean, 4% to sugarcane, and 16% to other crops (Office of Agricultural Economics, 1995). Over the past decade, the three most heavily applied pesticides in Thailand were insecticides, herbicides, and fungicides. These chemicals, which released from non-point sources of cultivated land, contribute to major impacts on environmental quality and health effect because of their residues in soil, surface water, groundwater, as well as in agricultural products. For example, carbofuran, endosulfan, dicofol, atrazine, and 2,4-D were found in groundwater samples from 210 wells of seven provinces in central Thailand with the maximum concentration of 0.620, 1.692, 0.306, 1.890 and 0.210 ppb, respectively (Pollution Control Department, 1995). Pesticide residues can also be found in many kinds of food products such as vegetables, fruits, milks, fishes, and so on. It was reported that 48%, 27%, and 13% of crop samples (i.e., fruits, vegetables, and other crops) were polluted by pesticides (Thapinta and Hudak, 2000). By this report, insecticides particularly organophosphate and organochlorine compounds were commonly detected. Carbamates, pyrethroids, and fungicides were also found, particularly in vegetables. In the case of health effect, there are a lot of cases showing both acute and chronic effects due to improper use of pesticides. This makes an increasing number of patients and deaths every year. According to the government report, there were 2,511 patients and 10 deaths caused by pesticide poisoning in the year 2002 (Pollution Control Department, 2003a). Office of the National Environment Board (1991) also reported that the main causes of pesticide poisoning were occupational exposure (46%), suicide (36%), accidental exposure (6%), and residues in food products (2%), respectively.

According to the information described above, it is therefore the goal of this project to collect data about non-point source of agricultural pollution. These data can be used to assess current situation so that mitigation measures can be established to prevent such problem in the future. In addition, the outputs from this project will be shared with neighboring countries (i.e., Cambodia, Laos, Myanmar and Vietnam) in order to exchange experiences between Thailand and these countries to solve the problem. It is hoped that sharing of experiences through researches in the region would reduce agricultural pollution from non-point sources in Southeast Asian countries and results in sustainable development of agriculture and safe environment for population of all countries in this region.

3.1.2 Objectives

The objectives of this project are as follow:-

1) To compile and review information in respect to state of knowledge on non-point source pollution from agriculture,
2) To emphasize on current situation of existing researches and identify gaps for future works which can improve or update the knowledge on non-point source pollution from agriculture,
3) To recommend areas for collaborative researches and mitigation measures that can be shared with neighboring countries in the future.

3.1.3 Methodology

It is the scope of this project that literature review is based on secondary data derived from several sources such as government reports and policies, academic researches or journals, and other relevant published papers. Collection of the data is limited from the year 2000 to 2009 in order to evaluate current status on non-point source pollution from agriculture of the country. As a result, the final report of this project comprises of the following outlines:-

1) Existing government policies, strategies and guidelines,
2) Current status on non-point source pollution from agriculture,
3) Trend in non-point source pollution from agriculture,
4) A case study related to non-point source pollution from agriculture,
5) Gaps and needs in researches which can be used for improving the knowledge and database on non-point source pollution from agriculture in the future,
6) Recommendations for future researches and areas for collaborative researches with Southeast Asian countries.

3.1.4 Expected Outputs

1) Overview of current status on non-point source pollution from agriculture in Thailand,
2) Current status of responsible measures and guidelines from government sector to mitigate such pollution of the country,
3) Proposed areas for future researches in collaborating to neighboring countries in Southeast Asian region (i.e., Cambodia, Laos, Myanmar, and Vietnam).

3.2 RESULTS AND DISCUSSION

Non-point source pollution generally means any kind of pollution resulting from precipitation, runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric deposition. As runoff from rainfall or snowmelt moves, it picks up and transports natural pollutants and pollutants resulting from human activity, ultimately depositing them into rivers, lakes, wetlands, coastal waters, and groundwater (US.EPA, 2003). It can be stated that non-point source pollution is mainly caused by agricultural activities especially from planting cultivation where potential pollutants originate over large areas and the point of entry into water bodies cannot be precisely identified. Non-point source of agricultural pollution is particularly problematic because it is difficult to capture and treat the polluted water before it enters a stream. Therefore, efforts to minimize or eliminate pollutants from non-point source will focus on practices applied on or near farm fields. In other words, pollution prevention is

usually needed rather than the attempt to treat polluted water which is quite difficult to do so.

According to the Pollution Control Department (2006), pollutants from non-point source of agriculture are classified into 3 main groups including plant nutrients (i.e., nitrogen and phosphorus), pesticides, and organic matter. Therefore, the degree of non-point source pollution can be estimated by the following parameters; nitrogen, phosphorus, pesticides, and biochemical oxygen demand (BOD) as the indicator for organic matter. Nitrogen and phosphorus, commonly used as fertilizer, contribute to eutrophication of lakes, reservoirs, and other water bodies whereas pesticides and their degradation products can be toxic to aquatic ecosystem as a whole.

This chapter illustrates the overview of current status on non-point source pollution from agriculture in Thailand. Areas of discussion are described into 4 topics as shown below:-

1) Existing government policies, strategies, and guidelines,
2) Current status on non-point source of agricultural pollution derived from government reports and academic researches,
3) Trend in non-point source pollution from agriculture,
4) A case study showing good agricultural practice (GAP) and/or best management practice (BMP) to minimize the problems from non-point source pollution.

3.2.1 Existing Government Policies, Strategies, and Guidelines

As mentioned earlier, Thailand is an agricultural-based economy which can produce a variety of food for consumption in the country and for export worldwide. It is also apparent that the heavy usage of pesticides especially insecticides, herbicides, and fungicides has occurred over the past decade. This situation leads to major impacts on environmental quality and human health caused by contamination of pesticides in soil, water, crops, aquatic life and so on. By this reason, government sector needs to take actions in many ways through policy, planning, guidelines, and implementation so that those impacts can be minimized.

From the year 2002 to 2009, the Royal Thai Government has implemented 2 consecutive plans as the national guidelines for economic and social development policies. They are named as "The Ninth National Economic and Social Development Plan, B.E. 2545-2549 (A.D. 2002-2006)" and "The Tenth National Economic and Social Development Plan, B.E. 2550-2554 (A.D. 2007-2011)". Strategies of each plan are as follows:-

1) The Ninth National Economic and Social Development Plan, B.E. 2545-2549 (A.D. 2002-2006)

This plan was created by aiming at a concept called "People-centered Development". It also adopted the philosophy of sufficiency economy as the guiding principle of national development and management. In order to achieve the objectives and targets of this plan, seven strategies were conducted as prescribed below (Office of the National Economic and Social Development Board, 2002):-

a. The good governance strategy,
b. Development of human potential and social protection strategy,
c. Restructuring of management for sustainable rural and urban development strategy,

d. Natural resources and environmental management strategy,
e. Macroeconomic management strategy,
f. Upgrading national competitiveness strategy,
g. Strengthening of science and technology development strategy.

2) The Tenth National Economic and Social Development Plan, B.E. 2550-2554 (A.D. 2007-2011)

During the period of this plan, Thailand has faced major changes in many contexts; for example, the increase in world population has caused deterioration in the world's environment and natural resources. As a result, international agreements and treaties such as the Convention on Biological Diversity and the Convention on International Trade in Endangered Species of Wild Fauna and Flora have been signed. In addition, there are more trade barriers related to aspects of environment and natural resources. Hence, Thailand must upgrade its standards of environmental management in order to protect the resource base and maintain a sustainable balance in the natural environment.

To cope with this situation, development under the Tenth Plan has pursued a concept called "Green and Happiness Society" under the direction of the sufficiency economy philosophy. Therefore, this plan has been designed on the basis of the following strategies (Office of the National Economic and Social Development Board, 2009):-

a. Strategy for development of human quality towards a knowledge-based and learning society,
b. Strategy to strengthen community and society as basis of national security,
c. Strategy to reform the structure of the economy for balance and sustainability,
d. Strategy for development of biodiversity and conservation of the environment and natural resources,
e. Strategy to promote good governance aiming at social justice and sustainability.

It can be concluded that both the Ninth and Tenth Plans focus on the policies to conserve natural resources and environment. None of the strategies mentioned above states directly about the management of non-point source pollution from agriculture. However, there are some words in the explanation of these strategies (i.e., ecological balance, sustainable development, and safeguarding the environment) which imply that non-point source pollution is a part of these plans.

In association with the Tenth National Economic and Social Development Plans B.E. 2550-2554, there is another plan involved in natural resources and environment. The detail of this plan can be described in the following item:-

3) The Environmental Management Plan, B.E. 2550-2554 (A.D. 2007-2011)

This plan was prepared by Office of Natural Resources and Environmental Policy and Planning under the National Enhancement and Conservation of Environmental Quality Act, B.E. 2535 (1992). An important objective of this plan is to create a balance between use of natural and environmental resources for development and for enhancement of the country's competitive capacity, and the need to preserve, conserve and rehabilitate natural and environmental resources at their optimum level, consistent with the carrying capacity of the

ecologies and raising life standards of the people. Therefore, the following strategies have been proposed in order to achieve this objective (Office of Natural Resources and Environmental Policy and Planning, 2009):-

a. Strategy for promoting participation and creating collective knowledge by all sectors for natural resources and environmental management,
b. Strategy for enhancing the efficiency in natural resources and environ- mental management of all sectors,
c. Strategy for creating the driving force for local governments to manage their natural resources and the environment more aggressively,
d. Strategy for facilitating better and more equitable access and utilization of resources and alleviating poverty,
e. Strategy for encouraging balanced and sustainable utilization of natural resources,
f. Strategy for monitoring, maintaining, and rehabilitating environmental quality at its balance and sustainable level.

In the same manner as the Ninth and Tenth Plans, the overall of these strategies focus on natural resources and environmental management. However, it is stated in details of the last strategy that pollution from agriculture should be controlled by promoting agricultural practice to become more environment-friendly. Table 3.1 shows the guidelines for government agencies to manage such pollution.

Table 3.1: Guidelines for agricultural pollution management by government sector.

No.	Guidelines	Responsible Agencies
1	Establishing knowledge for Good Agricultural Practices (GAPs) to reduce the use of chemical fertilizers and pesticides by farmers. [1/]	- National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives.[1/]
2	Establishing knowledge for Best Management Practices (BMPs) to reduce environmental impact caused by agricultural activities. [2/]	- Pollution Control Department, Ministry of Natural Resources and Environment. [2/]
3	Establishing knowledge for soil and water conservation, soil fertility improvement, and land utilization. [1/]	- Department of Land Development, Ministry of Agriculture and Cooperatives. - Department of Water Resources, Ministry of Natural Resources and Environment. [1/]
4	Controlling the use of highly toxic chemicals in farm land by legislative and social measures. [1/]	- Department of Agriculture and Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. [1/]
5	Reducing the potential of agricultural runoff and discharges of wastewater from farm land. [1/]	- Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. - Pollution Control Department, Ministry of Natural Resources and Environment. [1/]
6	Controlling the quality of wastewater discharged from aquaculture activity to meet effluent standard. [1/]	- Department of Fisheries, Ministry of Agriculture and Cooperatives. - Pollution Control Department, Ministry of Natural Resources and Environment. [1/]
7	Setting up effluent standards in order to control the discharge of waste-water from livestock and aquaculture farming. [2/]	- Pollution Control Department, Ministry of Natural Resources and Environment. [2/]
8	Monitoring the quality of wastewater discharged from farm land for the purpose of law enforcement. [2/]	- Pollution Control Department, Ministry of Natural Resources and Environment. [2/]
9	Promoting the use of clean technology in farm land in order to reduce the degree of agricultural pollution. [2/]	- Pollution Control Department, Ministry of Natural Resources and Environment. [2/]
10	Providing technical supports for local officers as well as for farmers in the context of agricultural pollution management. [2/]	- Pollution Control Department, Ministry of Natural Resources and Environment. [2/]

Source: 1/ Office of Natural Resources and Environmental Policy and Planning, 2007.
2/ Water Quality Management Bureau, 2006.

3.2.2 Current Status on Non-point Source Pollution

The current status on non-point source pollution from agriculture in Thailand can be figured out by analyzing data derived from government reports and academic researches. Followings are the overview of present situation about the loading of those pollutants into the environment:-

Government projects on the estimation of non-point source pollution

During the year 2004 to 2005, the Pollution Control Department conducted a project for studying the degree of non-point source pollution from agriculture in Thailand. By this project, estimation of pollutant loading (i.e., nitrogen, phosphorus, pesticides, and organic matter in the form of BOD) to the environment was done separately according to their generating sources which included planting cultivation, livestock farming, and aquaculture activity.

1) Estimation of pollutant loading by planting cultivation

In this study, a number of crops were sampled for calculating the releasing rates of nitrogen, phosphorus, pesticides, and BOD from their planted areas. The result of this study is summarized in Table 3.2.

Table 3.2: Pollutant releasing rate from crop land during the year 2004 to 2005.

Type of crop	Area (million rai)*	Pollutant releasing rate (ton/year)			
		Nitrogen	Phosphorus	Pesticides	BOD
1. Transplanting rice	36.64	161.90	859.40	1.61	68,148.59
2. Direct seeding rice	29.75	17,695.73	2,827.67	2.46	58,377.65
3. Fodder Corn	7.04	74,375.22	1,603.34	610.38	3,828.92
4. Mung bean	1.42	5,137.86	52.08	41.12	1,053.00
5. Soybean	1.01	576,03	51.94	84.43	1,115.87
6. Sugarcane	6.67	27,795.96	541.97	161.59	3,074.32
7. Cabbage	0.07	1,343.04	1.76	7.18	11.90
8. Cauliflower	0.07	808.85	1.35	1.63	5.75
9. Sweet potato	0.05	1,462.98	0.43	17.71	10.90
10. Watermelon	0.11	565.38	1.26	3.89	10.92
11. Onion	0.11	224.14	0.67	3.67	25.91
12. Guinea-pepper	0.49	2,849.67	311.84	49.06	1,652.59
13. Tea	0.07	628.33	0.96	2.21	335.26
14. Palm oil	1.94	1,237.66	0.03	57.43	717.44
15. Mango	2.08	1,467.74	69.80	136.81	2,084.21
16. Rubber tree	13.02	2,813.99	0.49	838.43	9,299.90
17. Orchid	0.02	318.48	0.55	3.06	33.77
18. Cucumber	0.93	4,835.60	1.05	0.52	55.96
19. Yard long bean	0.13	7,687.55	27.34	36.85	245.99
20. Grape	0.03	1,142.76	20.30	28.52	78.89

Source: Pollution Control Department, 2006.
Remark: * 1 hectare = 6.25 rai

It can be concluded from the result in Table 3.2 about the loading of each pollutant in terms of releasing rate as follow:-

a. Fodder corn, sugarcane, and direct seeding rice were the first three crops that produced the highest loading of nitrogen at the releasing rates of 74,375.22, 27,795.96 and 17,695.73 ton/year, respectively.

b. Direct seeding rice, fodder corn, and transplanting rice were the first three crops that produced the highest loading of phosphorus at the releasing rates of 2,827.67, 1,603.34 and 859.40 ton/year, respectively.

c. Rubber tree, fodder corn, and sugarcane were the first three crops that produced the highest loading of pesticides at the releasing rates of 838.43, 610.38 and 161.59 ton/year, respectively.

d. Transplanting rice, direct seeding rice, and rubber tree were the first three crops that produced the highest loading of BOD at the releasing rates of 68,148.59, 58,377.65 and 9,299.90 ton/year, respectively.

It is also indicated that most of the sampling crops in this study produced the loadings of nitrogen and BOD at the higher releasing rates than those of phosphorus and pesticides. This means that both nitrogen and organic matter in the form of BOD were the major causes of non-point source pollution generated from planting cultivation.

2) Estimation of pollutant loading by livestock farming

Table 3.3 shows the result of estimating the loading of nitrogen, BOD, and phosphorus generated from livestock farming. In this study, a number of dairy cattle, beef cattle, swine, and poultry were sampled for calculating the releasing rate of these pollutants to the environment.

Table 3.3: Pollutant releasing rate from livestock farming during the year 2004 to 2005.

Type of livestock farming	Numbers of livestock	Pollutant releasing rate (ton/year)			
		Nitrogen	Phosphorus	Pesticides	BOD
1. Dairy cattle	478,836	7,661.38	2,633.60	-	31,746.83
2. Beef cattle	7,796,272	2,803.23	26,360.46	-	1,182.08
3. Swine	8,174,526	408.73	24,523.58	-	111,827.52
4. Poultry (duck)	21,540,345	187.53	1,069.24	-	273.30

Source: Pollution Control Department, 2006.

It can be concluded from the result in Table 3.3 about the loading of each pollutant as follow:-

a. Dairy cattle and beef cattle produced the loadings of nitrogen at the releasing rates of 7,661.38 and 2,803.23 ton/year which were much higher than those produced by swine and poultry.

b. Beef cattle and swine produced the loadings of phosphorus at the releasing rates of 26,360.46 and 24,523.58 ton/year which were much higher than those produced by dairy cattle and poultry.

c. Swine produced the loading of BOD at the releasing rate of 111,827.52 ton/year which was the highest rate when compared to those produced by

other farming.

As a result showing above, it can be stated that organic matter in the form of BOD was the most important impact of agricultural pollution generated from livestock farming especially by swine farm. Also, phosphorus and nitrogen seemed to be other non-point source pollutants caused by this activity as well.

3) Estimation of pollutant loading by aquaculture activity

Table 3.4 shows the result of estimating the loading of nitrogen, BOD, and phosphorus generated from aquacultures which included white shrimp, snake-head fish, and tilapia. It can be concluded from the study that the releasing rate of BOD was the most important factor to cause environmental problem rather than those of nitrogen and phosphorus.

Table 3.4: Pollutant releasing rate from aquacultures during the year 2004 to 2005.

Type of aquaculture	Area (rai)	Pollutant releasing rate (ton/year)			
		Nitrogen	Phosphorus	Pesticides	BOD
1. White shrimp	225,000	810.00	472.50	-	14,107.50
2. Snake-head fish	1,929	956.78	153.93	-	3,515.41
3. Tilapia	333,975	2,738.60	667.95	-	29,055.83

Source: Pollution Control Department, 2006.

Another government report on non-point pollution was issued by Office of Agricultural Economics in the year 2007. Table 3.5 shows the pollutant releasing rate of BOD generated by paddy fields in each region of the country.

Table 3.5: Pollutant releasing rate from paddy fields during the year 2006 to 2007.

Regions of Thailand	Planted area (rai)		BOD (ton /year)
	Major rice	Second rice	
Northern region	12,779,212	3,477,315	24,970
North-eastern region	32,773,544	900,130	54,955
Central region	7,185,152	5,017,894	18,744
Eastern region	2,629,187	468,009	4,757
Southern region	2,018,826	210,800	3,425
Total	57,385,921	10,074,148	106,851

Source: Office of Agricultural Economics, 2007.

Data from Table 3.5 indicates that the amount of 106,851 ton/year of BOD loading was polluted to the environment. This confirms the result of BOD loading reported by the Pollution Control Department's project which concluded that BOD was the major non-point source pollutant generated from planting activity.

3.2.3 Academic researches on the estimation of non-point source pollution

To emphasize on the current status of non-point source pollution from agriculture in Thailand, relevant researches from the year 2000 to 2008 have been thoroughly reviewed. These researches can be categorized into 3 major issues including planting cultivation, livestock farming, and aquaculture activity. Followings are some of the researches indicating the situation of non-point source pollution from each activity.

1) Estimation of pollutant loading by planting cultivation

Suviboon (2006) conducted a study on runoff potential in order to evaluate geo-spatial distribution pattern of non-point source pollutants which included nitrogen, phosphorus, and organic matter in Songkhla Lake catchment. The results of this study revealed soil characteristics of the catchment area into four parameters as follow; (1) average pH was 5.3 ± 0.7, (2) average organic matter content was 1.4 ± 0.8%, (3) average concentration of available P was 20.1 ± 38.4 (1.2 - 262.4) mg-P/kg, and (4) average concentrations of nitrate-N, ammonia-N, and total inorganic-N were 2.4±4.5 (ND-36.01), 30.8 ± 34.4 (1.2-197.6), and 35.1 ± 39.1 (1.3-401.2) mg-N/kg, respectively.

Thongyang (2006) compared organic loading as BOD from agriculture and forest land in Bang Pakong river basin during wet and dry periods of the year 2005. The result showed that most of the organic loadings in main stream exceeded surface water quality standard level for class 3, especially stations close to the outlet of the river. It was also reported that average organic loadings detected from agricultural land were 3,467.74 and 5,696.53 kg/day in dry and wet periods which were higher than standard level for class 3 as well. In addition, the study indicated that agricultural land had high level of BOD concentrations when compared to the concentrations of BOD detected from forest area.

Wongwiang (2006) also conducted a research on nutrients loading from agricultural land and forest area in Bang Pakong river basin. In this research, nutrient loadings in the form of ammonia-N, nitrate-N, and phosphate were detected during the wet and dry periods of the year 2004. The following table shows loading of those nutrients compared between agricultural and forest land uses.

Table 3.6: Nutrient loading from agricultural land and forest area in Bang Pakong river basin in 2004.

Source of Pollution	Area ($km.^2$)	Ammonia-N (kg/day)		Nitrate-N (kg/day)		Phosphate (kg/day)	
		Wet period	Dry period	Wet period	Dry period	Wet period	Dry period
Agricultural land	9,733.9	2,338.1	861.5	312.5	150.9	142.1	96.4
Forest area	5,671.3	229.1	469.6	304.6	219.5	134.4	82.8

Source: Wongwiang, 2006.

According to Table 3.6, it can be said that most of nutrient loadings detected in wet period had more concentration than those detected in dry period. The reason of this phenomenon is due to runoff which is normally occurred with high rainfall during the wet season. One other thing found in this research was that the concentrations of ammonia-N, nitrate-N, and phosphate generated from agricultural land were higher than those generated from forest area. This is because both nitrogen and phosphate play an important role as the

major components of fertilizer used by Thai farmers in farm land. These nutrients were then released by runoff from agricultural land to the Bang Pakong River Basin.

In addition to nitrogen, phosphorus and organic matter, many researches on pesticide residues have been done in Thailand. Followings are some examples of the researches dealing with organochlorine pesticides (OCPs), Polychlorinated biphenyls (PCBs), and Polycyclic aromatic hydrocarbons (PAHs):-

Duangkaew (2002) analyzed organochlorine pesticides (OCPs), PCBs and PAHs residues in mussels, oysters, and sediments from the east coast region of Thailand. As a result, OCPs residues were detected in mussels, oysters and sediments in the ranges of 7.02 - 33.88, 12.70 - 96.45, and 1.06 - 3.71 ng/g dry weight, respectively (Table 3.7). It was also found that concentrations of OCPs, PCBs, and PAHs were very high in oysters and mussels when compared to those found in the sediments.

Table 3.7: Concentrations of OCPs, PCBs and PAHs from the east coast of Thailand.

Sources	Concentration (ng/g)		
	OCPs	PCBs	PAHs
Mussels	7.02 – 33.88	1.60 – 18.48	0.21 – 0.94
Oysters	12.70 – 96.45	6.61 – 51.43	0.87 – 1.57
Sediments	1.06 – 3.71	0.04 – 3.03	0.24 – 1.15

Source: Duangkaew, 2002.

Rohitrattana (2005) studied the accumulation of organochlorine pesticide residues in food chain of fishes at Klong 7, Rangsit agricultural area in Pathum Thani province. It was found that biomagnifications factor (BMF) values were 1.61 – 2.27 for ΣDDT and 4.19 – 8.80 for ΣEndosulfan from primary consumers, herbivorous, detritivorous fish to the top predator fish.

Siriwong (2006) studied the residual occurrence of OCPs in aquatic ecosystem and health risk assessment of local agricultural community at Rangsit Klong 7, Pathum Thani province. The results showed that OCPs concentration levels in aquatic ecosystem were quite low. The average concentration of OCPs compared in various matrices indicated that ΣEndosulfan was found at the highest level in water whereas the highest level of DDT and its derivatives were detected in plankton, aquatic plants, and fishes (Table 3.8). It is noted that even OCPs were banned for agricultural purposes in Thailand, their accumulation and transformation still existed in aquatic food web from the lowest up to the highest tropic level.

Table 3.8: Concentration of OCPs residues in aquatic ecosystem of Klong 7, Rangsit agricultural area in Pathum Thani province.

Environmental Compartments	n	Average concentration OCPs (ppb)			
		ΣHCH	Heptachlor & Hept.epoxide	DDT & Derivatives	Σendo sulfan
Water *	108	0.01	0.007	0.02	0.08
Sediments *	108	9.36	14.67	12.05	6.36
Aquatic plants ** (water hyacinth)	84	5.44	5.90	9.25	7.91
Plankton	51	1.80	1.79	3.65	3.29
Fishes **					
- Moonbeam gourami	24	4.08	4.32	23.75	7.80
- Silver barb	30	2.13	3.35	4.16	3.18
- Three-spot gourami	24	3.71	4.88	12.66	11.90

Source: Siriwong, 2006.
Remark: * ng/g dry wt. and ** ng/g wet wt.

2) Estimation of pollutant loading by livestock farming

Koomjawhaw (2006) examined the impact of odor pollution caused by excretion from livestock farming located in Rajamangala Institute of technology, Lampang campus. It was found that excrement in the form of urine and fecal wastes from farm field was a major factor to cause high intensity of odor. This led to the impact on physical and mental health of administrators, lecturers, and students of the campus. Therefore, management approach should be improved so that odor pollution can be mitigated. Examples of this approach are recycling those animal wastes as fertilizer for planting cultivation and using proper chemicals for controlling flies and mosquitoes in the farm field.

Promma (2008) conducted a research on waste management in dairy farms located alongside of Mae On watercourse, San Kampaeng District, Chiang Mai Province. It was reported that there were 35 dairy farms in this area. Of these, 10 farms treated their wastes by storage wells, 9 farms by storage ponds, 7 farms by biogas wells, and the rest had no waste treatment system. However, there were cow manures spreading over ground surface on the farm field. These wastes were washed out by runoff and caused the release of nutrient loading (i.e., organic matter and nitrogen) into water bodies. Table 3.10 illustrates the concentrations of both nutrients in the form of BOD and TKN during winter, summer, and rainy season.

Table 3.9: Nutrient loading from dairy farms alongside of Mae On watercourse.

Sampling site	BOD (mg/L)			TKN (mg/L)		
	Winter season	Summer season	Rainy season	Winter season	Summer season	Rainy season
1. Upstream	7.00	-	6.60	158.00	-	5.53
2. Midstream	2.00	5.00	28.00	-	-	15.50
3. Downstream	2.00	-	17.00	-	-	1.60

Source: Promma, 2008.

As shown in Table 3.9, most of BOD loadings detected from upstream, midstream, and downstream of Mae On watercourse exceeded surface water quality standard level for class 3 which is equal to 2.0 mg/L. Also, TKN loadings detected from the same area were higher than 5.0 mg/L which is the surface water quality standard level for class 3 as well. As a result, it can be concluded that organic matter and nitrogen were the most important impact of agricultural pollution generated from dairy farming.

3) Estimation of pollutant loading by aquaculture activity

Buranaprattheprati et al. (2002) conducted a study on seasonal variations of freshwater, salt, dissolved inorganic phosphorus (DIP), and dissolved inorganic nitrogen (DIN) in Bang Pakong estuary. As a result of the study, variation in interaction between coastal seawater and inland water discharged to the sea played an important role in controlling the characteristics of estuarine water. Moreover, it was found that high peak concentrations of DIP and DIN loadings were related to the long residence time in the transition period between dry and wet seasons. Therefore, a strong eutrophic condition could possibly occur at that time, especially from April to July. Accordingly, Bang Pakong estuary was reported to generate the loadings of DIP and DIN at 38.2 and 4.9 tons/month, respectively.

Szuster and Flaherty (2002) conducted a research on assessing organic waste production by low salinity shrimp farms in Bang Pakong river basin. In this research, three scenarios were developed in order to estimate BOD loading released to different sub-basins. Those scenarios included (1) Scenario A represented the "best case" situation in best management practices for waste production, (2) Scenario B represented the "worst case" situation in poor management practices, and (3) Scenario C represented an intermediate case between Scenario A and B. Table 3.10 shows the comparison of annual estimation of BOD loadings between those three scenarios. It was apparent that Scenario A, the best practices, polluted a lower amount of BOD to the river basin than Scenario B and C, respectively.

Table 3.10: Annual estimation of BOD loadings generated by low salinity shrimp farms in Bang Pakong river basin.

Sub-basin	BOD loading (kg/year)		
	Scenario A	Scenario B	Scenario C
Nakhon Nayok	932,686	15,841,357	8,399,815
Prachinburi	1,547,196	26,278,602	13,834,590
Lower Bang Pakong	3,200,439	60,480,651	32,020,775
Total	6,040,780	102,600,610	54,320,695

Source: Szuster and Flaherty, 2002.

Rodkuen (2005) conducted a study on the culture pattern, socio-economic, cost benefit, and environmental quality caused by aquacultures (i.e., cage culture and shrimp culture) located in Palian district, Trang province. The result from this study showed that nutrient concentrations in surrounding water and total organic matter in sub-surface of sediment at Klong Rae and Klong Susong were higher than other areas because these two Klongs are dominated by both cage culture and shrimp culture.

Kukato et al. (2007) investigated the application of nitrification bio-filter on nitrogen treatment in outdoor aquaculture. As a result, the bio-filter played a major role to treat ammonia-N over phytoplankton and consequently provided the better quality of water for shrimp culture. Therefore, it was recommended from this study to use this technique for improving water quality in outdoor aquaculture.

Generally, intensive farming of aquacultures such as cage culture and shrimp culture generate a large amount of nutrient loadings especially in the form of nitrogen to water bodies. These loadings come from different sources which include urine and fecal wastes excreted by fishes or shrimps and also from the remaining of feed applied to those aquatic lives. Because of this, eutrophication or algae bloom is likely to occur in the surrounding area of intensive farming. It is noted that inland and coastal aquacultures may create different impact to the environment depending on their physical, chemical, and biological factors. In the case of coastal aquaculture, nutrient loadings can be dispersed around the coastal area because the current and tidal waves are very dynamic. On the other hands, dispersal of these loadings is rarely to occur in the inland aquaculture because hydrodynamic condition is simply lower than the coastal area.

3.2.4 Trend in Non-point Source Pollution from Agriculture

It is quite difficult to assess or predict trend in non-point source pollution from agriculture in Thailand. To achieve this goal, however, relevant data such as existing or current situation of major pollutant loadings and the change of agricultural land use are really needed. These data can be the factors to point out the direction and magnitude of non-point source pollution from agricultural activities in the future. In this study, loading of major pollutants are categorized as nitrogen, phosphorus, organic matter in the form of BOD, and pesticides, respectively. The current situation of these pollutants was given by the Pollution Control Department's project which has been discussed earlier. Therefore, it is the aim of this study to assess trend in non-point source of agricultural pollution on the basis of this situation.

Table 3.11 illustrates the current situation of major pollutant loadings in terms of releasing rate in accordance with their generating sources which include planting cultivation, livestock farming, and aquacultures.

Table 3.11: Releasing rate of four major pollutants generated by planting cultivation, livestock farming, and aquacultures.

Agricultural Activity	Pollutant releasing rate (ton/year)			
	Nitrogen	Phosphorus	Pesticides	BOD
Planting cultivation				
Fodder Corn	74,375.22	1,603.34	610.38	3,828.92
Direct seeding rice	17,695.73	2,827.67	2.46	58,377.65
Transplanting rice	161.90	859.40	1.61	68,148.59
Sugarcane	27,795.96	541.97	161.59	3,074.32
Rubber tree	2,813.99	0.49	838.43	9,299.90
Livestock farming				
Swine*	408.73	24,523.58	-	111,827.52
Dairy cattle*	7,661.38	2,633.60	-	31,746.83
Beef cattle	2,803.23	26,360.46	-	1,182.08
Poultry (duck)*	187.53	1,069.24	-	273.30
Aquacultures				
Tilapia*	2,738.60	667.95	-	29,055.83
White shrimp*	810.00	472.50	-	14,107.50
Snake-head fish*	956.78	153.93	-	3,515.41

Remark: * Point source agriculture

From this table, it is possible to point out the trend in non-point source pollution generated by each type of agricultural activities as follow:-

a) ***Fodder corn*** is expected to be the most important crop to pollute ***nitrogen*** into the environment. This is because its releasing rate of nitrogen at 74,375.22 ton/year was highest when compared to those generated by other crops such as sugarcane, direct seeding rice and rubber tree.

b) ***Direct seeding rice and fodder corn*** are expected to be the most important crops to pollute ***phosphorus*** into the environment. This is because their releasing rates of phosphorus at 2,827.67 and 1,603.34 ton/year were highest when compared to those generated by other crops such as transplanting rice and sugarcane.

c) ***Rubber tree and fodder corn*** are expected to be the most important crops to pollute ***pesticides*** into the environment. This is because their releasing rates of pesticides at 834.43 and 610.38 ton/year were highest when compared to those generated by sugarcane, direct seeding rice and transplanting rice.

d) ***Transplanting rice and direct seeding rice*** are expected to be the most important crops to pollute ***BOD*** into the environment. This is because their releasing rates of BOD at 68,148.59 and 58,377.65 ton/year were highest when

compared to those generated by other crops such as rubber tree, fodder corn and sugarcane.

e) ***Dairy cattle farm*** is expected to be the most important livestock activity to pollute ***nitrogen*** into the environment. This is because its releasing rate of nitrogen at 7,661.38 ton/year was highest when compared to those generated by beef cattle and swine farms.

f) ***Beef cattle and swine farms*** are expected to be the most important livestock activities to pollute ***phosphorus*** into the environment. This is because their releasing rates of phosphorus at 26,360.46 and 24,523.58 ton/year were highest when compared to those generated by dairy cattle and poultry farms.

g) ***Swine farm*** is expected to be the most important livestock activity to pollute ***BOD*** into the environment. This is because its releasing rate of BOD at 111,827.52 ton/year was highest when compared to those generated by dairy cattle and beef cattle farms.

h) ***Tilapia*** is expected to be the most important aquaculture farming to pollute ***nitrogen, phosphorus and BOD*** into the environment. This is because it released the amount of nitrogen, phosphorus and BOD at 2,738.60, 667.95 and 29,055.83 ton/year which were the highest rates among those generated by other aquaculture farming.

Another factor used to point out the direction and magnitude of non-point source pollution is changing in agricultural land use of major crops from year to year. It means that if the planted area of crops increase, the magnitude of non-point source pollution tends to increase and vice versa. Table 3.12 shows the percentage of land use change of each crop from the year 2006/2007 to 2009/2010. It can be analyzed from this table that land use change of these major crops is unpredictable due to several factors to be involved. For example, if the market prices of crops increase, the planted areas of crops are likely to increase as well.

Table 3.12: Land use change of major crops during the year 2006/2007 to 2009/2010.

Type of crop	Planted area (million rai)				Land use change (%)			
	2006/ 2007	2007/ 2008[1/]	2008/ 2009[1/]	2009/ 2010[1/]	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010
1. Fodder Corn	7.04	6.36	6.69	6.63	-	-9.65	5.19	-0.90
2. Sugarcane	6.67	6.88	6.43	6.55	-	3.15	-6.54	1.87
3. Rice*	66.39	70.19	69.13	67.08	-	5.72	-1.51	-2.96
4. Rubber tree	13.02	15.36	11.37	11.51	-	15.97	-25.98	1.23

Source: 1/ Office of Agricultural Economics, 2009.
* Direct seeding rice + transplanting rice

Since there is only beef cattle farm which is considered as non-point source activity (Table 3.11). Therefore, the other types of livestock farming (i.e., dairy cattle, swine and poultry) will not be discussed in this study. Table 3.13 shows the percentage of changing in number of beef cattle from the year 2006/2007 to 2009/2010. It is found that the number of beef cattle varies thoroughly from year to year. This is due to many factors such as market price of beef, outbreak of cow diseases, and lack of grazing area, etc.

Table 3.13: Change in number of beef cattle during the year 2006/2007 to 2009/2010.

Livestock	Number of livestock (million head)				Change in number of livestock (%)			
	2006/2007	2007/2008[1/]	2008/2009[1/]	2009/2010[1/]	2006/2007	2007/2008	2008/2009	2009/2010
1. Beef cattle	7.80	6.48	6.70	6.60	-	-16.92	3.39	-1.49

Source: 1/ Office of Agricultural Economics, 2009.

By the same reason as dairy cattle, swine and poultry, it is known that tilapia, white-shrimp and snake-head fish farms are not considered as non-point source activities (Table 3.11). Therefore, these activities will not be discussed in this study for assessing the trend in non-point source pollution from agriculture.

It would finally be stated that the existing data are not enough to assess trend in non-point source pollution from agriculture more accurately. However, by using current situation of pollutant releasing rates of five major crops and beef cattle together with the changes in land use of those crops and the number of cattle, trend in non-point source of agricultural pollution in the future can be described as the following conclusions:-

1) Planting cultivation

Fodder corn tends to be the most important crop among the others to generate non-point source pollution in terms of releasing rate of major pollutants especially nitrogen, phosphorus, and pesticides. The increase of these releasing rates may not be the case because the change in planted area of fodder corn was rather small and varied in the narrow range of approximately 6 - 7 million rais each year during 2006/2007 to 2009/2010. On the other hand, transplanting rice and direct seeding rice will play a role as the major sources of polluting organic matter in the form of BOD to the environment. Their BOD loadings in the future might not be different from the current situation because the planted area of rice has not been changed very much since the last four crop years from 2006/2007 to 2009/2010.

2) Livestock farming

Beef cattle farm tends to be the major activity to cause non-point source pollution from livestock farming. Unfortunately, none of existing government projects or academic researches pay attention in other non-point source activities such as paddy field duck. Therefore, the trend in non-point source pollution generated by livestock farming cannot be predicted more precisely.

3) Aquacultures

None of existing projects or researches has been studied on non-point source pollution generated by aquaculture activity especially from fish cage culture alongside of the main river. Therefore, no data can be used to assess the trend in non-point source pollution from this activity.

3.2.5 Case Study

This is a case study showing good agricultural practice (GAP) and/or best management practice (BMP) to minimize problems related to non-point source pollution from agriculture. It was the project on BMP for rice cultivation conducted by the Pollution Control Department

in Chainat province. The objective of this project was to compare the result of management practices with 4 different patterns of pesticide and fertilizer application. The management practices consisted of using bio-pesticide, bio-fertilizer, chemical fertilizer, phosphate, herbicide and manual weed control which is illustrated in Table 3.14.

Table 3.14: Comparing management practices for rice cultivation in Chainat province.

No.	Management practices						Production (kg/rai)
	Bio-pesticide	Bio-fertilizer	Chemical fertilizer	Phos-phate	Herbicide	Manual weed control	
1	x	x	-	-	-	x	747
2	x	x	-	x	-	x	710
3	x	x	x	-	-	-	788
4	-	x	-	-	x	-	856

Source: Pollution Control Department, 2003b.

It can be concluded from Table 3.14 about the result of management practices for rice cultivation as follow:-

a. Pattern no.1 comprised the use of bio-pesticide, bio-fertilizer, and manual weed control and yielded the amount of rice production at 747 kg/rai.

b. Pattern no.2 comprised the use of bio-pesticide, bio-fertilizer, phosphate, and manual weed control and yielded the amount of rice production at 710 kg/rai.

c. Pattern no.3 comprised the use of bio-pesticide, bio-fertilizer, and chemical fertilizer and yielded the amount of rice production at 788 kg/rai.

d. Pattern no.4 comprised the use of bio-fertilizer and herbicide instead of manual weed control and yielded the amount of rice production at 856 kg/rai which was the highest production per unit area when compared to the other management practices.

Table 3.15 shows nutrient loading of Nitrate-N (NO_3) and Phosphate (PO_4) generated by four patterns of pesticide and fertilizer application as mentioned earlier. Conclusions from this table can be discussed as the following items:-

a. Concentrations of both NO_3 and PO_4 detected during pre-planting period of rice cultivation were lower than those detected during pre-harvesting period for all patterns of pesticide and fertilizer application.

b. Concentrations of NO_3 found in every pattern of pesticide and fertilizer application were higher than those of PO_4 especially during pre-harvesting period of rice cultivation.

c. Concentrations of NO_3 among all patterns varied between 0.06-0.16 mg/L during pre-planting period and 1.84-2.47 mg/L during pre-harvesting period of rice cultivation. These values indicate that concentrations of NO_3 generated by all patterns did not differ very much among each other.

d. Concentrations of PO_4 among all patterns varied between 0.02-0.05 mg/L during pre-planting period and 0.30-0.49 mg/L during pre-harvesting period of rice cultivation. These values indicate that concentrations of PO_4 generated by all

patterns did not differ very much among each other.

Table 3.15: Nutrient loading by different management practices of rice cultivation.

No.	Sampling period	Concentration (mg/L)	
		Nitrate-N (NO_3)	Phosphate (PO_4)
1	Pre-planting	0.08	0.02
	Pre-harvesting	2.47	0.31
2	Pre-planting	0.08	0.05
	Pre-harvesting	1.84	0.30
3	Pre-planting	0.16	0.03
	Pre-harvesting	2.40	0.49
4	Pre-planting	0.06	0.03
	Pre-harvesting	2.33	0.44

Source: Pollution Control Department, 2003b.

According to the results shown in Table 3.14 and Table 3.15, it is apparent to state that Practice no.1 of this project should be the good agricultural practice (GAP) and best management practice (BMP) by two reasons. First, even this pattern did not yield the highest production of rice when compared to others, but it was considered as environment-friendly with no application of chemicals. Second, this pattern did not generate high concentration of nutrient loading in the form of NO_3 and PO_4 when compared to others.

3.3 CONCLUSIONS AND RECOMMENDATIONS

This chapter will be discussed on gaps and needs in academic research on non-point source pollution and areas for collaborative researches between Thailand and other Southeast Asian countries which include Cambodia, Laos, Myanmar, and Vietnam. It is expected that experiences gained from the researches will be shared together among these countries to make advantages in sustainable development of agriculture and safe environment for population of all countries in this region.

In the previous section, some academic researches have been reviewed in order to figure out the current status on non-point source pollution from agriculture which is divided into 3 areas including planting cultivation, livestock farming, and aquaculture activity. In fact, the total number of 61 researches conducted by graduate students, researchers in academic institutes and government offices during the year 2000 to 2008 has been investigated. Of these, 24 researches or 39% is in the part of planting cultivation, 15 researches or 25% in the part of livestock farming, and 22 researches or 36% in the part of aquacultures (Table 3.16). The titles of these researches in each area are listed separately in Appendix 1, 2, and 3.

Table 3.16: Current researches on non-point source pollution from agriculture during the year 2000-2008.

Year	Areas of academic research			
	Planting cultivation	Livestock farming	Aquaculture activity	Total
2000	2	1	2	5
2001	1	-	2	3
2002	5	1	2	8
2003	2	3	2	7
2004	1	-	2	3
2005	4	3	3	10
2006	6	3	5	14
2007	2	1	3	6
2008	1	3	1	5
Total	24 (39%)	15 (25%)	22 (36%)	61 (100%)

3.3.1 Gaps and Needs in Academic Research

According to the data from Table 3.16, it is found that the publication of researches in each area of non-point source pollution was quite low. This situation reveals that Thailand still lacks of prominent issues of research on non-point source pollution. Because of this, the prediction of trend in non-point source pollution caused by agriculture cannot be done precisely. Followings are gaps and needs in conducting academic researches in the future for all areas of this problem.

Gaps and needs in research on non-point source pollution from planting cultivation

Table 3.17compiles the gaps and needs relevant to researches on non-point source pollution from planting cultivation:-

Table 3.17: Gaps and needs in research on non-point source pollution from planting cultivation.

No.	Gaps	Needs
1	There were a few researches focusing on fodder corn, direct seeding rice, transplanting rice, sugarcane and rubber tree which were ranked as the major crops with high potential to generate non-point source pollution in Thailand.	Develop more researches on these major crops and focus the study on application of GAP or BMP so that the effects on non-point source pollution generated by these crops can be mitigated.
2	Lack of researches on estimation of nutrient loading (i.e., nitrogen, BOD, phosphorus) occurred in each water-shed area of the country especially in the upstream where pesticides and chemical fertilizers are widely used by farmers.	Develop the research topics on nutrient loading in upstream area and focus the study on application of bio-agriculture (i.e., bio-pesticide, bio-fertilizer) in order to make environ-ment friendly in that area.
3	National policy on expanding the planted area of energy crops such as sugarcane may increase the degree of non-point source pollution in the future.	Emphasize the researches on GAP or BMP for sugarcane and other energy crops especially in the area of soil conservation and proper uses of pesticides and fertilizers in order to reduce such pollution.
4	Lack of studies on other non-point source pollutants from agriculture (i.e., heavy metals, growth hormones) that certainly make a significant contribution to pollution on aquatic ecosystem.	Extend the area of researches in the future to cover such pollutants that have not yet been studied in recent years so that all of the problematic substances will be involved in assessing non-point source pollution from planting cultivation.

Gaps and needs in research on non-point source pollution from livestock farming

Table 3.18 compiles the gaps and needs relevant to researches on non-point source pollution from livestock farming:-

Table 3.18: Gaps and needs in research on non-point source pollution from livestock farming.

No.	Gaps	Needs
1	Lack of adequate researches on beef cattle which was considered as the major non-point source pollution from livestock farming.	Develop more researches to cope with non-point source pollution from beef cattle by focusing on the effect of their wastes (i.e., fecal and urinary wastes) and the improvement of grazing management system to reduce physical disturbance of soil and vegetation and minimize direct loading of animal wastes to sensitive areas.
2	None of the researches investigated on paddy field duck which is another important activity to generate non-point source pollution from livestock farming.	Develop the research topics related to paddy field duck by focusing on the estimation of pollutant releasing rate so that non-point source pollution by this farming activity can be estimated accurately.
3	Lack of studies on the contamination of coliform bacteria or other diseases from beef cattle and paddy field duck farming that may lead to health effect on human being.	- Develop the research topics on human health effects caused by the contamination of coliform bacteria or other diseases from beef cattle and paddy field duck farming. - Study on the application of BMP for beef cattle and paddy field duck farming in order to prevent the contamination of coliform bacteria or the outbreak of other diseases.

Gaps and needs in research on non-point source pollution from aquacultures

Table 3.19 compiles the gaps and needs relevant to researches on non-point source pollution from aquacultures:-

Table 3.19: Gaps and needs in research on non-point source pollution from aquacultures.

No.	Gaps	Needs
1	None of the researches conducting on fish cage culture especially alongside of the main rivers which is the most important non-point source pollution from aquacultures by releasing large amount of wastes directly to the river basins.	- Extend the area of researches to study on impacts of fish cage culture by assessing the total pollutant releasing rate and/or the total maxi- mum daily load (TMDL) in the main rivers of each watershed in the country. - Focus the study on investigating appropriate feed time during the production cycle of fish cage culture. - Develop the researches on using mathematical models to predict water quality surrounding fish cage areas by considering relevant parameters such as DO, BOD, Suspended solid, Ammonia, nitrogen, phosphorus etc. as the indicating factors.

3.3.2 Areas for Collaborative Research with CLMV countries

Non-point source pollution from agriculture has emerged as the largest threat to water quality in Southeast Asia especially in agricultural-based countries including Cambodia, Laos, Myanmar, Vietnam and Thailand (CLMV-T). In order to identify the recommendation of future researches and areas for collaborative research with these four neighboring countries, basic data on this scheme from every country are needed. Therefore, the collaboration and partnership among stakeholders from each country should be arranged for group discussion. However, the identification approach to develop future researches in the area of non-point source pollution from agriculture can be recommended as follow:-

a. Research network on non-point source pollution from agriculture among CLMV-T should be established and made agreement for selecting sensitive areas in the main watersheds of each country.

b. Areas of the future researches and also areas for collaborative research with CLMV-T should be emphasized on the application of GAP and BMP to reduce the pollutant releasing rates generated from planting cultivation, livestock farming, and aquacultures. The GAP and BMP proposed by each country should be integrated together and then developed as a guideline for green farming.

c. Appropriate technology such as mathematical models and geographic information systems (GIS) should be employed for the future researches so that current status on non-point source pollution from agriculture of the whole region can be predicted precisely. This will be useful for CLMV-T to develop their own policies to prevent such pollution in the future.

d. Collaborative partnership or internship program for graduate students, researchers from academic institutes and government agencies should be encouraged to conduct researches in CLMV-T.

e. Center of excellence in non-point source pollution research should be established so that researchers from CLMV-T will have an international forum to share experiences in doing their research works.

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CHAPTER 4: SYNTHESIS REPORT ON AGRICULTURAL SUSTAINABILITY: CHALLENGES IN ENVIRONMENT AND CLIMATE CHANGE

4.1 BACKGROUND AND OBJECTIVES

The objective of the synthesis paper is to summarize and synthesis the outcomes from the review papers on agricultural sustainability and environment that were carried out by researchers from Laos, Thailand and Vietnam. The synthesis covers the outcomes of the 6 projects, four in Thailand, one in Lao PDR and one in Vietnam carried out under the Collaborative Research Projects with Neighboring Countries supported by TRF as follow:

- Economic Growth and Environmental Degradation in Thailand: Linkage and Implications;
- Climate Change and its Mitigation Mechanisms: Implications on Agriculture and Food Security in Thailand;
- Understanding the Linkage of Biodiversity and Agricultural Sustainability under the Current Environmental Change in Thailand;
- Current Status on Non-point Sources of Pollution from Agriculture in Thailand;
- Food Security and Agricultural Sustainability: Challenge and Opportunity in Vegetable Production in the Lao PDR; and
- Food security and Environment: Case Study of Rice Production and its impacts on Environment in Go Cong Dong District, Tien Giang Province.

According to Figure 4.1, the first step is to identify gaps and needs of each project. The outcomes of this synthesis are then integrated with the outcome of a review on the current status on research on environment and climate change in CLMV countries as described in Chapter 2 to identify priority areas on environment and climate change. Finally, a framework for collaboration is recommended.

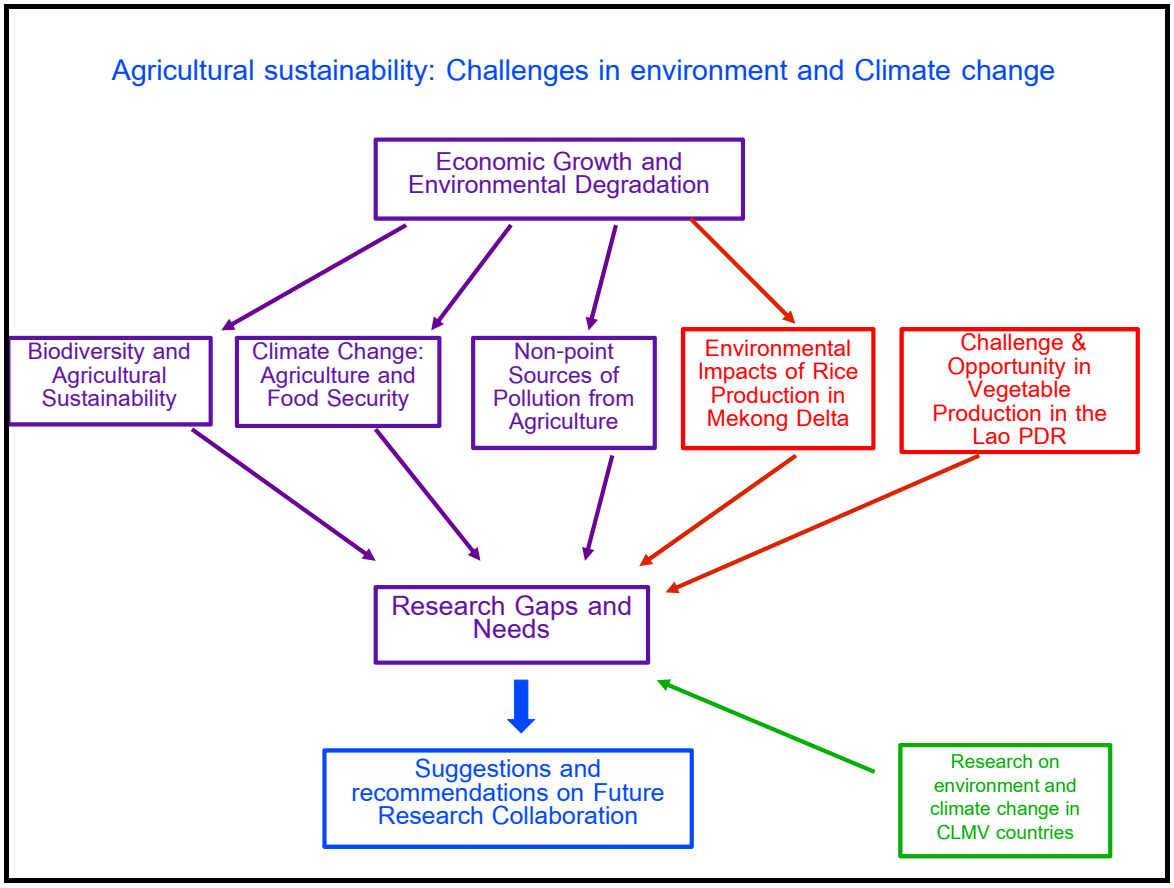

Figure 4.1: Projects and synthesis approach

4.2 OUTCOMES OF THE REVIEW PAPERS

The objectives, findings and recommendations of each paper are described in the following sections.

4.2.1 Economic Growth and Environmental Degradation in Thailand: Linkage and Implications

The main objective of this paper is to identify a relationship between economic growth and environmental quality focusing on the following environmental issues:

- pollution (air, water, and soil pollution),
- depletion of natural resources (deforestation, lignite and natural gas, and fishery), and
- GHG emission (carbon dioxide).

The review is based on the Environmental Kuznets Curve (EKC) and an economic-induced pollution hypothesis. The EKC is known as an inverted U-shape relationship given per capita income is on the horizontal axis. The EKC hypothesis states that the environmental quality will decrease as the economy grows until at a certain level of economic growth which the environmental quality starts to increase as the economy grows.

The economic-induced pollution hypothesis suggests that an expansion of economic activities will create more pollution depending on the scale of economy (scale effect), the share of environmental unfriendly products (composition effect), the prices of polluting products (price effect), and the access to cleaner technology (technique effect). The first three effects have positive relationships with pollution while the last one has a negative relationship.

In general it was concluded that the linkages of economic and environmental issues are complex. The results of the case study of Thailand are:

- In term of air pollution, data on CO and SO_2 showed the EKC relation but there is inconsistent result in the case of NO, SO_2 and NO_2;
- For forest including mangrove forests, results showed a monotonically decreasing trends of forest areas;
- Gross Provincial Products (GPP) played significant role in higher phosphorus residues in soil in the central region; and
- the income and the scale effects have significant impacts on air pollution across 19 provinces
- a region with higher Gross Regional Products (GRP) per capita has higher share of forest area than the other regions;
- the EKC may exhibit in the case of lignite;
- a constant trend of inland fishery capture and an inconclusive trend for marine fishery capture as GDP per capita increases;
- Pollution among 13 rivers, population density (a proxy of composition effect) dominates both income and technology effects; and
- A positive correlation between CO_2 emission per capita and GDP per capita.

This paper provided the following research questions relating to the economic-environmental linkage:

- How local people can participate in forestry management, especially the adjacent forest area of neighbouring countries;
- How to enhance joint benefits of managing natural resources, especially alternative energy and renewable energy;
- How to increase the stocks of fishery in the Mekong River and the Gulf of Thailand for the benefits to local people in these countries;
- How to manage water allocation in the Mekong River in order to increase food security and sustainable development in the region; and
- How these countries combat climate change together, both adaptation and mitigation approaches, with sharing benefits and minimizing costs.

4.2.2 Climate Change and its Mitigation Mechanisms: Implications on Agriculture and Food Security in Thailand

The paper provided the general perspective of agriculture and food security in Thailand, the problem of climate change in agriculture sector both in term of sources of Green House Gas (GHG) and the impact of climate change and existing mechanisms available for handling of climate change impact from the agricultural perspective. The results of this paper are:

Food security:

- Thailand are in surplus of food and a net exporter of agricultural products;
- Thailand's success in continuous improvement of undernourishment;

- Production of food is vulnerable to natural phenomenon particularly rainfall and is dependent on imports of fertilizer;
- With a need to find alternative source of energy, food production is threatened by the widespread of plantation for palm oil and sugarcane to produce biodiesel and gasohol.

Future research:

- adaptive techniques and its effect on crop and yield and the effect on the supply of agricultural products and food;
- policy on climate change and agriculture (problem-based rather than resource-based);
- coordinated framework of authority and enforcing policies.

4.2.3 Understanding the Linkage of Biodiversity and Agricultural Sustainability under the Current Environmental Change in Thailand

This paper aimed at conducting a review to develop a conceptual framework to explain linkages between biodiversity and agricultural sustainability and to provide topics for in depth research. The concept of agrobiodiversity was investigated in term of:

- the role of small scale farming system in conservation of biodiversity and the adaptive capacity of the system to environmental changes;
- Agricultural sustainability in Thailand after green revolution and Thailand's situation of on-farm biodiversity conservation.

This paper concluded that small scale farming system play a crucial role in conserving biodiversity and therefore promoting food security. Traditional or small scale farming system contributed to conserving biodiversity as several crop species and varieties are used in the farming system. The advantage of this system included efficient use of resources, nitrogen availability, reduction of deceases and pests, weed suppression and reduce soil erosion and moisture. In term of economic sustainability the advantages include marketing, labor and local diet. The Karen case study in the northern part of Thailand showed that small scale farmers used a wide varies of crops and changing cropping techniques to adapt to environmental changes.

In term of agricultural sustainability in Thailand, the country has experienced various environmental problems after the green revolution. It was not until the Seventh National Economic and Social Development Plan that the sustainable agriculture was introduced. The 7th Plan promoted integrated farming with livestock, aquaculture and agroforestry. The 8th Plan (1997-2001) encouraged five types of sustainable agriculture i.e. natural farming, organic farming, integrated farming, the "new theory" agriculture and agroforestry. The 9th Plan (2002-2006) integrated new technology and local knowledge and applied the philosophy of sufficiency economy in the farming system. It was concluded that the government approach fails to recognize the concept of agrobiodiversity. The government focused more on organic farming which promote farming without chemical use while ignoring conservation of local crop genetic resources. It was emphasized that conservation of crop genetic resource is needed to safeguard crop production and research is needed to understand the adaptive capacity of small scale farmers in coping with climatic changes.

4.2.4 Current Status on Non-point Sources of Pollution from Agriculture in Thailand

The paper reviewed the current status of non-point source of pollution from agriculture in term of present situation and existing problems, government policies, relevant researches from both government and academic sectors. It then identified gaps and needs related to non-

point source pollution in Thailand. It also recommended areas for future collaboration with CLMV countries. Based on the outcomes of gap analysis, it was concluded that more researches on non-point sources of pollution is needed in the following areas:

- major crops such as fodder corn, direct seeding rice, transplanting rice, sugarcane and rubber trees, beef cattle, paddy field duck farming and fish cages;
- estimation of nutrient loading in watershed areas;
- estimation of heavy metals, growth hormones and coliform bacteria.

With regard to the collaborative research, it was recommended that

- a network should be established to study selected watershed areas of the region;
- Developing guidelines for green farming by incorporating Good Agricultural Practices (GAP) and Best Management Practices (BMP);
- developing mathematical models and Geographic Information System (GIS) for estimating non-point sources of pollution;
- establishing a center of excellence as a forum for local researchers to share experiences on non-point sources of pollution.

4.2.5 Food Security and Agricultural Sustainability: Challenge and Opportunity in Vegetable Production in the Lao PDR.

The objectives of this paper are to review the current situation of vegetable production in different parts of Lao PDR and to determine challenges and opportunity in vegetable production. Data on vegetable production and distribution were obtained from statistical data and annual reports of the Agriculture Department and provincial agriculture and forestry offices. Interviews were conducted with 250 farmers in five provinces namely Vientiane, Louangprbang, loungnatha, Suvannakhet and Champassak.

There are four types of agricultural practices in Lao PDR which are traditional agriculture (little or no external input), organic agriculture, conventional agriculture and pesticide-free agriculture. There is a potential for vegetable production as the soil and environmental condition in Lao PDR is still in a good condition. Organic vegetable farming can be enhanced with application of good quality seeds, production and distribution techniques in order to achieve food security.

4.2.6 Food security and Environment: Case Study of Rice Production and its impacts on Environment in Go Cong Dong District, Tien Giang Province.

This study aims at understanding environmental impacts caused by intensive rice farming in Go Cong District and Tien Giang Province in the Mekong River Delta by conducting survey of farmers. The Mekong delta has undergone a rapid population growth. The region has a high percentage of people living in poverty and has experienced degradation of environment.

With the construction of irrigation system, rice production has dramatically increased since 2002 in term of rice area, yield and productivity. Rice production is based on application of high-yield varieties with three crops per year and excessive use of agro-chemicals.

Based on a household survey, it was concluded that the areas have experienced environmental problems such as saline intrusions, contamination of canals and loss of natural species. As this study was based on perception of local people by interviewing, there is a need for scientific data (environmental monitoring) to evaluate the actual environmental condition.

4.2.7 Summary of the outcomes of the six projects

Based on the outcomes of all six papers, recommended research areas can be summarized in four main topic areas:

1. Transboundary issues:
    - Local participation in transboundary forestry management;
    - Sustainable energy development: alternative energy and renewable energy;
    - Fish restocking in shared water bodies: the Mekong River and the Gulf of Thailand for well-being of local people;
    - Effective water allocation in the Mekong River to increase food security and sustainable development in the region; and
    - Regional climate change adaptation and mitigation approaches (with sharing benefits and minimizing costs).
2. Climate change
    - climate change adaptation techniques and its effect on crop and yield and the effect on the supply of agricultural products and food
    - problem-based policy on climate change and agriculture
    - coordinated framework of authority and enforcing policies
3. Biodiversity
    - adaptive capacity of small scale farmers to cope with current climatic change
    - Integrating agrobiodiversity into national agricultural policy: in-situ conservation of genetic resources
4. Food security and sustainable agriculture and pollution
    - Potential application of production, processing, packaging and storage technology the use of traditional method to promote organic farming;
    - Opportunity for export of organic vegetables
    - Environment impacts of rice farming in the Mekong delta.
    - non-point source of pollution from agriculture on (1) major crops such as rice corn, sugar cane and rubber; (2) beef cattle; (3) paddy field duck; (4) fish cages (5) heavy metals (6) Coliform bacteria

4.3 CONCLUSIONS AND RECOMMENDATIONS

Research on environment and climate change are still limited in CLMV countries. In general, there is more research state of natural resources such as forestry than pollution. There were sufficient data in term of changes in forest areas, although there was some inconsistency in data from different sources. There was also a lack of research work in forestry biodiversity. The outcomes of the six projects showed that the main priority areas for future research is similar to the priority areas identified by the review on Current status on research on environment and climate change in CLMV countries but not in detail as shown in Table.

Table 4.1: Research areas identified by the six projects and the review on environment and climate change research.

Six projects	Review on research on environment and climate change in CLMV countries
1. Transboundary issues (forestry and water resources)	1. Transboundary (water, air and marine)
• Local participation of transboundary forest management	• Haze pollution from forest fire
• Allocation of water resources	• Water pollution in Mekong River
• Agricultural waste from shared watershed	• Marine water pollution in the bordered areas
2. Climate change	2. Climate change
• Renewable energy (impact of energy crop on food security)	• GHG Inventory (activity data in forestry, energy and agriculture and emission factors)
• Adaptation capacity of small-scale farmers to climate change	• Mitigation measures: reforestation
• Adaptive techniques and its effect on crop yield	• Adaptation measures against temperature rise, precipitation, extreme weather and sea level rise
3. Agriculture	3. Agriculture
• Food security and sustainable agriculture (organic farming, GMP and BMP)	• Impact of pollution from agriculture such as sedimentation, use of fertilizers, pesticides and herbicides
• Pollution from agriculture	• Monitoring of hazardous chemicals from agriculture
4. Biodiversity	4. Biodiversity
• Conservation of local crop genetic resources	• Impact of deforestation on biodiversity
• The role of small scale farming in biodiversity conservation	• Impact of agriculture on biodiversity
	• Baseline data on fauna and flora (total species) and threatened species
5. Pollution	5. Pollution (air, water and solid wastes)
• Impact of industrial and urban pollution on agriculture	• Long term monitoring
	• Effluent and ambient standards

4.3.1 Priority areas for collaborative research

Based on the synthesis of all the six projects and the outcomes of Chapter 2, it can be concluded that priority sectors areas for all CLMV countries are agriculture and forestry. Agriculture is also a main source of food and income for rural people. Forestry is the main source for food and other household products for well being of poor people in the rural areas. Agroforestry also provide a major income for countries like Lao PDR, Cambodia and Myanmar. Both agriculture and forestry are necessary for poverty reduction as majority of the people are still poor. Figure 4.2 showed the linkages between agriculture and forestry, their environmental impact, poverty and food security.

Environmental problems arisen from these two activities are interlinked. Increase in agricultural land causes deforestation at the same time unsustainable logging causes degradation of agricultural land. Deforestation in the watershed areas also causes alteration of water flow, which will result in drought and flood. Furthermore, these two sectors can cause climate change, biodiversity and pollution, which are the main threats to food security.

Biodiversity conservation is needed to sustain agricultural production in the long term. Pollution from agriculture, especially non-point sources, has become more and more important as these countries have to apply fertilizers and pesticides to increase their food production to provide enough food for increasing population. Similarly, sustainable forest management is necessary to prevent deforestation. Reforestation programme can be developed as CDM projects as carbon sequestration to mitigate climate change.

On the other hand, climate changes could have profound impact on agriculture food production as a result of changes in temperature and precipitation. Adaptation is necessary for these countries to cope with the problems of climate change and enhance food security.

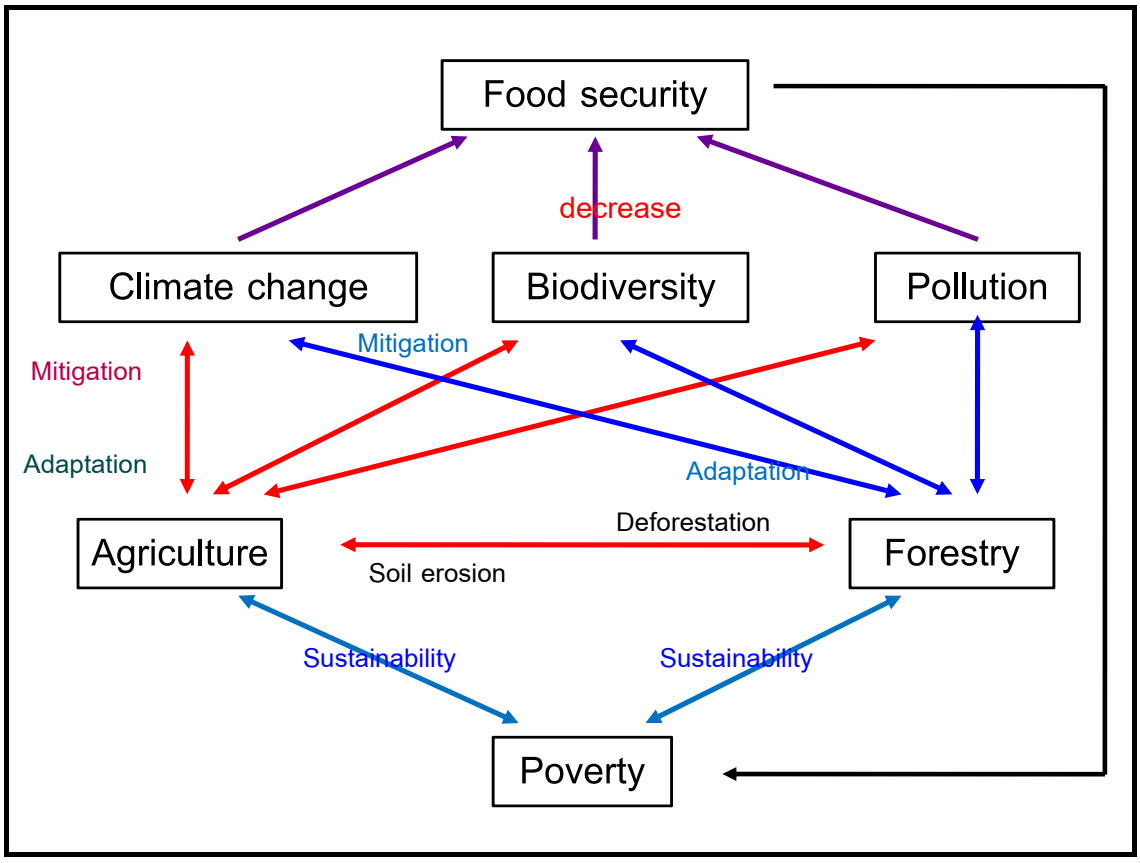

Figure 4.2: Linkages between sector, environmental problems and food security

Finally, transboundary environmental issues should be addressed in order to jointly manage the shared resources. Lack of research has been identified in almost all the areas, therefore collaborative research should be established in environment and climate change with linkages to forestry and agriculture.

Based on Table 4.1 and Figure 4.1, Priority areas for future collaboration can be summarized:

- Forestry
    - Impact of deforestation on sedimentation, soil erosion and biodiversity;
    - GHG Inventory from LUCF and development of CDM projects (CO_2 sequestration);
    - Long term monitoring change in forest areas;
    - Improve laws and regulations and law enforcement;
    - Community forest for poverty reduction.
- Agriculture
    - Impact of agriculture on deforestation, water pollution and biodiversity;
    - Impact of urban and industrial pollution on agriculture;
    - GHG Inventory and Adaptation to climate change;
    - Sustainable agriculture including GAPs, BMPs and organic farming to reduce poverty;
    - Role of small scale farmers in conservation of crop genetic resources;
    - Adaptive capacity of small scale farmers in response to environmental change.
- Transboundary problems
    - Mekong river: water allocation, water pollution, fisheries and migratory species;
    - Forest management and forest fire and haze pollution;
    - Oil spill and marine pollution;
    - Transboundary management of marine fisheries and habitats such as protected areas.

4.3.2 Framework for collaboration

Due to the similarity, both in term of socioeconomic and environmental problems between CLMV countries, each country has an opportunity to learn from its neighboring countries through collaborative research and a network of researchers. Exchange of data and information on research and development will facilitate and enhance capability of countries in dealing with increasing problems.

Cooperation can easily be built upon existing regional and sub-regional framework such as ASOEN, MRC and GMS. Plans established under such programmes can be effectively used to further identify priority areas of research for future collaboration. Existing network of universities and researchers in the region can also be used to build collaborative research programmes and projects as well as to organize workshop, training and monitoring for information exchange and sharing of experiences. Figure 4.3 showed the existing regional framework of cooperation and networking in the region.

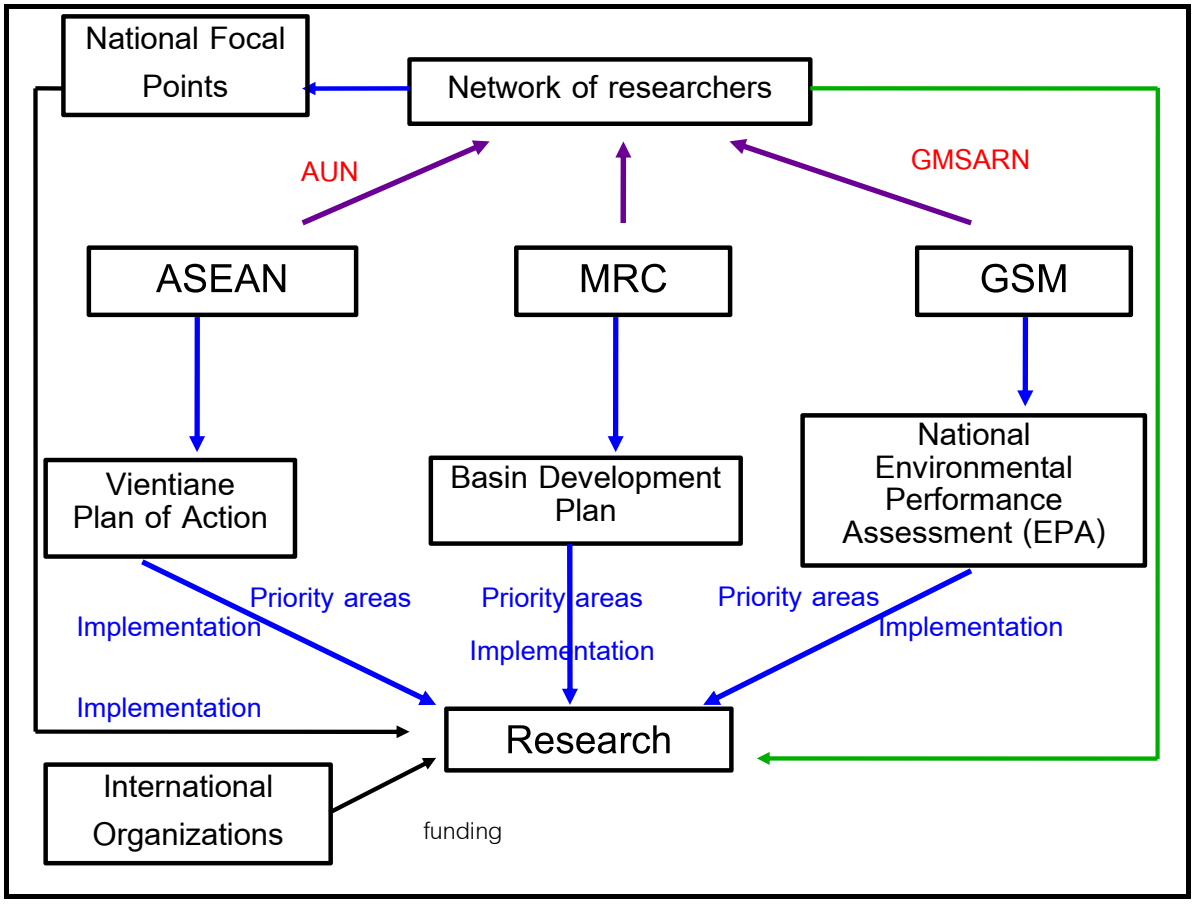

Figure 4.3: Existing regional framework of cooperation and networking in the region

Network of researchers

A network of researchers can be established based on existing network such as AUN and GMSARN. In addition to local researchers AUN included researchers from outside the region such as EU, China, Korea, Japan, India and Russia. Lists of research projects and researchers developed by AUN and GMSARN can provide good inputs to establishing a research network on environment and climate change. National focal point of both networks should be contacted for identify researchers or national research institutions in each country. Based on such information, a national focal point should be established in each country to collaborate local researchers at a country level and regional researchers through a regional network.

Identification of Priority areas

Priority areas identified under this project can be used as background information to develop research projects to be conducted jointly among CLMV countries and Thailand. Joint researches can be developed in forms of national, bilateral and multilateral projects. However, identification of priority areas should be ongoing process in the long term as state of the environment and socio-economic conditions will change through time. There are several approaches in identifying priority areas.

Regional plans, programmes and projects such as ASEAN, MRC and GMS can also provide useful inputs to identify priority areas for research. VAP set goals and targets towards promoting environmental sustainability and identifying priority areas for environment and natural resources management from 2004-2010. These programmes and plans are usually

Identification of priority areas could be done by organizing regular brainstorming meeting

among regional researchers in order to respond to any new and emerging issues. International and regional experts could be invited to present new scientific findings to provide framework for local researchers to discuss and identify priority areas. Participation of local researchers and other relevant government officers in identify priority areas will ensure that research to be carried out will respond to country's need. This will lead to practical and effective research results which can be incorporated into the management framework of each country.

Joint Research Project

Joint research projects can be developed on common issues of participating countries. For example in the area of forestry, reforestation programme can be developed under REDD and CDM where funding is available. Sustainable agriculture is another potential area for joint research. Research on application of GAP and BMP could be developed in the mountainous areas in Lao PD and Myanmar to solve the environmental problems as well as promote poverty reduction. Joint research project should also deal with transboundary issues such as forest fire and haze pollution and water pollution in Mekong River.

Technical and training workshops

Collaboration should be carried out by organizing technical workshops, meetings, training and implementing monitoring programme. As mentioned in Chapter 2, research conducted in the past was mostly done through international and regional assistance programme. Technical inputs to these projects have mainly been from international experts, mostly outside the region. Technical workshops, meetings and seminars provide fora where local researchers can present their works and exchange information with other researchers. Lack of environmental monitoring programme has been identified by Cambodia, Lao PDR and Myanmar. Training programmes can be conducted by countries with more experiences such as Thailand and Vietnam. Simple monitoring methods carried out by more advance countries could be applied to setting up a practical monitoring system. Ad hoc training could be another useful method which trainees could have hand on experience in conducting monitoring programme.

The initial phase has laid a good foundation in establishing future collaboration on research on the environment and climate change. It is suggested that existing mechanisms should be reviewed in more detail in order to set up a specific mechanism for future collaboration. A brain storming workshop will be a forum where all representatives from these regional organizations and networks could discuss and suggest what research areas on environment and climate change could be promoted and collaborated. Inputs from government departments and national research institutions are necessary in order to set up an effective collaboration programme.

4.4 REFERENCES

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Thavornyutikarn, S. and Sirasoontorn, S. 2009. Climate Change and its Mitigation Mechanisms: Implications on Agriculture and Food Security in Thailand. Report submitted to Thailand Research Fund. Bangkok

Kansuntisukmongkol, K. 2009. Understanding the Linkage of Biodiversity and Agricultural Sustainability under the Current Environmental Change in Thailand. Report submitted to Thailand Research Fund. Bangkok.

Thapinta, A., Utarasakul, T. and Thapinta, S. 2009. Current Status on Non-point Sources of Pollution from Agriculture in Thailand. Report submitted to Thailand Research Fund. Bangkok

Douangsavanh, L. and Phouyyavong, K. 2009. Food Security and Agricultural Sustainability: Challenge and Opportunity in Vegetable Production in the Lao PDR. Report submitted to Thailand Research Fund. Bangkok

Thuy, N. N. 2009. Food security and Environment: Case Study of Rice Production and its impacts on Environment in Go Cong Dong District, Tien Giang Province. Report submitted to Thailand Research Fund. Bangkok

APPENDIX 1: LIST OF RESEARCH TOPICS ON NON-POINT SOURCE POLLUTION FROM PLANTING CULTIVATION

No.	Title	Authors	Year	Source
1	Natural Resource Aspects of Sustainable Development in Thailand	Government of Thailand	2000	http://www.un.org/esa/agenda21/natlinfo/countr/thai/natur.htm#agro
2	Pesticide use and occurrence in Thailand	Thapinta, A., and Hudak, F. P.	2000	Environmental Monitoring and Assessment
3	Distribution of DDT in fish from the Songkha Lake, Thailand	Kumblad, L., Olsson, A., Koutny, V., and Berg, H.	2001	Enviromental Pollution
4	Seasonal Variations in Inorganic Nutrient Budgets of the Bangpakong Estuary, Thailand	Buranaprattheprati, A., Yanagi, T., Boonphakdee, T., and Sawangwong, P.	2002	Journal of Oceanography
5	Organochlorine Residues, PCBs, and PAHs in Marine Bivalves and Sediments from the East Coast of Thailand	Doungkaew, K.	2002	Chulalongkorn University
6	Determination of Organochlorine Pesticides in Commercial Fish by Gas Chromatography with Electron Capture Detector and Confirmation by Gas Chromatography–Mass Spectrometry.	Therdteppitak, A. and Yammeng, K.	2002	Science Asia
7	Pesticide Residues in Environment	Sasithorn Tanthong	2002	Phetchaboon Rajabhat University
8	Water pollution from agriculture (non-point source type) management	Pollution Control Department	2002	Pollution Control Department
9	Assessment of Pesticide Residues in Upper Maan Reservoir by GCMS	Kittipong Chuchit	2003	Loei Rajabhat University
10	Concentration of Organochlorine in Egg Yolk and Reproductive Success of *Egretta garzetta* (Linnaeus, 1758) at Wat Tan-En Non-Hunting Area, Phra Nakhon Si Ayutthaya Province	Keithmaleesatii, S.	2003	Chulalongkorn University
11	Assessment of Water Quality Problems and Mitigation Potentials by using Material Flow Analysis – A Case-Study in The Tha Chin River	Schaffner, M.	2004	Swiss Federal Institute for Environmental Science &

No.	Title	Authors	Year	Source
	Catchment Area, Thailand			Technology
12	Application of Nutrient Quantities and Ratios for Assessment of Aquatic Resources Status of Bangpakong River, Ban Pho District , Chachoengsao Province	Junchompoo, C., Meksumpun, C., Meksumpun, S.	2005	Kasetsart University
13	Accumulation of Organochlorine Insecticide Residus in Food Chain of Fish at Khlong 7, Rangsit Agricultural Area, Pathum Thani Province	Rohitrattana, J.	2005	Chulalongkorn University
14	Accumulation of organochlorine residues in water, sediment, and aquatic invertebrate at Khlong 7, Rangsit agricultural area, Pathum Thani province.	Thongkongoum, P.	2005	Chulalongkorn University
15	Assessment of River Water Quality Problems and Mitigation Potentials by using Material Flow Analysis: A Case Study in the Tha Chin River Basin, Thailand.	Schaffner, M.	2005	Conference “Role of Water Sciences in Transboundary River Basin Management”, Thailand
16	Assessment of Organic Loading as BOD from Agriculture and Forest Land use in Bang Pakong River Basin	Thongyang, U.	2006	Kasetsart University
17	Polluted Nutrients Loading from Agriculture Land in Bangpakong Watershed	Wongwiang. J.	2006	Kasetsart University
18	Spatial Variability of Non-point Sources Nitrogen and Phosphorus in Songkhla Lake Basin	Suviboon, H.	2006	Prince of Songkla University
19	Organochlorine Pesticides and Their Usages in Thailand:A Review	Thirakhupt, K., Sitthicharoenchai, D., Keithmaleesatti, S. and Siriwong, W.	2006	Journal of Scientific Research Chulalongkorn University
20	Organochlorine Pesticide Residues in Aquatic Ecosystem and Health Risk Assessment of Local Agricultural Community	Siriwong, W.	2006	Chulalongkorn University

No.	Title	Authors	Year	Source
21	Concentration of organochlorine in egg yolk and reproductive success of Egretta garzetta (Linnaeus, 1758) at Wat Tan-en non-hunting area, Phra Nakhorn Si Ayuthaya Province, Thailand.	Keithmaleesatti, S., Thirakhupt, K., Pradatsudarasar, A., Varanusupakul, P., Kitana, N., and Robson, M.	2006	Ecotoxicology and Environmental Safety
22	Accumulation of Organochlorine Pesticide Residues in Aquatic Plants	Siriwong,W., Thirakhupt, K., Sitticharoenchai, D., and Robson, M.	2007	Journal of Scientific Research Chulalongkorn University
23	Applying a Material Flow Analysis Model to Assess River Water Pollution A Case-Study in the Thachin River Basin, Central Thailand	Monika Schaffner	2007	University of Bern, Switzerland
24	Utilization and Contamination of Pesticides in Pao Watershed, Kalasin Province	Aranya Nontarat	2008	Kalasin Rajabhat University

APPENDIX 2: LIST OF RESEARCH TOPICS ON NON-POINT SOURCE POLLUTION FROM LIVESTOCK FARMING

No.	Title	Authors	Year	Source
1	Factors Affecting Small Farmers' Adoption of Kamphaeng Saen Beef Cattle in Kamphaeng Saen District, Nakhon Pathom Province	Petchprayoon, P.	2000	Chiang Mai University
2	Utilization of Broiler Litter as a Source of Crude Protein for Cattle II. Productive Performance Aspects	Suppadit, T., Kittikoon, V., Key, J.P., Chaicumpa, W., Jaturasitha, S. and Pongpiachan, P.	2002	Thai Journal of Agricultural Science
3	The Recycle of Broiler Litter as a Feed Ingredient for Cattle to Reduce Environmental Pollution II. Nutrient Values of Broiler Litter	Suppadit, T.	2003	Thai Environmental Consultants Journal
4	Policy, Technical and Environmental Determinants and Implications of the Scaling-up of Livestock Production in Four Fast-Growing Developing Countries."	Delgado, C., C. Narrod, and M. Tiongco	2003	IFPRI (International Food Policy Research Institute)
5	The Shifting Role of Large Livestock in Northeast Thailand	Suchint Simaraks, Sukaesinee Subhadira, and Somjai Srila	2003	Southeast Asian Studies
6	Good Agricultural Practices for Beef Cattle Farming	National Bureau of Agricultural Commodity and Food Standards,	2005	Ministry of Agriculture and Cooperatives
7	Geographical Determinants and Environmental Implications of Livestock Production Intensification in Asia	Gerber, P., P. Chilonda, G. Franceschini, and H. Menzi.	2005	Bioresource Technology
8	Managing the Livestock Revolution Policy and Technology to Address the Negative Impacts of a Fast-Growing Sector	The World Bank, Agriculture and Rural Development Department	2005	The World Bank
9	Adoption of Good Agricultural Practices	Suppadit, T.,	2006	KMITL Sci.

No.	Title	Authors	Year	Source
	for Beef Cattle Farming of Beef Cattle – Raising Farmers in Tambon Hindard, Dan Khunthod District, Nakhon Ratchasima Province, Thailand.	Phumkokrak, N., and Poungsuk, P.		Tech. Journal
10	Management Problems of Odor Pollution from Excrement of Livestocks at Rajamangala Institute of Technology, Lampang Campus.	Koomjawhaw, S.	2006	Chiang Mai University.
11	Adoption of Good Agricultural Practices for Beef Cattle Farming of Beef Cattle – Raising Farmers in Tambon Hindard, Dan Khunthod District, Nakhon Ratchasima Province, Thailand	Tawadchai Suppadit1*, Nittaya Phumkokrak2 and Pakkapong Poungsuk3	2006	KMITL Sci. Tech. J.
12	Rethinking the Traditional Concept of Livestock Services: A Study of Response Capacity in Thailand, Malaysia and Vietnam	Tuong Vu	2007	FAO: PPLPI Working Paper No. 41
13	Waste Management in Dairy Farms in the Mae On Watercourse Area of Amphoe San Kamphaeng, Changwat Chiang Mai	Promma, K.	2008	Chiang Mai University.
14	Cultivation of Spirulina (Spirulina platensis) in Dairy farm wastewater for dairy cattle feed	Nikorn Tharkwang	2008	Maejo University
15	Determinants and Implications of the Growing Scale of Livestock Farms in Four Fast-Growing Developing Countries.	Delgado, L.C., Narrod, A. C., and Tiongco, M. M.	2008	International Food Policy Research Institute Report

APPENDIX 3: LIST OF RESEARCH TOPICS ON NON-POINT SOURCE POLLUTION FROM AQUACULTURES

No.	Title	Authors	Year	Source
1.	Present status of fish cage-culture in Thailand	Menasveta, P.	2000	Chulalongkorn University
2.	Aquaculture Development Beyond 2000	FAO and NACA	2000	Conference on Aquaculture in the Third Millennium.
3.	Cumulative Environmental Effects of Low Salinity Shrimp Farming in Thailand	Szuster, B.W.	2001	Dissertation. Department of Geography, University of Victoria.
4.	Monitoring water quality in culture ponds of black tiger shrimp and water quality in the coastal shrimp culturing area in 1997-2000	Pongmaneerat, J., Silakes, S., and Rakbangleam, J.	2001	Coastal Aquaculture Division, Department of Fisheries
5.	A Regional Approach to Assessing Organic Waste Production by Low Salinity Shrimp Farms	Szuster, B. and Flaherty, M.	2002	Aquaculture Asia 7(2)
6.	Water Quality Control using Spirulina platensis in Shrimp Culture Tank	Benjamas Chuntapa, Sorawit Paotongsook, and Piamsuk Mennasaveta	2002	Chulalongkorn University
7.	Coastal Pollution Management in Thailand	Pornsook Chongprasith and Ekachai Praekulvanich	2003	Diffuse Pollution Conference, Dublin
8.	Shrimp Farming in Thailand's Chao Phraya River Delta: Boom, Bust and Echo	Brian W. Szuster	2003	International Water Management Institute
9.	An occurrence of eutrophication in Songkhla Lake: A review	Sompongchaiyakul, P.; Laongsiriwong, N. and Sangkarnjanawanich, P.	2004	Proceedings of the International Workshop on Integrated Lake Management
10.	Preliminary study of substance flows of phosphorus and cadmium in the agricultural soil of Songkhla Lake catchment	Sereewatthanachai, W.; Ratanachai, C; Sompongchaiyakul, P and	2004	Thai Environmental Engineering Journal 18(1):

No.	Title	Authors	Year	Source
		Sangganjanavanich, P.		May-August
11.	Modeling the water and nutrient flows of freshwater aquaculture in Thailand	Wittmer, I.	2005	Diplomarbeit, Eawag, ETH Zürich, Switzerland
12.	Environmental Quality for Fish Cage Culture in Palian District. Trang Province	Rodkuen, P.	2005	Kasetsart University
13.	The Master Plan for Songkhla Lake Basin Development	Ratanachai, C. et al.	2005	Prince of Songkhla University, Taksin University and Songkhla Rajabhat University
14.	Trace Metals Levels in Surficial Sediment of Songkhla Lake.	Nakinchart, P. and Sompongchaiyakul, P.	2006	Proceedings of the International Conference on Hazardous Waste Management for Sustainable Future
15.	Non-Point Source Pollution Modeling for Environmental Management of Songkhla Lake Basin	Kitbamroong, K.; Sompongchaiyakul, P. and Padmanabhan, G.	2006	Proceedings of the International Conference on Hazardous Waste Management for Sustainable Future
16.	Evaluation of Non-point Sources Nitrogen and Phosphorus in Songkhla Lake Catchment.	Suviboon, H.; Sompongchaiyakul, P. and Chatupote, W.	2006	Proceedings of the 5th National Environmental Conference
17.	Effect of Oxygen and Salinity on Benthic Nitrogen and Phosphorous in the Outer Songkhla Lake	Maitreekaew, S.; Sompongchaiyakul, P.; Sirinawin, W. and Fraser, I.	2006	Proceedings of the 5th National Environmental Conference
18.	Waste Output and Loading in Prawn (*Macrobrachium rosenbergii De Man*) Culture at Different Size and Feeding Frequencies	Sontipan Pasugdee, Prathak Tabthipwon, Orapint Jintasataporn and Uthairat Na-nakorn	2006	Proceedings of the 44th Kasetsart University Annual Conference,

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				Kasetsart, 30-January - 2 February, 2006.
19.	Use of Nitrification Biofilter on Nitrogen Treatment in Outdoor Aquaculture Tank	Kutako, M., Srisamrit, B., Arnthong, J., Powtongsook, S., and Menasveta, P.	2007	Journal of Environmental Research
20.	A Review of Shrimp Farming in Central Thailand and its Environmental Implications	Brian W. Szuster	2007	Book: Shrimp Culture: Economics, Market, and Trade
21.	Efficiency of *Avicennia marina* Seeding for Nutrient Treatment of Shrimp Farm Effluent	Piyawan Nuangmutcha and Pravit Nuangmutcha	2007	Nakhon Sri Thammarat Rajabhat University
22.	Catchment scale modeling of point source and non-point source pollution loads using pollutant export coefficients determined from long-term in-stream monitoring data	S. Shrestha, F. Kazama, L.T.H. Newham, M.S. Babel, R.S. Clemente, H. Ishidaira, K. Nishida and Y. Sakamoto	2008	Journal of Hydro-environment Research