AN ALTERNATIVE APPROACH TO BIODIVERSITY EVALUATION: CASE STUDY IN THE LOWER MEKONG BASIN

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A thesis submitted towards the degree of
Doctor of Philosophy
University of Edinburgh
March 2000

EX BIBL. UNIV. EDIN.

DEDICATION

To my beloved family; Jay, Plai and Proud Gajaseni with my heart and soul for their sacrifice, endurance and encouragement.

DECLARATION OF ORIGINALITY

I hereby declare that this thesis has been composed by myself and the work is my own, unless otherwise stated.

Nantana Gajaseni

March, 2000

ABSTRACT

Biodiversity has played an important role in human society, not only through direct economic benefits but also through indirect non-economic benefits. As biodiversity changes so humans need to reconsider its value. Biodiversity evaluation is poorly quantified because it is highly complex at different levels – genetic, species and ecosystem - and based on multidimensional concepts. It is difficult to incorporate biodiversity value into an impact assessment (IA) even though it is a desirable process, which helps to ensure that the project / programme / policy / development avoids damaging the environmental, social and economic sectors.

This study aims to explore constructive biodiversity evaluation with regard to 1) ***species level*** as species composition, species richness and species diversity; 2) ***ecosystem level*** as carbon storage and other services; and 3) ***human level*** as socio-economic aspects. These indicators are normally identified as non-monetary values or are sometimes valued from an economic point of view through contingent valuation or shadow pricing. Specifically, this study attempts to quantify the value of biodiversity indicators within the ecosystem structure and function. Species and habitat diversity can represent a component of ecosystem structure and, at the ecosystem level can also represent ecosystem functions (goods and services). Carbon storage in ecosystems becomes a legitimate representation of ecosystem services related to CO_2 mitigation, and global climate change objectives. Moreover, humans are considered as a component in biodiversity to take account of socio-economic aspects. These biodiversity indicators must be weighed equally.

To assess wider biodiversity evaluation and a new alternative IA approach, these developments have been tested in a case study of the planned Ban Koum Hydropower Project in the Lower Mekong Basin. An analysis of species composition, richness and diversity showed that main effects of dam construction would be a quantifiable loss of the riparian zone and destruction of its plant associations. Construction also causes major loss of species diversity in phytoplankton and change in dominance. It is estimated that 0.66×10^6 tonne of stored carbon will be lost from terrestrial ecosystem through inundation but a further 3.60×10^6 tonne will be lost as the loss of carbon storage potential and the result of human encroachment into primary forest over a period of 50 years. This compares to a gain of 0.56×10^6 tonne if there is no dam construction. Depending on mitigation options, the economic value of carbon loss is $47-851 million and the carbon gain without construction would be $13-244 million. A questionnaire survey of local families before and after dam construction showed a decline in quality of life, economic security and job opportunity from the dam development project.

This revised IA approach can lead to improved assessment of proposed developments through more reliable techniques that focus on consideration of carbon storage at the global scale, species diversity at the regional scale and socio-economics at the local scale. This revised IA can also improve the decision-making process by providing a more holistic and realistic approach to natural resource use.

ACKNOWLEDGEMENTS

I would like to express my deep thanks to my country, Thailand and the Royal Thai Government for providing me with a scholarship to study in the Ph.D. programme at the University of Edinburgh. With this scholarship, I have been given the opportunity to upgrade my academic knowledge and experience so that I can contribute more to my students at Chulalongkorn University in the future.

I would like to express my gratitude to my supervisors: Professor J.B. Dent, Professor O.W. Heal, Professor G. Edwards-Jones and Dr. N.B. Lilwall, who have all contributed and supported me not only academically but also in spiritual matters during my study. I wish to especially thank Professor O.W. Heal and Dr. N.B. Lilwall who contributed valuable guidance until this thesis was complete.

Sincere thanks go to all my friends, Julie Ann Gustanski, Lise Tole, Isaac A.O. Odeyemi and the Kantachuvejsiri Family for their thoughtful hearts and wonderful friendships they have given to my children and me during my period of study. For technical support in Edinburgh, I would like to thank Dr. Jim Wright for GIS support, Mr. Alister Kydd for computer help and Mr. Chanen Munkong for graphic assisstance. For field support in Thailand, my thanks go to Dr. Suwit Ongsomwang, Miss Pensri Srikanha, Miss Pankaew Rattanasingunchan, Mr. Bhuvadol Gomontien, all the rangers at Pha Taem National Park and the people of Ban Kum for the data collection.

I would like to express my heartfelt gratefulness to my dad, mum, brothers and sisters who always support me with such love and care.

With my concerns to thank all people who could not be mentioned here.

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ACRONYMS

ADB	Asian Development Bank
AMRC	Autralian Mekong Research Center
APAR	Absorbed Photosynthetically Active Radiation
BOD	Biological Oxygen Demand
C	Carbon
CA	Correspondence Analysis
CAA	Community Aid Abroad
CBA	Cost-Benefit Analysis
CBD	Convention on Biological Diversity
CEA	Cost-Effective Analysis
cm	Centimeter
cms	Cubic meter per second
CO_2	Carbon dioxide
CVM	Contigent Valuation Method
DA	Decision Analysis
DO	Dissolved Oxygen
EDL	The Electricite du Lao
EGAT	Electricity Generation Authority of Thailand
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
FAO	Food and Agriculture Organisation
FIO	Forest Industry Organisation
FIS	Forest Information Service
GDP	Gross Domestic Product
GIS	Geographic Information System
GNP	Gross National Product
GPP	Gross Primary Productivity
Gt	Giga tonne
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
Gwh	Giga watt-hour
ha	Hectare
HIA	Health Impact Assessment
HPM	Hedonic Pricing Method
IA	Impact Assessment
IAIA	International Association for Impact Assessment
IGBP	International Geosphere Biosphere Programme

IPCC	Intergovernmental Panel on Climate Change
IRN	International Rivers Network
IRRI	International Rice Research Institute
IUCN	The World Conservation Union
km	Kilometer
KST	Kaeng Sue Tean
Lao PDR	Lao People Democratic Republic
LDC	Less Developed Country
m	Meter
MCA	Multi-Criteria Analysis
mm	Millimeter
MSA	Measure of Sampling Adequacy
MSL	Mean Sea Level
MRC	Mekong River Commission
Mt	Mega tonne
MUA	Multi-attribute Utility Analysis
MW	Megawatt
NEAP	National Environment Action Plan
NEP	Net Ecosystem Productivity
NPP	Net Primary Productivity
OECD	Organisation for Economic Cooperation and Development
ONEB	The Office of the National Environment Board
PAR	Photosynthetically Active Radiation
PCA	Principle Component Analysis
PRA	Probabilistic Risk Assessment
RFF	Resource For the Future
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
sq. km	Square Kilometer
STENO	Science, Technology and Environment National Organisation
TCM	Travel Cost Method
TDRI	Thailand Development Research Institute
TEI	Thailand Environment Institute
TEM	Terrestrial Ecosystem Model
TEV	Total Economic Value
TSS	Total Suspended Solid
Twh	Terra watt-hour
UN	United Nations
UNEP	United Nations Environment Programme

WTA	Willingness-To-Accept Compensation
WTP	Willingness-To-Pay

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CHAPTER ONE
INTRODUCTION

1.1 OVERVIEW OF THE STUDY

Nowadays biodiversity[1] has become a major concern to all people because of environmental pressures such as climate change, acid rain, pollution and depletion of natural resources such as forests, wetlands, wildlife and so on. The healthy environment can support biodiversity sustain the innumerable plants, animals, microorganisms as well as people. Biodiversity is now considered as a priority for conservation including the use of biodiversity as biological resources; the role in maintenance and support the human society and other living species; and the potential resource use for future generations. Generally, biodiversity is complex to understand its functions and difficult to measure. Therefore, it makes rigorous biodiversity evaluation difficult as a whole, and it is difficult to link the value of genetic, species and ecosystem diversity to processes and functions and to anthropocentric value. Measurements of biodiversity can be monetary and non-monetary, with strengths and weaknesses in each method. Therefore, it is necessary to search for a new approach of biodiversity evaluation based on ecological concepts, which can express some major functions to represent their value.

This study explores a new approach to biodiversity evaluation by focusing on the different diversity levels such as species level, including humans, and ecosystem level while genetic level is assumed to vary within species. This study did not evaluate genetic diversity, because of the complexity described in chapter three. At species diversity level the traditional species indicators are considered in the evaluation while humans are considered in terms of social and economic evaluation.

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[1] Biodiversity is the diversity of life at all levels of organisation, ranging from the genetic, population, and species levels to the community and ecosystem levels (Daly & Ehrlich, 1995). It means not only the number of species (species richness), but also genetic variant within a species, evolutionary lineages, functional groups of organisms, and ecological communities (Orian et al., 1996).

At ecosystem diversity level, *carbon storage*[2] is proposed as an ecosystem diversity indicator representing ecosystem services, associated with nutrient cycles and more recently involving global climate changes.

In addition, to stop or delay the problem of biodiversity loss, it is essential to be focusing on three main topics: conservation, sustainable use and the fair and equitable benefit sharing of natural resources. Generally, biodiversity utilisation flows to the global community at large scale. Relatively few benefits are provided to the local people who mostly encounter the negative impacts.

In the interest of this study, the Lower Mekong River Basin is very important because it is described as the richest in biodiversity and less developed than other major international river basins. It has high potential physical characteristics for hydropower development, and it is very attractive to the developed countries to invest in this region regarding globalisation[3] of economy. Especially, the developing countries along the Mekong River Basin are under economic and political trauma so that they intend to implement hydropower projects for electricity production to improve their economies. If biodiversity is utilised effectively, sustaining the whole system, it will have to be developed with speed, to redress this imbalance of use.

Currently, impact assessment (IA) is a process to provide information for the decision-makers by ensuring the development project/programme/policy is scrutinised on environmental and social grounds. In general, the development projects need to do the IA in order to evaluate the possibility of positive and negative impacts and to mitigate or monitor the environmental conditions after the project implementation. This seems to be the rational legitimacy obligation of development projects in most of the developed countries and some developing countries. In the

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[2] Carbon storage as defined in this study, is only carbon in above-ground vegetation biomass in terrestrial ecosystem and phytoplankton biomass in aquatic ecosystems. The turnover of carbon in ecosystems will be ignored in this study because the aim of study is to consider the existing carbon storage in each ecosystem.

[3] Globalisation refers to global economic intergration of many formerly national economies into one global economy, mainly through free trade and free capital mobility, but also by easy or uncontrolled migration. Globalisation is the effective erasure of national boundaries for economic purposes (Daly, 1999).

traditional IA, the process of ecological evaluation is focused on human beings, flora, fauna and physical environmental factors, which are measured in the total economic value as part of the ecological evaluation. Because of the complexity of biodiversity, the evaluation has hardly been expressed in terms of monetary value except for the value of marketable species. Therefore, the economic analysis, particularly cost-benefit analysis of the development project, usually gives the attractive economic benefit return due to inadequate quantification of biodiversity value.

Therefore, traditional IA is recognised to have weakness because biodiversity has not been addressed in the process of IA. If biodiversity is ensured and widely seen for environmental improvement and then the needs of humanity can be harmonised to achieve the idea of sustainable development[4] for the future generations. Thus this study gives emphasis to a holistic approach with integration of multiple interactions among environmental, social and economic aspects into the new approach of biodiversity evaluation in IA that can improve the decision-making process and making it more rational and acceptable for sustainable natural resource use.

1.2 OBJECTIVE OF THE STUDY

This study will explore the rational and potential application of a new wider approach based on biodiversity evaluation. The case study concentrates on the area of the Lower Mekong River Basin where the Mekong River Commission has proposed to construct the hydropower dam named *Ban Koum Hydropower Project*. It is located on the mainstream of the Mekong River between the boundary of Thailand and Lao PDR (Figure 1.1). The purpose of this study is to attempt to provide more constructive biodiversity evaluation at various spatial and temporal scales, focusing on the different levels of biodiversity, mainly the species and ecosystem levels, and with emphasis on human at social and economic aspects. It also establishes the integration of environmental, social and economic consideration

[4] Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Developmnet, 1987). Sustainable development is argued to be a strategy for balancing the benefit of environment and economy but it depends on the spatial and the temporal scale.

in IA and decision-making process, which has important implications for the efficiency and sustainability of development.

Thus, the objectives of this study will be concentrated on topics as follows:

- To quantify the existing conditions of biodiversity in terms of species diversity indicators (species composition, richness and diversity); *carbon storage* as a simple and practical indicator of ecosystem level; and socio-economic impact index indicating the socio-economic condition of people.
- To evaluate each biodiversity indicator for without- and with-project development. Some biodiversity indicators are presented as non-economic quantitative numbers, but carbon storage is converted to monetary value having regard to the different costs of CO_2 mitigation options.
- To integrate biodiversity indicators particularly *carbon storage value* into the new approach of alternative IA for comparing the without- and the with-project conditions based on economic analysis.
- To explore and provide the possibility of the different scenarios for the decision-maker related to single objective and multivariable indicators including biodiversity and economic indicators by a weighting system.



Figure 1.1: Map of Thailand and Lao PDR.

(Source: http://www.lib.utexas.edu/Libs/PLC/Map_collection/middle_east_and_asia/Thailand.jpg)

1.3 HYPOTHESIS OF THE STUDY

The hypothesis of this study will modify the new horizon of biodiversity evaluation, with emphasis on biodiversity as resource use not only for human society but also for members in other living communities. Hypothetically, there are the following:

1. Each biodiversity level can be quantified and evaluated to provide a holistic approach including environmental, social and economic aspects.
2. *Carbon storage* represents an indicator of ecosystem services, represented in terms of monetary value regarding CO_2 mitigation objectives and integrated into the economic analysis in IA process.
3. Integrating all biodiversity and economic values can improve the scenarios for the decision-making process regarding to a holistic approach and sustainable resource use.

This new approach should be more reliable in assessing biodiversity value than the traditional one, based on the fundamental goods and services for humans only. According to this study, it is possible to predict the impact of the development project through the alternative IA. Finally, the decision-makers will have a clearer vision for implementation of development projects based on a sustainable approach that is to balance human needs and aspirations with ecosystem constraints.

1.4 CONCEPTUAL MODEL OF THE STUDY

The conceptual model illustrates the study, step by step, clearly presenting the whole framework of idea formulation in Figure 1.2. The details are given in chapter four, five, six and seven.

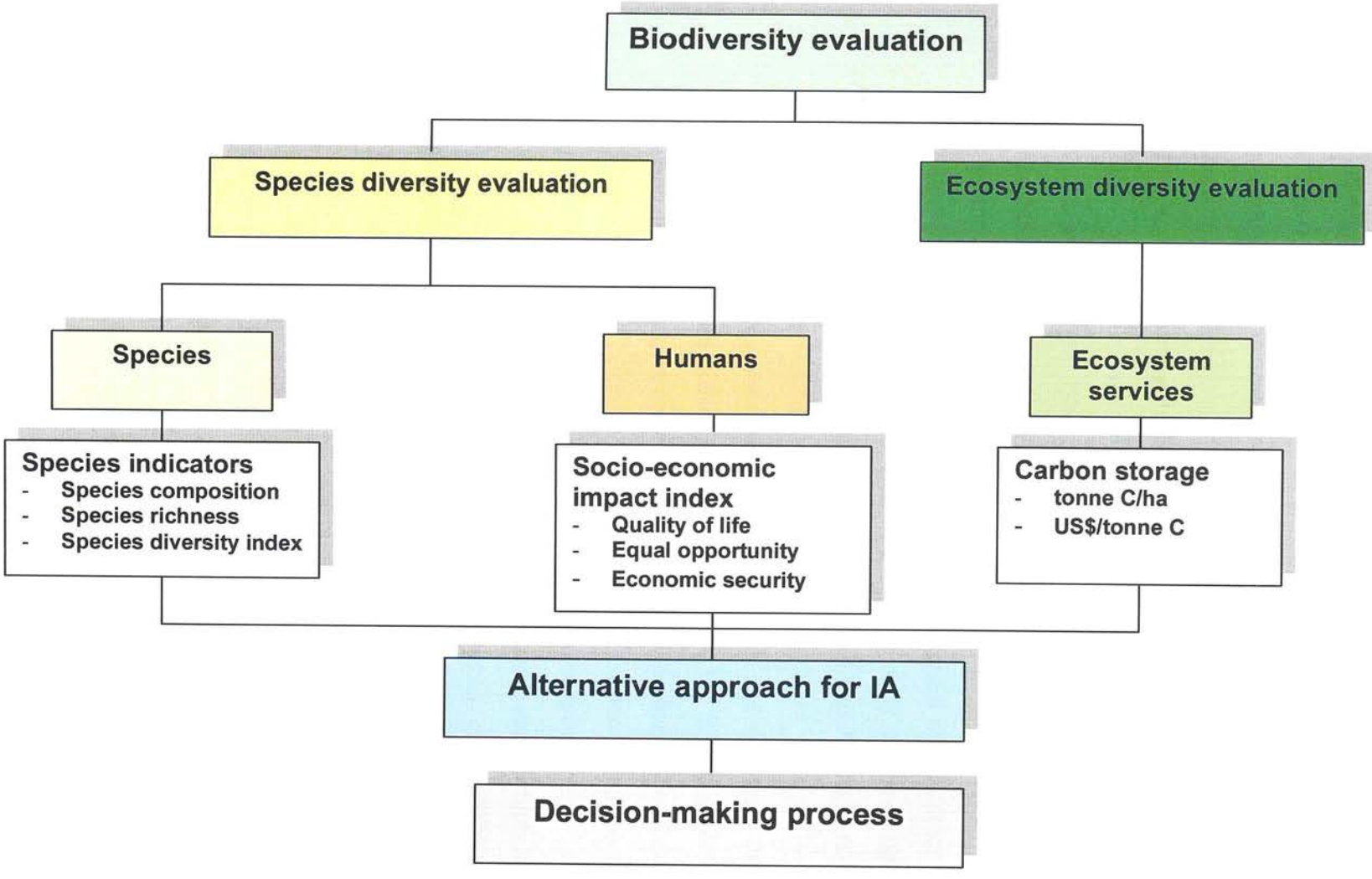


Figure 1.2: A conceptual model of the study.

1.5 ORGANISATION OF THE STUDY

The thesis will be organised into eight chapters as follows:

- ***Chapter one*** is an introduction providing an overview of the study, objectives, hypotheses and the conceptual model. The model provides the framework of study.
- ***Chapter two*** describes the Mekong River Basin including physical, biological and socio-economic characteristics in the basin. Then the international organisation in the Mekong River Basin, which plays the major role in natural resource management, is described in relation to development plans for people in the riparian countries. The ecological and socio-economic situation in Thailand and Lao PDR is illustrated by comparison. The potential of the Lower Mekong River for a hydropower dam is discussed and the case study will be mentioned. Finally, the impact assessment situations in Thailand and Lao PDR will reflect the degree of environmental concerns.
- ***Chapter three*** describes the ecological concepts and evaluation that explains the background of the different biodiversity levels, the ecological functions and the strength and weaknesses of current methods of biodiversity evaluation. The new approach of biodiversity evaluation is based on carbon storage as a representative of ecosystem services introducing the impact assessment process.
- ***Chapter four*** describes the species diversity evaluation, which is based on the traditional ecological indicators such as species composition, richness and diversity index. The case study, Ban Koum Hydropower Project, is selected from the Mekong River Commission's proposal and Pak Mun Dam is selected as an existing reference dam for comparison. The results of species diversity evaluation are compiled in chapter seven for testing of the new alternative impact assessment and decision-making process.
- ***Chapter five*** describes the ecosystem diversity evaluation, which explores *carbon storage* as an ecosystem value representing ecosystem services. The comparison of ecosystem evaluation is presented in relation to the carbon storage gain

without-project development and the carbon storage loss under the with-project implementation. Moreover, the carbon is priced in monetary terms based on the CO_2 mitigation management options. The results are integrated into chapter seven.

- ***Chapter six*** describes the socio-economic evaluation, which is associated with the local people of the case study area in the Ban Koum Project and Pak Mun Dam. The results are quantified in socio-economic impact index comparing without-project and with-project implementation. Finally, the socio-economic impact index is integrated into the analysis of alternative impact assessment and decision-making in chapter seven.
- ***Chapter seven*** describes the result and discussion of the alternative approach to the impact assessment and decision-making process based on the integration of biodiversity evaluation at the different diversity levels as well as the different scales of concerns such as global, regional and local. The study finally provides an approach to rational decision-making for sustainable natural resource use.
- ***Chapter eight*** concludes and also presents the recommendations of this study, including the trends of future research.

CHAPTER TWO
OVERVIEW OF THE MEKONG RIVER BASIN

The Mekong River Basin is an area of natural wealth and diversity nourished by the Mekong River and its tributaries. As the river flows through the Indo-China region it carries with it a rich silt-load that is deposited on fertile flood plains. Whilst it is home for some 65 million people in the Mekong River Basin, it is also home to a massive array of terrestrial and aquatic life. The Mekong is one of the most biologically diverse river systems in the world, surpassed only by the Amazon and possibly the Nile (CAA, 1999). Farming and fishing are the ordinary local livelihood activities, which are closely linked to the forest and river ecosystems and sustain their daily life. With the indigenous knowledge and the relationships with the environment, the people know how to deal with, adapt to, and survive in the natural condition.

The Mekong region is also characterised by a rich cultural heritage and diversity, for instance, hundreds of different ethnic groups – with their own language, traditions and beliefs – live in the lowland, upland and highland communities throughout the region. As a result, the Mekong River is strongly recommended as a prosperous river, which contributes its natural resources to not only mankind but also other terrestrial and aquatic life in this region. The information in the next section of this chapter of the Mekong River Basin focuses on the Lower Basin:

2.1 CHARACTERISTICS OF THE MEKONG RIVER BASIN

2.1.1 Physical characteristics

The Mekong River Basin, the 21st largest in the world, is only one of the major international rivers in the Indo-China Region, which flows through six countries; China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. The river flows for approximately 4,800 km, the 12th rank in the world, from the origin on the Northeast rim of the Tibetan Plateau to the South China Sea through the Mekong Delta of

Vietnam (Figure 2.1). The Mekong River Basin is divided into two basins as 'Upper Mekong Basin' and 'Lower Mekong Basin'. The Upper Mekong Basin is located in Yunnan, China and the East of Myanmar. The Lower Mekong Basin is located in Lao PDR, Thailand, Cambodia and Vietnam.

The hydrological regime of the river is primarily dependent on the climatic conditions of the alternating wet and dry season, with mean annual precipitation in the Lower Mekong Basin is 1672 mm (MRC, 1996). Therefore, the Mekong River's condition is water flow and flooding in rainy season, which produces total runoff of 475,000 million cubic metres annually (MRC, 1996). The hydrological characteristics include a high water period from August to October and a low water period from February to April. The flood season in the mainstream and tributaries, from June/July to November/December accounts for 85-90 percent of the total annual water volume. The peak month of September accounts for 20-30 percent of the annual flow (MRC, 1996).

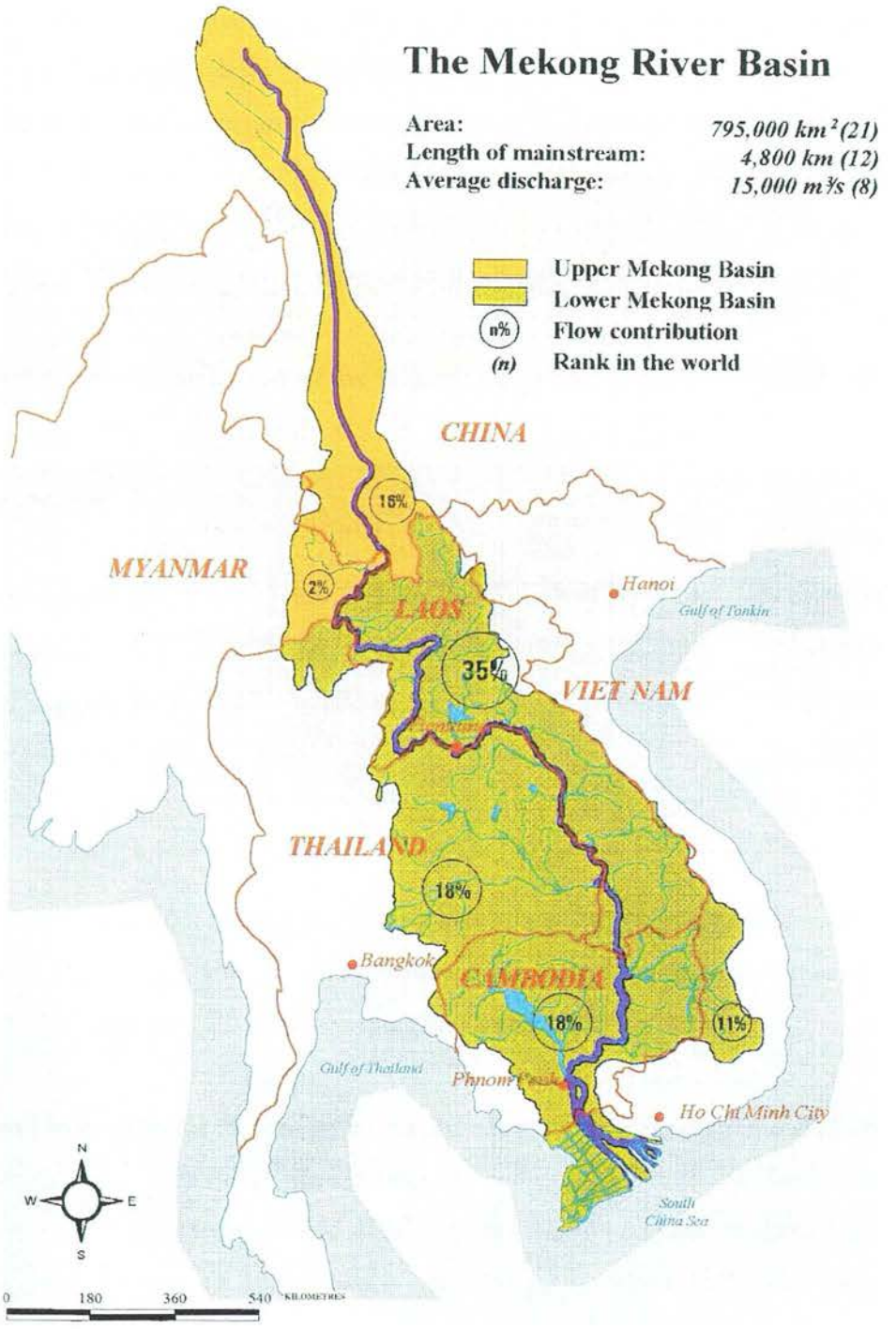


Figure 2.1: General characteristics of the Mekong River Basin (MRC, 1995).

Owing to the different landforms of the watershed, this Mekong River Basin is divided into six sensitive geographical areas (Table 2.1). The one sensitive area in the Lower Mekong River is "Korat Plateau" in Northeast Thailand and the Southwest Lao PDR because there are some environmental problems through limited water resources; floods and drought; salinisation and low fertility (MRC, 1996). Korat Plateau has relatively dry climatic conditions with annual rainfall at range 1,000-1,600 mm. This plateau is the driest of all landform areas.

Table 2.1: The characteristics of the Mekong River Basin landforms (MRC, 1996).

Landforms	Covered area	Rainfall (mm/year)
1. Lanchang River Basin	Yunnan, China	600-2,700
2. Northern Highlands	East Myanmar, North Thailand, North Lao PDR	2,000-2,800
3. Korat Plateau	Northeast Thailand, Southwest Lao PDR	1,000-1,600
4. Eastern Highlands	Southeast Lao PDR, Southwest Vietnam	2,000-3,000
5. Lowlands	South Lao PDR, North Cambodia, South Vietnam	1,100-2,400
6. Southern Uplands	Southwest Cambodia	Up to 4,000

There are two general categories of soil in the Lower Mekong River Basin as:

- Upland soils: podsols, red-and-black soils, lateritics and mountain soils.
- Lowland soils: alluvial, basaltic and sandstone.

The soil type in Korat Plateau is the lowland soils, which are characterised as a fine and sandy loam, with heavy accumulation of sodium chloride. The Korat Plateau is underlain by evaporated rock salt, which leaches into the soil and is also raised to the soil surface. As a result, soil quality is generally poor, showing low clay content and salinity problems (MRC, 1996). In addition, the soil quality and productivity are affected by natural processes (e.g. wind, leaching of salts and acids, saltwater intrusion) and human impacts (e.g. intensive farming and deforestation). The erosion rates are high (e.g. in the central highland, the rates reach 150-170 ton/ha/year on slope of 20-22 degree) (MRC, 1996). Related nutrients loss is equivalent to:

- Organic matter 5.6 ton/ha
- Nitrogen (total) 199.2 kg/ha
- Phosphorus (total) 163.2 kg/ha
- Ca-Mg 24-33 kg/ha

In the catchment area of the Mekong River Basin about 25 percent of total catchment area belongs to the Upper Basin and 75 percent to the Lower Basin (Table 2.2). The majority of catchment area in the Lower Basin is located in Lao PDR and Thailand, of which Lao PDR has 97 percent of total land area located in this basin. The annual flow is greatest when the water flows through the mountainous plain in Lao PDR.

Table 2.2: The Mekong River Basin (MRB) water resources (MRC, 1996).

Description	Upper Basin		Lower Basin			
	China	Myanmar	Lao PDR	Thailand	Cambodia	Vietnam
Catchment area (km^2)	147,000	24,000	202,000	184,000	155,000	65,000
Catchment area as % nation	38%	4%	97%	36%	86%	20%
Catchment area as % MRB	22%	3%	25%	23%	19%	8%
Average flow (m^3/sec)	2,410	300	5,270	2,560	2,860	1,650

Water quality throughout the Mekong River Basin is generally good, but water quality in some localised areas has moderate to severe levels of eutrophication, nutrient loss, organic pollution, salinisation, acidification, toxic metals, and microbial pollution. The Mekong's water quality is strongly related to the flow rate and the local physiography. The majority of water quality problems are from these natural processes, particularly salt and acid-soil leaching and saltwater intrusion. The means of water quality indicators in the Lower Mekong River Basin during 1985-1993 are (MRC, 1996):

- Water temperature 27°C
- pH 7.8
- Total suspended solids 222.9 mg/l

- Dissolved oxygen 7.4 mg/l
- PO_4-P 0.03mg/l
- Total-P 0.08 mg/l
- NH_4-N 0.1 mg/l
- Total-N 0.5 mg/l

The total suspended solid loads in the Mekong River are high, but not excessive compared to other rivers. According to Global Environmental Monitoring System median value for world rivers are used for comparison. The Mekong's total suspended solids concentration is 294 mg/l, compared to the Ganges River in India at 1,130 mg/l (MRC, 1996).

2.1.2 Biological characteristics

Due to the overlap of distribution of fauna in Himalayas[1] and Sunda[2] zoogeographical zones, all countries in the Mekong River Basin show high biodiversity in term of genetic, species and ecosystem diversity. Because the fauna from the southern oriental region in Sunda zone can distribute northwards to the Southeast Asia continent, while the fauna from Himalayas zone can distribute southwards to Indo-china sub-region. Moreover, species of both zones are found in cohabitation in the Lower Mekong Basin, especially, the areas with rich biodiversity are located along the national borders because these areas are inaccessible and remote from human settlement area and transportation link.

For biodiversity status in the Mekong River Basin, there are various types of ecosystem (e.g. terrestrial, wetland and aquatic ecosystem) as well as rich in population and species diversity. The list of fauna and flora which have been

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[1] Himalayas zoogeographical zone is defined as Indo-Chinese subregion of the oriental zoogeographical region, which the distribution of fauna from Indo-Chinese subregion has been prevented from spreading northwards by the himalayas (Beaufort, 1951 and Lincoln et al., 1998).

[2] Sunda zoogeographical zone or the Greater Sunda Islands is defined as the southern oriental region, which the distribution of fauna from Sumatra, Borneo and Java has been merged northwards through Malayan peninsular (Beaufort, 1951).

recorded in the Lower Mekong River Basin is shown below, which indicates that the Lower Mekong River Basin is very rich in biodiversity at 'species level' (Table 2.3).

Table 2.3: The list of fauna and flora in the Lower Mekong River Basin (MRC, 1996).

Feature	Lao PDR	Thailand	Cambodia	Vietnam
Mammals (Total)	157	282	117	275
Mammals (Endemic)	1	8	1	5
Birds (Total)	609	930	545	744
Birds (Endemic)	3	2	0	4
Freshwater fishes	N/A	650	850+	N/A
Amphibians (Total)	37	107	28	80
Amphibians (Endemic)	N/A	13	N/A	N/A
Reptiles (Total)	66	298	82	180
Reptiles (Endemic)	N/A	31	N/A	N/A
Swallowtail butterflies	39	56	22	37
Insects	N/A	N/A	N/A	6,000
Vascular plants (Total)	8,290	15,000	7,570	12,000
Vascular plants (Endemic)	1,457	2,742	1,175	4,800
Ferns	N/A	600	N/A	800
Fungi	N/A	3,000	N/A	600
Total of biodiversity	10,655	23,665	10,389	25,516

Note: N/A is not available.

The total number of species were identified in each country from high to low, which is Vietnam, Thailand, Lao PDR and Cambodia at 25,516; 23,665; 10,655; and 10,389 species, respectively. The number of species in Lao PDR and Cambodia are low but they do not reflect the true biodiversity richness in those countries, despite higher forest cover. The low number is probably an artefact arising from little research and documentation in both countries.

In the Mekong River Basin, ecosystems can group into three categories: terrestrial, wetland and aquatic ecosystems. Each ecosystem has different characteristics depending on space and time.

2.1.2.1 Terrestrial ecosystems

Terrestrial ecosystems in the Lower Mekong River Basin are dominated by forests, as indicated by the forestry data for 1990 to 1995 (FAO, 1999) (Table 2.4). The characteristics of tropical forest are species-rich in terms of plants and animals. There are only 1.4 million species of plants and animals have been recorded and of these about 500,000 species in tropical ecosystem (Grainger, 1993). The tropical forest in this basin is clearly under high pressure with a deforestation rate of 1.2 to 2.6 percent compared to the world annual tropical forest change rate at 0.3 percent (FAO, 1999). Especially, Thailand is the highest annual forest change rate at 2.6 percent, which is interpreted as the highest natural resources utilisation among the riparian countries. It is evident that the forests are deteriorating because there is only 22.8 percent of forest cover left in Thailand. However, Lao PDR and Cambodia still have forest area over 50 percent of the total area. Grainger (1993) indicated that the causes of tropical deforestation related to land use problems more than forestry problems. The causes are shifting cultivation, the excessive or inefficient commercial logging, land encroachment for human settlements, farming and infrastructure development, heavy fuel wood use. These activities are complicated by unclear land ownership (MRC, 1996).

Table 2.4: The forestry statistical data in the riparian countries in the Lower Mekong River Basin (FAO, 1999).

Tropical forest	Lao PDR	Thailand	Cambodia	Vietnam
Forest area 1990 (x1000ha)	13,177	13,277	10,649	9,793
Forest area 1995 (x1000ha)	12,435	11,630	9,830	9,117
% forest 1995	53.9	22.8	55.7	28
Forest change 1990-1995 (1000*ha)	-742	-1,647	-819	-676
Annual change rate (%)	-1.2	-2.6	-1.6	-1.4

2.1.2.2 Wetland ecosystems

Wetland ecosystems[3] are characterised by the presence of water at or near the surface, often with unique soil properties that differ from adjacent areas. The vegetation are adapted to wet conditions. This ecosystem is sensitive and can be damaged or destroyed by many different mechanisms, many of them caused by humans. It also contributes wider socio-economic value that arises from its functioning e.g. flood control, water quality improvement, production of food and natural building materials. Wetland ecosystems in the Lower Mekong River Basin are closely linked to the ecological balance and economic well being. They are the major habitats for fish, which is the major protein-source for the basin's inhabitants. The wetland ecosystems are also significant as wildlife sanctuaries for bird, amphibian, reptile, etc. The population dynamics of the aquatic plants and animals of wetland ecosystems (including shrimp/prawn, crayfish and fish) revolve around the seasonal ebb and flow of the monsoon rains and floodwaters. Flooded areas provide a variety of spawning habitats and nutrient-rich nursery grounds. With the ebb of the floodwaters, following the onset of the dry and cool Northeast monsoons, most young and adult fishes return to river tributaries, but some remain in the wetlands providing year-round harvest.

[3] Wetland ecosystem comprises a wide range of forms, including subtidal or intertidal coral and seagrass, river channel, wet rice fields, flooded crops or orchards, natural lakes, man-made reservoirs, farm ponds, borrow pits, etc (IUCN, 1989).

In addition, the wetland trees are cut for fuelwood, charcoal and construction materials. Large mangrove areas are cleared for shrimp ponds. Thailand's wetlands are being encroached upon and polluted by industry and human settlements. As a result, most wetlands in the Northeast Thailand have suffered a marked decline in water bird populations and associated biodiversity (MRC, 1996).

The causes of wetland loss are classified into natural causes and man-made causes. The natural causes are erosion, drought, sea level rise and vegetation invasion. The man-made causes are conversion for aquaculture or agriculture, construction of dam or flood control system, pollution and hydrological alterations by canals, roads and other structures (Barbier, 1995). Because of the development activities in wetland ecosystem, the environmental situation is severely impacting wetland as well as wildlife. For instance, mangrove forest and *Melaleuca* forest[4] are wetland ecosystems in the Mekong Delta in Vietnam have high fishery productivity. Because of defoliation during the war; deforestation due to logging; firewood collection; and increase in rice and shrimp farming, the wetland forest has been reduced from original 500,000 ha to 233,229 ha in 1988 (Hirsh and Cheong, 1996).

2.1.2.3 Aquatic ecosystems

Aquatic ecosystems in the Lower Mekong Basin represent significant biological value in terms of species composition and diversity. The Mekong River Commission (MRC) reports that there are 1,200 different fish species in this basin (MFNN, 1996a). The Mekong River Basin produces as much as 1 million tonnes of fish annually (MFNN, 1996b). For instance, there are two groups of freshwater fish are distinquished based on their spawning behaviour and environmental tolerance such as White fish (Family: *Cyprinidae* and *Schilbeidae*) and Black fish (Family: *Clariidae, Siluridae* and *Ophiocephalidae*). There are of economic value to riparian inhabitants (MRC, 1996). Because of its biodiversity richness, the basin is of

[4] *Melaleuca* forests predominate on acid-sulphate soils. These forests provide *Melaleuca leucadendron* timber for construction material (valuable due to its strength, durability and resistance to insect and fungi attacks) (MRC, 1996).

considerable value in terms of conservation as well as being a highly productive area for not only regional people but also globally. For instance, ichthyologists recently found 6 new species of freshwater fish in the Mekong Basin which were classified into Family: *Nandidae* (1 species) (Vidthayanon et al, 1996), *Cobitidae* (3 species) (Taki & Doi, 1995; Roberts, 1995), and *Cyprinidae* (2 species) (Doi & Taki, 1994; Vidthayanon and Kottelay, 1995). Moreover, there is an important and famous fish in the Mekong River, the "Giant catfish (*Pangasinodon gigas*), which is the world's largest freshwater fish and commonly weights 150-200 kg (MRC, 1996). At this moment, their life cycle is still unknown, particularly the pattern of migration and breeding.

Naturally, a large percentage of Mekong species inhabits large rivers during the dry season, when the smaller streams dry-out or are reduced to a trickle. In May and June, with the arrival of the monsoons, the fish migrate to the new fresh water to feed and reproduce. Many Mekong species are believed to take long annual migrations up and down the largest rivers, including the Mekong River Mainstream. For instance, schools of *Pangasius kempfii*, the large economically important catfish are reaching more than a meter in length and weighing 15 or more kilograms. It is believed this species migrate well over 1,000 km from the South China Sea and Mekong Delta in Vietnam up the mainstream past Cambodia and deep into tributaries in Lao PDR and Thailand (Rothert, 1994). Other species, such as huge anguilla eels, which are known to reproduce far out at sea, and various species of anchovies and herring, are also believed to migrate up and down the Mekong River from the South China Sea to Lao PDR and Thailand.

2.1.3 Socio-economic situation in the Mekong River Basin

Within a total land area of 795,000 sq. km in the Mekong River Basin, the approximate 65.7 million inhabitants depend on the natural resource base to sustain their livelihood (MRC, 1996). There are various ethnic groups that reside in mountainous and undeveloped areas, and there is no conflict among the different ethnic groups. Generally, they are poor and swidden agriculturists. Most of

nationalities have their own languages, traditional customs, production patterns, religions, etc.

Demographic data of the riparian countries are described in Table 2.5. The population and growth rates are key factors now contributing to environmental degradation. The total population among the riparian countries in the Lower Mekong River Basin is highest in Vietnam at 76.7 million and Lao PDR is lowest at 4.8 million. The average annual growth rate in the Lower Mekong River Basin during 1991-1997 is 1.2-2.7 percent, which is highest in Cambodia and lowest in Thailand. It means that the population growth in Thailand is under control at the low growth rate compared to the other riparian countries. As a result of the population growth, the shifting cultivation cycle is shortened to accommodate more people and more forest products are harvested, which in turn results in soil eroding at a faster rate. Fisheries are over exploited, water courses are polluted with increasing amount of human waste, and solid wastes are pilling up and contaminating groundwater sources (MRC, 1996). Social indicators such as the percentage of population below the national poverty line, the life expectancy at birth and the percentage of illiteracy, indicate the people of Lao PDR and Cambodia to have poor social situation. Particularly, the life expectancy is below 59 years as the baseline of low-income countries. In terms of the percentage of illiteracy of age over 15 years old is also below 47 percent at the baseline of the low-income countries (World Bank, 1998a) indicating more people in the riparian countries to be capable to read than people in the low-income countries. Thailand and Vietnam have not only the low percentage of illiteracy people at 6 percent of total population but also the high life expectancy at birth at 69 years and 68 years, respectively.

Table 2.5: Socio-economic data of the riparian countries in the Lower Mekong Basin (World Bank, 1998a).

Description	Lao PDR	Thailand	Cambodia	Vietnam
Population 1997 (million)	4.8	60.6	10.5	76.7
Average annual growth rate (1991-97, %)	2.6	1.2	2.7	2.1
Poverty (1991-97, %)	46	13	N/A	51
Life expectancy at birth (1991-97, years)	53	69	54	68
Illiteracy of age 15+ (1991-97, %)	43	6	35	6
GDP 1997 (US$ billions)	1.7	153.9	3.1	24.8
GNP per capita 1997 (US$)	400	2,800	300	320

Concerning the economic situation, the Gross National Product (GNP) per capita in 1997 is highest in Thailand at US$2,800 and lowest in Cambodia at US$300 (Table 2.5). These riparian countries have a quite different and mostly poor economy when compared to the GNP per capita in East Asia and Pacific countries (US$970) and the low-income countries (US$350) (World Bank, 1998a). The Gross Domestic Product (GDP) is highest in Thailand at US$153.9 billion and lowest in Lao PDR at US$1.7 billion. Thailand's GDP, including export earning, level of industrialisation and standard of living, surpasses those of other riparian countries in the basin. Even the Southeast Asia crisis was occurred in 1997, Thailand still has the strongest economy among the riparian countries in the Lower Mekong River Basin.

2.1.4 The existing dams in the Mekong River Basin

Based on the distinguishing characteristics of the Mekong River, there are major attempts to utilise the hydro energy for the development in the Indo-china region. To describe the hydro energy utilisation, the existing dams are constructed in the Upper Basin to the Lower Basin for each country as follows:

- ***China*** has planned to construct many dams on the Mekong River, which are in the Upper Mekong Basin. There are two dams called Lancang dam at Dachaoshan and Manwan Dam on the Upper Mekong River Basin in Yunnan

Province, China. The topography of the upper basin is of mountain characteristics and makes the river rich in hydraulic energy resources and favourable for hydropower development. The filling of Manwan Dam in 1994, created navigation problems on the Lao stretch of the Mekong River. This dam also caused erosion of riverbank in Lao PDR, which led to loss of national territory where the river forms the border with Thailand (Hirsch and Cheong, 1996). In addition, the water level of the existing Tonle Sap (Great Lake) in Cambodia decreased during the filling of the Manwan dam. After 1994, the water level increased as water was released from the dam. This kind of fluctuation affected the annual flooding, which this great lake depends on, and supports the natural habitat for fish migration up and down stream and also fish breeding ground. The reductions of flow downstream cause the salt water to intrude further upstream and threaten the rice production in the Mekong Delta.

- In ***Lao PDR***, many dams have been constructed in the Lower Mekong River Basin. For instance, Nam Theun-Hinboun dam is located in Bolikhamxai and Khammouane Provinces of central Lao PDR and officially opened in 1998. Severe and unmitigated impacts are being experienced by villagers as a result of the dam including declines in fish production, transportation difficulties, flooding and erosion of fertile riverbanks (IRN, 1999). Another, the Nam Ngum Dam located in Nam Ngum watershed is a representative of a wide range of existing and potential resource users. This dam is of international significance as the international hydropower project in Lao PDR. There are ten countries involved in financing and construction of Nam Ngum Dam (Hirsch and Cheong, 1996). Since most of the power is exported to Thailand, the driving forces for resource exploitation come from beyond the borders of Lao PDR. Nam Song diversion dam is located in Nam Ngum watershed, which has had a recent impact such as logging in the reservoir and in parts of the upper watershed also replaces demands on the resource base. Nam Luek Dam is located in Vientiane Province, it began in early 1997 and is tentatively planned to be completed in 1999. In conclusion the impacts of dams in Lao PDR are anticipatory resettlement under very poor conditions, uncontrolled

logging, inadequate compensation for affected villagers, problems with regulation and the conduct of environmental impact assessments (IRN, 1999).

- In ***Thailand***, the Pak Mun Dam was constructed on the Mun River, a tributary of the Mekong River in Thailand and completed in 1994. This dam has caused the serious social and environmental problems since project implementation. As a direct result of the dam, more than 2,000 people have been affected by the drastic reductions in fish populations upstream of the dam site, the debilitating disease schistosomiasis and other changes to their livelihoods. The conflicts between local people and Thai government are still unsolved because the people demand compensation from the government and the World Bank. The World Bank has consistently refused to take any responsibility for this project's problems (IRN, 1999).
- In ***Cambodia***, there is no existing hydropower dam in the country. The present electricity generation is entirely by thermal power plants using imported fossil fuel. Cambodia has the second highest hydropower generating capacity in the Lower Mekong River Basin, therefore, the World Bank and the Asian Development Bank (ADB) have recently offered 'soft' loans for the construction of three dams (Hirsch and Cheong, 1996). One of three is 'Sambor' dam project, Kratie Province, the Northeast Cambodia, which is prioritised, in the first rank of the mainstream run of river projects.
- In ***Vietnam***, Yali Falls Dam is sited on the Se San River at Yali Falls. The river is the largest eastern tributary of the Mekong River and originates from the Ngo Clinh Mountains, the largest mountain range in the south of Vietnam. The Yali Falls Dam is the second largest dam in Vietnam. Construction began in 1994 and was proposed to finish by 1998-2000 (Hirsch and Cheong, 1996). It is claimed by Cambodian authorities the fish stocks in Cambodia have been reduced since the construction commenced.

2.2 INTERNATIONAL ORGANISATION IN THE LOWER MEKONG RIVER BASIN

The Mekong River, an international river in the Indo-China region, flows through six countries. Only four riparian countries (Lao PDR, Thailand, Cambodia and Vietnam) established an international organisation, which is very important to co-operate the policy planning for sustainable development, utilisation, management and conservation of water and related resources of the Mekong River Basin. Therefore, the Mekong River Commission (MRC) was established with the signing of 'the Agreement on the Co-operation for the Sustainable Development of the Mekong River Basin' in 1995. This commission replaced the previous two acting bodies as the Mekong Committee established in 1957 and the Interim Mekong Committee established in 1978. The MRC depends on the resources from member countries, international donor community and co-operating agencies.

2.2.1 Role of Mekong River Commission

The MRC has three permanent bodies, namely: (1) The council (at minister/cabinet level); (2) the joint committee (at department head level); (3) the secretariat (the technical and administrative arm of the Commission). The mandate of MRC is:

- To co-operate and promote in a constructive and mutually beneficial manner in the sustainable development, utilisation, conservation and management of the Mekong River Basin.
- To protect the environment, natural resources, aquatic life and conditions, and ecological balance of the Mekong River Basin from pollution or other harmful effects resulting from any development plans and uses of water and related resources in the Basin (MRC, 1996).
- To define as the 'general planning tool and process that the Joint Committee would use as a blueprint to identify, categorise and prioritise the projects and programmes to seek assistance for and to implement the plan at the basin level'.

2.2.2 Development plans in the Lower Mekong River Basin.

The Mekong River, is considered to have high potential for hydroenergy source for generating electricity in the Indo-china region because the river is large enough to be efficiently absorbed in the economies of the riparian countries. Therefore, hydropower dam projects are considered and proposed in MRC development plans, which might be built on the mainstream. The 1994 Run-of-River Hydropower Plan was premised by the need to select sites to minimise socio-economic and environmental impact (MRC, 1994). The total energy generating capacity of the nine proposed dams is about 13,350 MW (MRC, 1994) (Figure 2.2).

Of the nine proposed hydropower dam projects on the mainstream (Table 2.6) two are along the Thai-Laotian boundaries and four upstream in Laotian boundary which will generate electricity for Thailand. Downstream, in Laotian-Cambodian boundaries, there is also one proposed hydropower dam and another two in Cambodia. However, all hydropower dams will generate electricity in order to commercialise Thailand. The run-of-river study is still very much at a preliminary stage and it needs further research. Nevertheless, the integrity of the basin's ecosystems is increasingly threatened by development impacting on biodiversity, especially, habitat loss. Therefore in the near future, the ecological resources are likely to be further deteriorated if the developments in the Lower Mekong River Basin are implemented without holistic environmental consideration.

Table 2.6: The nine proposed hydropower dam projects in the Lower Mekong River Basin (MRC, 1994).

Dam Project	Hydropower capacity (MW)
I. Ban Koum (Thailand & LAO PDR)	2,700
I. Don Sahong (LAO PDR & Cambodia)	240
I. Sambor (Cambodia)	4,110
II. Pak Beng (LAO PDR)	1,410
II. Luang Prabang (LAO PDR)	2,560
II. Sayaburi (LAO PDR)	1,260
II. Pak Lay (LAO PDR)	1,760
III. Pa Mong (Thailand & LAO PDR)	2,440
III. Stung Treng (Cambodia)	1,190

Note: I are the first priority projects.
II are the second priority projects.
III are the third priority projects.

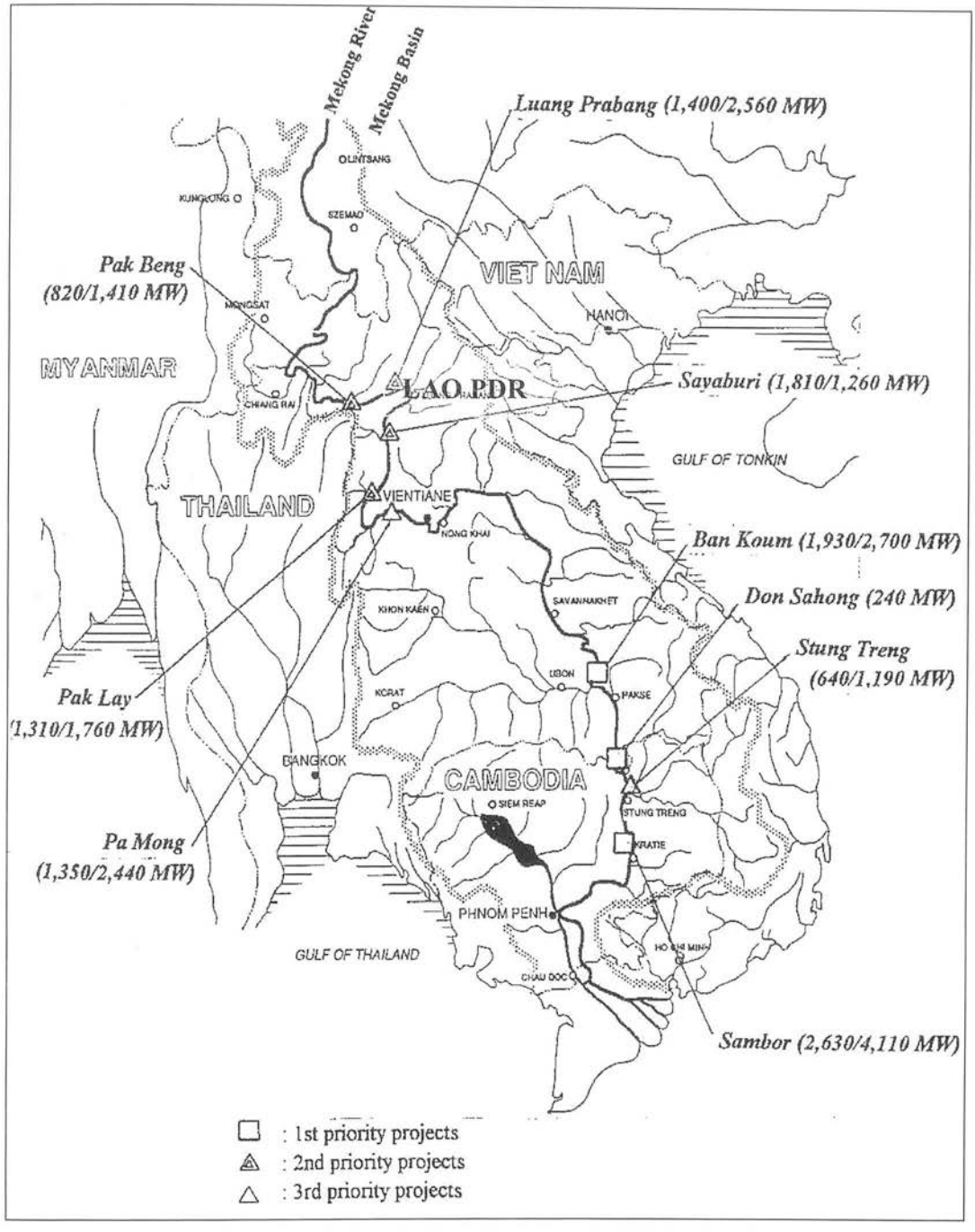


Figure 2.2: The proposed hydropower projects on the Lower Mekong Mainstream (MRC, 1994).

2.3 ECOLOGICAL AND SOCIO-ECONOMIC SITUATION IN THAILAND AND LAO PDR

The Mekong River carves a common border between Thailand and Lao PDR for 900 km of 1400 km Thai-Laotian common border, starting near Chiang Saen where the borders of Thailand, Myanmar and Lao PDR meet. It lies mostly in Thailand's Northeast provinces, collectively known as Thai E-san (89.5 percent) together with a small part of its eastern region (2.2 percent) and also its northern tip of Thailand (8.3 percent). The 36 percent of total area in Thailand are located in the Lower Mekong River Basin (Table 2.2). So this basin is important to socio-economic, cultural and political life of Thai people.

In terms of biodiversity, the international border area between Thailand and Lao PDR is listed as one of the richest biodiversity hot spots. Lao PDR ranks as one of the biologically richest countries in the Indo-China Region, because it is significantly covered by relatively intact and contiguous original forest, thus providing substantial original natural habitats (MRC, 1996). Thailand contrasts with Lao PDR because there are limited forest areas with extensive agricultural practices to reduce biodiversity in the basin, except along the national border areas. Because the national border areas are quite inaccessible and remote from populated area and transportation links, the biodiversity is still rich.

2.3.1 Thai situation

Thailand's geographical area is approximately 513,111 sq. km (51.3 million hectares) located between latitude 5-21 N and longitude 97-106 E and under wet and dry monsoon climate (TEI, 1996). Natural terrestrial vegetation is comprised of dry deciduous forests, with teak and the *Dipterocarpus* species being the dominant stands, whereas vegetation in the southern part of country consists of tropical evergreen species. It has been estimated that Thailand contains 6 percent of the world known species as vascular plants, 10 percent of fishes, 10 percent of birds, 5 percent of reptiles, and 3 percent of amphibians. Currently, 109 faunal species and

100 floral species are listed under the endangered category (MRC, 1996).

In the Lower Mekong River Basin of Thailand, the majority of the population relies on agriculture, showing the low levels of industrialisation and services sector development, compared to the rest of the country. Soil quality in Northeast Thailand is generally poor with low clay content and salinity problems. The expansion of irrigation and construction of reservoirs will worsen salinity problems by raising the water table. It is estimated that saline soils and unsuitable topography make about 75 percent of land in the Northeast Thailand poorly suited to reservoir development. The poor land quality is reflected in the population in the Northeast Thailand, which has relatively poor socio-economic status compared to the rest of the country.

Thailand is a rapidly developing agro-industrial country within Southeast Asia and as the gate to Indo-China Region it has high potential as a supporting system for economic growth. In the past, Thailand built its economic wealth on its abundant natural resources (including teak, rice, fish and tin) but now gets an increasing GNP from manufacturing and services. During 1987-1997, the economic situation was boosted with GDP average annual growth at 8.7 percent and GNP per capita at 7.2 (World Bank, 1998a). GNP per capita in 1997 was US$2,800 (World Bank, 1998a). The Thai economy is rapidly increasing and is described as the most powerful local economic force in the region. Thailand's GDP, export earning, level of industrialisation and standard of living surpasses those of neighbouring countries in this basin. Behind the economic boom, there is increasing concern that this growth is not sustainable and is causing unacceptable ecological damage.

To continue its economic growth, Thailand needs to develop infrastructure and services to meet the requirement for industrial bases and services. Therefore, electricity demand becomes a major factor in development. Energy demand is rising rapidly e.g. the rate of electricity demand increased from 61.6 TWh in 1993 to 411.3 TWh in 2020, an increase of 10 percent per year (MRC, 1996). Electricity generation from the hydropower resources in the Mekong River Basin is a major component of Thailand's strategy to meet the increase in national demand. Due to

the gradual reduction in the number of suitable sites for new hydropower dam and the constraint of investment arisen from lacking of public acceptance, the Thai government has to implement the new energy policy strategy. The strategy is to purchase electricity from neighbouring countries under the joint development of energy resources with neighbouring countries (Keeratiwiriyaporn, 1999). However, the Electricity Generation Authority of Thailand (EGAT) is the State enterprise, it is also to continually search for new available energy resources from outside of country. Dam construction is a serious cause of deforestation in Thailand, especially, since the Thai government banned logging in January 1989 resulting in timber becoming a very high value natural product in the markets (WRI, 1992). Thus the dam projects represent a strategy to harvest timber from inundated site. In 1995, FAO (1999) reported that the forest area in Thailand was only 22.8 percent of total land area and was decreasing at 2.6 percent per year.

Recently, Thai non-governmental organisations (Thai-NGO) considerably activated local people to have environmental consciousness and to consider their natural resources for the next generation. So the hydropower projects in Thailand are becoming sensitive issues and people might be against them in terms of environmental protection and conservation. Based on past experience, Thailand faces a situation of natural resources decline within the Thai economy and needs to search for the availability of resources in the neighbour countries. For instance, timber is imported from the neighbouring countries according to Thai market demand after Thai government banned timber logging in 1989 (Figure 2.3).

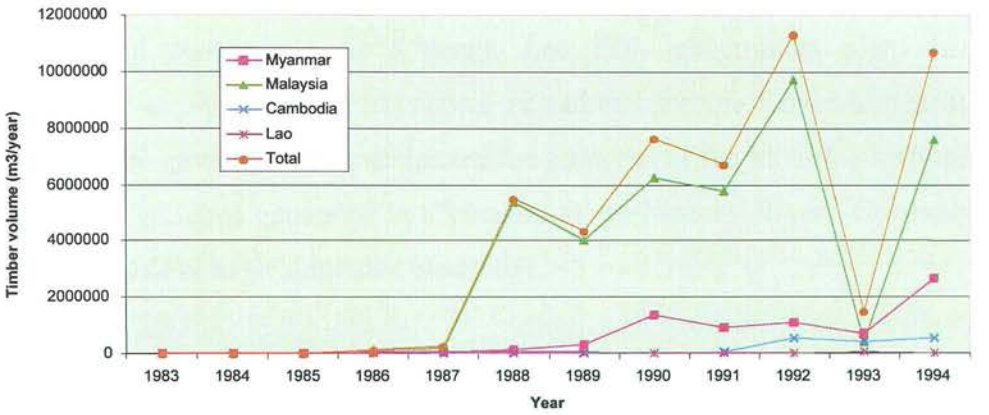


Figure 2.3: Thailand imported timber (m^3/year) from the neighbouring countries during 1983-1994 (Gajaseni, 1997).

2.3.2 Laotian situation

Lao PDR, is one of riparian countries with the Mekong River flowing through its north and south boundaries. The catchment area in Lao PDR includes 25 percent of the total catchment area of the Mekong River Basin. This represents 95 percent of the national territory. The catchment area of the basin in Lao PDR drains westwards to the Mekong River, often through hilly or mountainous terrain, particularly in the north and east of country. Lao PDR ranks as one of the biologically richest countries in the region because a significant area of the country is covered by relatively intact primitive forest. With a low population density and low disturbance, Lao PDR is considered to be the last wild habitat for Indochina endemic species and 25 species of mammals and birds are endangered. For instance, Southeast Asia endangered species are elephant, leopard, barking deer and the large-antlered muntjac (*Magamuntiacus vuquangensis*) (MRC, 1996). Geographical characteristics indicate that about 35 percent of all water in the Mekong River originate from watershed within Lao PDR (Figure 2.1). Therefore, any watershed development projects in Lao PDR, whether in tributaries or the mainstream of Mekong River, have the potential to affect downstream neighbouring countries.

The major development plans in Lao PDR are focusing on hydropower projects, which aim to sell electricity to Thailand. Since 1986, Lao PDR government has

restructured the economic policy, which has liberalised to become an open-door market-based economy. As a result, Lao PDR government plans to utilise hydropower as a primary natural source of national income for development of the country. The government has estimated the potential of the basin for hydropower at 8,000 MW, which is generated in tributaries of the Mekong River. Currently, there are only 200 MW to be generated electricity.

From an environmental perspective e.g. land, water and forest, it could be argued that Lao PDR has richer natural resources than the neighbouring countries. Although, Thailand has the better financial situation it has poor natural resources. Nevertheless, aquatic life of the Mekong River is characterised as the major source of animal protein to the Laotian, comprising from 30-50 percent of the total animal protein consumption. Therefore, wild fisheries have long played an integral role in the lives of rural people in Lao PDR. By land-use type, Lao PDR covers a land area of 237,000 sq km of which 53.9 percent is covered by natural forest (FAO, 1999). By contrast, only 3 percent of the country is cultivated (Rigg & Jerndal, 1996). Most of land degradation in Lao PDR is officially associated with shifting cultivation because of poor soil fertility, weed infestation and rapid loss of soil moisture due to fallow periods. With a population density of only 20 capita/sq. km (FAO, 1997) and population growth rate at 2.6 percent during 1991-1997 (World Bank, 1998a), the pressures on land and natural resources would seem to be limited.

Considering the economic situation, Lao PDR's GNP per capita in 1997 was US$400, compared to the average income in East Asia and Pacific region of US$970 (World Bank, 1998a). Lao PDR is classified as one of the ten poorest countries in the world and in World Bank terms is classified as a LDC (Less Developed Country) (Rigg & Jerndal, 1996). World Bank (1998a) reported that Lao PDR is progressive in GDP annual average growth during 1987-1997 at 6.7 percent and GNP per capita at 4.0 percent. In terms of the natural resource base, Lao PDR is the last of the resource-rich countries in the region. This makes Lao PDR attractive to the neighbouring countries and those outside the region who may wish to take advantage of their natural resources.

2.3.3 Comparison of Thailand and Lao PDR

A summary of the ecological and socio-economics indicators of difference between Thailand and Lao PDR is given in Table 2.7. Lao PDR is smaller than Thailand but most of land area lies within the Mekong catchment area. Because of the characteristics of the catchment area, Lao PDR has a higher potential to generate hydropower energy than Thailand. The Laotian government looks to hydropower development as the primary source of income for the country in the future. This is seen as an important export opportunity for country that is very poor in GDP per capita terms and quality of life indicators. While the energy demand in Lao PDR is so low when compared to Thai's energy demand in 2020 at 0.3 and 61.8 GW, respectively.

Population density in Lao PDR is very low when compared to Thai's population density at 20 and 118 capita/sq. km, respectively. The demand of natural resource utilisation in Lao PDR will be less than Thai's demand. The annual forest change rate shows that Lao PDR has a higher deforestation rate than Thailand but its forest cover area is still higher than Thai's forest area. It means that Lao PDR has more natural habitat for wild flora and fauna but the number of flora and fauna species in Lao PDR seems to have less than the species in Thailand. However, the reason is because the number of species recorded does not provide the true reflection of biodiversity in the two countries because of different intensity of studies.

Table 2.7: A comparison of ecological and socio-economic situation between Thailand and Lao PDR.

Description	Thailand	Lao PDR	Source
Total land area (sq. km)	513,111*	237,000**	* TEI, 1996; **FAO, 1999
Catchment area as % nation	36	97	MRC, 1996
Hydropower potential (GWh/year)	26,100	102,300	MRC, 1996
Power demand in 2020 (GW)	61.8	0.3	MRC, 1996
Population 1997 (million)	60.6	4.8	World Bank, 1998a
Population density 1997 (capita/sq. km)	118	20	Adapted from TEI, 1996; FAO, 1999; and World Bank, 1998a
GNP per capita (1987-1997)	7.2	4.0	World Bank, 1998a
GNP per capita 1997 (US$)	2,800	400	World Bank, 1998a
% forest area	22.8	53.9	FAO, 1999
Annual forest change rate (%)	-1.2	-2.6	FAO, 1999
Terrestrial fauna	1,510	832	MRC, 1996
Terrestrial flora (Vascular plants)	15,000	8,290	MRC, 1996

With the poor economic situation of Lao PDR, it is necessary to consider economic reforms to boost their economy for their people life. However, the economic situation obviously involves natural resources exploitation and extraction e.g. timber logging, mining, dam construction for export forest products, raw materials and electricity to neighbouring country, in particular Thailand. Hirsch and Cheong (1996) mention that rapid depletion of the forest in Lao PDR is due to:

- Poorly planned and managed logging
- Highly unsustainable level of wood extraction
- Forest fires
- Encroachment by lowland farmers
- Expanding shifting cultivation

These need to be addressed in the decision-making by Laotian government to ensure

sustainable resource use.

Unexpectedly, the Southeast Asia economic and financial crisis developed in 1997 (Table 2.8). A massive devaluation of the Southeast Asia currencies has taken place with devaluation in Thailand and Lao PDR of 24.1 and 36.8 percent, respectively. The currency devaluation also effected the implicit GDP deflator in 1997 at 5.4 and 20.8 percent, respectively. It emphasises that the people of Lao PDR have to absorb higher domestic consumer prices than Thailand. Devaluation generally increases the competitiveness of exports, especially the export of low-capital and import-intensive products including those associated with natural resource exploitation such as logging, and the production of plywood, pulp, and palm oil (World Bank, 1999). The World Bank has considered that the use of natural resources may increase as a result of currency depreciation and also poverty may increase pressure on fragile ecosystems.

Table 2.8: The impacts of economic and financial crisis to Thailand and Lao PDR (World Bank, 1998a).

Description	Thailand (Baht/US$)	Lao PDR (Kib/US$)
Exchange rate 1996	25.3	921.1
Exchange rate 1997	31.4	1,260.0
Currency devaluation (%)	24.1	36.8
Implicit GDP deflator 1996 (%)	4.0	12.9
Implicit GDP deflator 1997 (%)	5.4	20.8

The economic crisis will also reduce energy demand in Thailand; some analysts are predicting a 10 year recession for Thailand (Imhof, 1998). As a result, the Electricity Generating Authority of Thailand (EGAT) is apparently revising its power development plan, in which Lao PDR will sell approximately 467 MW of electricity to Thailand instead of the 1,500 MW predicted in 1993 (Imhof, 1998). This economic crisis will therefore delay the hydropower development projects in the Lower Mekong River Basin in relation to the decline in power demand.

2.4 PROPOSED HYDROPOWER DAM PROJECT IN THE MAINSTREAM OF THE LOWER MEKONG RIVER BASIN

Basically, the energy demand for economic development in this region, especially in Thailand, is increasing at a high rate of over 1,000 MW per year (MRC, 1995). Therefore, the MRC foresees the potential of the Lower Mekong River to generate electricity and supply according to the riparian countries needs. This electricity from the mainstream hydropower dam will provide the low cost energy to improve the energy supply situation in the region. The hydropower energy is usually considered as cheap energy when compared to energy from the other sources. At the moment, there are many hydropower dams constructed in the basin not only on the mainstream but also on the tributaries of the Mekong River (Table 2.9).

The MRC study for the possibility of mainstream hydropower implementation indicates nine hydropower dams start from Lao PDR downstream to Cambodia (Figure 2.2). In the ranking of decision-making process, MRC identified Don Sahong, Sambor and Ban Koum would be acceptable for the future investment. The screening of hydropower projects is based on technical viability, economic viability and environmental viability (MRC, 1994).

Table 2.9: Some of existing hydropower dams on the mainstream and tributaries of the Mekong River.

Hydropower dam	Location	Country	Source
Lancang Dam	Upper Mekong Basin	China	Hirsch and Cheong, 1996
Manwan Dam	Upper Mekong Basin	China	Hirsch and Cheong, 1996
Nam Ngum Dam	Lower Mekong Basin	Lao PDR	Hirsch and Cheong, 1996
Nam Song Dam	Lower Mekong Basin	Lao PDR	Hirsch and Cheong, 1996
Nam Theun-Hinboun Dam	Lower Mekong Basin	Lao PDR	IRN, 1999
Nam Luek Dam	Lower Mekong Basin	Lao PDR	IRN, 1999
Pak Mun Dam*	Lower Mekong Basin	Thailand	IRN, 1999
Yali Falls Dam	Lower Mekong Basin	Vietnam	Hirsch and Cheong, 1996

Note: * Pak Mun Dam is selected in this study as the control sample under the condition of 'with-project implementation' (Figure 2.4).

In this study the Ban Koum Project was selected as a case study largely because this hydropower dam project is located on the Thai-Laotian border. It will probably have impacts not only to the natural resources but also the local communities of both countries. The condition of the Ban Koum Project will be more complicated because there are many organisations involved such as MRC, Thai and Laotian government and the international financial supports. For instance, the institutions involved (MRC, 1995):

- In Lao PDR:
  - The Lao National Mekong Committee
  - The Hydropower Project Office, Ministry of Industry and Handicrafts
  - The Electricite du Lao (EDL)
  - Ministry of Agriculture and Forestry
- In Thailand:
  - The Thai National Mekong Committee
  - The Department of Energy Development and Promotion
  - The Electricity Generating Authority of Thailand
  - The Fisheries Department

- The Town Planning Office, Ministry of Interior

In addition Ban Koum Project is a project in the first priority group of the mainstream river-run-of hydropower dam among the nine projects in MRC's development plans in the Lower Mekong River Basin (Table 2.10 and Figure 2.4). It indicates that the Ban Koum Project is highly beneficial in term of economic analysis among the all projects. The other first rank projects are located in Cambodia.

Table 2.10: A comparison of the nine proposed hydropower dams based on the economic analysis (MRC, 1994). B/C is the benefit to cost ratio.

Dam Project	B/C ratio	Internal Rate of Return (%)	Energy cost US$/kW
I. Ban Koum (2,700 MW)	1.4	13.9	3.2
I. Don Sahong (240 MW)	1.5	14.6	3.6
I. Sambor (4,110 MW)	1.5	14.6	3.0
II. Pak Beng (1,410 MW)	1.2	11.7	3.7
II. Luang Prabang (2,560 MW)	1.4	14.0	3.0
II. Sayaburi (1,260 MW)	1.4	13.8	3.2
II. Pak Lay (1,760 MW)	1.5	14.9	3.0
III. Pa Mong (2,440 MW)	1.4	13.9	3.2
III. Stung Treng (1,190 MW)	0.9	8.8	5.1

Note: I is the first priority projects.
II is the second priority projects.
III is the third priority projects.

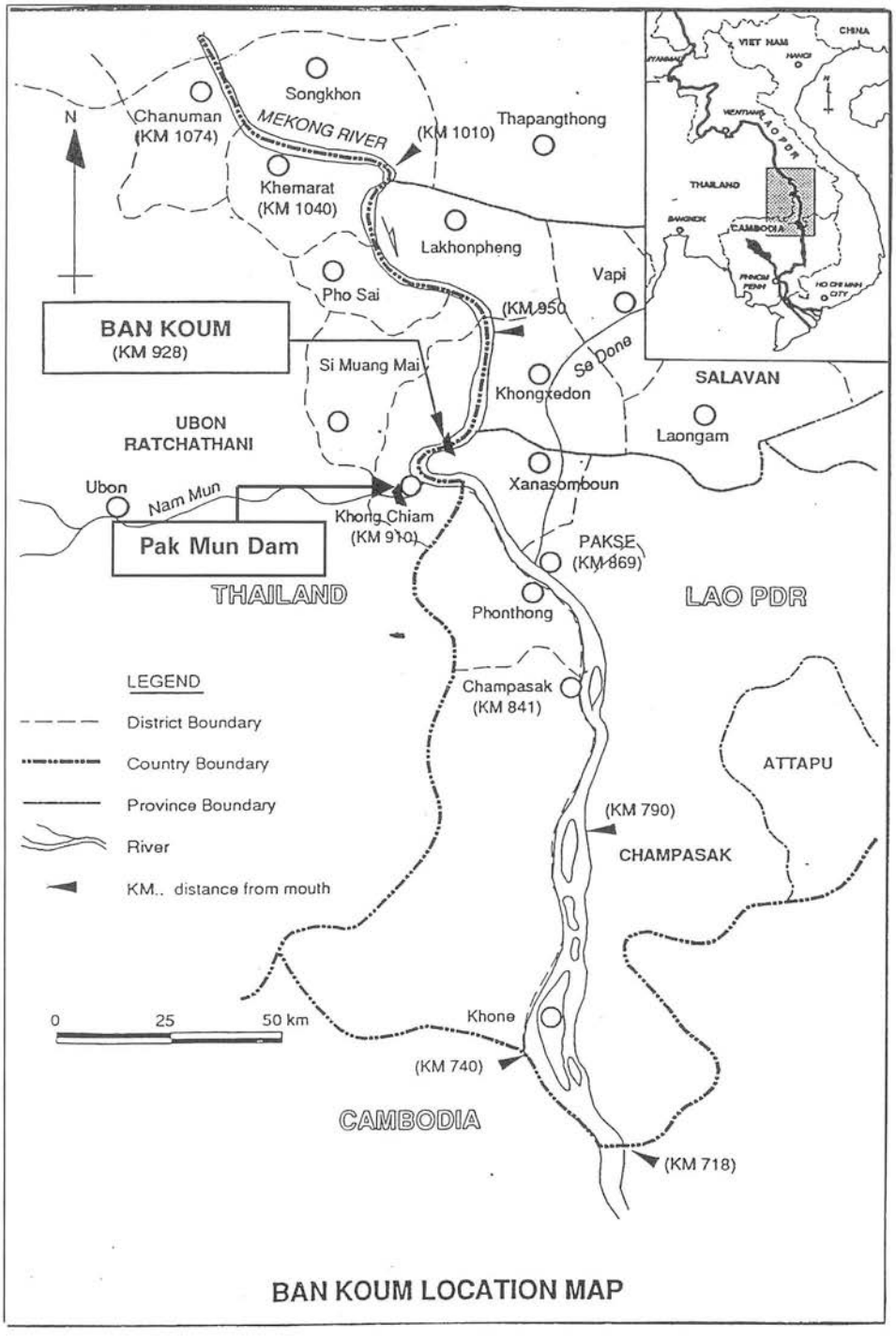


Figure 2.4: Ban Koum location map on the Mekong River Mainstream (MRC, 1994) and Pak Mun Dam on the Mun River, a tributary of Mekong River as the reference hydropower dam with-project implementation.

This project is located 928 km from the river mouth and the operated pool elevation is 120 m above mean sea level (MSL) (Figure 2.4). This dam will be constructed on the mainstream, and will flood over Thai-Laotian riparian area. The location of the project has been chosen at km 928, because the river is made of two channels, separated by Don Koum Island. This island is 1500 m long and averages 300 m wide, which is advantageous in terms of low construction cost. The affected areas start, from Ban Kum, Amphoe Khong Chiam, Ubon Ratchathani, Thailand and Ban Sura, the northern Champasak, Lao PDR, approximately 150 km to 50 km upstream, depending on the flow. The land use affected by this project is shown in Table 2.11.

Table 2.11: The details on the over-flooded area of proposed Ban Koum hydropower project (MRC, 1994).

Decription	Area (km^2)
1. Original area of water	39
2. River bank and island area	18
3. Agricultural area	4
4. Forest	72
5. Developed area	0
Total future reservoir area	133

Along both sub-watersheds of this area, forest provides the dominant land covers and is mainly Dry Dipterocarp forest, located at 0-200 MSL. The dominant tree is *Dipterocarp* spp. and *Shorea* spp. (Lao-Swedish Forestry Co-operation Programme, 1992). The sub-watershed in Thailand has been legally registered as Pha Taem National Park since 1991 and previously was subjected to legal and illegal logging activities.

From an engineering point of view, the capacity of dam is 2,330 MW, generating annual energy of 10,230 GWh by two powerhouses. The sediment sluices have been installed in order to avoid the storage of the sediments in front of the powerhouse during floods, thus filling the intakes of the turbine units.

The current economic evaluation of this project has focused on the construction cost; environmental and socio-economic cost; and management-administration-engineering cost (Table 2.12). In terms of environmental and socio-economic aspect, this project estimated environmental mitigation cost[5] as only 3 percent of total cost as US$2,193 million, which is approximately as US$49.2 million. According to the social stage, 330 households including 2,570 inhabitants in seven villages have been recognised as needing to be resettled at a cost of US$8.5 million (MRC, 1994). The economic analysis is concerned with ecological assessment only as marketable goods to human society; it does not include the value of ecosystem services.

[5] Environmental mitigation cost includes the cost of mitigation measures such as erosion protection, flood protection dykes, creation of managed wetlands, and the cost of local community development (MRC, 1994).

Table 2.12: The cost estimation of Ban Koum hydropower project on the mainstream of Mekong River (MRC, 1994).

Description	Cost (10^6 US$)
1.Feasibility study	10.36
2. Preliminary works	57.50
3. General civil works	184.83
4. Power house civil works	144.56
5. Navigation lock civil works	78.53
6. Spillway civil works	41.36
7. Closure dams	5.05
8. Electro-mechanical equipment	882.94
9. Environmental and socio-economic	
Environmental mitigation (3% of direct cost)	49.20
Resettlement costs[6]	8.49
10. Management, administration and engineering	128.44
11. Transmission line and system	366.44
Total project cost including commission cost (10^6 US$)	2,193

[6] Resettlement cost includes compensation, resettlement and new facilities for the displaced population (MRC, 1994).

The benefit of Ban Koum hydropower project is based on economic analysis of the electricity production (Table 2.13). It estimates that the Ban Koum project can provide a high profit and justifies searching for financial support.

Table 2.13: The benefit estimation of Ban Koum hydropower project on the mainstream of Mekong River (MRC, 1994).

Description	Benefit (10^6 US$)
1. Net Present Value (NPV) based on 10% discount	1340
2. Internal Rate Return (IRR) over 50 year period	13.9%
3. Benefit to cost ratio	1.4
4.Benefit of the project (per year)	415

As a result of this analysis the project has been classified as a first priority in the comparison evaluation with the other proposed project (Table 2.10). The development plans for the Lower Mekong River Basin could have evaluated ecological and socio-economic changes. However, in terms of justification and prioritisation of these serial hydropower dam projects, MRC evaluated the project based largely on economic analysis as benefit to cost ratio, net present value, and internal rate of return which outweigh ecological and socio-economic components.

2.5 IMPACT ASSESSMENT[7] SITUATION IN THAILAND AND LAO PDR

Impact assessment is an important tool for improving the long-term viability of projects, plans or policies and its use can help to avoid mistakes that can be expensive and damaging in environmental, social, and/or economic terms. This assessment also provide a mechanism for learning from past experience to avoid some costly mistake or accident and can improve the management before, during and

[7] Impact assessment is a process to improve decision-making and to ensure that the project/programme options under consideration are environmentally and socially sound and sustainable. Impact assessment is used as an umbrella term for a range of techniques including: (1) environmental impact assessment (EIA); (2) cumulative effects assessment; (3) health impact assessment; (4) risk assessment; (5) social impact assessment; (6) strategic environmental assessment;

after the implementation of projects, plans or policy.

In Thailand, environmental impact assessment was introduced and adopted from the USA, and was adjusted to be appropriated to Thai situation. History of EIA in Thailand started at the first three of 5-year Thai National Economic and Social Development Plans (1961-1976), which emphasised economic growth almost exclusively. The noticeable depletion of forest resources, deterioration of soil quality, and shortages of water supply led to the introduction of resource protection and rehabilitation approaches into the fourth Thai National and Social Development Plan (1976-1981). Then, the fifth National Plan (1981-1986) focused on a more integrated approach in relation to natural resources development and co-ordinated with local socio-economic progress (Gilpin, 1995). Therefore, the Office of the National Environment Board (ONEB) was established in 1975 and authorised for the administration of the environmental impact assessment (EIA) process in Thailand. However, ONEB only received strengthened authority in 1992 under the National Environmental Quality Act (Sriburi, 1995). Formally, the EIA process has been legal requirement in Thailand since 1984 (Gilpin, 1995). Under the National Environmental Quality Act 1992, the proponent for a development project approval legally requires the EIA process. Thailand has national guidelines related to general EIA, coastal zone and water resources (Roe et al., 1995). It includes 19 development activities such as dam or reservoir, irrigation, airport, hotel and resort, expressway, mining, industrial estate, harbour, power plant, industry, sea landfill, development project in the first class of watershed area, etc (Sriburi, 1995).

Generally, there are three stages of the impact assessment process as screening[8], preliminary assessment[9] and scoping[10], which are important in order to determine the

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(7) technology assessment (Roe et al., 1995).

[8] Screening is to decide whether or not a project requires assessment, and the level of assessment that may be necessary (Roe et al., 1995).

[9] Preliminary assessment identifies key impacts on the local environment; describes the magnitude and significance of the impacts; and evaluates the importance of the impacts for decision-makers (Roe et al., 1995).

[10] Scoping involves the identification and narrowing-down of potential environmental impacts to ensure that assessment focuses on the key issues for decision-making (Roe et al., 1995).

extent and focus of the impact assessment required (Roe et al., 1995). Since 1984, it has been a requirement that EIA reports have to be prepared by consultant firms registered with ONEB. The environmental-consultant firms alone have the right to conduct EIA. Once submitted to ONEB, a review team is set up to ensure impartial and well-qualified review. In Thailand, an EIA is described elsewhere as Environmental Impact Statement (EIS). Terms of reference are defined through discussion with ONEB before the preparation of an EIA. The public hearing is required at the final stage for the public participation and responses according to the development project, policy or planning. For public projects, the final decision-maker is the cabinet.

In relation to natural resource and environmental concern in Lao PDR, the government establishes the National Environment Action Plan (NEAP), which thoroughly assesses the status of the environment in this country (AMRC, 1999). Furthermore, the establishment of the Science, Technology and Environment National Organisation (STENO) in 1993 was intended to create a co-ordinating government office. The STENO is charged with developing environmental management legislation and assessing environmental impact reports. However, STENO is still limited in terms of human resources and the role has not been well defined (AMRC, 1999).

As a result, Lao PDR has not been listed in the table of country and agency guidelines in a 'Directory of Impact Assessment Guidelines' but Thailand has (Roe et al., 1995). A key of environmental concern is the ability of the government to fully assess the impacts of proposed development and to integrate multiple issues in the natural resource management. But the environmental policy and law is not empowered enough so the government still relies on the advice of numerous foreign consultants and agencies in the management of natural resources particularly hydropower development projects.

Regarding the high profile of the Lower Mekong River Basin, it is potentially important for the economic development in the region, even though the economic

crisis in the Southeast Asia still impacts on the riparian countries. However, the lower Mekong River Basin should be considered as much as possible in terms of the sustainable development for all humans and others in this and future generations. Therefore, this study attempts to explore the improved methods for biodiversity evaluation based on the ecological and socio-economic aspects, they will be described in the chapter four, five and six.

CHAPTER THREE
OVERVIEW OF ECOLOGICAL CONCEPTS AND EVALUATION

This chapter focuses on an ecological scheme for Impact Assessment with regard to the relationships of species and ecosystems. Biodiversity starts from genetics, expanding to species, and ecosystem, but genetics and species diversity integrate to play a role in ecosystem function (Figure 3.1). At the trophic level, the components also relate to the highly complex interactions with regard to energy flow and nutrient cycling from bottom to the top. Biodiversity houses the genetic library and organisms help to sustain a flow of ecological services that are prerequisites for many economic activities. These include (Folke et al., 1996 and Costanza et al., 1997) for example:

- Net primary production as the basis for provision of food and other renewable resources
- Soil generation and preservation
- Pollination of crops
- Recycling of nutrients
- Filtering of pollutants and waste assimilation
- Water retention and flood control i.e. operation of the hydrological cycle
- Climate moderation
- Maintenance of the gaseous composition of the atmosphere
- Carbon storage

These ecological functions sustain and secure human activities, and thus human well being. In economic terms, ecosystems are fundamental 'factors of production' – factors that are becoming increasingly scarce as a consequence of the rapid human population growth, and human behaviour towards the natural capital base (Folke et al., 1996). To understand and sustain biodiversity, Humans must be considered as one component of biodiversity.

If biodiversity loses its balance and declines, the whole system will be effected. Seemingly, the insurance function of biodiversity certainly includes its role in the

genetic evolution of microbial, plant, animal, and human life. However, it also includes the capacity of the ecosystems in which those reservoirs are contained to function under current and future environmental conditions.

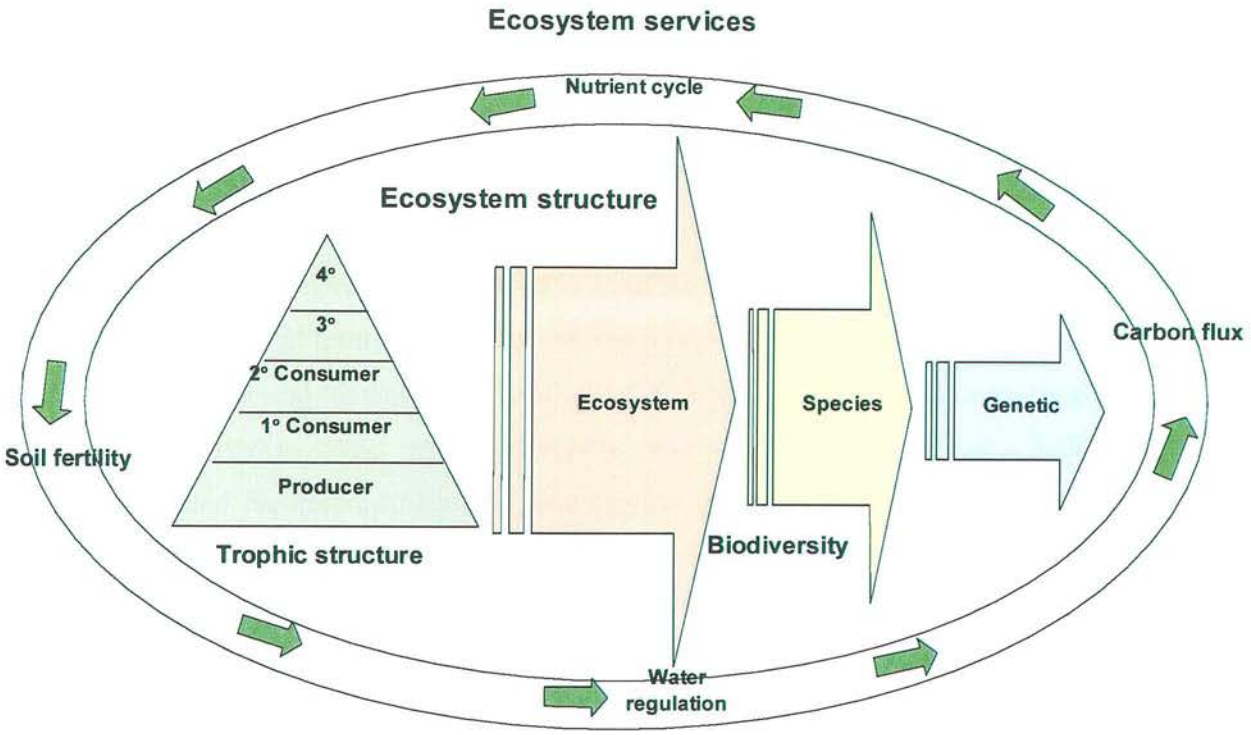


Figure 3.1: A flowchart of ecosystem structure and services.

Ecosystem structure includes trophic structure and biodiversity levels, which have inter-relationships and intra-relationships in order to be mutual support. The biodiversity level or structure is comparable to a set of Russian dolls, which genetic biodiversity is the smallest doll to be inside species diversity and both are inside the biggest doll as ecosystem diversity. The size of each biodiversity level should proportionately vary with regard to holistic concept. Ecosystem function provides goods and services such as nutrient cycles, carbon flux, soil fertility, water regulation etc. It is difficult to separate the ecological services from biodiversity because each biodiversity level plays the individual role according to energy transfer and nutrient cycle.

To concentrate on species and ecosystem diversity in this study, it is important not only to provide the ecological concept in relation to biodiversity as a component in

each level. Moreover, this chapter will propose the vision of current valuation concepts with regard to the goods and services of biodiversity, which are mostly established and associated with the economic base. It will discuss the pros and cons of biodiversity in either ecological or economic constraints. Finally, it will explore a new idea of biodiversity valuation based on carbon storage in ecosystems.

3.1 OVERVIEW OF BIODIVERSITY AT DIFFERENT LEVELS

There are several levels at, which it is possible to discuss biodiversity. Biodiversity is described in terms of genes, species, and ecosystems corresponding to three fundamental and hierarchically related levels of biological organisation (Pearce and Moran, 1994). The genetic diversity and species diversity have historically dominated the literature because they provide the resource material basis of human life. Recently, ecologists have begun to focus on all three levels of biodiversity. It is not only just the number of species, but also the variety, function, and uniqueness. Biodiversity is a multi-dimensional concept, difficult to define separately from each level in an operational sense and difficult to measure. Therefore, biodiversity has been recognised as the total complexity of all life, including not only the great variety of organisms but also their varying behavior and interactions. Biodiversity has functional interrelationships starting from genetic level pass messages as chemical compounds to maintain physiological process of individual species then species are consequently play a role to sustain ecosystem in the dynamic equilibrium. The function is based on energy transfer and nutrients cycling to support their systems.

Folke et al. (1996) believe that biodiversity should be recognised in large-scale ecological processes, and the intensifying human driving forces behind its loss. Because of the dominant economic influence, factors such as technological development, consumerism, the increasing size of governmental, industrial, and agricultural enterprises, and the growth of human population are responsible for most of the loss of biodiversity. Biodiversity is now considered as a priority for conservation. For the following reasons:

- To use elements of biodiversity as biological resources.
- To maintain the biosphere in a state supportive of human life.
- To maintain biodiversity per se and in particular all presently extant species.
- To be useful or vital at sometimes in the future owing to changing circumstance.

Although biodiversity is often measured simplistically by counting species, the variety of species is also important. A measure of biodiversity should aim to quantify the ***value*** to people for whom they are acting and considered as being in need of protection (Table 3.1). Table 3.1 indicates the general definitions, measures and values of biodiversity according to ecological concepts and human utilitarian needs.

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Table 3.1: A summary of Biodiversity in terms of definition, measure and value.

Biodiversity	Definition	Measure	Value
Genetic diversity	- Variation of genes within a species or population	- The amount of DNA per cell - Chromosome structure and number	***Resource value*** - Genetic resources - Commercial products i.e. - Pharmaceutical - products - Agricultural products - Genetic modification - Genetic engineering
Species diversity	- Number and types of species within a region	- Number of species in a region (Species richness) - Relative abundance - Rarity/endemism/ endangered - Functional groups (keystone species)	***Resource value*** - Foods - Raw materials - Medicines - Fuel - Miscellaneous ***Non-resource value*** - Aesthetics - Ethics
Ecosystem diversity	- The types of organism communities and the associated communities within a region.	***Ecosystem structure*** - % of area dominated by the community of species - Diversity index - Trophic structure ***Ecosystem function*** - GPP[a] - NPP[b] - NEP[c]	***Resource value*** - Food production - Water supply - Energy supply - etc. ***Non-resource value*** - Aesthetics - Ethics

Note: a = GPP is gross primary production.
b = NPP is net primary production.
c = NEP is net ecosystem production.

Costanza et al. (1998) mention that the valuation processes ultimately refers to their contribution to serve specific goals. For instance, a gene is valuable to the extent it contributes to the goal of survival of the individual organism using it and their progeny. If the goal is sustainability, it should assess value based on the contribution of the gene to achieving that goal. At present, ecological economics is built on the three integrated goals of sustainable scale, social fairness, and economic efficiency. Therefore, the valuation of biodiversity should relate to people by representing how biodiversity will provide new opportunities for their improvement in the future.

One of the more broadly shared and economically defensible values for conserving

biodiversity may relate to ensuring continued possibilities for adaptation and future use by people. Nevertheless, the biodiversity value should also take into account other mutual living organisms on the earth, which might not relate to human use. Therefore, biodiversity valuation is to include fair and equitable benefit-sharing mechanism at all levels, particularly with respect to genetic resources, species, ecosystems, and humans.

3.2 BIODIVERSITY AT GENETIC LEVEL

In the past, the genetic[1] and species diversity have been given more recognition than ecosystem diversity. Because species are economically interesting based on the genetic properties, genetic diversity makes distinct species of direct value for both human consumption and production (Perringss et al., 1995a). This is the basis for the traditional interest focusing on both genetic and species diversity. The genetic diversity is important for a variety of reasons:

- It determines the ability of individuals and populations to adapt to changing environmental conditions such as global warming or new diseases;
- It is essential for the continuing evolution of various species;
- It provides the basis for the selection and production of new resource organisms;
- It is also important for maintaining the distinctiveness of plants and animals in different locations, which has implications for our appreciation of nature;
- It provides a derive gene pool for potential commercial explortion.

Genetic variation exists in a variety of forms. It ranges from the number of alternative expressions of a single gene:

- To differences in the genetic constitution among individuals within a population
- To the division of a population into different breeding sub-units

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[1] Genetic diversity refers to the variation of genes within species. This covers distinct populations of the same species or genetic variation within a population (WRI, 1992).

- To differences between separate populations
- To the differences among species

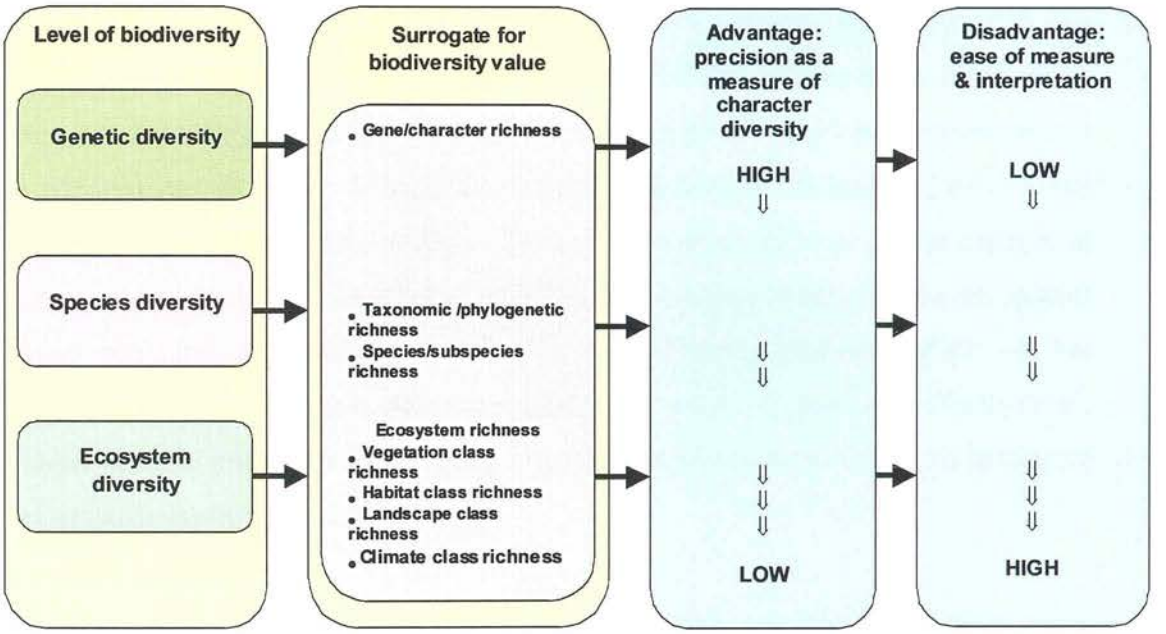
In addition, the genetic diversity can exhibit different structure or behaviour, depending on its environment. Thus individuals, populations or varieties can have the flexibility to survive under various environmental situations.

Loss of genetic diversity is caused indirectly or directly by human activities such as habitat destruction and modification, over-harvesting, and exploitation. This causes loss of genetic variation at the individual level or change of gene pool at the population or species level. Therefore, it is necessary to determine the major causes of genetic loss, not only for conservation of genetic diversity but also to maintain viability at all levels.

Some biologists have argued that the value in biodiversity is likely to be associated with the variety of different ***genes*** that can be expressed by organisms as potentially useful phenotypic traits or ***characters*** including different chemicals, morphological features, functional behaviour. Therefore, a measure of richness at the level of genes or characters may be based on the length of the total branch of DNA to express the number of characters. This approach presumes that all organisms have equal value because it is impossible to know which genes or characters will be most of value in the future.

An alternative assumption is that the greatest value will come from ensuring the persistence of as many different genes or characters as possible as a form of insurance. This alternative approach is recommended, which can provide a ***'currency'*** of value for biodiversity. It uses ***genetic diversity*** as a basis for valuing both ***species diversity*** (for their relative richness in different genes such as the amount of DNA per cell or chromosome structure and number). It also applies to ***ecosystem diversity*** (for their relative richness in the different processes to which the genes ultimately contribute).

The problem is that the detailed and reliable phylogenetic (genealogical and difference) information is often unavailable and the number of genes or characters cannot usually be counted directly (The Natural History Museum, 1998). Nevertheless, arguments for measuring biodiversity value as genes or characters richness do at least provide a philosophically and economically defensible starting point to answering the problem of what is valued in diversity (Figure 3.2).



Source: Adapted from the National History Museum (1998)
<http://www.nhm.ac.uk/science/projects/worldmap/diversity/Genes.html>

Figure 3.2: A flowchart of scale of surrogacy for biodiversity value at the three main scales of organisation.

On the other hand, the biodiversity valuation method based on gene or character richness is expensive. Thus, genetic value is to be considered according to the objective and purpose of use. At the current state of knowledge and technical application/utilisation, attempts to value genetic diversity are less practical than valuation of species and ecosystems. However, the valuation and conservation of species and ecosystems helps to conserve genetic diversity.

3.3 BIODIVERSITY AT SPECIES LEVEL

Present ecological knowledge suggests that species play two major roles in ecosystems. First, they mediate energy and material flows, and give ecosystems their functional properties. Second, they provide the system with the ability to respond to disturbances. Furthermore, in theory, no single species is indispensable in maintaining basic ecological processes on a global scale and that, in general terms, rare species have little ecological importance at the local level. Each species has an individual ecological role in the community. Species are able to survive in the many ranges of conditions and resource qualities, which persist and often conceive as a multi-dimentional space. It explains that most species have different ***niche*** or some species might have niche overlap. Through evolution each species is capable to adapt, and mutually live together even if they have niche overlap. Moreover, species have structural and functional evolution to develop biological pattern of life regarding to fecundity and survival opportunities as *r-selection*[2] and *K-selection*[3]. These specific properties of species are important to support the variety of species to exist dependently to the environment.

Many species are directly useful to humans, such as food, medicines, fuel, construction materials, and other utilitarian needs, but these species currently used are only a tiny fraction of total species diversity – the variety of species in the region. The current problem in relation to species diversity is not only the loss of species from ecosystems but also the extinction of species. Species extinction is a natural process, which usually occurs without the intervention of humans. However, the species extinction caused directly or indirectly by human activities, it is the result of increasing habitat perturbation. When human destroys species, the simplified communities may more quickly gain new species. But these species may be undesirable e.g. as weedy species invasion, it creates new communities that will persist and cause the extinction of native species. Similarly, species have the

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[2] *r-selection* defines as an expression of selection on traits that determine fecundity and survival to favour rapid population growth at low population density (Ricklefs, 1990).

[3] *K-selection* defines as an expression of selection on trait that have competitive ability at densities near the carrying capacity (Ricklefs, 1990).

capacity to recover from losses, and that recovery appears to be faster in simpler systems (Pimm, 1994). Species loss is of concern not only because of the value in and of themselves through their actual and potential use, but also because of their role in maintaining properly functioning ecosystems that provide valuable services. Therefore, it is necessary to conserve and maintain viable populations of species or identifiable populations, especially in their wild state and within their existing range.

Keystone[4] species play a major role in ecosystem functions as functional groups. The importance of keystone species frequently hinges on highly specialised relationships between keystone species and other organisms. For example, keystone species such as nitrogen-fixing microorganisms or detritivorous invertebrates (earthworms, termites) or mature fig trees as a reliable source of fruit to primates, birds, and other fruit-eating animals. The loss of keystone species can have a dramatic effect on other species, and can even lead to further extinction. Prugh et al. (1995) state that diversity provides a kind of insurance that, as conditions change and some species decline, a pool of other species will be available to fill the gap in essential ecosystem services.

In terms of valuation, species can have value as commodities and as amenities, and they can have intrinsic value (Norton, 1989). They can be described as:

- ***Commodity value of species*** means that they can be made into marketable products not only with direct commodity value but also with indirect commodity value.
- ***Amenity value of species*** means that their existence improves our lives in some nonmaterial way e.g. the experience of hiking, fishing in the forest or other natural habitats or as aesthetic value through beauty.
- ***Intrinsic value of species*** means that species have intrinsic value on their own, are valuable in themselves, and their value is not dependent on any use by humans.

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[4] Keystone species is a species having a large, disproportionate effect, with respect to its biomass or abundance, on it community (Power and Mills, 1995).

At present, there is not sufficient knowledge to calculate the value of most species. Consequently, economists, using a method called 'contingent valuation' create hypothetical markets in which they can ask people how much they would be willing to pay to protect a species or willing to accept to not utilise a species (Perringss, 1995). This approach allows moral value of species to be considered and measured in monetary units.

There are a number of debates on the valuation of biodiversity at the species level. Examples of the problems include:

- ***Irreversibility:*** when species are destroyed or disturbed from the natural system, they can only be returned at a financial cost. The exception is, of course, extinction. Consequently, economists have no ability and knowledge to estimate the option value of biodiversity.
- ***Uncertainty:*** estimation of present value often lacks knowledge of life characteristics, and of future value.
- ***Non-autonomy:*** species do not exist independently; they have coevolved in ecosystems on which they depend. It means that each species depends on some set of other species for its continued existence. To get the full value of species, it is necessary to determine the value of all other species that depend on it.

Because of these problems, the value of biodiversity may be more than the sum of the value of all species. The interdependence of species in systems is poorly understood and lacks sufficient information. The value of biodiversity has to include both the genetic variation within species across populations, and the variety of interrelationships in which species exist in different ecosystems (Norton, 1989).

3.4 BIODIVERSITY AT ECOSYSTEM LEVEL

Consideration of ecosystems as a level of biodiversity requires information on ecosystem structure and function, including goods and services, and its contribution to sustainability of the whole biosphere. Ecosystem structure is considered in terms of trophic organisation, which is based on energy transfer through the food webs starting bottom up from producer to each consumer level, represented as the pyramid of energy (Figure 3.1).

In terms of ecosystem services, the functional coupling of energy and elements in ecosystems is the principle that energy flows through ecosystems, while elements can cycle within the system. Due to both energy and elements, the ecosystem may be very inefficient in energy utilisation in order to be very efficient in nutrient utilisation. Firstly, the solar energy is captured by photosynthesis and then flows through ecosystems passing by many pathways. Species richness can influence the rate and quantity of energy flowing through the ecosystem such as primary productivity and biomass accumulation; carbon allocation and consumption; and so on.

Primary production of ecosystems has received more attention than secondary or heterotrophic production because their quantity, quality, and temporal patterns are important components of ecosystem functioning and are measured. Heal and Maclean (1975) show the heterotrophic production is directly related to primary production and most terrestrial ecosystems are similar in their organisation and efficiency of heterotrophic production. The role of the producer in the ecosystems is that plants influence animal biodiversity and productivity via two primary mechanisms.

- They provide the energy that supports animal populations.
- They also provide physical, temporal and biochemical heterogeneity.

Animals or microbial heterotrophs may increase primary productivity by maintaining plant individuals and plant populations in rapid growth phases by reducing the

accumulation of living plant biomass, by reducing respiratory losses, and by recycling nutrients (Orians et al., 1996). These effects are more important in aquatic and grassland ecosystem, than in tropical forest. The standing biomass in the tropical forest is high in relation to net primary production, and a relatively small amount of new primary production is typically consumed by herbivores. Herbivory, under natural conditions, has little effect on total net primary production (Huston and Gilbert, 1996). Therefore, the environmental factors are important to provide optimum conditions for species existing at all trophic level, thus the ecosystems will sustain autonomy.

As ecosystems are complex self-organising and homeostasic[5] systems, they are characterised by multiple locally stable equilibrium or persistent states. Each of the characteristics may correspond to a distinct set of environmental conditions, and may be controlled by a distinct set of keystone process species (Schneider and Kay, 1994, Perringss et al., 1995a). Reichle et al. (1975) indicate that the homeostatic mechanisms at the ecosystem level are unique in permitting persistence and growth of the total system even though individual populations do not survive. It means that the individual populations react to environmental gradients in a relatively independent manner. Homeostatic mechanisms at the ecosystem level obviously relate to collective population adaptation of producers or autotrophs, which ensure the continual existence of a secure energy base in the systems.

There are many approaches for identifying and comparing the value of ecosystems particularly within environmental decision-making. One valuation is to employ ecological techniques that focus on the expression and modeling of ecosystem functions. It can combine various levels of ecosystem indicators, resulting in the designation of certain areas as critical habitat or in the construction of multivariate indices of effects at the different biodiversity levels. It can be organisms or species as populations or ecosystem e.g. energy flow, nutrient cycling. A key to the identification and understanding of many ecologically based biodiversity value at

[5] Homeostasis is the maintenance of steady state in living organisms by use of feedback control processes (Pimm, 1984).

ecosystem level, is the role of uncertainty and variability in natural systems (Costanza and Comwell, 1992). However, the probabilistic analyses can be used to provide insight about either event-based uncertainty, which refers to a lack of data related to ecological relationships, or knowledge-based uncertainty, which refers to a lack of knowledge among experts. Therefore, it is important to the use of ecological relationships as tools for identifying ecosystem values. It also provides a clear link between many ecological functions and human welfare. Gregory (1999) proposes a tool for identifying ecosystem values or environmental values based on ecological relationships in Table 3.2.

Table 3.2: Tool for identifying ecosystem value for decision-making.

Tool	Use	Strengths	Weakness
Health	Relates ecosystem quality to the performance of key indicators	Provides useful summary measures to gauge impacts of changes over time	Hard to link cause and effect in ecological relationships; choice of indicators may be controversial
Integrity	Focuses on synergistic and system relationships	Recognises system-wide characteristics of complex ecosystems	Definition can vary greatly across experts; human vs. non-human factors problematic
Resilience[6]	Assesses the long-term vaiability of a resource	Captures threats to future environmental quality based on past events and ecosystem response	Difficult to measure; translation into comparable policy terms can be controversial
Carrying capacity[7]	Relates fundamental qualities of ecosystem value to productivity	Tracks key threats to future resource use and availability	Relation of productivity to value may be contested choice of impact baseline difficult

Source: Gregory (1999)

It seems ecologists have long recognised that diversity may be important in

[6] Resilience can thus be a measure of instability, for example, a high resilience means a quick return to normal conditions following some disturbance or systems may also be more resilient when they are simplified (Pimm, 1994).

[7] Carrying capacity is the number of individual that the resources of a habitat can support (Rickfefs, 1990).

determining the variability and persistence of ecological processes and their resistance to external changes. Following the loss of biodiversity, it often presents some understanding that the loss threatens ecological integrity, the environment becomes more fragile as diversity decreases, ecosystems have some capacity to resist change or to recover from it. It means that there is some balance of nature or stability, and this balance is affected by the loss of biodiversity (Pimm, 1994).

According to the definition, ***ecosystem diversity*** relates to the variety of habitats, biotic communities, and ecological processes in the biosphere as well as to the diversity within ecosystems. Ecosystem diversity is classified to terrestrial, wetland and aquatic ecosystems, which have different characteristics, properties and values. Most of these ecosystems are valued in terms of the biotic components in the system, which species can be utilised by humans. Humans hardly judge the value of the ecosystems as a whole, because of the complexity of systems, but current ecosystem valuations still price according to the utilisation and the attitudes of mankind.

3.4.1 Terrestrial ecosystems

Forests contain the greatest proportion of biodiversity of all the major biomes. In tropical forests, the environmental conditions have relative constancy of temperature, high annual rainfall, and the length and severity of dry season. These conditions are correlated to the seasonality of rainfall, which exerts a strong influence on temporal pattern in primary and secondary production (Orians et al., 1996). Consequently, species diversity is also positively correlated with annual rainfall and inversely correlated with the length of the dry season. Therefore, the tropical forests are characterised by both high species richness in many taxa and complex biotic interactions and linkages. Explanation of tropical species-richness is unclear. It might be that 'tropical ecosystems are species-rich because they are stable' or that 'tropical ecosystems are species-rich because they are unstable' (Orians et al., 1996), or because the climate is very favourable or a combination of these factors.

Biomass production in tropical forests under relatively constant conditions is

insensitive to species richness because the rate of biomass accumulation depends largely on the nature and intensity of disturbance (Orian et al., 1996). The rate of photosynthesis per unit area may be inversely related to species richness but the relevant data are yet to be gathered.

Most tropical soils are red, infertile and harden irreversibly when they are cleared and exposed to the sunlight. There are also some significant areas of highly fertile soils along rivers and in volcanically active areas. A reduction in species richness, vegetation layers, canopy height and mean leaf sizes is associated with a decrease in soil fertility in tropical forests (Brunig, 1983). The high rates of decomposition of detritus on the forest floors of tropical forests, results in most nutrients in the system being found in the bodies of plants, not in the soils. It indicates that the activities of detritivores are important to the nutrient cycles to provide nutrient inputs through the systems. Jordan (1985) also indicates that the large quantities of nutrients are stored and internally recycled in live biomass in tropical forests.

Human activities are causing a diverse array of disturbance in natural ecosystems, among which are increasing levels of atmospheric carbon dioxide, acid precipitation, changing global climates, increasing fragmentation of habitats and introduction of exotic species. Given disturbances to tropical ecosystems, it is necessary to restore, protect, and nourish the ecosystems as much as possible.

At present, the tropical forests also play an important role in global carbon budgets because of the large mass of carbon stored in biomass and its release by human disturbance, particularly felling and burning. Changes in management can contribute to combating global climate change with regard to increase carbon dioxide concentration in the atmosphere and reducing its impact on other ecosystems. The highly productive ecosystems in tropical forests also show a strong primary production response to elevated CO_2 (Koch and Mooney, 1996). There is evidence for both positive and negative feedbacks on plant productivity via elevated CO_2 - induced not only increase in belowground carbon flows and microbial activity but also altered rate of herbivory by insects and ruminants.

There are many studies to support the idea of carbon dioxide mitigation in relation to global climate change. Cannell and Milne (1995) describe how carbon is fixed by trees photosynthesis (carboxylation) and eventually returned to the atmosphere by processes of decomposition and decay involving other organisms or fire (oxidation). In forest ecosystems, the carbon residence times in woody structures and soil organic matter range from 50 to 150 years. The residence times of carbon and nitrogen vary by five orders of magnitude among components of the system (Reichle et al., 1975). Dixon et al. (1994a) also describes that the allocation of carbon between vegetation and soils differs by latitude. For instance, the low-latitude tropical forests are relatively heterogeneous and contain 59 percent of carbon in vegetation and 27 percent in soils.

Pearce and Moran (1994) state that all forests store carbon so that, if they are cleared for agricultural land, there will be a release of carbon dioxide. Then it will contribute to acceleration of the greenhouse effect and hence global warming. Carbon has been released at different rates according to the method of clearance and subsequent land use. With burning there is an immediate release of carbon dioxide into the atmosphere. However, some of the remaining carbon will be locked in ash and charcoal, which is resistant to decay.

3.4.2 Wetland ecosystems[8]

These ecosystems combine of terrestrial and aquatic conditions, which makes them among the most complex in the world (Bacon, 1997). A primary gradient exists between terrestrial uplands and flooded basins, lakes or riverbeds. These characteristics provide a range of goods and services and wetlands are of great indirect value through linkages with associated aquatic ecosystems. In addition, the transfer of organic matter and biota by downstream flow or tidal export influences

[8] Within wetland ecosystems, the environmental characteristics are determined largely by hydrologic processes, which may exhibit daily, seasonal or longer-term fluctuations, in relation to regional climate and geographic location of the site.

nutrient status and food webs outside the wetland itself. Wetland ecosystems tend to be high in species diversity as they provide an abundance of food and habitat for resting and feeding; while soils are rich in minerals and other nutrients to support living plants. During the dry period, the organic materials of terrestrial origin are decomposed in the drier soil and contribute to the enrichment of the flooding water during the inundation period. Therefore, the organic material enrichment processes help to support the high biodiversity, maintaining ecological equilibrium and making them so productive.

Wetland ecosystems perform essential functions such as control of floods and sedimentation, provision of water (including groundwater recharge), maintenance of water quality and abatement of pollution. Increasing development in human societies is causing the loss of wetland ecosystems, and impacts on associated systems. These include:

- The loss of nursery habitat can reduce fishery yields.
- The loss of migratory area for waterfowl and water birds can affect survival of individuals and populations.

The goods and services provided by wetland ecosystem are important in terms of the maintenance of environmental quality together with the direct health and welfare to both human as well as wildlife (Maltby, 1999). In wetland ecosystems, process interactions maintain ecosystem elements or components such as the water regime, character of soil, interstitial water, plant and animal populations, nutrient pools and soil or sediment properties. These goods and services can be directly valued in monetary terms e.g. forest resources, wildlife resources, fisheries, food resources, agricultural resources and water supply and the ecosystem services value includes groundwater recharge, flood control, shoreline stabilisation, sediment retention, so on (Barbier et al., 1997b). Given the high potential of utilisation, the wetland ecosystems are over-utilised by human activities such as:

- Draining for intensive cultivation.
- Providing land for urbanisation and tourist development.
- Infilling and inflow of polluted wastewater from urban, agricultural and

industrial sectors.

- Over-fishing and over-hunting.

Destruction of wetland ecosystems is also reflected in the reduction of the abundance and diversity of wetland-dependent flora and fauna including exploitable fish and shellfish stocks (Salathé, 1993). Wetland ecosystems also have a potential role in regulating climate and in reducing the greenhouse effect, through their capacity for retaining carbon in accumulated organic matter. This is especially so far peatland, which makes up almost half the world's wetlands (Maltby et al., 1992). For this additional reason, the wetlands probably need to be restored and conserved in their natural conditions.

3.4.3 Aquatic ecosystems

A river has particular characteristics of physical continuum, and aquatic life is adapted to these gradients. River ecosystems are dependent on seasonal variation and geomorphology of catchment. The balance between rainfall and evaporation within this system will determine the river flow regime. Nevertheless, the river ecosystems are complex in relation to year-to-year variations in the intensity of rains, which affect the extent of flood-plain inundation. Each river ecosystem has individual features, which arise from a complex combination of variables such as

- The magnitude of land-water interactions.
- The accumulated influence of all the upstream features.
- The local pattern of land use.
- The amounts of allochthonous inputs into the river system.

However, the river ecosystems also have autochthonous input in relation to high primary productivity by submerged algae and macrophytes, where primary production exceeds respiration (Ladle and Westlake, 1995). This increase of carbon input will provide more carbon downstream such as food resources, whereas fisheries perspectives on the river tend to only concern species distribution and productivity, in stead of the role of carbon (Dudgeon, 1995).

In many river ecosystems, the riparian forest seems to be critical for carbon processing and fish habitat. As the water inundates the floodplain, it produces a moving littoral unit, which prevents permanent stagnation and allows rapid recycling of nutrients and organic matter. This results in high productivity. Moreover, the biomass and productivity of river phytoplankton decline further during the flood season because of the high silt load and turbidity. Welcomme (1979) also concludes that phytoplankton productivity in large tropical rivers is low because turbidity is the limiting factor. On the other hand, the floodplain habitat has high primary productivity and is important for fish production (Dudgeon, 1995). Available data indicate considerably higher value for periphyton production in streams than for phytoplankton production in turbid rivers (Dudgeon, 1995). In addition, the Tropical Asian Rivers and associated wetlands support a diversity of aquatic macrophyte and phytoplankton. The abundance of phytoplankton probably indicates the potential for relatively high productivity (Liao et al., 1989).

Generally, the river ecosystems present a highly variable species richness, diversity, and functional feeding group structure in response to natural disturbances, habitat heterogeneity, and biotic control exerted by predators or competitors.

The effects of human disturbances[9] on river ecosystems are well documented and can be synthesised as a progressive decrease of species richness and diversity with the increasing intensity and/or frequency of disturbances (Prat and Ward, 1994). To restore and to conserve the river ecosystems in the natural conditions, water should not be viewed as a resource, but as a component of the ecosystems. It is necessary to change the idea that water is an unlimited resource for human civilisation. Each human population should learn to live with the resources of its ecosystem and the growth of population should be achieved without destroying the aquatic ecosystems.

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[9] Major kinds of human disturbances in river ecosystems include: flow regulation and diversion, habitat destruction, altered environmental conditions, food web manipulation, sediment dynamics, nutrient dynamics, so on (Prat and Ward, 1994).

3.5 ECOLOGICAL FUNCTIONS

Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystem. Primary productivity is a fundamental ecological variable, not only because it measures the energy input to the biosphere, but also because of its significance in indicating the condition and status of ecosystem functions. The primary productivity is classified as Gross Primary Productivity (GPP) and Net Primary Productivity (NPP). GPP can be considered as the total amount of CO_2 assimilated by plants. NPP is defined as the net carbon flux from the atmosphere into green plants per area per time and is basically assimilation minus plant respiration. Some of NPP in an ecosystem ends up as food for herbivores, carnivores and decomposers, the consumption of which regenerates nutrients necessary for primary production. Nevertheless, NPP is considered as a measure of plant growth, the difference between NPP and the release of CO_2 by herbivores and decomposers is defined as Net Ecosystem Productivity (NEP[10]) (Amthor and Koch, 1996).

With respect to the global carbon cycle, the relationship between NEP and elevated CO_2 in the atmosphere shows more sensitive impacts than the relationship between elevated CO_2 and NPP (Schlesinger, 1991). If the global climate change causes the increasing of atmospheric CO_2, the GPP, NPP, and NEP will be affected. In general, GPP can be enhanced by increased temperature, water supply, nutrient supply or status, length of growing season, or intercepted photosynthetically active radiation (Apps and Raven, 1995). Increased NPP due to elevated atmospheric CO_2 may lead to larger ecosystems, i.e., the ecosystems containing more carbon. Naturally, the ecosystem size cannot continue enlarging indefinitely. The ecosystem will reach its maximum size according to the carrying capacity; therefore, the terrestrial ecosystem can convert carbon from atmospheric CO_2 into organic carbon (biomass). Moreover, human land-use activities such as deforestation significantly affect local and regional NPP and NEP. Apps and Raven (1995) recommend three fundamental methods for increasing carbon sequestration as follows:

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[10] Net Ecosystem Productivity is defined as the difference between NPP and soil respiration (Goldewijk and Leemans, 1995).

- Increase the area of ecosystems with high carrying capacity.
- Increase the carrying capacity of a given piece of land and a given ecosystem such as increase the NEP of the specific ecosystem.
- Increase the fraction of the potential carrying capacity, which the ecosystem achieves.

In the early 1970s, the work on modeling NPP on the different ecosystems was based upon the correlation between NPP and vegetation period (i.e., length of growing season). The first NPP regression was constructed by Leith and Box in 1972 and entitled the C.W. Thornthwaite Memorial Model (Esser et al., 1997). Using climate data, the early correlative model was refined to give the following functions and published as the 'Miami Model' (Leith, 1972, 1973, 1975):

$$\mathbf{NPP = min\ [NPP_T, NPP_p]} \quad \text{(Equation 3.1)}$$

Where

$$NPP_T = 3000/(1 + e^{1.315-0.119T}) \quad \text{(Equation 3.2)}$$

$$NPPp = 3000(1 - e^{-0.000664p}) \quad \text{(Equation 3.3)}$$

T = mean annual temperature

p = mean annual precipitation

NPP (g/m2/year) is estimated as the minimum of two functions (between equation 3.2 and 3.3), which may be limiting productivity. The Miami Model continues to be used as a benchmark for simulation of global NPP (Foley, 1994). It was modified using soil fertility factors and published as the Hamburg Model (Esser et al., 1982). This study will adopt this 'Miami Model' to estimate NPP in terrestrial ecosystems.

Ecosystems also provide environmental stocks as natural capital, and the flow of goods and services as natural income (Costanza & Daly, 1992). Xu et al. (1995) classified natural capital into four categories as follows:

- 'Discovered and available' refers to those ecosystem services that are discovered and being used by present generations.
- 'Future available' refers to those ecosystem services that the present generation uses and the future generations will use, providing the productive

capacity of the ecosystem is well maintained.

- 'Discovered and unavailable' refers to those ecosystem services that, while known to be useful, are not now used due to technical economics, or social constraints of a specific economy or society.
- 'Undiscovered' refers to those ecosystem services that may one day be discovered as useful and converted into actual goods and services based on future technology, values and needs.

The current contribution of ecosystem services is less than the potential because some of its goods and services have not been discovered and used. So the actual contribution of ecosystem services may be only partly valued by the present economy. Such under-valuation could result in over-utilisation and inefficient use of biodiversity. If the ecosystem services are considered as the natural capital not only for the present generation but also for future generation, it will prolong the natural resources' consumption under the sustainable consciousness.

3.6 THE CURRENT BIODIVERSITY VALUATION

Concern for biodiversity value has become more significant to many individuals and to society during the past 25 years. As the biodiversity (genetic, species, as well as ecosystem) becomes scarce and increasingly understood, humans need to reconsider its value. In the past, there were some simple concepts: species could have value as commodities and as amenities, and they could have moral value. This economic approach has a built-in tendency to be expressed in terms of trade-offs. Norton (1989) believes that species have value as a moral resource to humans, as a chance for humans to form, reform, and improve their own value systems.

Debates over the proper methods of biodiversity valuation involve among not only economists and ecologists but also the public. Herendeen (1998) mentions that the monetary costing of ecosystem services is more visible now than ecological aspects but it needs to implement such biodiversity value seriously before ending up to the tragedy of common.

Pearce and Moran (1994) state that the economists have captured all biodiversity value into the concept of Total Economic Value (TEV) but this is obviously not correct (Table 3.3). An expanded TEV is needed to understand clearly the concept of the economic valuation in relation to biodiversity.

Economists have been unable to capture all values as economic values. Ecologists say that total economic value (TEV) is still not adequate and their discussion suggests three reasons why biodiversity is important:

- First, it is based on the concept of economic value, so that if biodiversity is economically important it should be shown up in the human expression of willingness to pay for biodiversity conservation.
- Second, the economic value measurement will understate 'true' economic value because of the probable failure to measure primary life support functions which are difficult to observe.
- Third, the economic value does not capture nor is it designed to capture 'intrinsic value' of biodiversity.

Table 3.3: Total economic values (TEV) of different level of biodiversity.

Use values			Non-use values	
Direct use[11] values	**Indirect use[12] values**	**Option[13] values**	**Bequest[14] values**	**Existence[15] values**
Genetic level - Pharmaceutical products - Genetic modification - Genetic engineering	*Genetic & species level* - Genetic resources - Biocontrol - Ecosystem resilience	*Genetic & species level* - Future information - Future uses (direct & indirect)	*Use & non-use values for legacy* - New gene combinations	*Biodiversity*
Species level - Raw materials - Foods - Fiber plants - Medicinal substances - Bioenergy - Natural pesticides - Scientific & educational materials			*Species level* - Currently unused species for crops etc.	*Species level* - Ritual or spiritual values - Culture, heritage - Community values
Ecosystem level - Food production - Water supply - Recreation	*Ecosystem level (services)* - Gas regulation - Climate regulation - Disturbance regulation - Water regulation - Erosion control - Soil formation - Nutrient cycling - Waste treatment - Pollination - Biological control - Habitat/refugia			*Ecosystem level* - Landscapes and habitats with new interests

Source: Adapted from Costanza et al. (1997) and Barbier et al. (1997a).

[11] Direct use value is the value derived from direct use or interaction with resources and services (Barbier et al., 1997b).
[12] Indirect use value is the value of indirect support and protection provided to economic activity and property by the natural functions, or regulatory environmental services (Barbier et al., 1997b).
[13] Option value is defined as a value in use by present and future generation (Pearce and Turner, 1990).
[14] Bequest value is defined as a value in non-use by present generation but in use by future generation (Turner et al., 1994).
[15] Existence value is a value placed on unrelated actual or potential use of environment goods and services (Pearce and Turner, 1990).

The majority of economic valuations of natural resource uses, Pearce and Moran (1994) indicate that these economic studies are measuring the economic value of 'biological resource' rather than their diversity. Valuing biodiversity as such will be far more complex because we still do not clearly know what are the functions of diversity.

Therefore, there are two broad approaches to valuations direct and indirect. Direct methods seek to infer individuals' preferences for environmental quality directly, including biodiversity, by asking them to state their preferences for the environment (Freeman, 1993 and Hanley et al., 1997). For example, the contingent valuation method (CVM) has increased in popularity over the last decade in western countries as a convenient method for valuing non-use values. CVM relates to what people are willingness-to-pay (WTP) for some change in provision of a good or service or to prevent a change; and/or what they are willingness-to-accept compensation (WTA) to forgo a change or tolerate the change. Fankhauser (1995) also considers that there are many methods to measure the total value of a species or an ecosystem in terms of use, option, and existence value but the 'Contingent Valuation Method (CVM)' is appropriate.

Debates on CVM indicate that it is not only impossible for someone to place monetary value on natural resources but also that there will never be agreement between all interested groups. CVM is also weak in long term valuation, because current discounting practices make resources less valuable in the future, rather than maintaining or increasing in the value. Pearce and Moran (1994) comment that CVM is particularly problematic in terms of valuation of environmental loss or biodiversity loss. Perrings (1995) also debates that CVM relies on the subjective perception of respondents who are operating under incomplete ecological and economic information and have an incentive to respond differently depending on how the problem is communicated.

In contrast, the indirect methods seek to recover estimates of individuals' WTP for environmental quality by observing their behaviour in related markets (Hanley et al.,

1997). These methods include the hedonic pricing method (HPM)[16]; travel cost method (TCM)[17]; dose-response approach[18] and replacement cost techniques[19]. As such, the particular techniques are mainly based on their contribution to valuing biological resources as opposed to valuing biodiversity *per se*. All of the valuation techniques outlined have strengths and weakness as mentioned above. Thus the decision on which valuation techniques should take account of the use of particular applications, which requires experience and judgement on the part of an analyst. Accordingly, the kinds of methods need to be posed about the human use of biodiversity without considering the value of loss in output in production and consumption processes (Perrings, 1995). To consider the subjective evaluation of biodiversity by individuals with little understanding of ecosystem services might provide a false value.

There are a number of arguments that the valuation of ecosystems is either impossible or unwise because people cannot place a value on such 'intangibles'. Costanza et al. (1997) attempt to estimate values for ecosystem services per unit area by biome. This valuation of ecosystem services is essential to:

- make the range of potential values of the services of ecosystems more apparent
- establish at least a first approximation of the relative magnitude of global ecosystem services
- set up a framework for their further analysis
- point out those area most in need of additional research
- stimulate additional research and debate

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[16] Hedonic pricing method (HPM) attempts to evaluate environmental services, the presence of which directly affects certain market prices e.g. the property market in which the house prices are affected by environmental quality (Turner et al., 1994).

[17] Travel cost method (TCM) is used to estimate demand curves relationship between the price of visiting a recreational site (i.e. travel cost) and the number of visits made. The costs of visiting a site in some way reflect the recreational value of that site (Turner et al., 1994).

[18] Dose-response approach is associated to output from pollution stress. The output can be valued at market or shadow prices e.g. the loss of crop output from air pollution or the increased risk of illness or death (Turner et al., 1994).

[19] Replacement cost technique is used to estimate the cost of replacing or restoring a damaged asset. It uses this cost as a measure of the benefit of restoration e.g. the costs of cleaning building soiled by air pollution (Turner et al., 1994).

The valuation methods estimate both the market and non-market components of the value of ecosystem services, which are based, either directly or indirectly, on attempts to estimate the 'willingness to pay' by individuals for ecosystem services. The results indicate that the value of global ecosystem services is estimated to be in the range of US$16-54 trillion ($10^{12}$) per year, with an average of US$33 trillion (Costanza et al., 1997). The global ecosystem services value is 1.8 times the current global GNP. In addition to the uncertainties of the ecosystem involved, this value of ecosystem services is a crude initial estimate and is a useful starting point for future debate and development.

Another interesting valuation method is the value of ecosystem services based on the solar energy captured per unit area (NPP, $g/m^2/year$) compared to the monetary value by each biome (Costanza et al., 1998). Costanza et al. (1998) present the comparison between the study of Costanza et al. (1997) and the study of Whittaker and Likens (1975); Whittaker (1975); as summarised in Bolin (1977) in Table 3.4. Costanza et al. (1998) conclude that the correlation of NPP and the monetary value of ecosystems - terrestrial and marine ecosystem, indicate $R^2 = 0.98$, *significant at the 0.01 level,* and separates these from the lake or river ecosystem. It can be interpreted that NPP in terrestrial and marine ecosystem is an acceptable and practical indicator of ecosystem services because of the high correlation to monetary value.

Table 3.4: NPP and value of ecosystem services for major biomes.

Biome	Area (10^6 ha)	NPP[a] (g/m^2/year)	Value[b] (US$/ha/year)
Open ocean	33,200	125	252
Estuaries	180	1,500	22,832
Seagrass/algae beds	200	2,000	19,004
Coral reefs	62	1,000	6,075
Continental shelf	2,660	360	1,610
Lakes/rivers	200	400	8,498
Tropical forest	1,900	2,000	2,007
Temperate/boreal forest	2,955	1,000	302
Grass/rangelands	3,898	800	232
Tidal marsh/mangroves	165	3,000	9,990
Swamps/floodplains	165	3,500	19,580

Note: **a** = source from Whittaker and Likens (1975); Whittaker (1975); as summarised in Bolin (1977)
b = source from Costanza et al. (1997)

There are various biodiversity indices for evaluation to be quantified in ecological arena, Guo and Randel (1997) recommend the use of biomass or productivity is the most useful community or ecosystem diversity index. The biodiversity also measured as species richness in the community or the species dominance has the problem of rareness, i.e. unequal densities among species, and the use of density data in biodiversity indices has the problem of difference in plant size (Guo and Randel, 1997). The reason is both biomass and productivity can best represent per capita resource use and resource partitioning among organisms in competitive situations. Biomass provides an index of the physical size of an organism in terms of its dry mass, and thereby correlates for carbon and other nutrient resources sequestered by each species. The production of biomass reflects the use of available energy.

Perrings et al (1995a) suggested regarding to the characteristics of ecological economics that the biomass from any ecosystem might be thought of as a flow deriving from stock and consisted of the system itself. Productivity provides a

measure of the annual use of resources, and thus an analogue for aspects of competitive use of limited nutrients or other resources. Therefore, it strongly supports that biomass and productivity in relation to carbon storage has strong positive evident as the appropriate index for biodiversity evaluation.

Concerning to the weakness and uncertainty of the valuation methods, Pearce (1993) comments that:

'Valuation may be imperfect but, invariably, some valuation is better than none'.

Perrings et al. (1995b) recommend that establishing the value of ecosystem resilience and so the value of ecosystem components is amongst the highest priorities on the ecological economic agenda. It questions the adequacy of the new biodiversity valuation as estimates of biodiversity as a whole.

3.7 A POSSIBLE NEW APPROACH OF BIODIVERSITY VALUATION BY CARBON STORAGE IN ECOSYSTEMS

Carbon has naturally cycled between environment and living organisms through the photosynthesis, respiration and decomposition. Drawing CO_2 out of the atmosphere and into biomass is the only known practical way to remove large volumes of greenhouse gas from the atmosphere. Anthropogenic release of CO_2 into the atmosphere, mainly by burning of fossil fuels, increased aquaculture and reduced accumulation of soil organic matter, is recognised as the primary agent forcing global climate change. Generally, CO_2 emission from all human activities makes up only a small fraction of the carbon that cycles annually among the atmosphere, terrestrial biota, and aquatic ecosystems. Because of CO_2 emission from human activities accounts for the unwanted build-up of atmospheric CO_2, reducing these emissions should be incorporated into different methods and approaches to meet the goal of CO_2 mitigation.

Fundamentally, the carbon storage in the biosphere – in the ocean, soil, and above

ground vegetation – was an urgent environmental issue in the last decade. It has been debated on how to respond to the threat of climate change by a mitigation strategy.

Since the inter-governmental agreement reached at Kyoto in December 1997, Kyoto protocol in the UN Framework Convention on Climate Changes established the principle that forestry activities may be used to offset industrial CO_2 emission. The carbon storage or sequestration has been considered by implementing the forestry option. Therefore, it can mitigate or reverse the damage by industrial activities and deforestation, which results in a change of net carbon flux to atmosphere causing the global climate changes. The forest contains 20-50 times more carbon per unit area than agricultural lands (Melillo et al., 1993). As trees grow, they can sequester carbon in wood. Consequently, if the wood does not decay or burn, the carbon will be prevented from releasing to the atmosphere. Apps and Raven (1995) proposed the three fundamental methods for increasing carbon storage as follows:

- Increase the areal extent of ecosystems with high carrying capacity.
- Increase the carrying capacity of a given piece of land and given ecosystems (*i e,* increase the NEP of the specific ecosystem).
- Increase the fraction of the potential carrying capacity, which the ecosystem achieves.

From the Intergovernmental Panel on Climate Change (IPCC) point of view, the forestry practices can promote sustainable management of forests and at the same time conserve and store carbon (Brown et al., 1996). These are composed of three categories as follow:

- Management for conservation of existing pools in forests by slowing deforestation, changing harvesting regimes, and protecting forests from other anthropogenic disturbances.
- Management for expanding C storage by increasing the area and/or C density in native forests, plantations and agroforestry and/or in wood products.
- Management for substitution by increasing the transfer of forest biomass C into products such as biofuels and long-lived wood products that can be used

instead of fossil fuel based products.

The most effective long term (>50 years) projects in which to use forest to mitigate the increase in atmospheric CO_2 are to substitute fuelwood for fossil fuels and for energy-expensive materials. However, over the next 50 years, substantial opportunities exist to conserve and increase the C store in living trees and wood products.

Brown et al. (1996) also suggest that the tropical forests have the potential to conserve and store the largest quantity of C ranges from 45 to 72 Gt, more than half of which would be due to promoting natural forest regeneration and slowing deforestation. Englin and Callaway (1995) recommend that the forestation is useful management to mitigate the effects of global warming by increased sequestering carbon into the forests.

Considering carbon as an indicator of biodiversity value may integrate the role of ecosystem services there is some evidence to support the view that carbon storage in ecosystems is a representative measure of the biosphere. For instance, tropical forests contain large quantities of living biomass that can serve as important stores of carbon (Golley, 1983). In addition, carbon is stored in dead material in litter and fallen tree trunks, in surface soils, and as refractory material in deep soils. In past decades, tropical forests, eg. Brazil, were under high pressure of land-use change and forest clearing, resulting in a change in the transfer carbon between terrestrial and atmospheric pools (Schroeder, 1996).

Therefore, it is important to assess how valuable ecosystem services really are and to formulate mechanisms by which such function-based values can be realistically captured (Turner et al., 1998). Turner et al. (1998) also suggests that the world biodiversity value of non-timber products as ecosystem goods average at US$50/ha/yr. While people know that biodiversity is valuable, the willingness of the world to pay is a limiting factor on how much of this value can be translated into monetary term.

Fearnside (1997) suggests that converting ecological services (like biodiversity maintenance, carbon storage, and water cycling) into monetary flows that can support a population of forest guardians require crossing a series of hurdles. Reliable quantification of the magnitude of ecosystem services being offered is a primary requirement for a long-term environmental strategy to maintain natural resources. The biodiversity can be measured by surrogate method focusing on the stability of nutrient or energy flows through ecosystems (Smith, 1996).

Carbon stored in different forms in an ecosystem is completely inter-changeable; any atom of carbon stocked in forest has the same atmospheric effects (Fearnside, 1997). An atom of carbon stored in a forest plantation or in the ground as fossil fuel can be quantified in the same way. Although carbon may be held under different circumstances depended on the time considered, for comparative purposes on a carbon tonne per year basis, as completely equivalent (Fearnside, 1997).

Fearnside (1997) also recommends that establishing the value of ecosystem services require several steps. Firstly, it is necessary to quantify the amount of the services (tonnes of carbon, number of species or cubic meters of water). Secondly, the quantification must be translated into prices or subsidies. However, the carbon storage represents ecosystem services with regard to *quantity* only, does not consider the *quality of carbon*. If the carbon is characterised in terms of quality in each component, it will be totally different. For instance, the carbon in low molecular carbohydrates is the energy source to support life. In contrast, the carbon in lignin is much less important for biological energy but is very important for plant structure and soil organic matter formation. Fossil fuels are utilised as an energy source by mankind without any relation to biological functions.

Another point of view is that carbon has become dramatically important to human concern because it is the major element of greenhouse gases, as CO_2 impacts on global climate change. There is considerable theoretical and practical evidence that the increase in atmosphere concentrations will raise global atmospheric temperature.

IPCC (1992) reports that the global mean surface temperature has increased by between about 0.3 and 0.6 degree Celsius since the late 19th century. The trends can be attributed largely to human activities, mostly fossil fuel use, land use changes and agriculture. The impacts include sea level rise, and changes in climate zone, vegetation habitat type, the distribution of animal, and outbreaks of pests and diseases. On regional scale, there is clear evidence of changes in some extremes and climate variability indicators as follows:

- Changes in the total amount of precipitation and in its frequency and intensity to impact on the intensity of floods and droughts
- The composition and geographic distribution of many ecosystems (e.g. forests, rangelands, deserts, mountain systems, lakes, wetlands and oceans) will shift as individual species respond to changes in climate. There will likely be reductions in biodiversity and in the goods and services that ecosystems provide society.
- Crop yields and changes in productivity due to climate change will vary considerably across regions and among localities, thus changing the pattern of production. Productivity is projected to increase in some area and decrease in others, especially the tropics and subtropics.
- Climate change clearly will increase the vulnerability of some coastal population to flooding and erosional land loss.
- Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life. Direct health effects include increase in (predominantly cardio-respiratory) mortality and illness due to an anticipated increase in the intensity and duration of heat waves.

Parry et al. (1991) predict that a CO_2 doubling could result in a 3-6 degree Celsius mean annual temperature change in Thailand, although this appears to be a rather high estimate. The study predicts that northern Thailand will tend to be drier in most months except July. In Ayuthaya Province (the old capital city) the model predicts rainfall reductions in August-September, and rice yields will generally increase. Chiang Mai will have average yield reductions of 5 percent. Suratthani Province in southern Thailand, a case study calculates that 37 percent of the area would be

affected by a 1-meter rise in sea level, with loss of over 4,200 ha of agricultural land and many shrimp ponds. All the above means that carbon balance now is an urgent concern not only at the global scale but also at the local scale as well.

Thus, it strongly supports the purpose of this study in order to attempt constructive biodiversity valuation with regards to ecosystem services by a multidisciplinary approach – ecological and socio-econmic approach - to estimate service values based on ***carbon storage*** in ecosystems. The carbon storage approach as a surrogate measurement might also be a contribution to global carbon dioxide mitigation.

Although there are many current economic valuation methods of biodiversity and many techniques to mitigate carbon dioxide in atmosphere, but none of them has provided a fully satisfactory solution. Turner et al. (1994) mentions that carbon storage value as an example of an indirect use value for biodiversity.

Costanza et al (1997) indicate that ecosystem services are not fully captured in the commercial markets or adequately quantified in terms comparable with economic services and manufactured capital. They are often given too little weight in policy making.

Pearce et al. (1996) show that the damage of doubling CO_2 concentration is likely to be more severe in developing countries than in developed countries. For the Southeast Asia region, they estimated the damage costs of US$53.5 billion or 8.6 percent GDP. The damage in Organisation for Economic Cooperation and Development (OECD) European countries is estimated at US$56.5 billion or 1.3 percent GDP. There are some arguments on equity grounds that the damage cost of doubling CO_2 or climate change gives greater weight to impacts on low-income countries than would result from simply applying their shares in the global income base. From the various studies, it is judged that more than half of the damage would occur in the market sectors (such as agriculture) rather than in sectors outside the standard system of national accounts (e.g. biodiversity, amenity).

Carbon storage is thus an urgent issue of environmental concern. Meanwhile, the economists as well as ecologists are interested in carbon pricing through various approaches. The previous Intergovernmental Panel on Climate Change (IPCC, 1992) assessment reports the regional average annual costs of US$8/tonne C for tropical forestation and reduction of deforestation, increasing to US$28/tonne C for forestation in non-USA OECD countries. IPCC (1991) estimated that if the most aggressive biological mitigation strategies are implemented, net emission could be zero by 2000, and there could be a net sink of 0.5 Gt C/year. It means that the global communities need to corporate and sincerely act for emission reduction and carbon balancing control at the global scale.

Eade and Moran (1996) present the estimation of vegetation biomass in Belize at minimum, mean and maximum cost of US$13.2, 1,000 and 1,440/ha, respectively. It is estimated by carbon storage cost in forest ecosystem and implementing in Geographic Information System (GIS) technique.

Changes in carbon stored in terrestrial ecosystems accompany the clearing of tropical forest ecosystems for agricultural expansion, wood-product extraction, and shifting cultivation. Parks (1996) indicates that economically motivated land-use decision have direct influence on the area in terrestrial ecosystems devoted to different uses, which can influence atmospheric CO_2 concentrations.

Table 3.5 compares the carbon stored in the different ecosystems under the various condition or practices. It indicates that the closed forest has higher potential to store carbon than the opened forest. Primary forest is also capable to store more carbon than the secondary forest. However, the secondary forest has high potential for short-term accumulation of carbon and therefore, it is appropriate to replant and conserve as the carbon sink of ecosystem. Carbon in temperate forest is obviously less than in tropical forest. Soils in tropical forest seem to store more carbon than aboveground biomass.

Table 3.5: A comparison of carbon stored in the ecosystems under different conditions.

Ecosystem	C-storage (tonne C/ha)	References	Remarks
Tropical forest			
- Closed primary forest	283	Pearce & Moran, 1994	Land use conversion
- Closed secondary forest	194		
- Opened forest	115		
Low-latitude zone			
- Forestation	60-240	Trexler & Haugen, 1994	Land use pattern
- Agroforestation	50-125		
- Forest conservation	80-260		
- Siviculture	10-100		
Low-latitude zone			
- Tropical forest in Asia	174	Dixon et al., 1994a	Carbon stored in different forests based on Brown et al., 1991 & 1992.
- Tropical forest in Malaysia, Indonesia	250		
Afforestation			
- Opened tropical forest	50	Nordhaus, 1991	Carbon stored in 40 years.
- Opened temperate forest	30		
Tropical primary forest			
- Aboveground Carbon	97	Nilsson & Schopfhauser, 1995	Carbon stored in the natural ecosystems.
- Soil Carbon	117		
Tropical logged forest			
- Aboveground Carbon	70		
- Soil Carbon	88		

The most suitable option will depend on local environmental, social and economic factors. Table 3.6 compares the comparative costs of CO_2 mitigation in the different options and summaries the carbon cost in relation to mitigation objective by the different options. It seems that the forestry option would be the cheapest option when compares to the high technology option. In the fact that the unit cost of C storage in forestry option has excluded the land costs and other transaction costs to conserve and store the carbon in the forest systems. Especially, the transaction costs may significantly increase these estimated carbon cost. The carbon cost of forestry option can be several times higher than this estimation. If the land and opportunity costs and/or the costs of establishing infrastructure, protective fencing, training programs, and tree nurseries are included, their costs can be offset by revenues from

timber and non-timber products (Brown et al., 1996). Moreover, the costs of removing atmospheric CO_2 basically emphasis on (Hourcade et al., 1996):

- the forestry option as carbon sequestration
- the cost of changing from fossil to non-fossil fuels
- the substitution of different substances for greenhouse gases
- the new technologies for efficiency improvements in the energy systems
- decentralised biomass combustion and biogasification

Hall and House (1994) indicate that forestry options were only part of an overall strategy. The options should include energy efficiency, alternative fuels as clean energy, and emission control technologies. The prevention of deforestation should be persuaded vigorously and immediately wherever possible. Nordhaus (1991) suggests the forestry option as the reforestation of open forest or disturbed forest can potentially expand the natural accumulation of carbon and appear to be moderate economic option (relative to extreme levels of control on carbon fuels). Nilsson and Schopfhauser (1995) also recommend that the forestry option for the mitigation of carbon include slowing the rate of tropical deforestation, increasing the forest productivity and increasing afforestation.

Table 3.6:A comparison of CO_2 mitigation cost in the different scenarios.

Scenarios of CO_2 mitigation	US$/tonne C	Reference
1.Forest plantation[20]		
- Teak plantation (Thailand)	2-18	Wangwacharakul & Bonwanwiwat, 1995
- Eucalyptus plantation (Thailand)	4-13	Wangwacharakul & Bonwanwiwat, 1995
- Teak plantation (Thailand)	56.5	FIO, 1999*
- Eucalyptus plantation (Thailand)	9	FIO, 1997
- Agroforestry (Tropical)	2-11	Dixon et al., 1994b
- Tree plantation (Nepal)	16	Faeth et al., 1994
2.Reforestation[21]		
- Tropical forest (NE Thailand)	11	Faeth et al., 1994
- Reforestation (South Africa)	8	Winjum et al., 1993
- Reforestation (India)	15	Winjum et al., 1993
- Reforestation in community forest (Thailand)	11	TEI, 1998
3.Energy efficiency		
- Developed countries	Up to 40	Hall & House, 1994
- Developing countries	-	Hall & House, 1994
4.Nuclear energy		
- Developed countries	35-70	Hall & House, 1994
- Developing countries	80-120	Hall & House, 1994
5.Solar energy		
- Developed countries	25-100	Hall & House, 1994
- Developing countries	50-200	Hall & House, 1994
6.CO_2 scrubbing		
- Developed countries	100-200	Hall & House, 1994
- Developed countries	100-200	Hall & House, 1994

Note: * Carbon cost is estimated from the FIO (1999) report, which is based on the first rotation (30 year period from 1999-2028) of teak plantation project.

[20] Forest plantation or afforestation defines as the establisment of a tree crop on an area from which it has always or very long been absent (FAO, 1997).

[21] Reforestation defines as the establishment of a tree crop on forest land (FAO, 1997) or as the restoration of tree cover on areas formerly classed as forest land to at least the threshold canopy cover ore greater (FIS, 1998).

In the above, the cost of CO_2 mitigation by tropical forest plantation in developing countries is similar to those for reforestation. However, the forest plantation and reforestation options are about 10 percent of the other options of CO_2 mitigation. Hall and House (1994) recommend that forestry is a potential option for mitigating the greenhouse effect by maintaining and increasing biomass, which is both practical and low cost compared to the other methods. These cost of forest plantation and reforestation have not included cost of land or forest with regard to the markets, but these capital costs are low when compared to other costs in the processes. For instance, the Forestry Industry Organisation of Thailand has paid the land rental as the capital cost at US$1.7 per hectare per year to the Royal Thai Government. It seems that the most of the capital costs are based on operational, maintenance, and manpower costs (FIO, 1999).

There are some studies to estimate land rental costs at US$148/ha by Moulton and Richards (1990) for the United States; a land purchase price is estimated between US$400 and US$1000/ha by Sedjo and Solomon (1989). Land prices are likely to be lower in developing countries. In case of Thailand, the present value of the opportunity cost of land is estimated to be between US$44 and US$89/ha (Wangwacharakul and Bowonwiwat, 1995). Therefore, the carbon cost of teak forest plantation in Thailand is estimated at US$56.5/tonne C by FIO (1999), which include the costs of planting tree, operational cost, maintenance cost, infrastructure cost and land rental cost. This carbon cost will be considered to adopt for carbon pricing in this study as forest plantation scenario.

Thailand is a member of the F-7 Tropical Forestry and Global Climate Change Network (a group initiated by the United Nations Environment Programme, UNEP). As such Thailand has to contribute to the international effort to forestall global climate change. UNEP (1994) reports that Thailand's CO_2 emission baseline in 1990 was 751.4 Mt CO_2. After the economic boom, Thailand is one of the countries with increasing energy consumption and high rate of deforestation. Thailand is projected to reduce emission by 29.5 percent in 2030 as long term abatement from the baseline in 1990 (UNEP, 1994). This report assessed the potential for emission reduction in

the countries through energy efficiency improvements and a shift towards supply technologies with lower carbon intensity. The results show that Marginal Abatement Cost (MCA), Average Abatement Cost (AAC) and Total Abatement Cost in 2030 are equal to US$171, 9.4 /t CO_2 and million US$2089, respectively. MCA can be converted to US$46.64/tonne C by conversion factors 0.273 based on molecular weight of carbon.

IPCC has extensively reviewed the potential impacts of climate change and the best studied regions remain the developed countries, in particular the United States (Fankhauser, 1997). Most of studies usually deal with only a subset of damages, and are often restricted to a description of impacts in physical terms especially in agricultural impacts and the cost of sea level rise. Attempts at comprehensive monetary quantification of all impacts relatively rare. In the past, the social cost of CO_2 emission is used to estimate the carbon cost with regard to social cost of damages as increased mortality or shadow price based on uncertainty or market and non-market damage cost by willingness to pay or willingness to accept compensation. It is summarised in Table 3.7. Because of variations in methodology and differences in geographic area, it is so difficult to make direct comparison of the carbon costs. Therefore, it is a problem how to make decision for the rational carbon cost from the economic based analysis.

Table 3.7: A comparison of the units of carbon storage cost based on damage assessment in the different geographic area and methods.

Ecosystem	Carbon cost (US$/tonne C)	Methods	References
Global ecosystem	27.9 89.9 171.7	Marginal cost of reduction at 20% Marginal cost of reduction at 40% Marginal cost of reduction at 60%	Nordhaus, 1991
Global ecosystem	10.0-22.0	Shadow value for estimating CO_2 emission (1991-2030)	Peck & Teiberg, 1992
Global ecosystem	45.0 243	Shadow price beginning by using a zero utility discount rate (1992) Shadow price beginning by using a zero utility discount rate (2100)	Cline, 1992
Global ecosystem	5.9-15.2	Cost-benefit analysis by actual marginal cost of CO_2 emission cost	Madison, 1993
Global ecosystem	20.0	Central value of damage for carbon released	Fankhauser, 1994
Global ecosystem	20.0 28.0	Shadow price for social cost from greenhouse gases emission (1991-2000) Shadow price for social cost from greenhouse gases emission (2021-2030)	Fankhauser, 1995
Amazonian tropical ecosystem	Low = 1.8 Medium = 7.3 High = 66.0	Greenhouse gases emission from deforestation	Schneider, 1994
Tropical	7 1-9	Cost of forest plantation without land cost Cost of forest management without land cost	Dixon, Schroeder and Winjum, 1991
South Asia	2.0-66.0	Average carbon storage cost by agroforestry	Dixon et al., 1994a
Northeastern Thailand	10.8	Cost of restoration & plantation	Faeth et al., 1994
Thailand	46.6	Marginal abatement cost at 29.5% reduction	Adapted from UNEP, 1994.

This table shows the different economic methods of estimating carbon cost based on the different appraisals e.g. shadow price, damage cost, capital cost, abatement cost. The range of carbon costs are depended the target of reduction but most of carbon

costs are closed to average of US$20/tonne C based on economic methods. The carbon costs estimated based on forestry aspects such as restoration, plantation and forest related, these costs are lower than based on technological mitigation or damage cost to society. It seems that the carbon costs depend on the objectives and reliable practices of mitigation atmospheric carbon at the certain level, which are on the ground of human perception.

This chapter provided the ecological concepts with regard to biodiversity, the current biodiversity valuation, and the possibility of a new approach of biodiversity valuation. This information will now be used in the case study in chapter four (species diversity evaluation) and chapter five (ecosystem diversity evaluation).

CHAPTER FOUR
SPECIES DIVERSITY EVALUATION

This chapter concentrates on evaluation at species diversity level. It examines indices to distinguish variation within both terrestrial and aquatic ecosystems in the case study of the Lower Mekong River Basin. The study attempts to quantify indices of biodiversity in order to incorporate them in the process of impact assessment to improve the decision-making processes. Therefore, it is focused on alternative and rational indices of species, which represent the existing condition (without-hydropower) and to predict the impact of the with-hydropower in the tributary of the Mekong River.

The study compares conditions in the river and catchment area before dam construction (Ban Koum Dam Project as without-project condition) with these in an adjacent area where a dam has already been built (Pak Mun Dam as with-project condition) (Figure 2.3). This chapter is organised as follows:

- Overview of species diversity measurements
- Scope of the study
- Background of the study areas including the area of proposed hydropower project and the existing hydropower
- Methodology including data collection and data analysis
- Results and discussion
- Conclusion

4.1 OVERVIEW OF SPECIES DIVERSITY MEASUREMENTS

Diversity is generally described as a composite property that reflects which species or taxa are presented the number of species ***(richness)*** in the community and the ***evenness*** with which abundance is distributed among the different species (Myers et al., 1995). The most popular indices proposed for measuring diversity are:

- ***Species composition*** is represented by the species in terms of taxonomic classification identified into *Genera* or *Species,* preferably providing both

local and scientific names. Information on species composition provides the basis for interpreting the structure of the community in terms of ecological niche, functional role and trophic relationships.

- ***Species richness*** measures the number of species in the community. For instance, ***Jack-knifing estimation technique*** is a useful technique for reducing the effect of sampling. The Jack-knifing technique provides an estimated standard error, which provides an approximate confidence interval for the number of species (Myers et al., 1995). This technique is based on the observed frequency of rare species in the community and is obtained per quadrat (Krebs, 1989). The presence or absence of each species is recorded in a series of random quadrats. A unique species is defined as a species that occurs in one and only one quadrat. The variance of Jack-knifing of species richness estimates at the 95 precent confidence interval, the range of number of species (minimum to maximum).

$$\hat{S} = s + \left(\frac{n-1}{n}\right)^{k}$$

(Equation 4.1)

Where $\hat{S}$ = Jack-knifing estimation of species richness

s = Observed total number of species present in n quadrats

n = Total number of quadrats sampled

k = Number of unique species

The variance of this Jack-knifing estimation of species richness is given by

$$Var(\hat{S}) = \left(\frac{n-1}{n}\right)\left[\sum_{j=1}^{s}\left(j^2 fj\right) - \frac{k^2}{n}\right]$$

(Equation 4.2)

Where $Var(\hat{S})$ = Variance of jack-knifing estimation of species richness

f_j = Number of quadrats containing j unique species

($j = 1,2,3, \ s$)

k = Number of unique species

n = Total number of quadrats sampled

This variance can be used to obtain confidence limits of species richness at minimum and maximum of species as follows:

$$\hat{S} \pm t_{\alpha} \sqrt{\text{var}\left(\hat{S}\right)}$$

(Equation 4.3)

Where t_{α} = Student's ***t*** value for $n-1$ degree of freedom for the appropriate value of α

The Jack-knifing estimation of species richness tends to have a positive bias, that is it tends to overestimate the number of species in community (Krebs, 1989). This bias is usually less than the negative bias of the observed number of species (***S***), which is less than the true value of species richness in the community. So it presents the range of number of species which probably exist in an ecosystem.

- ***Indices of species diversity*** are mathematical functions of the relative abundances of the individual species in a community. For instance, the ***Shanon-Wiener index of species diversity (H')*** is identified as 'type I indices' because it is sensitive to changes in the rare species in the community sample. This is considered an important means for comparisons of community structure and stability or measured 'heterogeneity in community/system' (Allaby, 1996 and Krebs, 1989).

$$H' = \sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

(Equation 4.4)

Where H' = Information content of sample (bits/individual) or index of species diversity

s = Number of species

p_i = Proportion of total sample belonging to ***i*** th species

The Shanon-Wiener index of species diversity increases with the number of species in the community and in theory can reach very large values. In practice, for biological communities ***H'*** does not usually exceed 5.0 (Washington, 1984).

These indices are applied to this study in relation to species diversity level in terrestrial and aquatic ecosystems. The indices are applied only to autotrophs (primary producers) as they are the basis of the trophic structure in ecosystems. The indices are incorporated in the alternative methodology of Impact Assessment in chapter seven.

4.2 SCOPE OF THE STUDY

The scope of species diversity evaluation is illustrated in Figure 4.1.

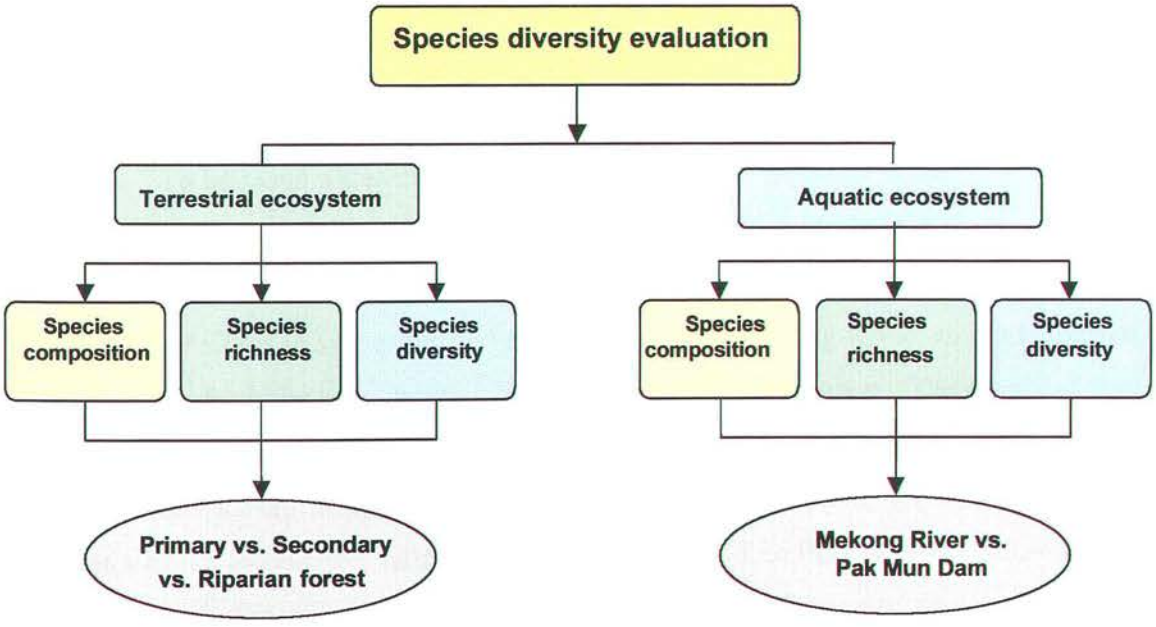


Figure 4.1: Scope of the study at species diversity level.

4.3 BACKGROUND OF THE STUDY AREA

The Mekong River has high potential in terms of hydropower resources in this region and is a target for social and economic development. To utilise natural resources efficiently and sustainably, it is necessary to have a good tool for decision-making process as guidance. This study explores a new approach for biodiversity valuation through a case study in the Mekong River. The case study is focused on the proposed hydropower project, ***Ban Koum Project*** on the Lower Mekong River Basin between Thailand and Lao PDR (MRC, 1994) (Figure 2.3).

This study follows the baseline information in the report of pre-feasibility study by Compagnie Nationale du Rhône, France in cooperation with Acres International Limited, Canada and Mekong Secretariat Study Team, Thailand (MRC, 1994). The project has the multipurpose objectives:

- To produce electric energy to supply in the region
- To maintain low-river flows and to increase flows during dry season
- To control salinity intrusion during low-river flows
- To reduce flood peaks during rainy season
- To improve water transportation
- To make water available for irrigating land for the whole year

The study site is in sub-watershed area in the Lower Mekong River, which is located at 928 km from the river mouth in the South China Sea, Vietnam. The proposed Ban Koum hydropower project is approximately 19 km upstream from the confluence of the Mun River, Amphoe Khong Chiam up to Amphoe Khemmarat, Ubon Ratchathani Province, Thailand and the Southwest of Lao PDR between Salawan and Champasak Province (Figure 2.2 and 2.4). This hydropower project has been selected as a study site because:

- Ban Koum Dam will control the natural water flows from upstream for hydropower generation purpose, and will have ecological, social and economic impacts.
- The dam will be constructed on an international river, which is a borderline

between two countries with different ecological, political and socio-economic situations.

- Pak Mun Dam is located downstream from Ban Koum Dam it has controlled the effluent of the Mun River to the Mekong River mainstream and has been operated since 1994.

4.3.1 Hydropower project area: Ban Koum Dam

Generally, this area is affected by flooding during the rainy season so the river physical characteristics are obviously different between rainy season and dry season (Figure 4.2 and 4.3). These seasonal variations affect the pattern of living not only of the flora and fauna but also of the local people along the river.

In terms of direct ecological and social impacts from this hydropower project. Some villages are located in the operating level of the Ban Koum Project at 120 m above mean sea level. During low flow conditions the 120 m operating pool will influence flow depths in the river upstream for up to 140 km (MRC, 1994). It is also estimated that over 2,570 local people will be resettled and some 1,800 ha of wetland and 7,600 ha of forest and agricultural area will be directly affected.

Therefore, the study sites were selected for the systematic random sampling along the riverbank, which are mainly composed of forests in both Thai and Laotian boundaries. Some areas are occupied by local people and utilised as home-garden system and paddy rice field. Most of these areas are close to the riverbank and affected by flooding every year. The inundated area will be determined by the topographic contours along the river. The east riverbank belongs to Lao PDR and has steep slopes of 1:3 to 1:5. In contrast, the west riverbank in Thailand has slopes ranging from 1:10 to 1:15. However, it seems that in the Laotian area more land area will be inundated because its topographic contour is lower elevation than the proposed dam's level. The left hand side of river bank is located in the Pha Taem National Park in Thailand and the right hand side is located in a protected area in Lao PDR, which is designated for the control of a natural habitat with high biodiversity.



Figure 4.2: The Mekong River near Ban Kuom Hydropower Project during the rainy season 1997.



Figure 4.3: The Mekong River near Ban Kuom Hydropower Project during the dry season 1998.

The Thai study site is located in Pha Taem National Park, Amphoe Khong Chiam, Ubon Ratchathani Province of North-east Thailand. Geographically it is in the Korat Plateau and part of Phanom Dongrak range (MRC, 1996), this area is far from Bangkok approximately 920 km. This study site is composed of 6 different land-use types: primary forest[1], secondary forest[2], riparian forest[3], grassland[4], bamboo forest[5] and agricultural land (mainly home garden and paddy rice field) (Figure 4.5 to Figure 4.10). The profile of land use types as follows:

- The small area of primary forest is also representative of the existing forest in Lao PDR (Figure 4.4).
- Secondary forest dominates the Thai forest because of the effects of legal and illegal logging before the designation as the National Park (Figure 4.5). It shows evidence of illegal logging (Figure 4.6).
- The riparian forest is distributed in parallel to the riverbank, which the floods affect during rainy season (Figure 4.7).
- The grassland exists in an ecotone near the forest edge (Figure 4.8).
- The bamboo forest is distributed widely in the secondary and the riparian forest and it is not distinguished as a significant area. Thus the bamboo forest is included into the secondary forest or the riparian forest depending on its distribution.
- Home gardening system cultivates banana, corn, vegetables and herbs, basically for household sustenance. The production surplus is traded to the local market (Figure 4.9).
- Paddy rice practices cultivate sticky rice (*Oryza sativa* Linn.) once a year during the rainy season because the cultivation depends on rain from the monsoon. Usually the produce is for household consumption because the

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[1] Primary forest is a forest largely undisturbed by human activities, which relatively intact natural forest and remain unmodified for the past 60-80 years (WRI, 1992).
[2] Secondary forest is defined as the results from continuous human use of forests such as grazing, fuel wood collection and burning (Brown, 1990).
[3] Riparian forest is the band of forest that has a significant influence on a stream or river ecosystem or is significantly affected by the stream or river (Natural Resources Canada, http://www.nrcan.gc.ca/cfs/proj/sci-tech/arena/gloss_e.html)
[4] Grassland is an ecosystem whose dominant species is grass.
[5] Bamboo forest is a forest dominated by bamboo mixed with some trees.

sticky rice production is low as a consequence of infertile soil. The produce is not enough to household sustenance for the whole year (Figure 4.10).

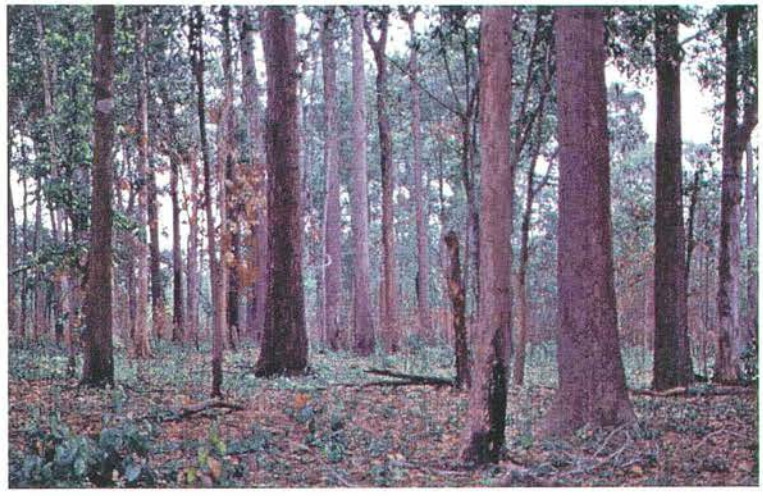


Figure 4.4: Primary forest during the dry season 1998.

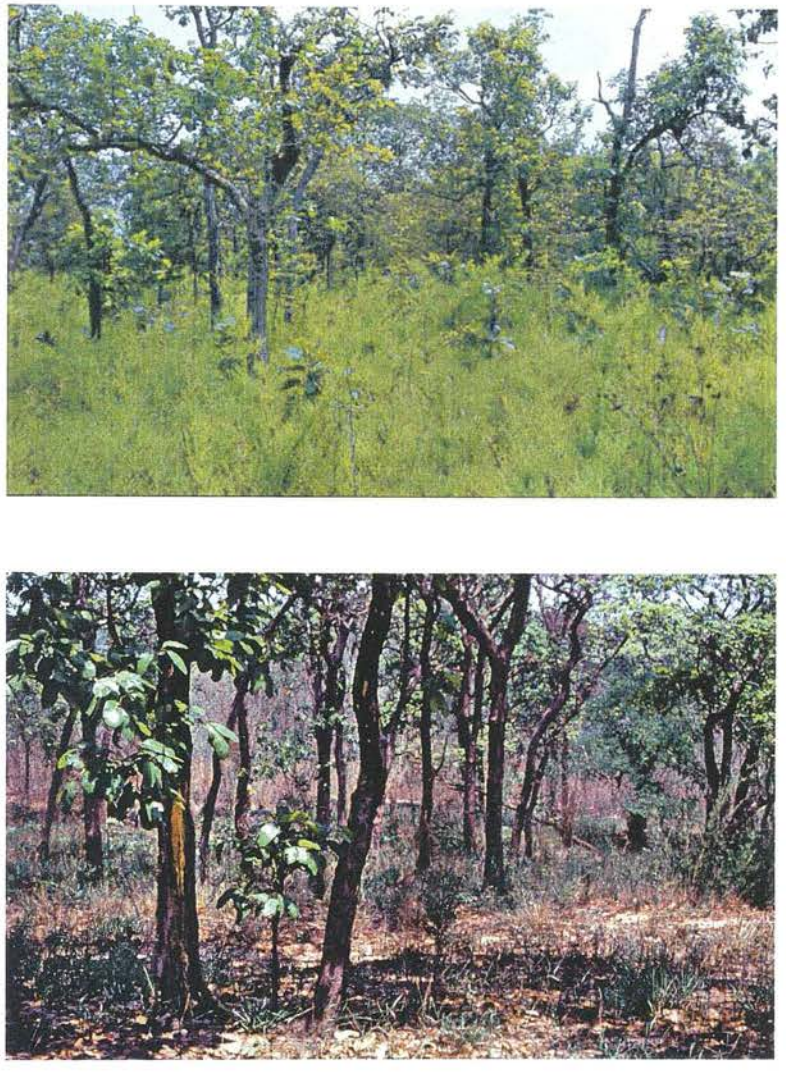


Figure 4.5: Secondary forest during the rainy season 1997 and the dry season 1998.

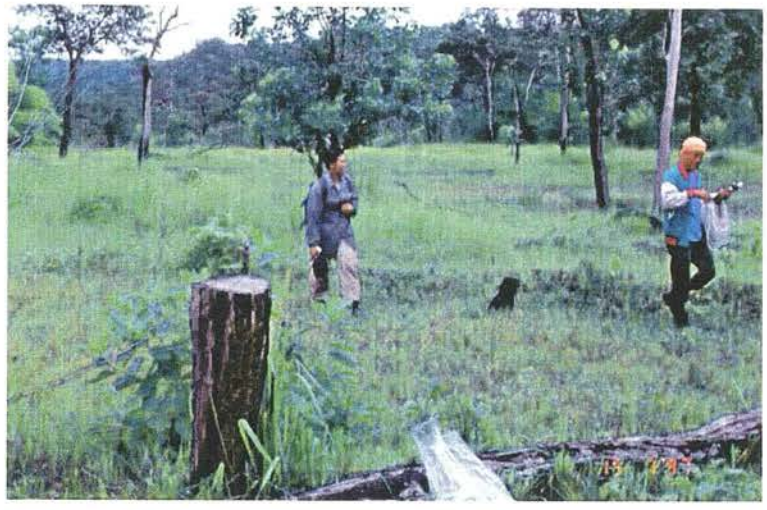


Figure 4.6: Secondary forest with the evidence of recent illegal logging in Thai study site.

The Laotian part of the Ban Koum Project study site is located in two governmental zones, in Salawan Province to the north and in Champasak Province to the south. This area is politically sensitive because there is a military camp along Mekong River. There are three villages along river such as Ban Sura, Ban Kom Tue and Ban Khan Tong Chai. Unfortunately the Laotian authority in Vientiane did not give permission to allow field works at the site and the local authority as a head village also rejected all data collection, field survey and interview. Due to political and bureaucratic constraints in Lao PDR, it was impossible to access the Laotian forest. However, the primary forest with the Thai boundary is considered to be representative of the Laotian study site, based on local knowledge, information on environmental conditions and evidence from satellite image interpretation (RFD, 1998).

Finally, the substituted area is located in the Pha Taem National Park, near Ban Hung Lung, Amphoe Sri Muang Mai, Ubon Ratchathani Province at co-ordinate 15° 42.178 N, 105 ° 34.148 E. This area has not been affected by illegal logging because it is not only in a remote area but also has no road access. Access to this primary is mainly possible in the dry season, either by foot or by off-road vehicle. Access during the rainy season is only possible by foot. Therefore, this site is similar in

isolation to the Laotian site and should be similar in terms of species composition and species diversity.

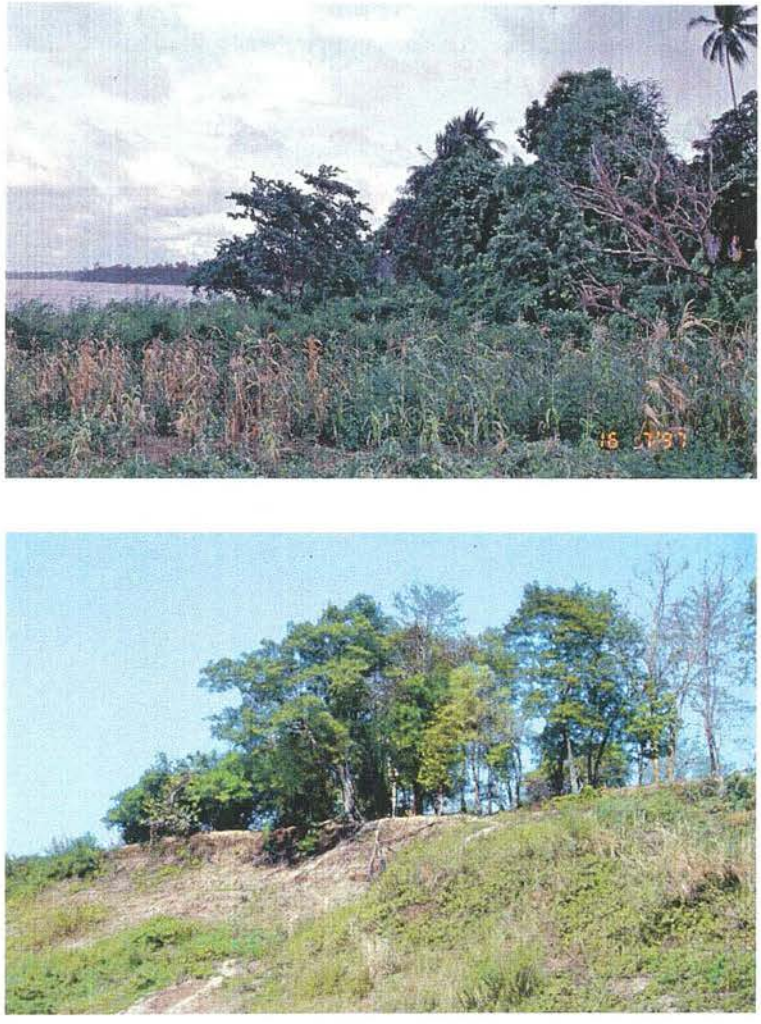


Figure 4.7: Riparian forest and riparian zone during the rainy season 1997 and the dry season 1998.

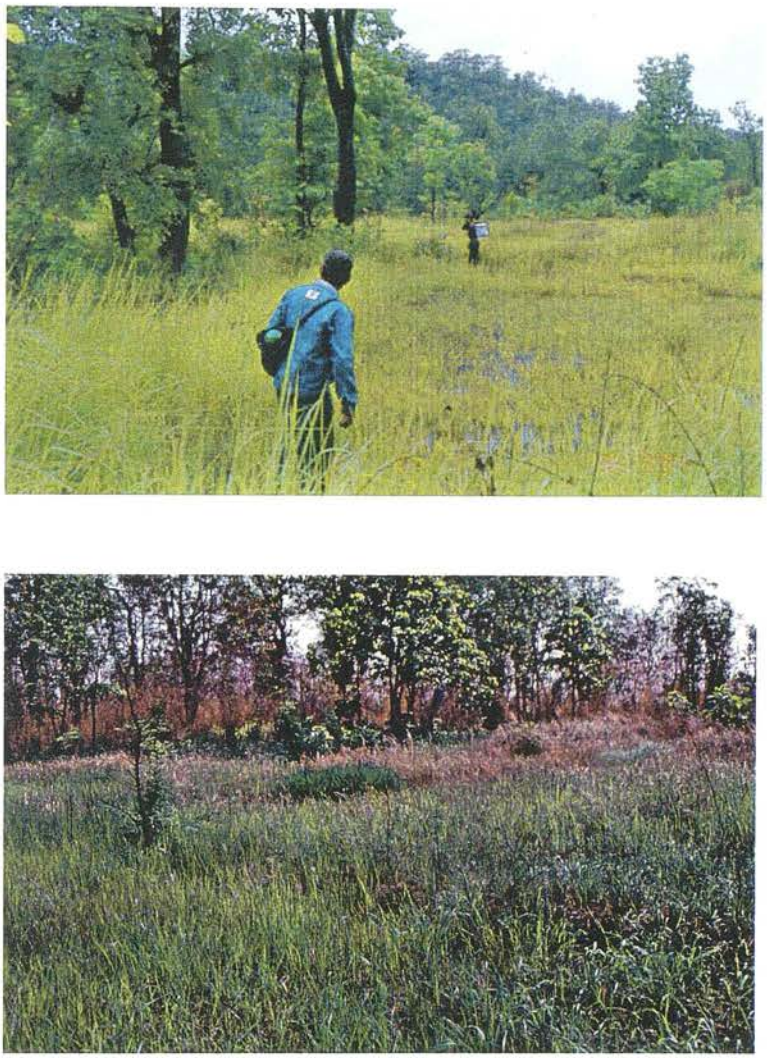


Figure 4.8: Grassland ecosystem during the rainy season 1997 and the dry season 1998.



Figure 4.9: Home garden during the rainy season 1997.



Figure 4.10: Paddy rice field during the early rainy season 1997.

4.3.2 Reference dam area: Pak Mun Dam

The Pak Mun Dam was selected to examine the actual effects of dam construction. It is located 6 km above the outlet of the Mun River, which merged into the Mekong River at Amphoe Khong Chiam, Ubon Ratchathani Province, the northeastern Thailand (Figure 4.11). The Mun River flows through the lower Northeast region from the West to the East and has total length of over 600 km. Average annual runoff is 24,000 million m^3, which the second highest runoff from the Chao Phraya River in the central region. The Mun River is the largest tributary to the Mekong River with a catchment area of 117,000 km^2. The Pak Mun Dam is 17 m high, creating a lake of 65 sq. km within the 80 sq. km Kaeng Tana National Park. The beautiful rapids of the Mun River, which were blasted during the construction of dam, used to be one of the greatest tourist attractions in Thailand. The rapids were the parts of the river richest in oxygen, and therefore the most important fishing area. As a result this dam seems to provide a good reference area for this study.

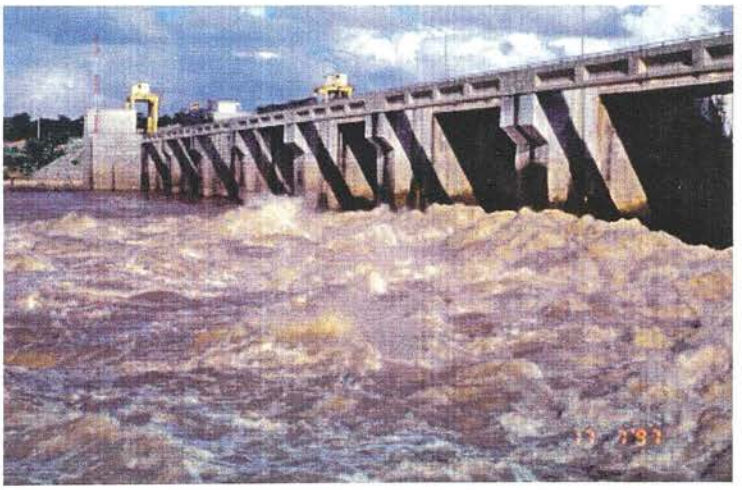


Figure 4.11: Pak Mun Dam located on the Mekong tributary in Thailand that has the same construction and water regulation system as Ban Koum Dam.

The development of Pak Mun Dam had been through the different studies such as the preliminary investigations, the feasibility study during 1967-70, the updated feasibility study in 1979, the environmental and ecological investigation in 1982, and the final study in 1988. In 1990 the Thai government cabinet approved the Pak Mun Dam project. The dam construction began shortly and the commercial operation began in November 1994 (WCD, 1999). The details of Pak Mun Dam are consisted of the following:

Table 4.1: The information of Pak Mun Dam project.

Categories	Information	Units
Reservoir (run-of-river)		
- Maximum area	60	km^2
- Maximum storage	225	mcm
- Maximum operating level	108	MSL
- Minimum operating level	105.5	MSL
- Dam height	17	m
- Dam length	324	m
Hydropower generation		
- Annual generation	280	GWh
Project cost		
- Physical infrastructure	201	mUS$
- Resettlement and compensation	20	mUS$
- Environmental mitigation	12	mUS$
Total cost	**233**	**mUS$**

The details of environment mitigation cost are associated with the following (WCD, 1999):

- Forest conservation: the Kaeng Ta-Na National Park is located about 1km downstream of the dam site (Figure 4.12). It was affected by the dam construction. This project compensated to set up a national park protection unit, a security guard unit, a first aid station, and a patrol road and the park borderlines at the cost of US$700,000.
- Tourist attraction: two suspension bridges were constructed to connect the Kaeng Ta-Na island with the shores of the Mun River. The cost is US$700,000.

- Fisheries development: it is focused on fisheries study, set-up of fishery development and conservation unit, a fish ladder (Figure 4.13) and a fish husbandry promotion unit. The cost is US$850,000.
- Health impact mitigation: it aims to monitoring and prevention of water-bourne by increasing awareness of the population and conducting surveillance of Schistosomiasis and liver fluke infections. It also emphasised their snails and first hosts in the project area, improving the health status of the affected population by strengthening the capabilities of the health service system and undertaking research work on Schistosomiasis. The cost is US$200,000.
- Transport improvement: the elevating road for 1km distance at cost of US$440,000.
- Archeological salvage: the archeological site was brought to higher grounds at cost of US$60,000.
- Public information and relation programme: the cost for regular information by mass media is US$1,000,000.
- Environmental monitoring: the regular monitoring of environmental data and socio-economic data is proposed in the certain area. Its cost is US$890,000.
- Project monitoring and valuation: the overall monitoring and evaluation of Pak Mun's socio-economic mitigation plans is the cost at US$80,000.

It seems that the environmental mitigation cost mostly associated with more social aspect than ecological aspect. The resettlement and compensation and environmental costs are approximated at 9 and 5 percent of total cost of Pak Mun Dam, respectively.

Limnological and socio-economic data from Pak Mun Dam represent the with-project implementation or the post-dam construction's condition and related ecology. This dam has the same historical background and locality as Ban Koum Dam. Limnological and socio-economic data were collected to assess ecological as well as socio-economic changes after dam construction. The dam has changed the aquatic environmental conditions from rapid running water to an almost stagnant water system. Because the west bank of Pak Mun Dam is located in the Kaeng Tana

National Park, the terrestrial environmental conditions have no human encroachment regarding to strictly controlled in the surrounding areas (Figure 4.12).

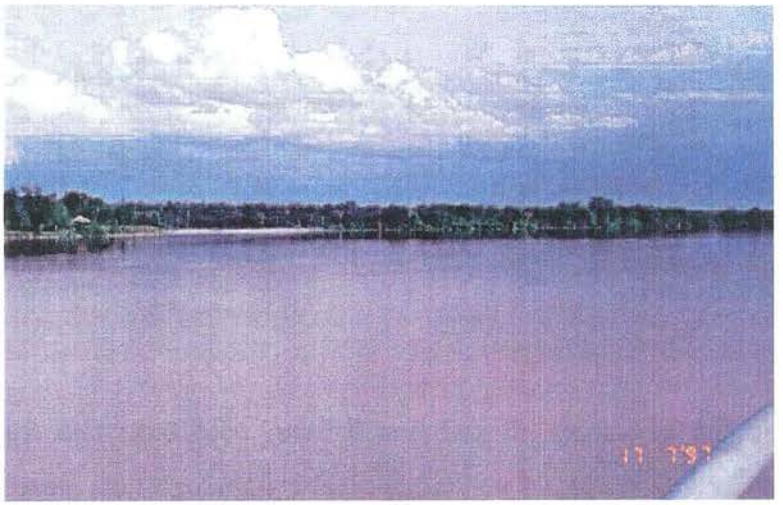


Figure 4.12: The scenery of Pak Mun Dam and Kaeng Tana National Park (far side) during the rainy season 1997.



Figure 4.13: A fish ladder has been installed to reduce the impact on fish migration in the Pak Mun Dam.

At the beginning of the project, a fish ladder was considered not necessary because most of the fish species caught in the Lower Mun River were found to have survived and reproduced successfully in other reservoirs in the Northeastern Thailand (Figure 4.13). In addition, a fish stock programme could be undertaken in order to increase reservoir fish production. In 1992, the construction of fish ladder was considered in detail to minimise adverse effects on fish migration. The site and direction of the fish ladder was thus confined to certain areas. The lack of spillway management could cause failure for fish to reach the ladder (WCD, 1999). According to the local people, only small size fish with the least economic value could achieve successful migration.

4.4 METHODOLOGY

The study considers the standard methods for measurement and analysis of species diversity level in both terrestrial and aquatic ecosystems. In terrestrial ecosystems, the measure of species diversity can be applied at a variety of scales as follows (Pielou, 1995):

- Where the study area is small (10 hectare or less), sampling plots (quadrats)

of 1x1 or 4x4 m^2 may be used and all species of vascular plants and bryophytes in each plot listed. These data will allow estimation of a high-resolution value of species richness.

- Where the study area is about 100 hectares, plots of 16x16 to 25x25 m^2 may be sampled and either the genus of all sampled plants or all woody plants identified to species.
- Where the study area is of the order of 1,000 hectare, lower resolution data can be obtained from 100x100 m^2 or 1 hectare plots with list trees and tall shrubs only.

The sampling size in this study was divided into two types. Firstly, the 25x25 m^2 plot size was adopted for the secondary forest, the riparian forest, the bamboo forest and the home gardening system because these forest types are fragmented by human activities. Because of the small area of bamboo forest in the study sites data are included with the secondary forest for analysis. Secondly, the 100x100 m^2 or 1 hectare plot size was adopted for the primary forest as the representative of Laotian forest, which is considered as a natural primary forest. The 1-hectare plot was divided into 16 small 25x25 m^2 plots and within each small plot sapling and ground floor vegetation collections were obtained in 1x1 m^2 plot. Grassland was sampled in 1x1 m^2 plots for direct harvesting biomass.

In the aquatic ecosystems, the method of sampling followed the limnological technique of Wetzel and Likens (1991). At each sampling station, water temperature, dissolved oxygen (DO), pH and light transparency were measured *in situ*. Temperature and pH were measured by pH meter and light transparency by Secchi disk. These physical parameters are measured at 0.2 m depth from the water surface.

4.4.1 Data collection

There are two types of data collection for this study as follows:

- First, the primary data collection was basically focused on the seasonal variation and was limited by resources for field works. Data collection was planned to collect in the terrestrial and aquatic ecosystems according to seasonal variation during the rainy season with high water period in June and July 1997 (Figure 4.2) and dry season with low water period in April and May 1998 (Figure 4.3).
- Second, the secondary data were collected from the various reliable sources including the report of pre-feasibility study of Mekong mainstream run-of-river hydropower (MRC, 1994) and other sources from the Mekong River Commission Secretariat, Bangkok, Thailand; hydrological and meteorological data from the Department of Energy Development and Promotion, Bangkok, Thailand; and the soil data from the Department of Land Development, Bangkok, Thailand.

Terrestrial ecosystems

Data were collected from the study sites. The study site along the Mekong River represents the without-project implementation' that is the condition existing before development of the Ban Koum Dam

Data of remote sensing interpretation have been extracted from satellite image (TM) at path126/row49 in 1995 interpreted by The Royal Forestry Department of Thailand and GTZ (MRC/GTZ, 1997)(Appendix 4.1). The GIS maps show the forest and vegetation cover types in Thailand (Figure 4.14) and Lao PDR (Figure 4.15). These data provide the baseline information for the ground check in the field and sampling for biomass (in chapter five), species diversity and species richness.

Stratified randomized sampling method was applied for data collection (Figure 4.16). It illustrates the location of sampling plots of this study in relation to Appendix 4.2. Especially at the Thai boundary study sites various types of land-use occurred, such as secondary Dry Dipterocarp forest, riparian ecosystem, bamboo forest, home

gardening and paddy rice field as well as grassland. Within each land-use type randomized sampling was adopted. The 30 sampling plots on Thai side of the Mekong river were distributed from Ban Kum to Ban Khan Tha Kwean. The 16 sampling plots in the primary forest were represented Laotian side. The designed sampling plot is following:

- The 46 sampling plots for tree and sapling were 25x25 m^2
- The five sampling plots for ground-floor vegetation were 1x1 m^2, randomly distributed in the 25x25 m^2 plots.

Every tree in the sampling plot with diameter greater than 4.5 cm at 130 cm height was recorded. Saplings, with diameter smaller than 4.5 cm, were destructively harvested for biomass measurement. Species present in plots were identified based on the taxonomic classification of Smitinand (1980) and Boonkerd et al. (1982). The taxonomists at Herbarium Division, Royal Forest Department in Bangkok, assisted in taxonomic classification and identification. Ground floor vegetation was also harvested for biomass measurement (see chapter five).

Because the survey of Laotian study site was prohibited, the digitised data from satellite images was used to select forest on Thai sites with similar characteristics to the Laotian forest opposite to Thai site at Ban Hung Luang, Amphoe Sri Mueang Mai, Ubon Ratchathani Province. The sampling plot of 1-hectare was divided into 16 small plots (25x25m^2) based on the assumption that the Laotian primary forest is reasonably homogenous. Sampling followed the same randomised method as in other Thai study sites.

- The meteorological primary data are collected in the field, which contain:
- Relative humidity (%) is measured by wet and dry hygrometer in sampling plots during rainy season in 1997 and dry season in 1998.
- Air and soil temperature is measured by thermometer in sampling plots during rainy season in 1997 and dry season in 1998.

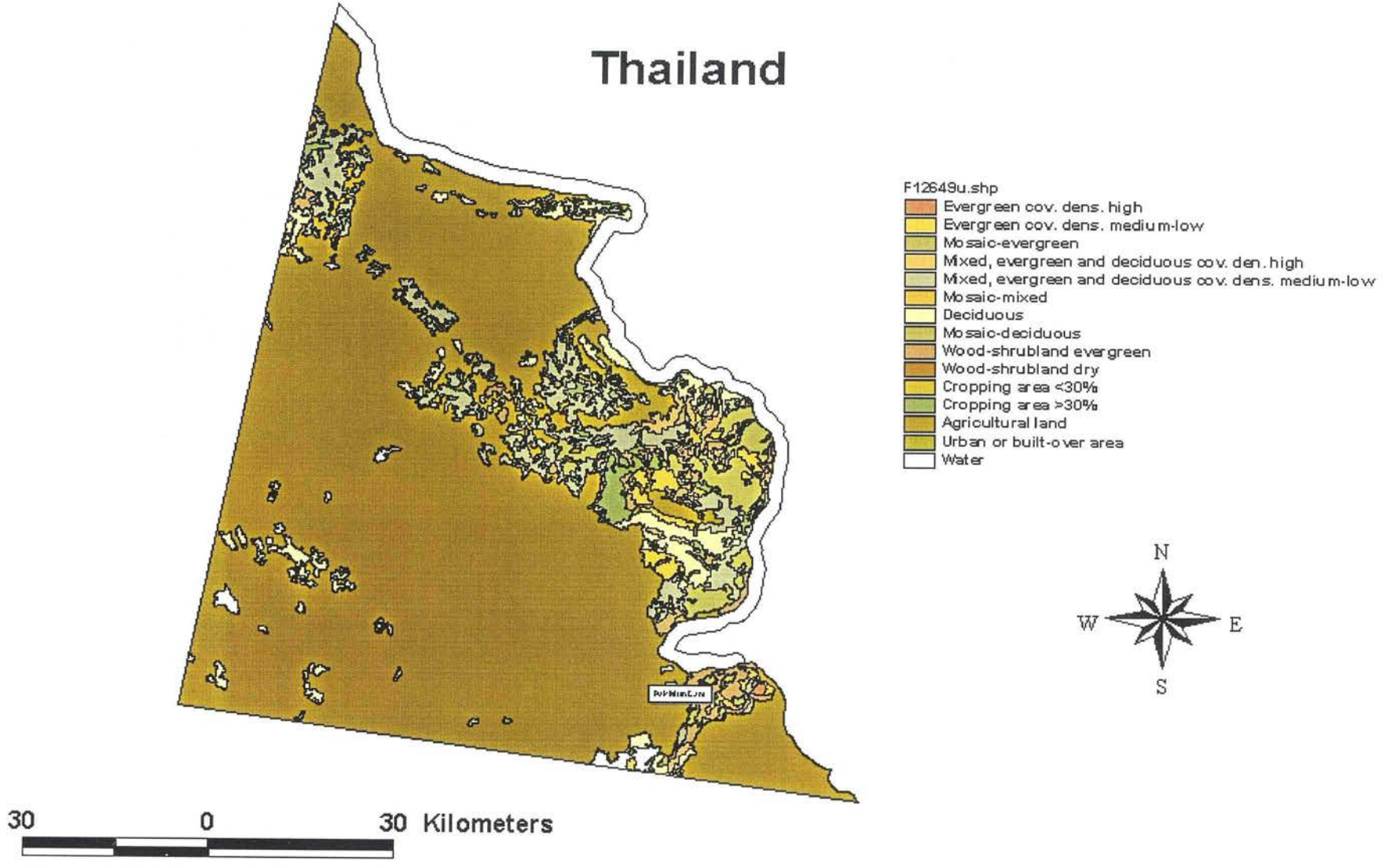


Figure 4.14: GIS map indicates the forest and vegetation cover types in Thailand (RFD, 1998).

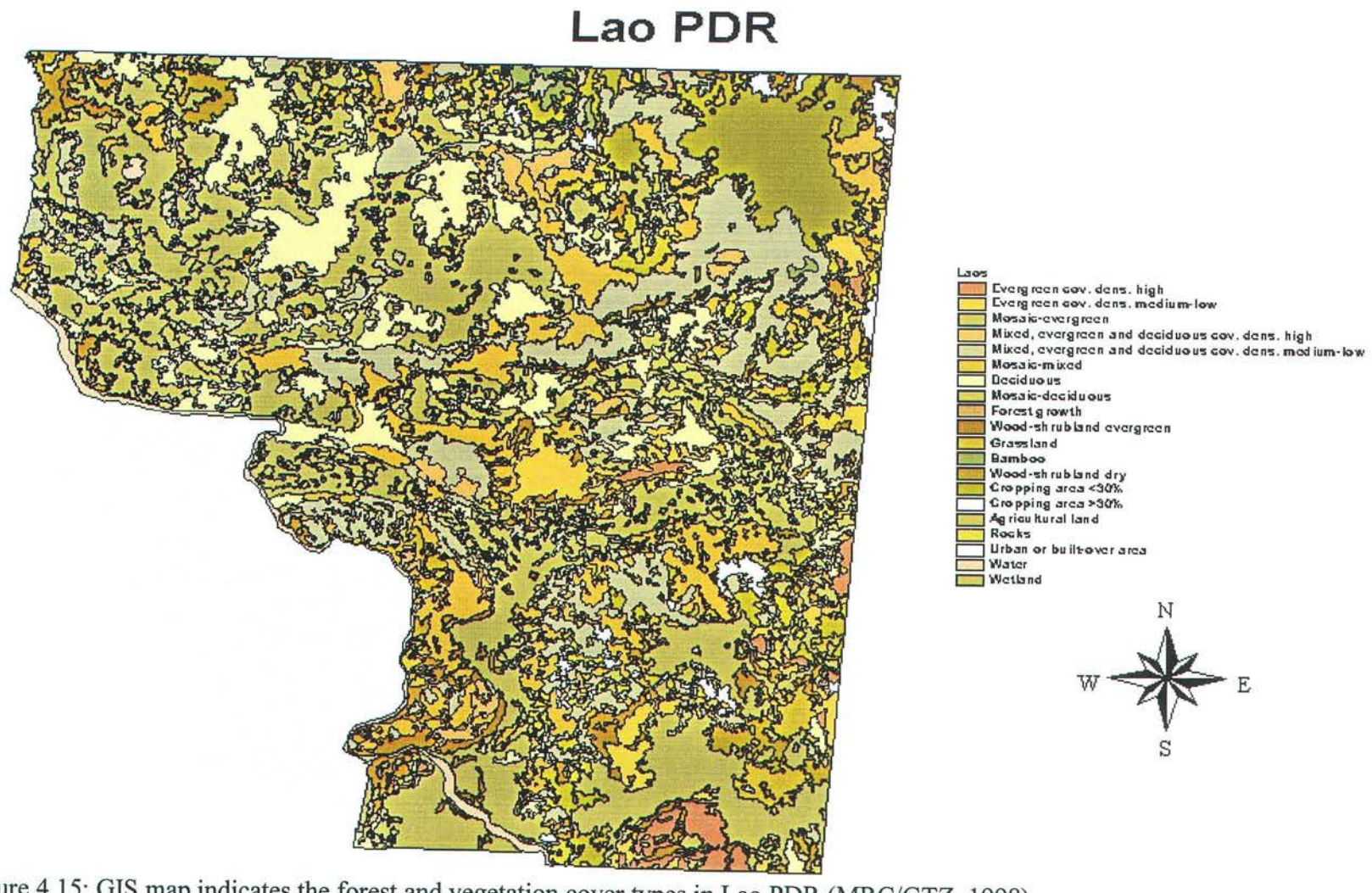


Figure 4.15: GIS map indicates the forest and vegetation cover types in Lao PDR (MRC/GTZ, 1998).

(No scale is available from the GIS map, but the left-hand site of the river shows in Figure 4.14).

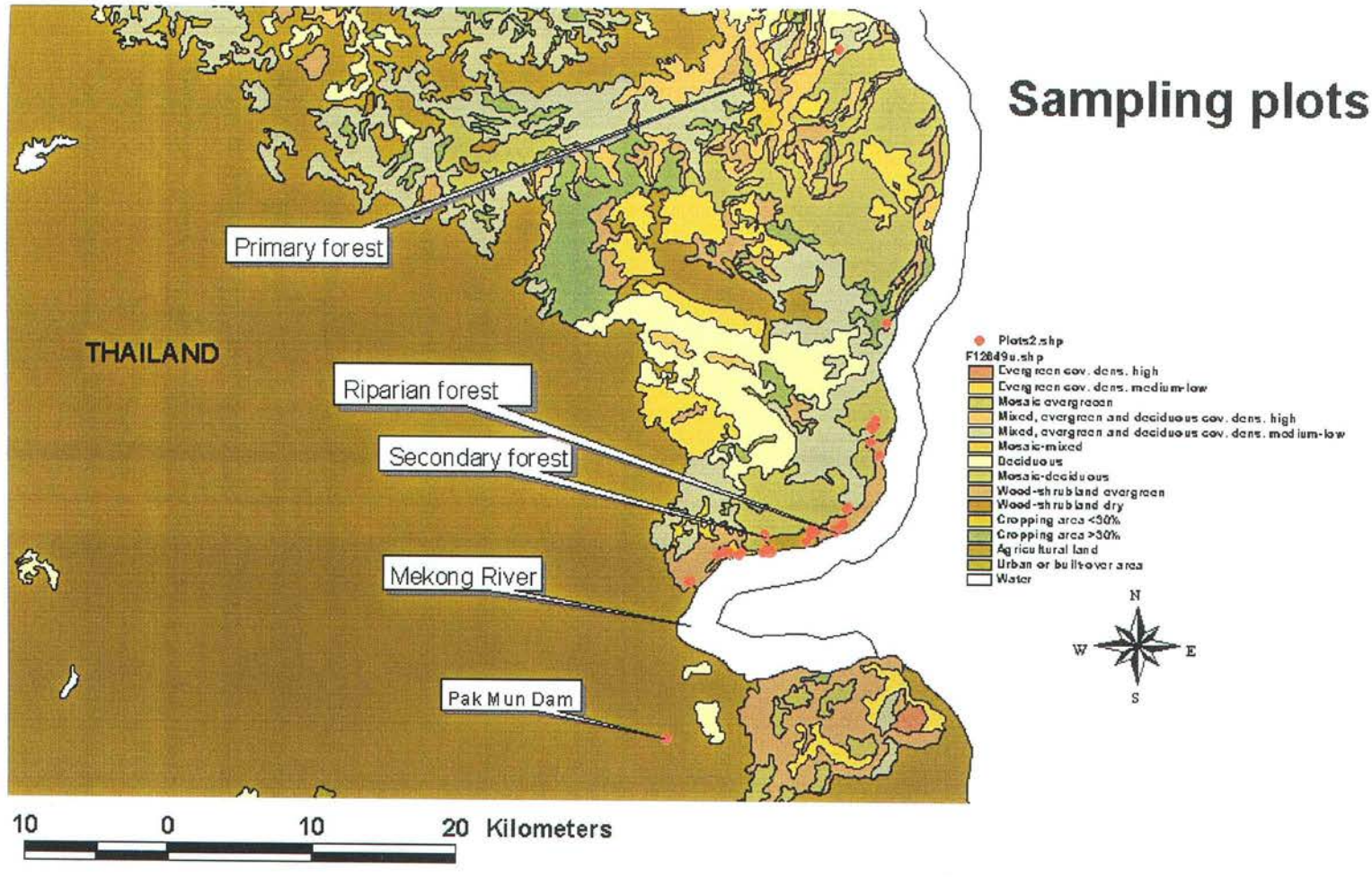


Figure 4.16: A map of sampling plots in this study (RDF, 1998).

Aquatic ecosystems

Data collection in the aquatic ecosystems have been collected during the rainy season in 1997. There are four sampling stations representing the proposed area of Ban Koum hydropower in the Mekong River, which collected samples from Ban Kum up to Kaeng Soi upstream from Kan Tha Khwian (Figure 4.17 and Appendix 4.2).

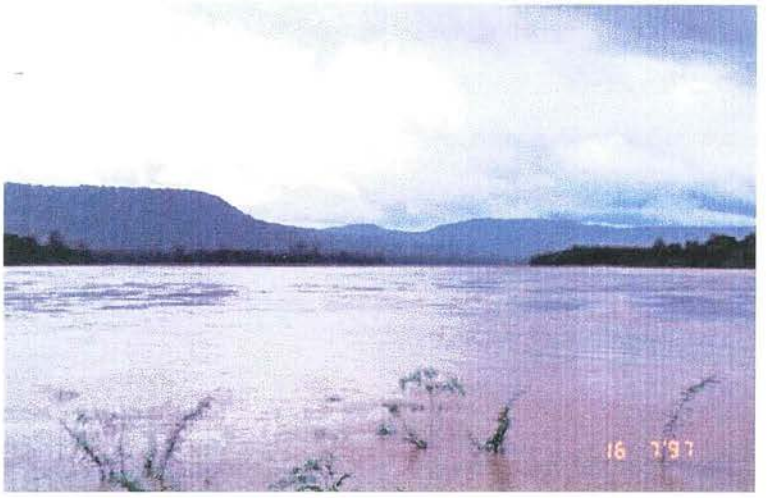


Figure 4.17: The Mekong River sampling station during the rainy season 1997.

Physical factors were collected as primary data as follows:

- Water and air temperature is measured by thermometer.
- pH is measured by pH meter.
- Transparency depth is measured by Secchi dics.
- Dissolved oxygen is measured by titration method.

The secondary data such as annual precipitation, water temperature; air temperature, pH, dissolved oxygen (DO), total suspended solid (TSS), flow rate and conductivity were collected from the Department of Energy Development and Promotion in Bangkok, which are illustrated in chapter five.

The water temperature, transparency depth and pH were measured at the sampling

stations. Net primary productivity was measured by the dark-light method (using BOD bottles) with incubation in natural condition for three hours during the afternoon and all samples were analysed by titration.

Phytoplankton was collected by trawling, plankton net size 20 and 70 micron, which collected the large size of phytoplankton. Wetzel and Likens (1991) recommend that sampling may be made more effective by less precise analyses of replicated samples from the same place rather than by very precise analyses of a single sample. Therefore, four sampling stations in Mekong River and three stations in Pak Mun Dam were sampled. At each station four replicate samples were collected, each by trawling ten times at the same distance, and preserved as a composite water sample. All samples were preserved in Lugol's solution for taxonomic identification in a laboratory. The water volume was calculated to estimate phytoplankton density. For the reference dam in Pak Mun Dam, the samples were collected following the same methods as the above.

All preserved samples were brought to the Institute of Ecology and Resource Management at the University of Edinburgh. Observations were made using 200 magnification and a Sedgwick-Rafter counting cell, thus concentrating on the large forms of plankton. A count of 30 fields was repeated in each counting cell, based on McAlice (1971) who suggested that 30 replicate fields can be expected to reveal 90 to 95 percent of the species present.

4.4.2 Data analysis

In the terrestrial ecosystems, tree and sapling species in the different forest types are considered as species indicators. The other land-use types are not considered to this species level because they are man-made ecosystems such as home-gardening system and paddy rice field. However, the land-use types are considered in terms of the carbon storage capacity in chapter five. In the aquatic ecosystems, the river ecosystem of the Mekong River and the reservoir ecosystem are compared based on phytoplankton in relation to species composition, richness and diversity.

The data of species composition are statistically tested by 'Correspondence analysis' (Hair et al., 1998) in order to describe the relationships between two ecosystems. Kruskal-Wallis test (One-way Anova) is needed to analyse variance or chi-square and to compare both aquatic ecosystems.

For species richness, the 'Jack-knife Estimate' (Krebs, 1989) is used to estimate the probable number of species in the different ecosystems. Species richness in the forest is based on presence or absence of tree and sapling species in sample plots. In the aquatic ecosystems, the number of taxa per sample volume of water provides the basic unit for cmparison. For species diversity the 'Shannon-Wiener Index' is used (Krebs, 1989) as an index for each ecosystem and statistically tested by the one-way Anova.

4.5 RESULTS AND DISCUSSION

4.5.1 Physical factors

Terrestrial Ecosystem

A comparison of the relative humidity among Thai sampling plots during rainy season and dry season shows the mean at 76.2±5.4 and 61.4±11.05 percent, respectively (Figure 4.18). As a result, the relative humidity has the same pattern of fluctuation during the different seasons. It is higher in the rainy season than the dry season because of heavy rain and high moisture in the atmosphere during the rainy season. Particularly, the plot number 16 and 26 are the lowest relative humidity because the habitat type of both plots - grassland and bamboo forest are exposed to sunlight and dry condition. The air temperatures in both plots are very high according to the result in Figure 4.19.

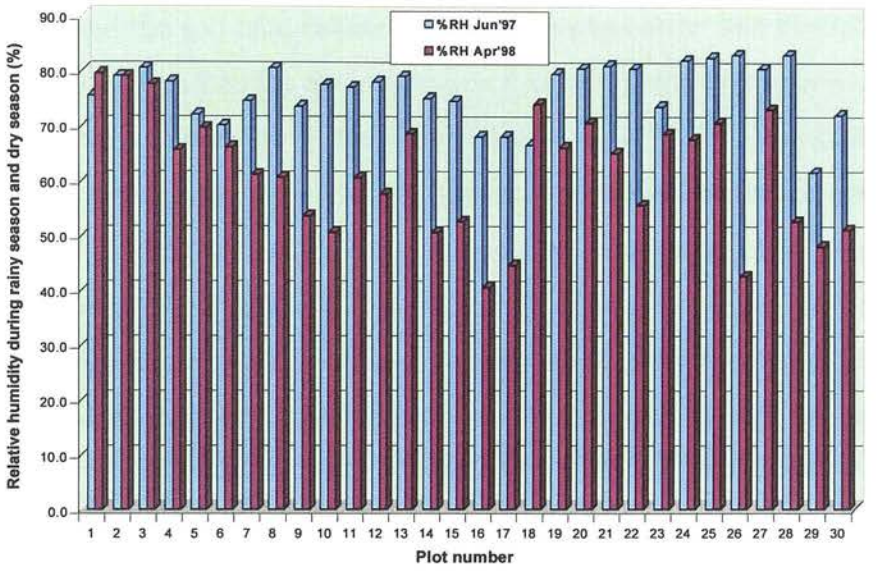


Figure 4.18: A comparison of relative humidity (%) in Thai study sites during the rainy season 1997 and the dry season 1998.

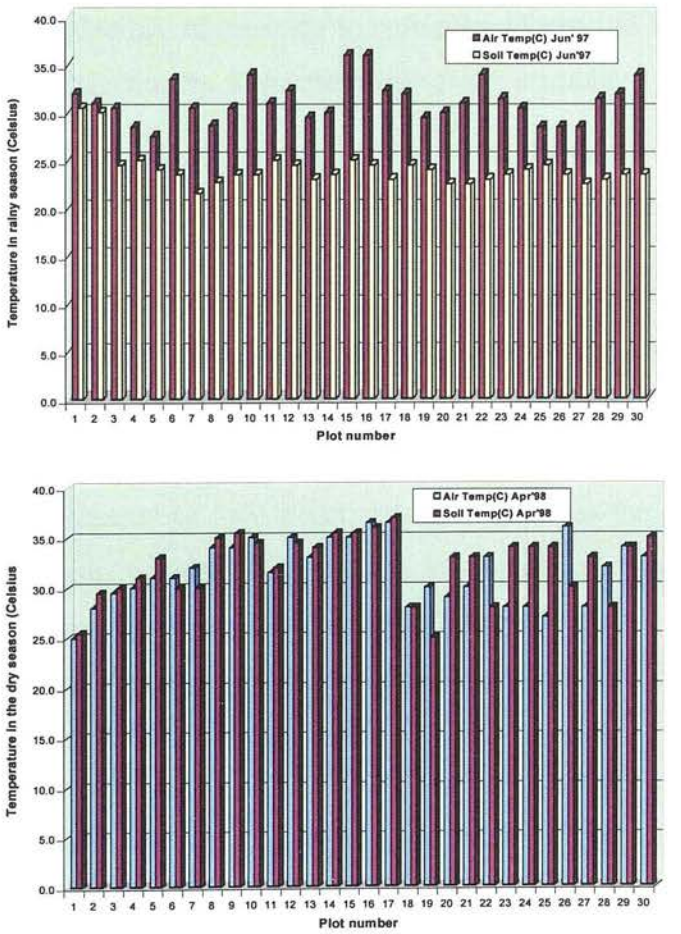


Figure 4.19: A comparison of air and soil temperature in Thai study sites during the rainy season 1997 and the dry season 1998.

The air and the soil temperatures in sampling plots show that the soil temperatures are mostly lower than the air temperature particularly in rainy season. The means of air and soil temperature in the rainy season are at 31.2±2.2 and 24.1±1.9 degree Celsius, respectively. In the dry season, the temperatures are not significantly different at 31.6±3.1 and 32.3±3.2 degree Celsius, respectively. Seasonal variation in the means of air temperature in this area seem to be similar, while the means of soil temperature obviously indicate more variation in relation to greater ground floor cover and more rain percolation through soils. Because the soil is sandy mixed with little gravel of sandstone with high heat conductance, the soils can store more heat energy after being exposed to sunlight during the dry season.

As a result, the physical factors can influence to the distribution of species composition - tree, sapling and ground floor vegetation. The temperatures can indicate the availability of moisture in both atmosphere and soils, which associates with primary production by stimulating biological functions.

Aquatic ecosystems

In terms of a comparison of physical data between the Mekong River and Pak Mun Dam during the rainy season 1997 (Table4.2), the transparency depth in the Mekong River is less than Pak Mun Dam in response to the high turbidity from upstream and runoff. In this case, transparency depth or optical depth is interpreted as a parameter to reflect the potential of light penetration into water as the energy source for the aquatic ecosystems, which is important in the context of primary production (Kirk, 1994). It is measured as the water depth (cm) from the surface to the lowest depth of light penetration. It is interpreted that the Pak Mun Dam has higher potential of light than the Mekong River.

The watercolour might indicate the higher turbidity and suspended solids in the Mekong River causing less light penetration through the water body. The water is clear and yellow-green colour in the Pak Mun Dam, which the sediments from upstream deposited into the dam because of the very low water flow controlled by

the dam.

Table 4.2: A comparison of physical data between the Mekong River and the Pak Mun Dam during the rainy season 1997.

Categories	Mekong River	Pak Mun Dam
Transparency depth (Secchi disc depth, cm)	7.00±0.82	11.00±0.00
Watercolour	Red-brown with high turbidity	Yellow-green, clear
Water temperature (°C)	26.75±0.96	28.17±0.29
Air temperature (°C)	29.25±1.50	31.17±0.29
pH	7.78±0.06	7.11±0.12
Dissolved oxygen (mg/l)	6.54±0.09	5.82±0.06

The air and the water temperatures show the big different in the dam of about 3 degree Celsius and 2.5 degree Celsius in the river because the solar energy can be accumulated in the water body related to the low flow rate in the dam. The pH of the river and the dam indicates neutral condition at 7.78±0.06 and 7.11±0.12, respectively. The dissolved oxygen (DO) is higher in the river at 6.54±0.09 than in the dam at 5.82±0.06 mg/l. The DO value indicates the water quality is quite good in both aquatic ecosystems.

4.5.2 Species composition

Terrestrial ecosystems

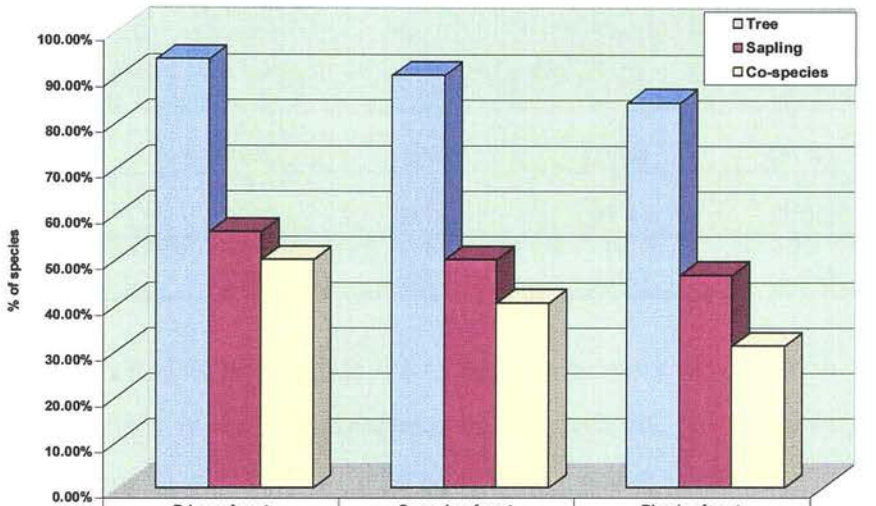
Species composition is based on taxonomic knowledge merged with the indigenous knowledge of local people for providing identification. The local and scientific names were indicated in Appendix 4.3, with some species defined as 'unidentified' because of the limitation of information and taxonomic expertise. The species mostly existed in both tree and sapling forms, and occured in all forest types. These common species were *Canarium subulatum* Grill., *Randia dasycarpa* Barkh.f. and *Wrightia pubescens* R. Br.. The total number of tree and sapling species in primary, secondary and riparian forest was 66, 74 and 45 species, respectively (Table 4.3 and Appendix 4.3). Most of forest types have approximately 50 percent of total species as the common species (Figure 4.20).

Table 4.3: A comparison of the number of species recorded as tree, sapling and both forms in the different forest types.

Type of vegetation (number of species)	Primary forest	Secondary forest	Riparian forest
Tree	62	67	38
Sapling	37	39	21
Common species (tree & sapling)	33	31	14
Total species in each forest type	66	74	45

This study area contains a total of 116 species of tree and sapling of which 6 species were presented only as sapling species. These saplings might be types of shrubs. 49 species occurred only as trees and 61 species are found as both trees and saplings in this area.

The data are graphically presented in Figure 4.20 and show the similar pattern of species composition as trees and saplings in the different forest types.



	Primary forest	Secondary forest	Riparian forest
Tree	93.94%	90.54%	84.44%
Sapling	56.06%	50.00%	46.67%
Co-species	50.00%	40.54%	31.11%

Figure 4.20: A comparison of the percentage of tree, sapling, and the common species existing in the different forest types during the dry season 1998.

The result indicates that most of species in each forest type occur in tree form, which is highest at 94 percent in the primary forest and lowest at 84 percent in the riparian forest with the secondary forest intermediate at 91 percent. Only 50-31 percent of species occurred as both tree and sapling forms that some sapling species occur only as a small shrub or understorey species. The shrub species occur most in the riparian forest and least in the primary forest. This riparian forest has specific physical conditions, where varieties of shrubs can adapt and survive.

Table 4.4: A summary of the number of tree and sapling species recorded as co-existing in two or more forest types.

Type of vegetation (number of species) (%)	Primary & secondary forest (%)	Primary & riparian forest (%)	Secondary & riparian forest (%)	Primary & secondary & riparian forest (%)	Total species (%)
Tree	12 (29%)	3 (7%)	11 (27%)	15 (37%)	41 (63%)
Sapling	7 (29%)	3 (13%)	8 (33%)	6 (25%)	24 (37%)
Total species	19 (29%)	6 (9%)	19 (29%)	21 (33%)	65 (100%)

The main conclusion from Table 4.4 is that the primary and riparian forests have major differences in species composition. In contrast, the secondary forest has species in common with both the primary and the riparian forests.

Table 4.5: A comparison of the dominant species of tree and sapling in the different forest types during the rainy season 1997 and the dry season 1998.

Categories	Dominant species	Relative abundance (%)	
		Rainy season 1997	Dry season 1998
Primary forest:			
- Tree	*Shorea floribunda* Kurz	N.A.	15.00
	Anisoptera costata Korth.		11.30
- Sapling	*Canarium subulatum* Grill.	N.A.	11.34
	Mitragyna javanica Koord. & Val.		8.25
Secondary forest:			
- Tree	*Shorea obtusa* Wall	18.99	18.04
	Xylia xylocarpa Taub.	10.38	10.50
- Sapling	*Xylia xylocarpa* Taub.	12.62	14.14
	Shorea obtusa Wall	9.30	10.47
Riparian forest:			
- Tree	*Homalium tomentosum* Benth.	13.78	11.38
	Xylia xylocarpa Taub.	12.00	11.98
- Sapling	*Terminalia corticorsa* Pierre	32.26	13.33
	Wrightia pubescens R. Br.	17.74	5.00
	Hymenodictyon excelsum Wall	3.23	13.33

This study identified the dominant species in the different forest types as shown in Table 4.5. Primary forest had only one data set in dry season because of the difficulty of having official permission and the political constraints in Lao PDR. However, the dominant species in the primary forest in dry season should not differ from the rainy season; the forest structure is stable without illegal logging pressure in comparison to the secondary and the riparian forest. It is necessary to compare the data between the rainy season in 1997 and the dry season in 1998 among the different forest types. Basically, the tree and sapling species are similar in the secondary and the riparian forest types in both seasons, although the percent relative abundance may be slightly different as a result of forest fire. On the other hand, in the riparian forest there are marked seasonal variations in the percent relative abundance and the dominant species, probably resulting from physical factor changes such as humidity, temperature and competition pressures among vegetation.

The primary forests are dominated by *Shorea floribunda* Kurz and *Anisoptera costata* Korth., which originate in Dry Deciduous forest at altitude of 60-1,200 m from mean sea level (RFD, 1972). From the GIS map of satellite imagery, the forest cover in the sampling site of primary forest indicates a forest type as 'Mixed evergreen and deciduous forest' (Figure 4.16), which corresponds to *Shorea spp.* as dominant species. *Shorea obtusa* Wall. and *Xylia xylocarpa* Taub. are dominant in the secondary forest, which have ecological characteristics of Dry Dipteropcarp forest and lathelitic soil type (RFD, 1972, 1975 and 1983). The GIS map points out the forest type in the sampling site of secondary forest as 'Mosaic deciduous forest' (Figure 4.16), which can be characterised as disturbed or secondary forest. The riparian forest has *Homalium tomentosum* Benth. and *Xylia xylocarpa* Taub. as the dominant species in relation to productive soil and deep soil profile, which is naturally distributed in Dry Dipterocarp and Deciduous forest (RFD, 1983). The GIS interpretation indicates the sampling site of riparian forest to be identified as 'Wood-shrubland evergreen' (Figure 4.16) where shrub is highly diversified among all forest types. The conclusion is that the field study produces similar results to the GIS interpretation of forest and vegetation cover types.

The dominant species are classified in the same Genus as *Shorea floribunda* Kurz and *Shorea obtusa* Wall in the primary and the secondary (Figure 4.4 and 4.5). The natural habitat of this Genus is described as Dry Deciduous forest, particularly, *Shorea obtusa* Wall is dominant in the sedimentary terrain with lathelitic soils (RFD, 1972). Generally, the Dry Dipterocarp forests are distributed in a more open space condition, they may have a crown cover of only 40 percent of total area. The second dominant species in the secondary and the riparian forests is the same species, *Xylia xylocarpa* Taub., which has its natural habitat as Dry Dipterocarp forest or Deciduous forest in low land near river.

Due to topographic conditions of riparian forest, the proximity of the river and superficial sheets of water perform an important role, in which *Xylia xylocarpa* Taub. and *Homalium tomentosum* Benth. are capable to distribute in the riparian zone. Kiratiprayoon et al. (1995) indicated that the dominant species in the secondary Dry

Dipterocarp forest at Ngao, Lampang Province, northern Thailand are *Shorea simensis* Miq. and *Shorea obtusa* Wall., with a species diversity of Shanon-Wiener index of 3.51.

The % relative abundance of saplings are fairly variable between seasons with saplings dying or burnt by forest fire during the dry season. In the riparian forest, the % relative abundance of sapling tended to decrease in the dry season, while it changed positively in the secondary forest. Natural and man-made forest fires activated the process of seed germination and regeneration of both *Shorea* and *Xylia* and the chief of Pha Taem National Park informed me that the forest fires increased in intensity and damaged larger areas of the park during the dry season in 1998.

Correspondence Analysis has been widely used as a method to examine the relationships between vegetation types, based on their species composition. Graae and Heskjær (1997) also used Correspondence analysis to evaluate the relative influence of the environmental variables on the vegetation composition and to look for species characteristic of untouched and managed deciduous forests in Denmark. Thus correspondence analysis is appropriate in this stage of study to illustrate a perceptual mapping of forest type related to species composition (Figure 4.21).

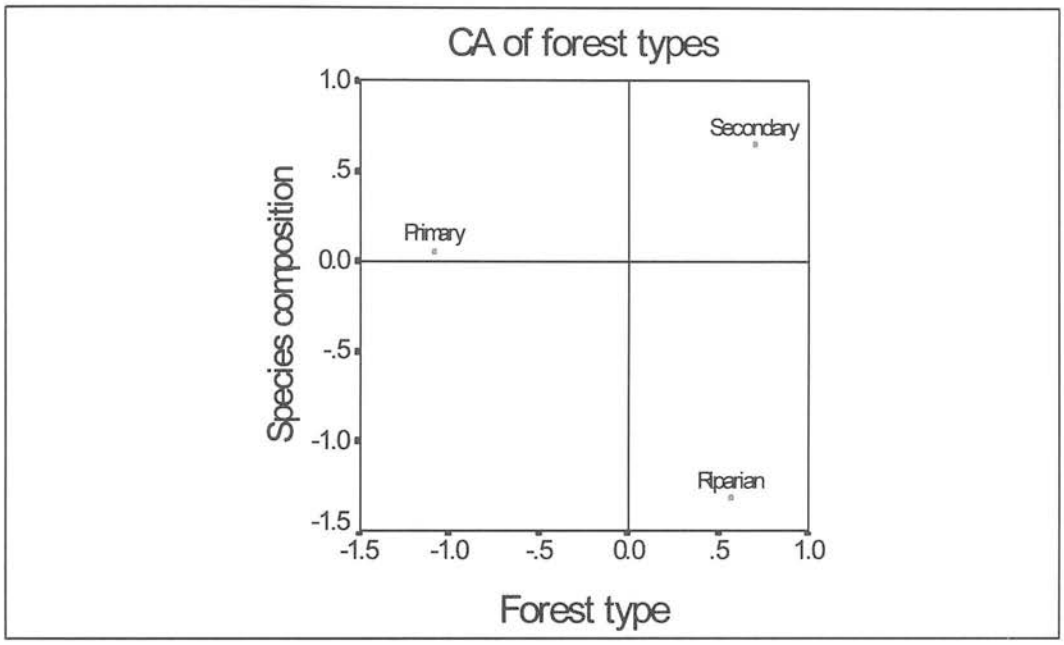


Figure 4.21: A perceptual mapping of forest types and related to species composition.

The mapping in Figure 4.21 shows that the overall composition of the primary, the secondary and the riparian forests are clearly different from each other regarding to the type of species present. Correspondence analysis does not describe the significant difference, which has been tested by '*Kruskal-Wallis test*' (Table 4.6). The test shows that the species composition of the different forest types are significantly different at $X^2 = 228.07$, $p = 0.00$.

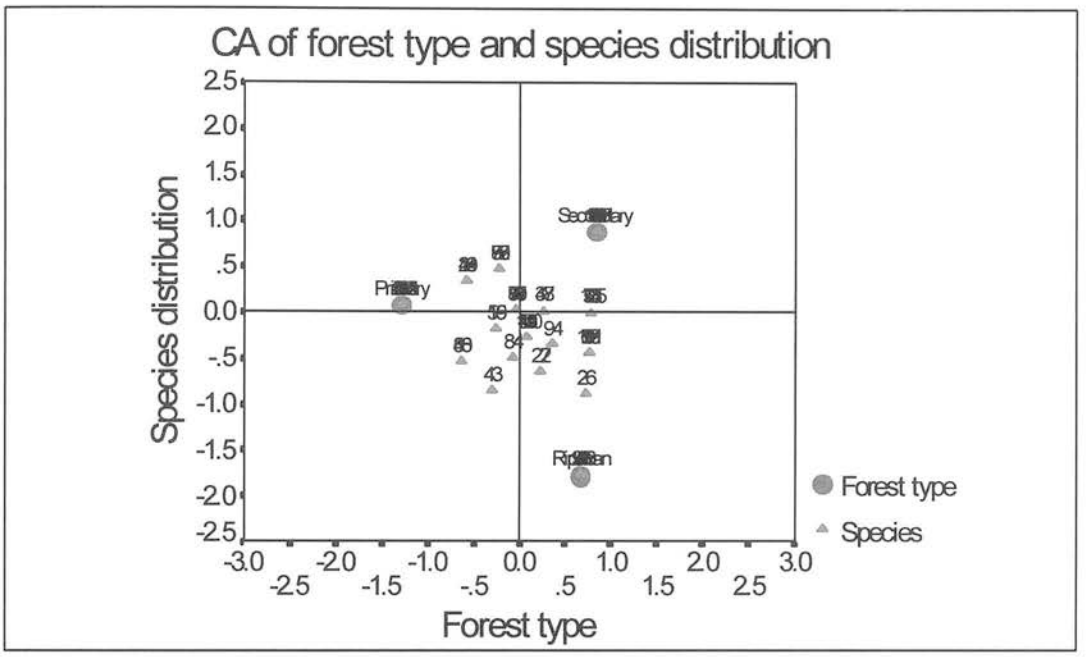


Figure 4.22: A perceptual mapping of forest types and related to species distribution.

Figure 4.22 shows the mapping to describe the relationships between the individual species distribution in relation to the three forest types. The number represents the species with regard to scientific name in Appendix 4.3. Each type of species was considered for its potential distribution in the different forests. Thus some species overlap in their distribution among the different forest types, for example, the species number 26 and 84 are *Cratoxylum pruniflorum* Gogel. and *Shorea obtusa* Wall. which occurred in both secondary and riparian forests. Species number 43 is *Gigantochloa albocilato* Munro which occurred in both primary and riparian forests. Because of the similarity of microclimate e.g. annual precipitation and annual temperature, the species composition of each forest type have features in common and only a few rare species are specific to a single forest type. Endemic species or rare species provide markers of certain forest types. For example, there are a few of the endemic or rare species such as *Adinandra integerrima* T. Andres. Ex Dyer and *Calophyllum saigonense* Pierre, which are found in the primary forest. *Dillenia obovata* (Bl.) Hoogl. and *Gardenia coronaria* Ham. are rare species in the secondary forest. *Dillenia pentagyna* Roxb. and *Strychnow rupicola* Pierre ex Dop. only occur in the riparian forest. The result of the limited number of species restricted to

particular different forest types is that there is no significant difference in Table 4.6 ($X^2 = 0.89$, $p = 0.64$), in the correspondence analysis in Figure 4.22.

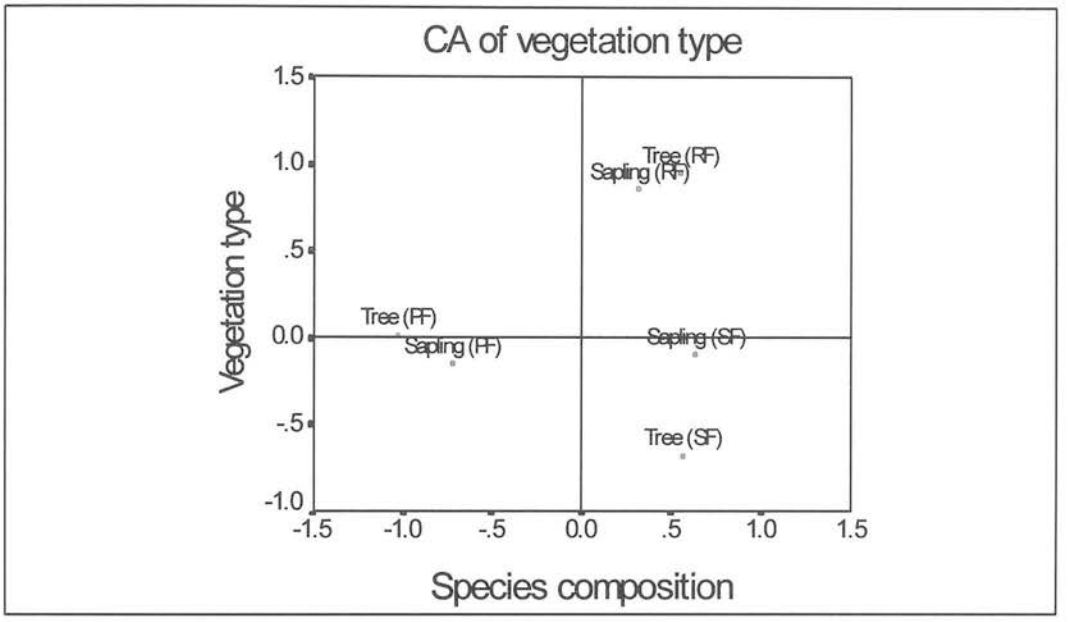


Figure 4.23: A perceptual mapping of species composition and vegetation types (tree and sapling) in relation to forest type (PF = primary forest, SF = secondary forest and RF = riparian forest).

A third correspondence analysis was done to examine the relationships between tree and sapling species among the different forest types (Figure 4.23). The mapping shows that the tree and sapling are closely associated with each other in most of the forest types. The sapling species in the secondary forest are further in characteristics from the trees in that forest, and the pattern indicates links to the primary and the riparian forests.

Table 4.6: A statistical comparison of the relationships of species composition, species distribution and vegetation types between the different forest types during the dry season 1998.

Categories	$\chi 2$	*p-value*	Remarks
Forest type vs. species composition	228.07	0.00	Figure 4.21
Forest type vs. species distribution	0.89	0.64	Figure 4.22
Species composition vs. vegetation type	237.31	0.00	Figure 4.23

It illustrates that the species distribution of trees and saplings among forest types is significantly different between the different forest type at $X^2 = 237.31$, $p = 0.00$ (Table 4.6). The Kruskal-Wallis test of difference also shows that the tree and the sapling species within the same forest type are not significantly different. The X^2 of the primary, the secondary and the riparian forests are 0.17, 0.01 and 0.32, respectively.

Thus the Correspondence Analysis shows that although there are many species in common between three forest types, each forest type has a distinctive combination of species and close relationships between the composition of trees and saplings.

Aquatic ecosystems

There are two study sites of aquatic ecosystems in which phytoplankton was sampled from the Mekong River and the Pak Mun Dam. All phytoplankton samples were classified and identified into 'Phylum' and 'Genus' based on a taxonomic system (Prescott, 1982). Because of limited experience and information, I was unable to identify many taxa to 'Species'. The details of taxonomic composition are tabulated in Appendix 4.4. The % relative abundance is classified with regard to phylum in order to describe the dominant groups of phytoplankton in the different aquatic ecosystems (Table 4.7).

Table 4.7: A comparison of % relative abundance of phytoplankton in the Mekong River and the Pak Mun Dam during the rainy season 1997.

	% Relative abundance	
Phylum	**Mekong River**	**Pak Mun Dam**
Chlorophyta	**37.3**	37.2
Cyanophyta	19.4	**41.9**
Chrysophyta	9.0	11.6
Bacillariophyta	21.7	4.7
Euglenophyta	2.2	2.3
Chloromonadophyta	2.2	0.0
Pyrrhophyta	5.2	2.3
Cryptophyta	3.0	0.0
Total taxa	100.0	100.0

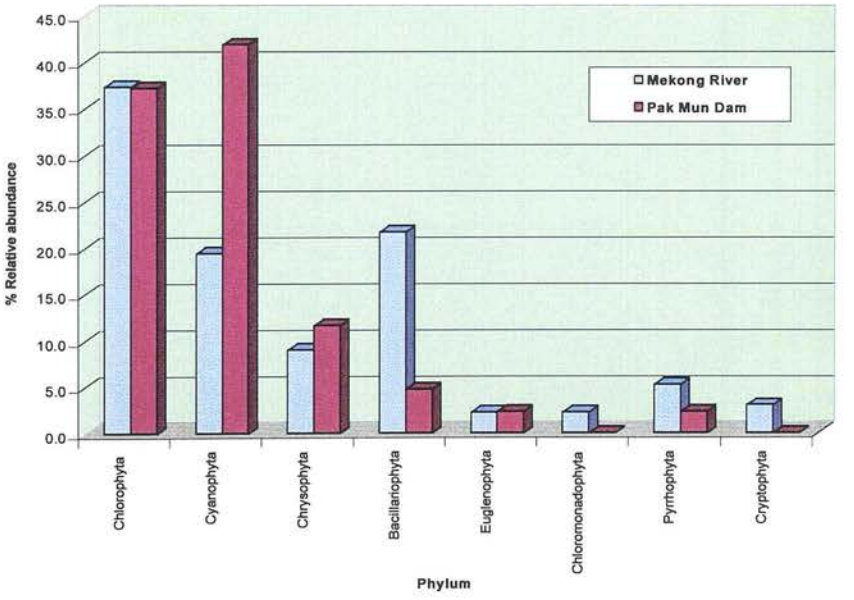


Figure 4.24: A comparison of % relative abundance of phytoplankton in terms of phylum in the Mekong River and the Pak Mun Dam during the rainy season 1997.

Figure 4.24 illustrates that there are eight phyla of phytoplankton in the Mekong while only six phyla occur in the Pak Mun Dam. The percent relative abundance of

phytoplankton that Chlorophyta is the dominant group in Mekong River within lotic condition and Cyanophyta as dominant group in Pak Mun Dam within lentic condition. The percent relative abundance of these dominant phyla is 37.3 and 41.9, respectively (Table 4.7).

Bacillariophyta or diatoms are the second dominant phylum in the Mekong River and rather higher than in the Pak Mun Dam. The favoured situation for diatoms is a high silica concentration, which is the essential element for valve formation. Bormans and Webster (1999) describe that the concentration of diatom or Bacillariophyta is fairly uniform along the river during times of high flow (rainy season) as the diatoms have insufficient time to grow before being advected downstream. Dudgeon (1995) explains that diatom abundance and dominance is related to high silicate concentrations in the rivers. Akbay et al. (1999) report that the phytoplankton species in a dam are mostly dominated by Cyanophyta and Bacillariophyta in relation to warm temperature and high nutrient concentration, a water character normally occur in reservoirs or dams.

Correspondence analysis was used to facilitate the relationships between the Mekong River and the Pak Mun Dam although the data could only consider the trend of phylum composition between in both aquatic ecosystems.

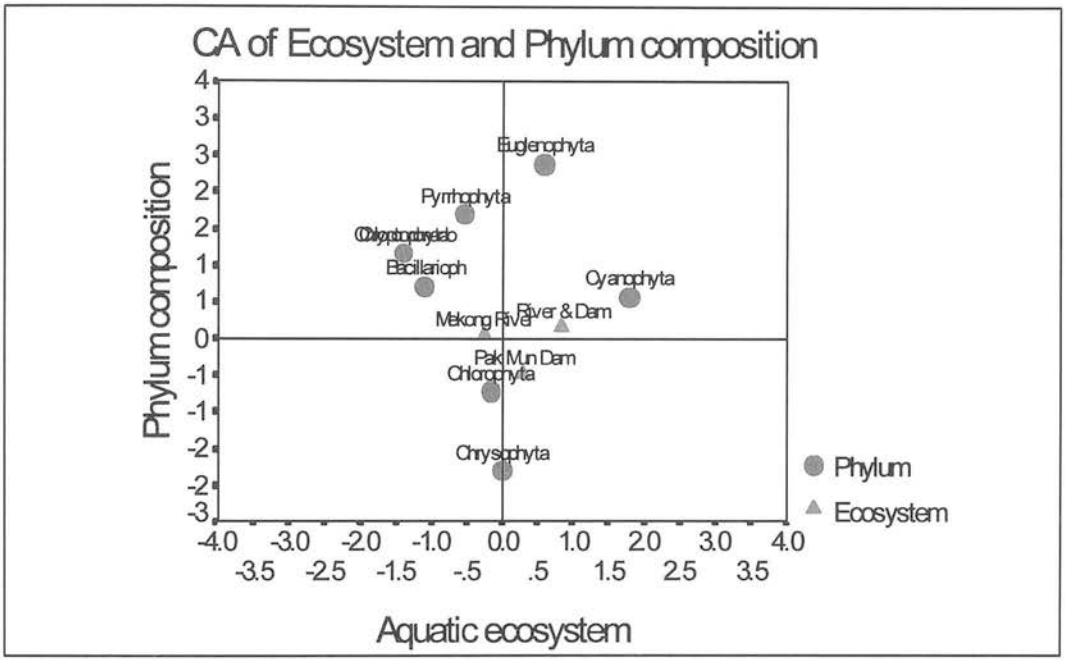


Figure 4.25: A perceptual mapping of the relation of aquatic ecosystems and phylum composition of phytoplankton.

The perceptual mapping (Figure 4.25) indicates the relationships of phytoplankton phylum between the Mekong River and the Pak Mun Dam, with Bacillariophyta, Chloromonadophyta and Pyrrhophyta closely associated with the river ecosystem. Ward (1994) states that the plankton of rivers consists of lentic plankton whcih tolerate riverine conditions.

Chlorophyta and Chrysophyta are associated with the dam ecosystem, while Cyanophyta and Euglenophyta are associated to both ecosystems (Figure 4.24 and 4.25) but Cyanophyta becomes the dominant group in the dam.

The *Kruskal-Wallis test* of difference shows a significant difference related in phylum composition of phytoplankton in the two aquatic ecosystems at $X^2 = 3.58$ at

$p = 0.05$. Thus the hydropower dam changes the ecological condition from a running water system to a standing water system, which affects on phytoplankton compositions and structures.

4.5.3 Species richness

Terrestrial ecosystems

The thai study site was composed of various land use types including forest characteristics such as dry dipterocarp, bamboo and riparian forests. These types of forest were considered as the secondary forest with an ecological succession period related to the pressure of illegal logging practices in the past. In the case of the bamboo forest, it was classified as secondary forest because it exists only in small areas and the number of sampling plots was not enough to provide a more rational analysis. The Laotian study site was characterised as primary forest based on the GTZ information of forest cover.

Table 4.8: Jack-knifing estimation of species richness of tree and sapling in the different forest types during the dry season 1998.

Categories	Upper limit of species richness	Lower limit of species richness	Observed species richness
Primary forest:			
- Tree	73	51	62
- Sapling	54	21	37
Secondary forest:			
- Tree	76	58	67
- Sapling	48	31	39
Riparian forest:			
- Tree	56	20	38
- Sapling	37	5	21

A result of Jack-knifing estimation of species richness shows the expected range and observed number of species in the different forest types during the dry season (Table 4.8 and Appendix 4.5a,b and c). The number of tree species is estimated the range of 73 to 51 in the primary forest while the observed value of species is 62. The range of 76 to 58 tree species is estimated in the secondary forest and the observed species is

67. The number of tree species range of 56 to 20 is estimated in the riparian forest while the observed value is 38. Comparison of tree species richness among all types of forest indicates low species richness in the riparian forest compared to the other two forests, which are similar and higher in species richness.

Sapling species richness indicates a similar trend to tree species, with the sapling species richness lowest at the range from 37 to 5 species and the observed species of 21 in the riparian forest. The primary and the secondary forests have similar sapling species richness (Table 4.8). Ferreira and Stohlgren (1999) studied the effect of river level fluctuation on tree species richness, diversity and distribution in floodplain forest in Central Amazonia. They found species richness and diversity of trees along the edge of dams or reservoirs was significantly lower than riverine and streamside areas. The interpretation is that the dam construction can cause the reduction of tree species richness in the riparian zone because of the inundation process.

Table 4.9: A composition of tree and sapling species which are found only (endemic) in the different forest types.

Endemic species	Primary forest	Secondary forest	Riparian forest
Tree	27	26	7
Sapling	1	3	1
Total species	28	29	8

The results in Table 4.9 provide an indication of potential changes when the Ban Koum dam is constructed. The loss of riparian forest will be the first ecosystem impact. Endemic species in the riparian will disappear, a loss of 12 percent of the total number of species in the area. The rest of species in the riparian forest will remain distributed among the primary and the secondary forests.

The next impact will be associated with the human encroachment to the primary forest. Consequently, the primary forest will potentially loose some of its endemic species (27 tree species, 1 sapling species) depending on the degree of encroachment

pressure. The secondary forest is likely to suffer a moderate impact regarding to the species level.

It is concluded that the primary and the secondary forests will retain some of the high diversity and uniqueness of species in the forest area. However, the damage to the riparian zone caused by implementation of the hydropower project will have an immediate and significant effect on the species diversity in the area. The impact will be not only through loss of endemic tree species, but also through loss of animal species associated with the particular riparian habitats.

Aquatic ecosystems

Despite the limitation of data, instruments and time, the phytoplankton data provide identification and classification to genera. The jack-knifing estimation technique has been used to indicate the approximate range of 'species' richness, which is based on presence and absence in the aquatic ecosystems.

Table 4.10: Jack-knifing estimation of 'species' richness of phytoplankton in the Mekong River and the Pak Mun Dam during the rainy season 1997.

Categories	Upper limit of species richness	Lower limit of species richness	Observed species richness
Mekong River	164	104	134
Pak Mun Dam	53	33	43

The result (Table 4.10 and Appendix 4.6) of the Jack-knifing estimation of phytoplankton species richness shows the number of 'species' range from164 to 104, with the observed value at 134 species in the Mekong River. The estimation of species richness ranges from 53 to 33, with the observed value of 43 species, in the Pak Mun Dam. Thus, the species richness of phytoplankton in the Mekong River is about three times higher than in the Pak Mun Dam. This represents the change of environmental condition, from the lotic condition in the river to the lentic condition. Previous studies have shown that the phytoplankton of rivers usually consists of

lentic phytoplankton species that can adapt and become relatively more abundant than in the lake or dam ecosystems (Ward, 1994). Prat and Ward (1994) mention that the effect of human disturbances on river ecosystems can result in a progressive decrease of species richness and species diversity with increasing intensity and/or frequency of disturbance. Some sensitive species can disappear from river ecosystem when it becomes the reservoir or the dam. Armengol et al. (1994) emphasise that the dam transforms fluctuations of river discharges related to change in the water flow and the water level, so that the nutrients of soil leachates and the organic matter of soils and terrestrial vegetation increase the primary production. Such changes provide optimum conditions for Cyanophyta, Chlorophyta and Bacillariophyta (diatom) growth.

4.5.4 Shanon-Wiener index of species diversity

The species diversity is expressed by the Shanon-Wiener index, which is based on the relative abundance of the rare species in the community (p. 94). This index indicates the structure and stability of heterogeneity in the community or ecosystem. This study is focused on two different ecosystems, terrestrial and aquatic, and considers the species diversity of autotrophs in each ecosystem.

The results of Shanon-Weiner index of species diversity (***H'***) based on tree species provide a comparison between the different forest types (Figure 4.26 and Appendix 4.7a, b and c). The mean of species diversity index in the primary, secondary and riparian forests are 3.14 ±0.85, 2.91±0.70, and 3.04 ±0.45, respectively with no significant difference at *F-prob.*

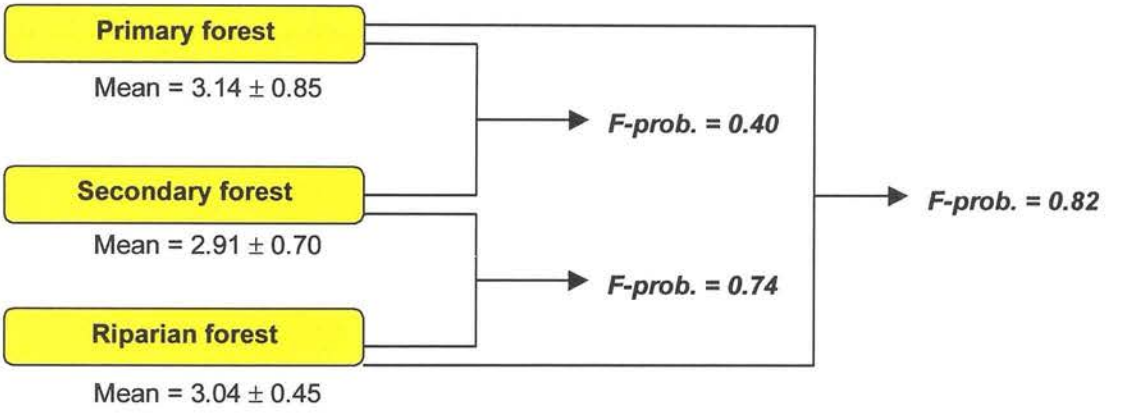


Figure 4.26: A schematic of Shanon-Wiener species diversity index between the different forest types during the dry season 1998.

The Levene test for homogeneity of variance, based on the species diversity index in the different forest types, showed significant homogeneity at $p=0.047$. The interpretation is that the species diversity of three forest types are similar and the quality of sample is appropriate for statistical analysis. This also confirms the forest homogeneity between Thai and Laotian study sites, which will be potentially affected by the Ban Koum Dam Project.

Kiratiprayoon et al. (1995) studied the species diversity of the secondary Dry Dipterocarp forest at Ngao, Lampang Province, northern Thailand in which the Shanon-Wiener index was 3.51. The species diversity index of 3.14 ± 0.85 and 2.91 ± 0.70 for the primary and the secondary Dry Dipteropcarp forest in the present study indicates that the forests in this northeastern region of Thailand near Mekong River have lower species diversity than the same forest type in the northern region. The

difference of species diversity between the two regions probably results from difference in microclimate, soil characteristics and meteorological factors.

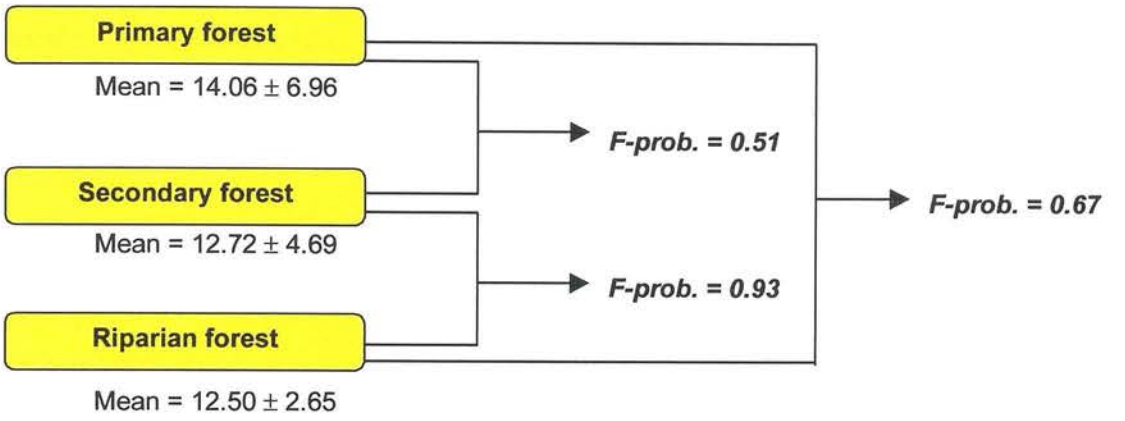


Figure 4.27: A schematic of the number of tree species per quadrat (25x25 m^2) between the different forest types during the dry season 1998.

One-way Anova was applied to compare means of variables among forest types. The number of tree species per sampling plot (25x25 m^2) shows that the primary, the secondary and the riparian forests were not significantly different at *F-prob.* = 0.51, 0.93, and 0.67, respectively (Figure 4.27). It can interpret that the study area has fewer disturbances in the primary forest than the secondary and the riparian forests regarding to the density difference. The Levene test for homogeneity of variances based on the density is significant at $p=0.001$. It means that the density of tree has similarity in the different forest types and the samples between groups are appropriate for statistical test.

Following the identification and classification of phytoplankton, all primary data were analysed density and species diversity. The Shanon-Wiener index of Species diversity and the density of phytoplankton for the Mekong River and the Pak Mun Dam are compared in Table 4.11 (Appendix 4.8).

Table 4.11: A comparison of Shanon-Wiener index of species diversity of phytoplankton between the Mekong River and the Pak Mun Dam during the rainy season 1997.

Categories	**Species diversity index (Mean ± SD.)**	**Density ($x10^6$ no./m^3) (Mean ± SD.)**
Mekong River	4.80 ± 0.08	1.01 ± 0.26
Pak Mun Dam	3.86 ± 0.30	0.24 ± 0.02
F-probability	0.002	0.004

In terms of Shanon-Wiener index of species diversity in Mekong River and Pak Mun Dam, statistical analysis of one-way Anova, shows that the Mekong River has significantly higher species diversity and density of phytoplankton than in the Pak Mun Dam, related to the environmental conditions. The rate of water flow and the continuum of physical factors are obviously reduced when the running water system becomes a standing water system. There is published evidence that the higher current and associated higher turbulence in the river maintains richer river phytoplankton than the lower water velocity with more laminar flow like in the dam system (Ward, 1994). Comparison with total phytoplankton density in tropical rivers shows that the density in the Mekong River is close to Ganges River in India at $1.2x10^6$ individual per m^3 but it is lower than Pearl River in China at $434.7x10^6$ individual per m^3 (Dudgeon, 1995).

4.6 CONCLUSION

This chapter has focused on the species diversity evaluation using basic ecological indicators for species composition, species richness and species diversity. The results are summarised for both terrestrial and aquatic ecosystems in the study area of the planned Ban Koum Project on the mainstream of the Lower Mekong River (Table 4.12).

Table 4.12: A summary of species indicator evaluation at species diversity level between terrestrial and aquatic ecosystems.

Ecosystems	Species indicator evaluation at species diversity level		
	Dominant species/phylum	Species composition and richness	Index of species diversity
Terrestrial ecosystems			
1. Primary forest	*Shorea floribunda* Kurz	62 (73-51)	3.14 ± 0.85
2. Secondary forest	*Shorea obtusa* Wall	67 (76-58)	2.91 ± 0.70
3. Riparian forest	*Homalium tomentosum* Benth.	38 (56-20)	3.04 ± 0.45
Aquatic ecosystems			
1. Mekong River	Chlorophyta	134 (164-104)	4.80 ± 0.08
2. Pak Mun Dam	Cyanophyta	43 (53-33)	3.86 ± 0.30

This study can conclude the without-project situation that

- The terrestrial ecosystems show a high diversity in terms of number of species exemplified by the 116 tree species. Many of these species are common between the three main forest types but the composition of the communities and the dominant species are significantly different in the three forests.
- The primary and secondary forests are richer in species than the riparian forests and have more endemic species (39-42 percent) than the riparian forest (16 percent). Overall, 56 percent of the 116 species are restricted to only one type of forest.
- Although the riparian forests are relatively poor in species, they will be completely removed through inundation following dam development,

resulting in a loss of 8 species which do not occur in other types of forest i.e. 7 percent of all tree species.

The prediction of the with-project situation indicates that

- Loss of the primary and the secondary forests are associated with the dam construction and the inundation of reservoir.
- Loss of the riparian forests will probably also result in the loss of specific fauna, which are associated with the particular conditions in that zone.
- Encroachment of people into the primary forest following dam construction is likely to occur and result in conversion to secondary forest with a probable further loss of endemic species.
- Comparison of phytoplankton in the Mekong River at the site of the planned Ban Koum Hydropower Project with the existing Pak Mun Dam reservoir showed a major reduction in species diversity, change in the dominant taxa, and reduction in density. These changes are related to modification of water flow and water quality.
- The forests of the Ban Koum belong to the Dry Dipterocarp type have biodiversity characteristics similar to this type of forest in other areas. Similarly, the results for the phytoplankton are similar to other major tropical rivers and to observe changes, which follow dam construction.
- Study of the species diversity of the Mekong River area has shown that qualitative and quantitative information can be readily obtained and interpreted in relation to the potential effects of hydropower dam construction.

The results of this chapter will be incorporated with ecosystem evaluation in chapter five and socio-economic evaluation in chapter six for the final chapter of a new approach of impact assessment in chapter seven.

CHAPTER FIVE
ECOSYSTEM DIVERSITY EVALUATION

Ecosystems have structures and functions, which provide habitats, energy and nutrients to support organisms inside the systems. By their nature, ecosystems are highly complex and it is difficult to quantify and understand the various roles which they play for mankind. From the past to the present, people depend on ecosystems for their natural resources of foods, medicines, materials, commodities and so on. The pressure of natural resource utilisation is gradually increasing and is not strongly controlled. Therefore, improved strategies are needed to utilise natural resources more efficiently without over exploitation and based on sustainable use. Ecosystem evaluation should be one of the strategies, providing a new challenge to bring scientific understanding into decision-making arenas. Ecosystem evaluation builds on scientific information to support and to help decision-makers to face up to the rationality and the reality of moral tensions and conflicts among present and future generations. It must also consider how to share natural resources with other living organisms.

Bingham et al. (1995) considered how to improve the availability and use of information about ecosystem values in making policy decisions. One of the limitations to ecosystem evaluation is that it is extremely difficult to measure ecosystem functions and processes and to predict the impacts of disturbances to those complex systems. Even the phrase 'ecosystem evaluation' presumes a level of agreement among the individuals and disciplines that cannot be taken for granted. Experts from within and between disciplines approach ecosystem evaluation from very different perspectives. It is especially critical to explore the problem of valuing ecosystem services so that it becomes a part of the information set used in policy decisions.

The problems of evaluating ecosystems can be categorised as follows:

- Improved application of available tools for monetary valuation, combined with greater use of existing information rather than to reliance on expensive

primary data gathering.

- Greater appreciation that good valuation depends on sound ecological knowledge. Ecosystem services can be valued in monetary terms only when they are well understood. In the meantime, decision criteria to adequately address ecological uncertainties need to be devised, and such criteria are likely to involve human values beyond monetary values.
- Recognition that even if ecosystem services were perfectly understood and evaluated in monetary units according to accepted economic precepts, the problems of ecosystem evaluation would not be completely solved. Some future values will always be unforeseen.
- The intrinsic values for species and ecosystems, as opposed to their values to people, need to be expressed. Categorising services that ecosystems provide may help in deciding what to measure and selecting valuation methods. For example, productivity and nutrient cycling are ecosystem services, which are important to sustain and maintain the ecosystems but they are not necessarily direct services to people.

Although there are many problems to address, some cases a single ecosystem service is usually the product of two or more ecosystem functions whereas in the other cases a single ecosystem function contributes to two or more ecosystem services (Costanza et al., 1998). It is difficult and complicated to emphasise on only one ecosystem service as the representative for the whole ecosystem functions but it is better than no recognition of ecosystem into the evaluation.

Therefore, this chapter will focus on the evaluation of a particular ecosystem service. It explores *carbon storage* as one simple indicator in ecosystem evaluation. Carbon storage can be defined in terms of 'ecosystem good' related to primary production in organic components with providing the energy to maintain biological needs and 'ecosystem service' also involved to nutrient cycling among organisms in the different trophic levels through food webs. The importance of carbon storage can be summarised as:

- Important feature of biological structure and functions

- Sensitive the natural and human changes
- Important in relation to the major global issue of climate change

The carbon storage has some limitations as an indicator of ecosystem diversity value because ecosystem diversity encompasses the broad differences between ecosystem types, and the diversity of habitats and ecological processes occurring within each ecosystem types. The carbon relates to only one of ecosystem service in ecosystem functions even though carbon can be stored at the different rate or capacity depending on the spatial and temporal scale without relationships to the evolutionary processes like species diversity level. However, the amount of carbon storage can reflect the potential of ecosystem to store carbon in biomass, which related to environmental factors and also ecosystem types. The production as biomass also supports the flow of energy and nutrient in the whole ecosystem. Therefore, the carbon storage is justified as an appropriate indicator for representing the ecosystem value at certain period of time scale.

The case study of Ban Koum hydropower project and the existing Pak Mun Dam (see 2.4 and 4.2 for main features) are used to test the hypothesis of this study. This chapter is organised as follows:

- Scope of the study
- Measurement of carbon storage in ecosystems
- Data collection and data analysis
- Results and discussion
- Conclusions

5.1 SCOPE OF THE STUDY

This chapter is focusing on the ecosystem level of biodiversity exploring carbon storage as an indicator of ecosystem services for biodiversity evaluation. It is important to generate a quantitative, practical and rational indicator as a representative of ecosystem services. Figure 5.1 indicates the scope of study in detail.

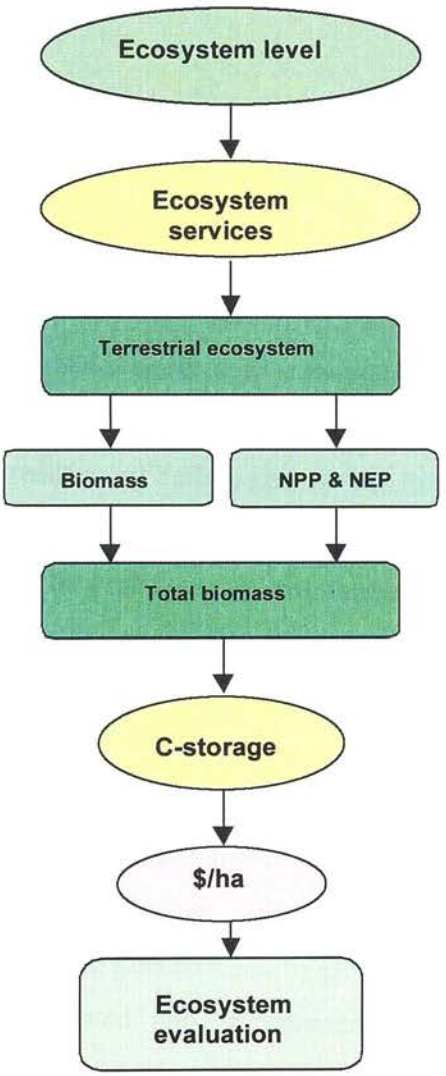


Figure 5.1: Scope of the ecosystem diversity evaluation.

The study distinguishes between terrestrial and aquatic ecosystems and in each ecosystem, biomass and NPP is measured as a basis for estimating the total biomass

change during 50 years period. The total biomass is converted into monetary values under three scenarios based on the CO_2 mitigation options. Finally, the results are applied to value the cost of terrestrial ecosystem and aquatic ecosystem services within the biodiversity evaluation for the new alternative impact assessment in the next chapter.

5.2 MEASUREMENT OF CARBON STORAGE IN ECOSYSTEMS

Ecosystems have a fundamental process of primary production (autotophy) by which carbon enters the biosphere from the atmosphere. Carbon may accumulate in plant biomass or be released in plant respiration. NPP provides a measure of plant growth over time and represents the balance between plant photosynthesis and respiration. Following death of plants, or consumption by animals, carbon may be sequestered in detritus pools or in soil and then released through biomass decay (respiration) and/ or burning. NEP thus represents the balance between NPP and heterotrophic respiration, giving a measure of carbon gain or loss in the ecosystem.

As ecosystems develop through successional stages and move towards a more steady state, they have additional growth tends to increase the biomass and sequester carbon. The standing biomass of ecosystem plus NPP provides an estimate of accumulating carbon stock in an ecosystem, the amount of carbon storage can then be explored in terms of monetary value. Thus, carbon storage may be a simple quantity as an ecological indicator for various ecosystem services in evaluation. From one particular point of view, carbon storage needs urgent consideration because it directly affects the phenomenon of global warming. If the carbon storage approach can be incorporated into environmental consideration and sustainable development, then it may provide an additional indicator for decision-makers to account for conservation of natural and managed ecosystems in relation to carbon storage for CO_2 mitigation.

The major parameters at ecosystem level that must be considered are biomass, NPP, NEP and carbon storage. The biomass of tree, sapling and ground floor vegetation in

terrestrial ecosystems is mainly considered because of their known potential for management of carbon sequestration. In aquatic ecosystems, although primary production may be high there is little carbon storage in plants because of the rapid phytoplankton turnover rate; storage is mainly in sediments and the system is relatively open with important lateral transfers.

However the potential measurement and application of carbon storage in both terrestrial and aquatic systems is considered, and the pathways for carbon the two systems are illustrated in Figure 5.2. This illustrates the pathways of carbon in terrestrial ecosystems (A) involving the biological process such as photosynthesis, respiration and decomposition in relation to the trophic structure. After carbon is absorbed by a plant through photosynthesis in its green parts, the carbon assimilate is transported and partitioned between the different plant tissues, such as leaves, branches, stems and roots. During this process some carbon is lost through respiration. The remaining carbon is stored and creates a carbon sink as living plant biomass. The primary production from autotrophs serves as the energy source to heterotrophs, including decomposer, microflora and microfauna which utilise the carbon organic matter for its energy source and release CO_2 (or CH_4) to atmosphere. In terrestrial ecosystems, organic carbon is broken down by a variety of organisms but predominantly by bacteria in neutral/alkaline soils and by fungi in acid soils (Verburg et al., 1995). Upon decomposition, in addition to carbon, nutrients are being mineralised. The carbon pathways in terrestrial ecosystem are not as complicated compared to the aquatic pathways (B).

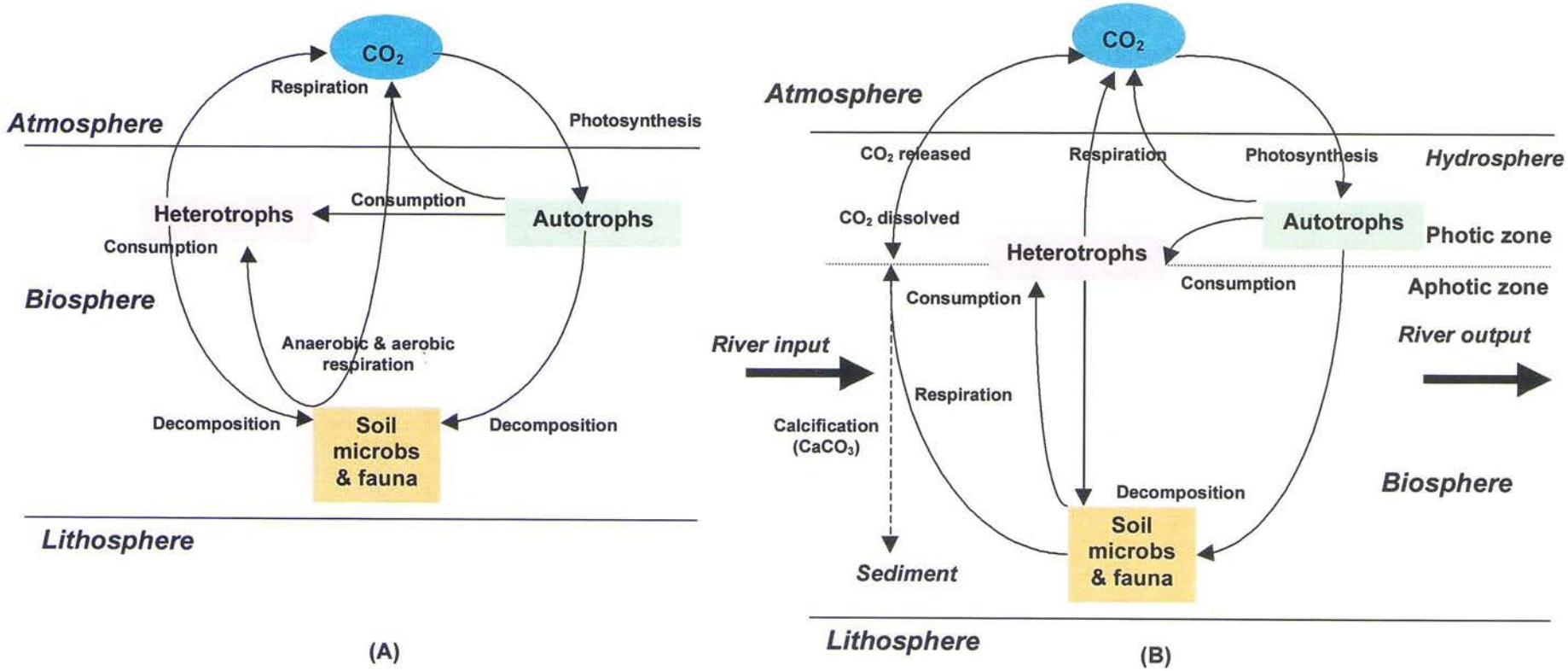


Figure 5.2: The pathway of carbon in (A) terrestrial ecosystem and (B) aquatic ecosystem.

From the literature reviews, it seems to give much more attention to the terrestrial ecosystem than the aquatic ecosystem in relation to the carbon mitigation. There are some reasons to explain why the terrestrial ecosystem is likely important and taken into the consideration according to the carbon pathways in Figure 5.2. In the aquatic ecosystem, the pathways of carbon are complicated because there are not only the biological process but also the physical and chemical process in the water and sediments. Further, the special characteristics of river ecosystems include the continuum property and the short retention time of nutrient input into the system.

Figure 5.2 (B) indicates that photosynthesis, respiration and decomposition are involved directly to carbon cycle in organisms between each trophic level. However, the physical processes involve the pathways of carbon in relation to sedimentation of detritus from upper water level to the bottom by gravity, which will allocate carbon from hydrosphere to the sediments.

5.3. DATA COLLECTION AND ANALYSIS

5.3.1 Data collection

Terrestrial ecosystems

The period of data collection was planned according to seasonal variation during the rainy season with high water period in July 1997 and dry season with low water period in April 1998 (Figure 4.2 and 4.3 in chapter four). The sampling plots were located in main types of land use as shown in Figure 5.3 based on the mapping of satellite imagery. The study sites are composed of various types of land-use such as primary forest, secondary forest (riparian forest, bamboo forest), riparian zone, home gardening, paddy rice field as well as grass land.

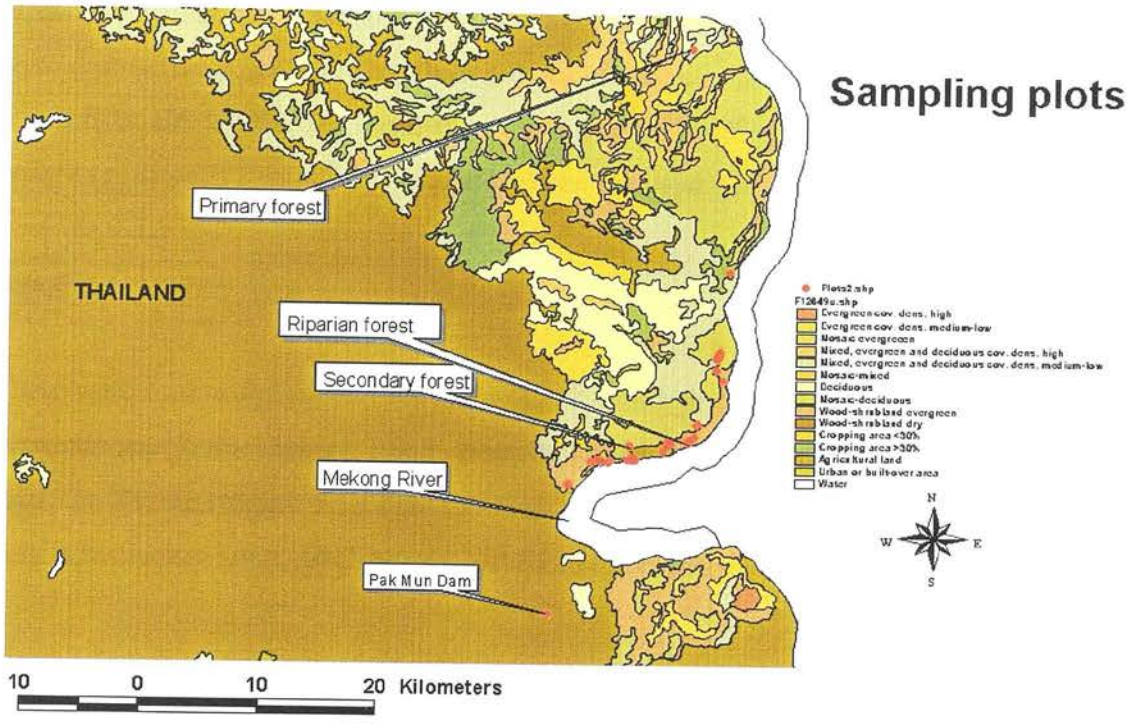


Figure 5.3: The location of the main sampling areas and plots on Thai boundary from GIS map (RFD, 1998) (See also Figure 4.14 and 4.16).

A randomised sampling method was adopted and each land use type was sampled at a quadrat size of 25x25 m^2 (Figure 5.4).



Figure 5.4: A sampling plot (25x25 m^2) in the secondary forest, Thai study area during the dry season in 1998.

In each sampling plot, five subplots (1x1 m^2) were randomised. Saplings and herbs were destructively harvested as aboveground biomass. All biomass of each subplot was left to air dry for 1-2 days, then oven dried at 105° C for 24 hours, and dry weight (g) directly measured at Chulalongkorn University laboratory in Bangkok.

Aquatic ecosystem

There were four sampling stations in the Ban Koum hydropower proposed area along the study site in the Mekong River, from Ban Kum up to Kaeng Soi upstream from Kan Tha Kwean (Figure 5.5). Three stations were sampled in the Pak Mun Dam (see details in chapter four). Each station had four replicates.



Figure 5.5: The location upstream on the Mekong River between Thailand (foreground) and Lao PDR (far side) during the rainy season 1997.

5.3.2 Data analysis

5.3.2.1 Physical and chemical factors

The physical factors were collected as annual precipitation, water temperature; air temperature, pH, dissolved oxygen (DO), total suspended solid (TSS), flow rate and conductivity, which have been regularly recorded by the Department of Energy Development and Promotion in Bangkok. The water temperature, transparency

depth and pH were measured at the sampling stations

5.3.2.2 Total biomass (tonne/ha)

Terrestrial ecosystems

The main challenge in measurement of biomass in terrestrial systems is the sampling of large trees. Fortunately, foresters have developed non-destructive methods through measurement of the diameter at breast height or 130 cm from ground (Phillip, 1994 and Gilbertson et al., 1985). This diameter is applied to regression equations e.g. Ogawa et al. (1965) in order to estimate tree height and above ground biomass in the dry dipterocarp forest, Thailand. For sapling biomass, the diameter above ground and height of sapling was directly measured and selected saplings destructively harvested for biomass measurement. The sapling biomass was then analysed for a specific regression equation to estimate all saplings in the study sites. Ground floor biomass was harvested and the dry weight directly measured. For bamboo, a sample was randomly harvested and weighted, and a mathematical equation in order to estimate the rest of bamboo biomass.

The aboveground biomass of trees was estimated according to the regression equation for dry dipterocarp forest in the northern Thailand by Ogawa et al. (1965) as follows:

$$Height\ (H) = 1/[(0.944/D) + 0.0278] \qquad \text{(Equation 5.1)}$$

$$Total\ above\ ground\ biomass\ (TAGB) = 0.043 * (D^2 H)^{0.950} \qquad \text{(Equation 5.2)}$$

Where H = Height of tree (m)

D = Diameter of tree (over 4.5 cm) at breast height (130 cm)

The application of similar regression equations developed by Brown et al. (1989 and 1992) in relation to tropical rain forest in Southeast Asia was also examined. The

regression equations of H and $TAGB$ by Brown et al. (1989) give $r^2 = 0.61$ and 0.97, respectively. These are as follows:

- Equation by Brown et al. (1989)

$$H = Exp[1.0710+0.5677*\ln D] \quad \text{(Equation 5.3)}$$

$$TAGB = Exp[-3.114+0.972*\ln(D^2H)] \quad \text{(Equation 5.4)}$$

The equation by Brown and Iverson (1992) with $r^2 = 0.61$ and 0.83, respectively are as follows:

- Equation by Brown and Iverson.(1992)

$$H = 6.972+0.468*(D)-0.0015(D^2) \quad \text{(Equation 5.5)}$$

$$TAGB = 1.276+0.034*(D^2H) \quad \text{(Equation 5.6)}$$

- Equation by Dean (1999)

An equation has also been developed by Dr. J. Douglas Dean (Institute of Terrestrial Ecology, Bush, Edinburgh, Scotland) based on Brown's data but adopting a specific gravity for a tropical tree of 0.71. This regression equation with $r^2 = 0.96$ is:

$$TAGB = 0.1+0.0370*(D^2H) \quad \text{(Equation 5.7)}$$

To examine the application of the four sets of equations for above ground tree biomass in the dry dipterocarp forest, each equation was tested against the same field data set generated in the present study. The result of comparison of the four equations is shown in Figure 5.6 (Appendix 5.1).

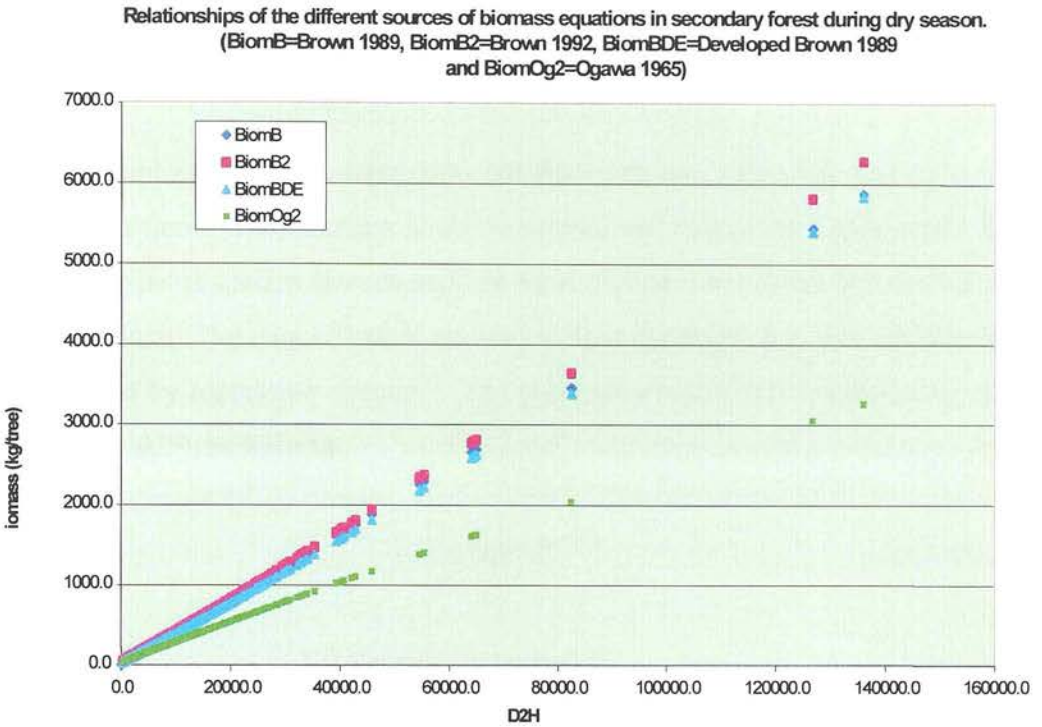


Figure 5.6: Relationships between total above ground biomass per tree and D^2H with regard to the different equations.

The Brown's equation (1989) (Equation 5.4) and the development of Brown's equation (Equation 5.7) give similar estimates of above ground biomass. There are slightly lower than Brown's equation (1992) (Equation 5.6). The estimates of these three equations are about double that given than by Ogawa's equation (1965) (Equation 5.2).

The reason for the lower estimate by Ogawa (1965) equation is probably the difference in type of forest. The Mekong study site is classified as *Dry Dipteropcarp forest,* based on the presence of *Shorea* spp.and *Xylia xylocarpa* Taub. as the dominant species and is similar to that described by Ogawa. This type of forest is much more open and has smaller trees than the tropical rain forest studied by Brown in Malaysia. The rain forest usually is dense and high biomass density identified as closed forest. According to Brown (1984) the general total forest biomass in tropical moist forest is about 63 percent of that of closed rain forest. Extrapolation to dry

open forest, as it is in the present study, is probably most realistically based on Ogawa.

For the saplings, samples were collected from primary, secondary and riparian forest at ground floor. The diameter at above ground and height were measured. Saplings of each type of species in each quadrat were chopped, left to air dry, then oven dried for 24 hours. The data of height and dry weight (biomass) for each species was then calculated by regression equation. The regression equation of sapling was estimated with $r^2 = 0.39$, as follows

$$Y = 0.068 * X^{2.429} \qquad \text{(Equation 5.8)}$$

Where Y = Sapling biomass (kg)

x = Diameter of sapling (cm)

This equation was applied to estimate the total samples of 306 saplings in the study area for the carbon storage estimation. It also estimated the average of sapling biomass at 1.84±0.52 kg/sapling in this study (Appendix 5.2).

In an independent study of *Shorea spp. (S. joharans, S. leprosula and S. parvifolia)* in the dipteropcarp forest in Indonesia, Mr. Mike Clearwater at Institute of Ecology and Resource Management (IERM), University of Edinburgh established a similar regression (Equation 5.9) for saplings, with $r^2 = 0.87$.

$$Y = 0.1053 * X^{2.4165} \qquad \text{(Equation 5.9)}$$

Where Y = Sapling biomass (kg)

x = Diameter of sapling (cm)

Application of Clearwater's equation to the individual sapling Thai sample data gave an estimated biomass an average 21percent higher than measured. The equation from the Thai site indicates biomass to be 20 percent lower than the field data. The

explanation is probably that most of sapling data in Clearwater's equation are for *Shorea spp.* which is a hardwood, while the sapling data in this study was collected from 14 species which are mainly softwood with only one *Shorea obtusa* in dry dipteropcarp forest.

The Thai study site has small patchs of bamboo forest mixed in the secondary forest and dominated by *Arundinaria ciliata* A. Camus. This bamboo species was also directly harvested from the sampling plot and a method was developed for rapid estimation of the biomass in bundles of bamboo sticks collected from the sample plots. The method is based on size of stick, the number of sticks per bundle and the circumference of bundle (cm). Samples of bamboo sticks were harvested and left to air dry, then dried in the oven at 105°C for 24 hours for measuring dry weight (kg). The result shows in Table 5.1.

Table 5.1: The characteristics of bamboo species *Arundinaria ciliata* A. Camus in the bamboo forest in Thai study sites.

Parameters	Mean	±SD.
Number of bamboo stick per bundle (stick/bundle)	24.55	16.61
Circumference of whole bundle (cm/bundle)	102.90	59.87
Biomass of bamboo stick (kg)	0.65	0.13

A regression equation was developed from the field data to estimate the number of bamboo sticks per bundle (r^2 = 0.88) based on the simple measurement of the circumference of a bundle:

$$Y = (0.2711*X)-3.34701 \qquad \text{(Equation 5.10)}$$

Where Y = Number of bamboo stick per bundle (stick)

X = Circumference of whole bamboo bundle (cm/bundle)

The estimated number of sticks per bundle was then converted to bamboo biomass by multiplying by 0.6535 kg/stick, which was measured for the original field data (Table 5.1). The estimated bamboo biomass was then included into the biomass of secondary forest.

5.3.2.3 Net Primary Productivity (NPP in g/m2/year)

NPP is defined as the difference between total carbon uptake through photosynthesis and losses through maintenance or growth respiration. NPP is a fundamental property contributing to ecosystem performance. It is dependent on the characteristics and interactions of the vegetation, soil, and weather, and integrates these effects in a spatially explicit manner. It provides a record of these interactions e.g. in annual growth increments of woody species. Because of its direct relationship to atmospheric CO_2 it plays a strong role in the global climate system. Seasonally it accounts for the latitudinal dependence of the atmospheric CO_2 concentration, which can be detected from satellites.

In the past, NPP has not been measured systematically or frequently because of the limitations of measurement methods. Thus, only typical values are available for various ecosystems, and information on the inter-annual variability is only available for a limited number of specific sites. It is difficult to measure NPP directly in the field because of many constraints, however, there are many approaches to estimate NPP by using mathematical models, satellite image interpretation or physio-ecological measurement of individual plants. In this study a widely used NPP model was adopted because of its potential general application.

Terrestrial ecosystems

Most global NPP models fall into one of the following three classes (IGBP, 1994):

- ***Statistical models,*** applicable at the global scale, based on the assumption that climatic factors determine NPP. They use empirical relationships between NPP and driving variables. They are constructed by using

regressions between experimental measurement of NPP and climatic variables such as precipitation or temperature. In the early 1970s, the work on modeling NPP on the different terrestrial ecosystems was based upon the correlation between NPP and vegetation period (i.e., length of growing season). An early NPP regression model was constructed by Leith and Box in 1972 and entitled the C.W. Thornthwaite Memorial Model (Esser et al., 1997). This was developed as the 'Miami model' (Leith, 1975) in which more than 1000 measurements of annual NPP were correlated with annual precipitation and temperature. The 'Montreal model' used actual evapotranspiration to generate simple exponential relationships (Esser (1991). Esser et al. (1994) improved the 'Miami model' by adding the capability to run it with a monthly time step and by taking into account the areas of natural vegetation and crops in each grid element, soil fertility, and also fertilizer use.

- ***Parametric models or 'top-down'***, lumped-parameter models (Jarvis, 1993, Vitousek, 1993) try to describe at a macroscopic level the main processes occuring within a plant or an ecosystem. The model computes the fraction of photosythetically active radiation (PAR) absorbed by the canopy (APAR = Absorbed PAR). An absorption coefficient is defined as the ratio APAR/PAR. A photosynthetic efficiency coefficient allows the amount of carbon or plant material fixed in photosynthesis to be calculated. The absorption coefficient can be estimated from various combinations of visible and near infrared reflectance, or vegetation indices, measured by sensors carried by satellites. This approach has been used with weekly or monthly satellite measurement.
- ***Mechanistic models*** integrate the knowledge derived from empirical and theoretical studies to describe the component processes underlying plant growth. These models describe explicity processes such as photosynthesis, respiration, water use, assimilate allocation and their dependence on environmental conditions (meteorology, soil type, nutrients). These models have been created more recently, for example, 'Terrestrial Ecosystem Model' (TEM) (Raich et al., 1991, Melillo et al., 1993). Depending on the objectives, these models emphasise different individual processes such as

photosynthesis, water balance, and nitrogen cycling and are run with the short time steps as hour to month. Whilst they are useful for exploring physiological relationships, they require large amounts of data and are difficult to validate over larger periods.

For the present exploratory study, a simple and practicable method to estimate NPP, the 'Miami model' was considered adequate. The objective is to provide variables for impact assessment, which are based not only on simple measurements but also allow general application of results to regional and global scales. Thus, using climate data, the early statistical (correlative) model was refined to give the following functions and published as the 'Miami Model' (Leith, 1972, 1973, 1975), which provided the basis for the development of more sophisticated models:

$$NPP = \min [NPP_T, NPP_p] \quad \text{(Equation 5.11)}$$

$$NPP_T = 3000/(1 + e^{1.315-0.119T}) \quad \text{(Equation 5.12)}$$

$$NPPp = 3000(1 - e^{-0.000664p}) \quad \text{(Equation 5.13)}$$

Where T = mean annual temperature

p = mean annual precipitation

NPP (g/m2/year) is estimated as the minimum of two functions (Equation 5.12 and 5.13), which limit productivity. The Miami Model continues to be used as a benchmark for simulation of global NPP (Foley, 1994). It was modified using soil fertility factors and published as the Hamburg Model (Esser et al., 1982). The 'Miami Model' was adopted to estimate NPP as total net primary productivity in the terrestrial ecosystems in the Mekong River Basin Area according to Equation 5.12 and 5.13.

Like NPP, Net Ecosystem Productivity (NEP in kg C/ha/yr.) includes the annual sum of carbon flux by daytime photosynthesis of carbon released by respiration of fixed carbon. Unlike NPP, NEP includes carbon released by heterotrophs through microbial respiration of organic compounds in dead plants and branches, in surface

leaf litter, and in soils, and respiration of animals as herbivores, carnivores or decomposers. Thus, NEP is a measure of the net annual carbon gained or lost from the long-term carbon stocks the ecosystem in any given region or location. As such, it is a critical variable in determining long-term behaviour of the terrestrial carbon cycle, and in defining changes in long-term carbon stocks. In general, NEP is positive during successional development of ecosystems, tending to zero at maturity and negative in old or degrading ecosystems or through disturbance such as fire.
The net fluxes between ecosystems and the atmosphere (NEP values) are essential for investigation of CO_2 content changes in the atmosphere and can be calculated by

$$NEP = NPP - Rh \qquad \text{(Equation 5.14)}$$

Where NPP = Net primary productivity
Rh = Total heterotrophic ecosystem respiration

Kobak (1995) calculated NEP in the different forests and found NEP of the young forests reaching a maximum of 20 percent of NPP while the mature forests become very low at maximum 4 percent of NPP.

In all cases described in this section, biomass estimates (weight/area) were converted to carbon/area using a common factor of 0.5 (Atjay et al., 1979; Iverson et al., 1992; Brown et al., 1993; Dixon et al., 1994 (a) and Cannell and Milne, 1995).

Aquatic ecosystem

NPP of aquatic ecosystem can be measured more directly and easily as the rate of phytoplankton photosynthesis in situ. Techniques for measuring rates of photosynthesis are based on the biochemical reactions e.g. rates of oxygen production, rates of utilisation of CO_2 or water, or changes in the concentration of organic matter. Changes in oxygen production or CO_2 uptake are measured in water samples incubated either in situ or under conditions of light and temperature

simulated for the depth from which the samples were collected during the rainy season in 1997.

In the present study water samples from 30cm depth were collected in both transparent (light) and in completely opaque (dark) bottles. This method is called "Dark-Light method" (Wetzel and Liken, 1991) in Figure 5.7. The bottles (usually duplicate light bottle and one dark bottle) were filled as rapidly as possible from the Van Dorn sampler. The dark bottle was covered with aluminum foil to make certain that no light penetrated into the bottle. A metered line was used to suspend the two light and one dark bottles at the same station for incubation in the river or dam. Time zero of the incubation was recorded when half of the bottles had been lower. All the replicate of light and dark bottles from all station were done in the same way. The bottles were incubated for three hours in water. The length of the incubation period is related to the intensity of photosynthetic activity. During the incubation of the samples of the phytoplankton, the initial concentration of dissolved oxygen (initial bottle value, *IB*) would be expected to decrease to a lower concentration in the opaque bottles from respiration (dark bottle value, *DB*). Conversely, the initial concentration would change to another concentration (light bottle value, *LB*) in the transparent bottles as a result of the difference between photosynthetic production and respiratory consumption of oxygen.

$IB - DB$ = Respiration per unit volume per time interval

$LB - IB$ = Net photosynthesis per unit volume per time interval

$(LB - IB) + (IB - DB)$ = Gross photosynthesis

To convert from mass of oxygen to mass of carbon, the values of oxygen production and consumption must be multiplied by the ratio of moles of carbon to moles of oxygen ($12mgC/32mgO_2 = 0.375$). Then,

$$Gross - primary - productivity = \frac{[(LB) - (DB)](1000)(0.375)}{(PQ)t}$$

(Equation 5.14)

$$Net - primary - productivity = \frac{[(LB)-(IB)](1000)(0.375)}{(PQ)t}$$

(Equation 5.15)

$$\text{Re}spiration = \frac{[(IB)-(DB)](RQ)(1000)(0.375)}{t}$$

(Equation 5.16)

Where

t = hours of incubation

IB, LB, DB = oxygen in mg/l

PQ = photosynthetic quotient of 1.2

RQ = respiration quotient of 1.0



Figure 5.7: Dark-light BOD bottle of the Mekong River sample station during the rainy season 1997.

The NPP of aquatic ecosystem can provide information in relation to the potential of the aquatic ecosystem to make use of atmospheric carbon through the primary production by autotrophs. Within the present study it was not possible to measure transfers to heterotrophs or accumulation of carbon in sediments or input and output through water transport. Thus NEP was not calculated for the aquatic system.

5.4 RESULTS AND DISCUSSION

5.4.1 Physical factors

5.4.1.1 Meteorological characteristics

Data from the Department of Energy Development and Promotion provide a ten year record (1988-1997) for the meteorological characteristics as follows:

- Annual maximum, minimum and mean air temperature in degree Celsius (Figure 5.8 and Appendix 5.2)
- Annual precipitation in millimeters (Figure 5.9 and Appendix 5.3)

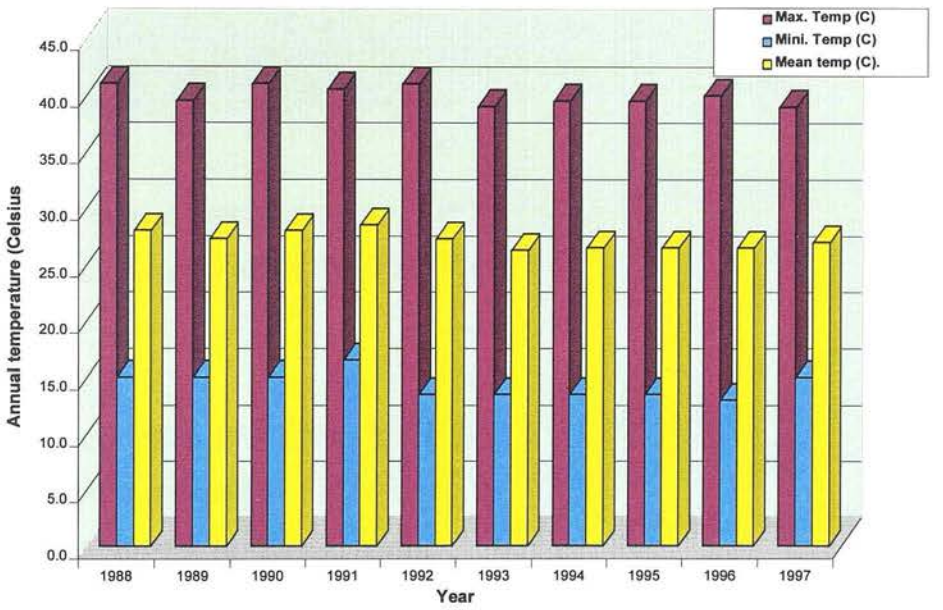


Figure 5.8: Annual air temperature (maximum, minimum, and mean) at Amphoe Khong Chiam, Thailand between the proposed Ban Koum Project and the Pak Mun Dam for a 10 year-period (1988-1997).

It represents the meteorological conditions for both study areas. The mean of annual maximum, minimum and mean are 39.9±0.9, 14.2±1.3 and 27.1±0.9 degree Celsius, respectively. The annual mean temperature of 27.1±0.9 degree Celsius was used for estimating NPP by 'Miami model'. The difference in temperature between dry and

rainy seasons is approximately 13 degree Celsius, and is likely to be reasonably constant during the 10 year-period.

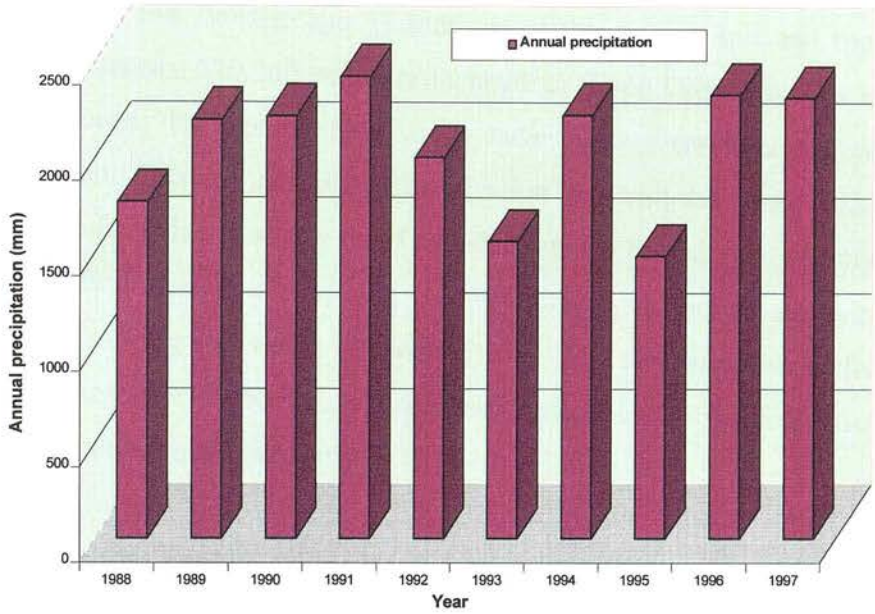


Figure 5.9: Annual precipitation at Amphoe Khong Chiam, Thailand between the proposed Ban Koum Project and the Pak Mun Dam during 10 year-period (1988-1997).

The mean of annual precipitation during the 10 years period was 2069±360 mm, which was also used for estimating NPP by 'Miami model'. Figure 5.9 shows that annual precipitation in 1988, 1992, 1993, and 1995 was below the average at 1763, 2000, 1559, and 1483 mm, respectively. These are the dry years which might cause the lower water flow and reduce net primary productivity in the Mekong River.

5.4.1.2 Soil characteristics

Data on soil characteristics were provided by the Soil Survey Division, Department of Land Development, Bangkok (Changprai and Chotimon, 1971) and include geologic features, soil parent material, landforms, soil name and soil suitability.

Ban Koum hydropower proposed area can be classified according to its features as a part of the Korat Plateau. The bedrock is mainly sandstone[1] and conglomerate[2], but there is some basalt. All of these rocks belong to the geologic Korat series, and are of Triassic and Jurassic age. Landform of this area is hill and mountains, rising above terraces. The hill soils are mapped as Slope Complex soils and are mainly under forest, but some small areas have been cleared and used for shifting cultivation. The soil suitability classification indicates that these soils are not useful for agriculture due to strong relief and shallowness to bedrock. Mostly shallow soils derived from sandstone and acid igneous rocks with limited agricultural potential, even for shifting cultivation (Pantulu, 1986). The few steep areas cleared for crops or left bare after timber harvest are very susceptible to erosion. Gully erosion is common along rocks and trails.

Related to low fertility, the paddy rice practices only take place in the rainy season because of dependence on the natural nutrients from flooding. The sticky rice production is low at 250 kg/rai (1 rai = 0.16 hectare) or 1.56 tonne/ha (from interviews with local people). In addition, IRRI (1995) quotes the rice production in Thailand and Lao PDR at 2.2 and 2.6 tonne/ha, respectively compared with irrigated rice production in Thailand of 4.0 tonne/ha (IRRI, 1993). Norman et al. (1995) report that the tropical paddy rice production averages 2.69 tonne/ha and provides 7.5 percent protein content. Rice provided 56 percent of the total calorie supply for Thai and 67% for Laotian people (IRRI, 1999). Usually the rice production is not enough to support the local family as a main subsistence for the whole year.

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[1] Sandstone is a sedimentary rock composed of sand sized grains of minerals and rock fragments cemented together (Changprai and Chotimon, 1971).

[2] Conglomerate defines as a clastic sedimentary rock composed of gravel or boulders cemented together (Changprai and Chotimon, 1971).

5.4.1.3 Water quality

Mekong River

The meteorological and surface-water quality data at Amphoe Khong Chiam were collected for a 10-year period (1988-1997) by the Department of Energy Development and Promotion, Bangkok, Thailand. Additional data were collected from the field in the present study. These data represent the existing conditions of the Mekong River. The surface-water quality is represented by the following (Appendix 5.4 and 5.5):

- Water level at mean sea level in meters
- Dissolved oxygen (DO) in milligram per liter
- Conductivity in mho second per meter (mS/m)
- Water temperature in degree Celsius
- pH of water
- Total suspended solid (TSS) in milligram per liter
- Monthly discharge (Flow) in cubic meters per second

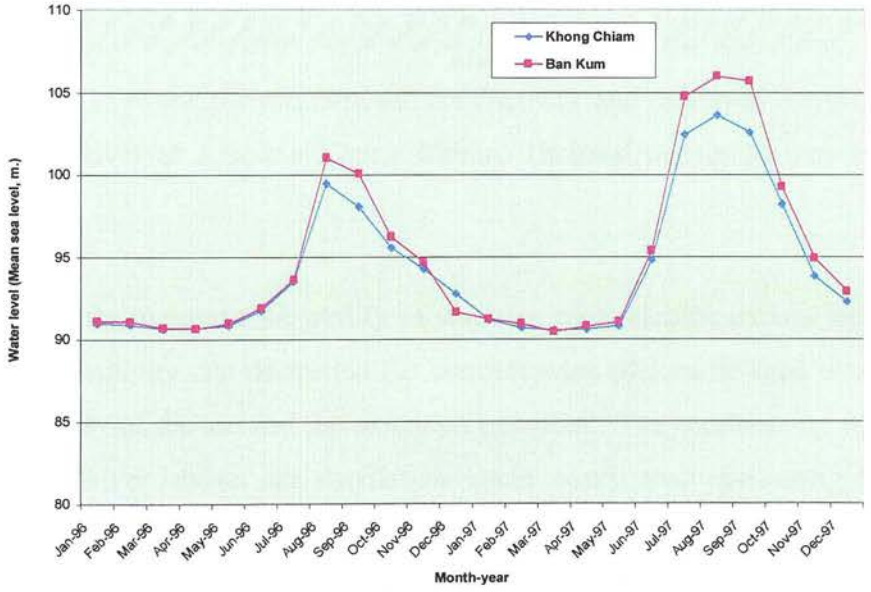


Figure 5.10: A comparison of water level between Khong Chiam station and Ban Kum station near the proposed Ban Koum Project during January 1996 to December 1997.

As the Ban Kum station is located upstream the water level is usually a little higher than Khong Chiam station in terms of mean sea level. The water level in the Mekong River between Khong Chiam station and Ban Kum station indicates a difference in water level of approximately more than 10 m at mean sea level during the dry season in April-May and the rainy season in July-September (Figure 5.10). The water level also indicates that in 1997 the Mekong River had greater water supply from upstream than in 1996.

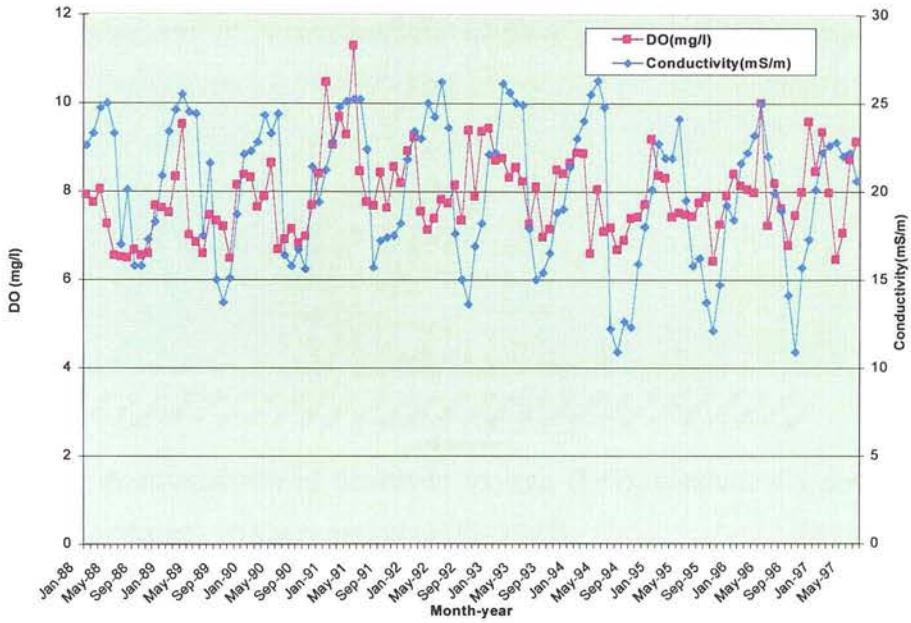


Figure 5.11: A comparison between conductivity and dissolved oxygen (DO) in the Mekong River at Amphoe Khong Chiam, Thailand during 10 year-period (1988-1997).

Conductivity measures the ability of water to carry electric current by ionic forms. This conductivity can determine the concentration of ions or total dissolved solids, the mobility of the ion and the oxidation potential. The conductivity of water in the Mekong River shows an oscillation cycle every year according to the ionic concentration of the water (Figure 5.11). The high range of conductivity is during March to May at the end of dry season and the low range is during August to November as the beginning of rainy season. The mean of conductivity during 10 year-period is 20.1±4.0 mS/m. The comparison between conductivity and dissolved oxygen (DO) indicates the positive correlation coefficient = 0.36 at $p<0.05$ pH is

also correlated with conductivity (r=0.39, p=0.000) but DO and pH show no significant correlation (r=0.03) (Figure 5.12). The means of DO, conductivity and pH during the 10 year-period were 7.90±0.94 mg/l, 20.11±4.03mS/m and 8.00±0.94, respectively.

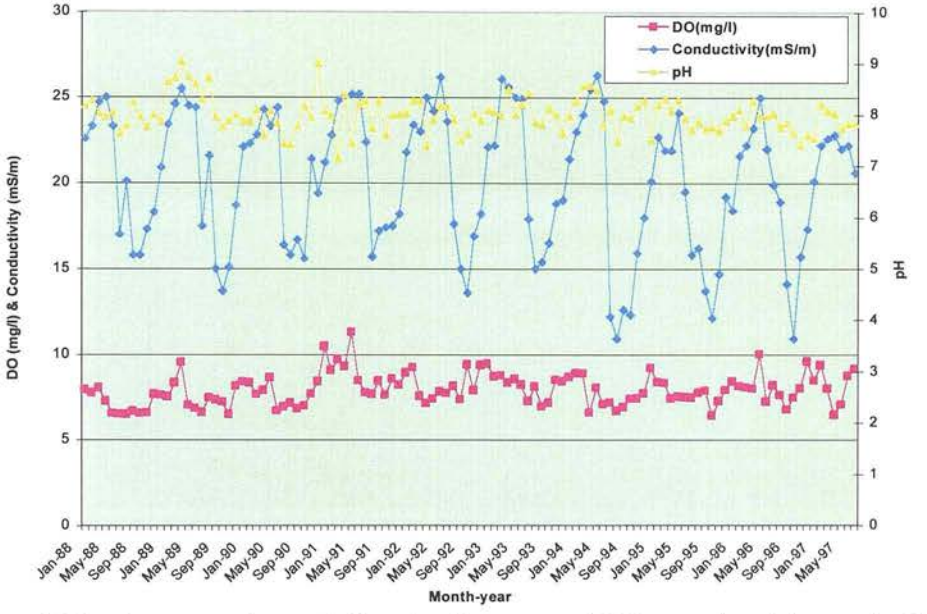


Figure 5.12: A comparison of dissolved oxygen (DO), conductivity and pH in the Mekong River during 10 years period (1988-1997).

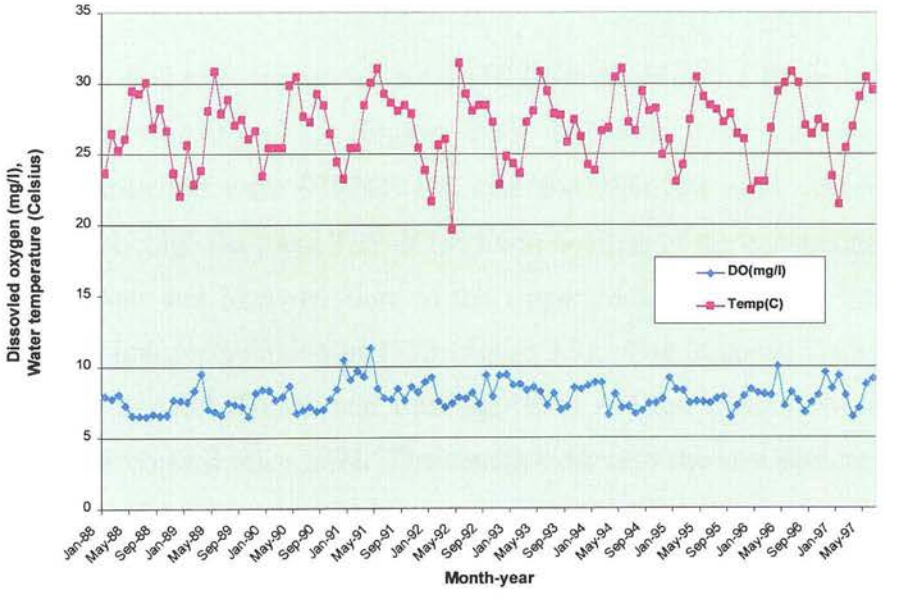


Figure 5.13: A comparison between dissolved oxygen (DO) and water temperature in the Mekong River during 10 year-period (1988-1997).

DO and water temperature were negatively correlated (r= -0.29, $p<0.05$) (Figure 5.13). The mean water temperature during the 10 year-period was 26.9±2.5 degree Celsius and, according to the DO and water temperature observations, the Mekong River could be characterised a having good water quality.

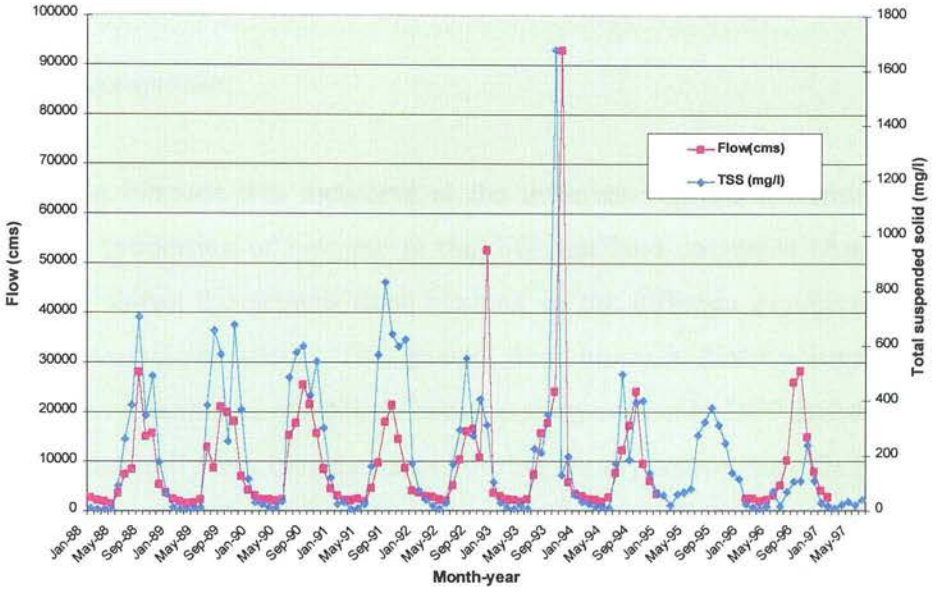


Figure 5.14: A comparison between flow and total suspended solids (TSS) in the Mekong River at Amphoe Khong Chiam, Thailand during 10 year-period (1988-1997).

Water flow and total suspended solid (TSS) in the Mekong River were positively correlated (r= 0.43,t $p<0.05$) (Figure 5.14). The mean water flow and TSS during the 10 year-period were 9392±12145 cms and 198±250 mg/l, respectively. The tremendously high flow and TSS in 1993 was because of the construction impacts of Lancang Dam and Manwan Dam in the Upper Mekong Basin in Yunnan, China, despite the low precipitation in 1993 (figure 5.9). The Manwan Dam began filling with water in 1994 (Hirsch and Cheong, 1996) and the water flow and TSS have obviously decreased since 1994. The conductivity also shows a declining trend since 1994 (Figure 5.11).

The analysis of water conditions in the study area of Thailand show that the flow rate and water quality is affected by construction activities at considerable upstream. The

resulting changes in flow rate and quality are likely to have negative impacts on nutrient input to the ecosystems downstream, and ecosystem productivity will probably decrease in the future.

5.4.2 Total biomass

Terrestrial ecosystems

The standing biomass was measured at the different vegetation forms in order to indicate the proportion of biomass in the different land use types (Appendix 5.6). Figure 5.15 shows the ground floor biomass in the different numbered plots and indicates seasonal variation. The ground floor biomass directly responds to the changes of environmental conditions between rainy season in 1997 and dry season in 1998, with generally less biomass stored during the dry season than the rainy season because of forest fire and drought. There are some plots to indicate increasing biomass accumulation in dry season because the locality and the conditions are fertile and less impact of forest fires.

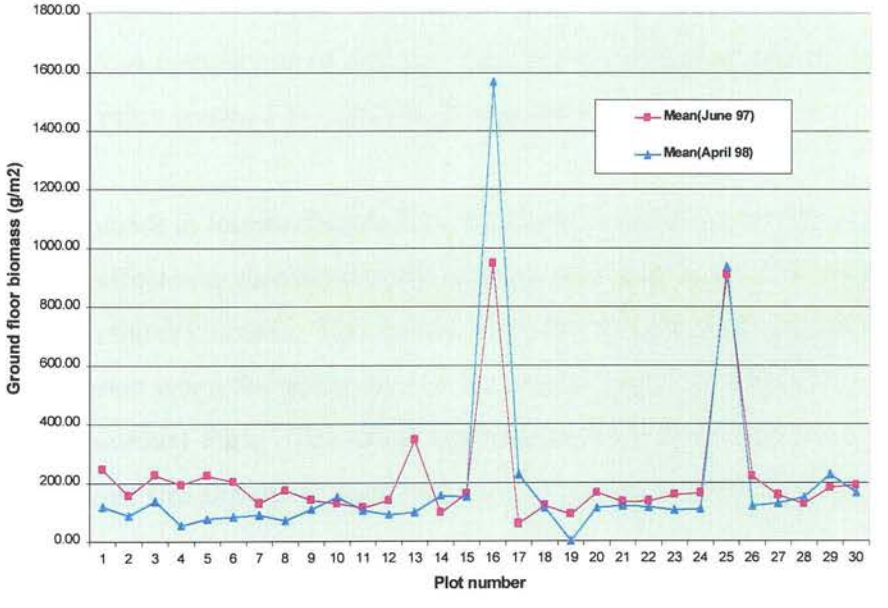


Figure 5.15: A seasonal comparison of ground floor vegetation biomass during the rainy season 1997 and the dry season 1998.

Plot numbers 16 and 25 are grassland, located as small patches in the secondary forest and environmental conditions apparently support grass growth during the middle of the dry season. The ground floor biomass was highest in the grassland ecosystem and much higher than the paddy rice field (plot number 19). There was no biomass in the paddy rice field during the middle of dry season rice cultivation is practised in this area only once a year due to constraints of water supply and unfertile soils.

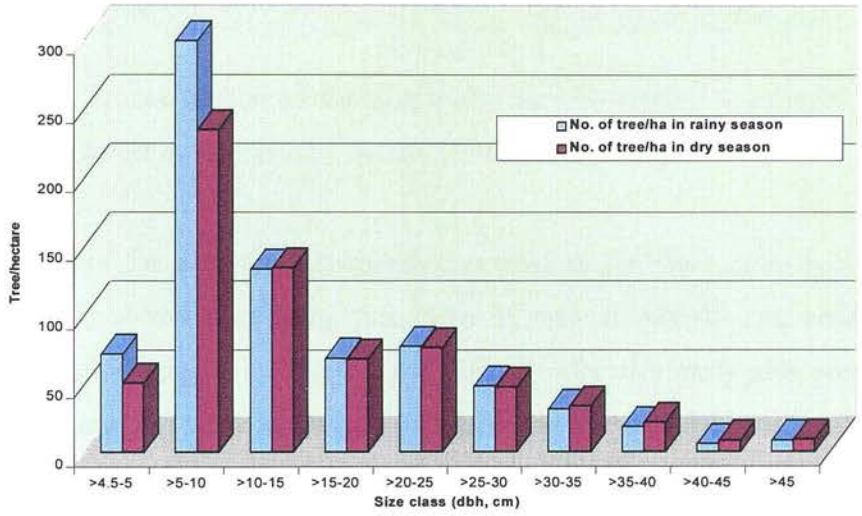


Figure 5.16: A comparison of dbh size class and tree density in the secondary forest during the rainy season 1997 and the dry season 1998.

For the biomass in forests, Figure 5.16 illustrates the effects of rainy and dry seasons. The main effect was that the density of small size class at >4.5-5 cm and >5-10 cm declined in the dry season. The reason of the declining density was forest fire during the dry season when the whole area of the natural park was affected according to the Head of National Park. The small size classes have less tolerance to disturbances such as forest fire and the drought and many of small trees tend to die. Thus it is the smaller size class that are sensitive to disturbances.

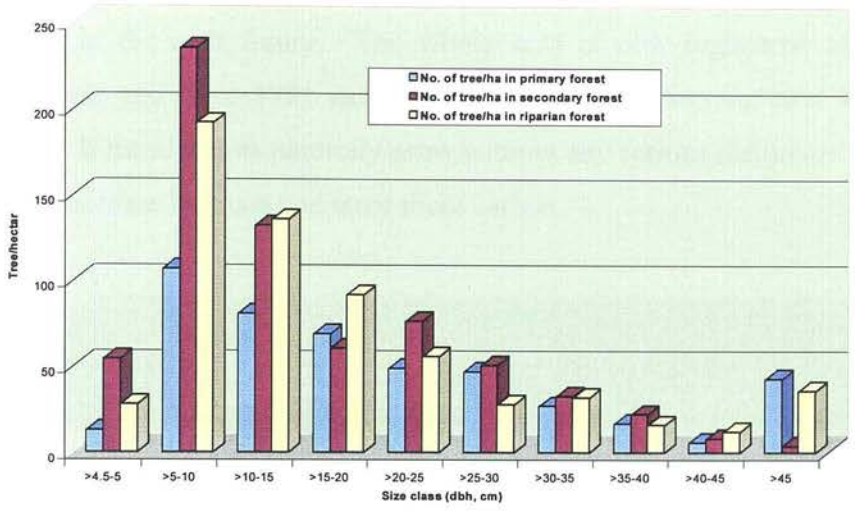


Figure 5.17: A comparison of dbh size class and tree density in primary, secondary and riparian forest during the dry season 1998.

Comparison of the size class distribution o trees in the three main types of forest (Figure 5.17) shows a missing size class of tree at >40-45 cm, resulting from selective legal logging in all forest types. Historically, this study area provided legal commercial logging with permission by the Royal Forest Department over 50 years ago. When legal logging ended, the forest was closed for natural regeneration and the primary and the riparian forest plots reflect the regeneration in the absence of illegal logging disturbances. In contrast, the secondary forest illustrates that the illegal logging was continued by local people after the forest was closed, resulting in the low number of trees in size class >45 cm. Legal logging usually destroyed the smaller size of tree during the tree felling and log dragging process (Gajaseni and Jordan, 1990), which reflects the reduction of size class >15-20 cm in the secondary forest. Johns (1988) finds that half of the small trees in a Dipterocarp forest in Malaya were killed in a logging operation when removed only 3.3 percent of tree stems.

All forests have a similar pattern of tree size class, with the dominant size class at >5-10 cm. This indicates that the samples of primary forest might give the underestimate the larger size classes in the Laotian forest, which passed through the selective logging phase even earlier. All forests also have similar size class

composition, which indicates the potential for growth to reach the climax stage of succession in the near future. The whole area is now registered as Pha Taem National Park and since 1991 encroachment and illegal logging have been strictly controlled. If these forests naturally grow without any serious disturbances, they will be able to increase biomass and store more carbon.

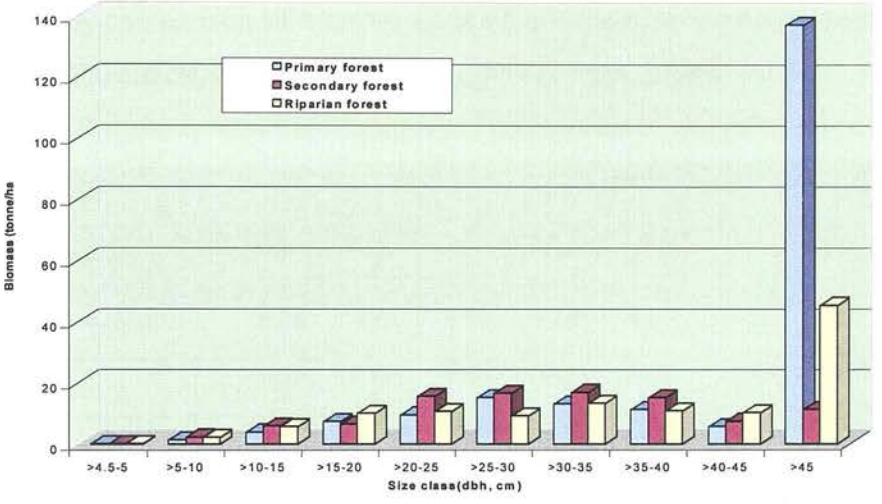


Figure 5.18: A comparison of dbh size class and biomass in primary, secondary and riparian forest during the dry season 1998.

Figure 5.18 shows that biomass accumulation is highest in the primary forest and riparian forest, but low in the secondary forest at dbh size class over 45 cm. This does not mean that the secondary forest is less important than the primary and the riparian forest in terms of biomass accumulation. It indicates that the trees in the secondary forest have high potential growth for accumulating biomass with high potential to store more carbon into the terrestrial ecosystems. Cannell (1999) also discusses that the increased forest growth rates will increase the rate of carbon storage and the fast growing trees can store more carbon rapidly than the slow growing trees. However, the primary and the riparian forests still store carbon in biomass although the rate of biomass accumulation will be slower than the secondary forest.

Comparison of biomass accumulation in the different vegetation forms among three forest types (Table 5.2), indicates the over 98 percent of biomass is accumulated in

tree form and less than 2 percent stored in the sapling and the ground floor vegetation. This is similar to Brown's study (1984) which found the biomass of under-story vegetation was less than 2 percent of total biomass in the closed tropical forest. The primary forest has the largest biomass store at an average of 205 tonne/ha in trees and less than 0.5 tonne/ha in saplings and ground floor vegetation.

Table 5.2: A comparison of biomass (tonne/ha) of ground floor vegetation, sapling and tree in the different forest types during the dry season 1998.

Biomass	Primary forest (tonne/ha)			Secondary forest (tonne/ha)			Riparian forest (tonne/ha)		
Categories	Mean	±SD.	%	Mean	±SD.	%	Mean	±SD.	%
Ground floor vegetation	0.25	0.12	**0.12**	1.247	0.54	**1.23**	0.92	0.15	**0.76**
Sapling	0.16	0.26	**0.08**	0.30	0.22	**0.30**	0.32	0.20	**0.26**
Tree	204.68	142.13	**99.80**	100.01	19.43	**98.47**	120.21	18.97	**98.98**

Table5.3: Biomass accumulation in the different land use types during the rainy season 1997 and the dry season 1998.

		Biomass in land use types (tonne/ha)						
Season		PF	SF	RF	RZ	HGS	PRF	GL
Rainy season in 1997	Mean	NA.	97.46	104.39	1.80	3.11	3.12	9.28
	±SD.	NA.	17.00	7.14	0.93	2.28	1.37	0.28
Dry season in 1998	Mean	204.68	100.01	120.21	1.11	5.57	0	6.62
	±SD.	142.13	19.43	18.97	0.09	6.23	0	2.54

Note: PF = Primary forest; SF = Secondary forest; RF = Riparian forest; RZ = Riparian zone; HGS = Home-gardening system; PRF = Paddy rice field and GL = Grassland.
NA. = Data is not available.

The comparison of biomass accumulated in the different land use types shows the largest biomass in the primary forest based on the dry season at 205 tonne/ha and the lowest biomass in the riparian zone (Table 5.3). The second largest is the riparian forest at 120 tonne/ha and the third is the secondary forest at 100 tonne/ha. The

riparian zone and grassland have less biomass accumulation in the dry season than in the rainy season. On the other hand, the home gardening system seems to increase in biomass in the dry season. The increment of biomass in home gardening system is associated with the growing period and harvesting of produce near the end of the dry season. The paddy rice field usually is abandoned during dry season so that there is no biomass accumulation

The results from the present study correspond well with published information. Ogawa et al. (1965) estimated the above ground biomass in the dry dipteropcarp forest, Thailand as 126 tonne/ha and total biomass as 143 tonne/ha. The ratio of total biomass to above ground biomass was 1.13. Pantulu (1986) estimated the total biomass in the dry dipterocarp forests in the Mekong River Basin as 65.9 tonne/ha, which was less than the biomass in the study areas. Flint and Richards (1996) summarise biomass estimates in Southeast Asia including India, Thailand, Cambodia, Malaysia and Indonesia, ranging from 35 tonne/ha or less in severely degraded tropical dry forest to almost 700 tonne/ha in relatively undisturbed mature tropical rain forest. The lower biomass values often reflect an immature forest.

Drew et al.(1978) report the above ground biomass in Northeast at 61 tonne/ha in degraded forest and 252 tonne/ha in undisturbed forest particularly mixed hill evergreen and dry evergreen forest. The biomass in degraded forest was 24.3 percent of the undisturbed forest. These results indicate that in relation to the result of the present study, the primary forest approximates to undisturbed forest and the secondary forest can be characterised as degraded forest.

Bernard and Kristoferson (1985) report the ratio of above ground biomass of rice to crop yield in Thailand to be 2.43 (kg/kg yield). In the present study the local yield was 1.56 tonne/ha with an aboveground biomass 3.12 tonne/ha, giving a ratio of biomass and rice yield from this study will be 2.0. If the local rice yield is converted by the ratio of Bernard and Kristoferson (1985), the biomass of paddy rice field would be 3.8 tonne/ha.

The general conclusion from the biomass studies are that measurement biomass for estimating the carbon storage in the terrestrial ecosystem, it is rational enough to be in practise for the further study of carbon storage. . If the forest is deforested and changed to become paddy rice field, it will potentially cause the carbon loss from terrestrial ecosystems in relation to deforestation and soil carbon release during dry season.

5.4.3 Net Primary Productivity (NPP)

Terrestrial ecosystems

NPP of terrestrial ecosystems was calculated by 'Miami model' using the data set of mean annual precipitation and mean annual temperature for the 10 year-period of 1988-1997 in Table 5.4 (Figure 5.8 and 5.9).

From the Miami model (Leith, 1972, 1973 and 1975), two equations were used to estimate NPP in this study as follows:

$$NPP_T = 3000/(1 + e^{1.315-0.119T}) \qquad \text{(Equation 5.11)}$$

$$NPPp = 3000(1 - e^{-0.000664p}) \qquad \text{(Equation 5.12)}$$

Where T = Mean annual temperature during 10 years period

and p = Mean annual precipitation during 10 years period

Based on the climate of the study area, the Miami model generates the following estimate of NPP:

$NPP_T = 2611.52$ g/m^2/yr

$NPP_T = 26.11$ tonne/ha/yr

$NPP_T = 13.06$ tonne C/ha/yr

$NPPp = 2311.62$ g/m^2/yr

$NPPp = 23.11$ tonne/ha/yr

$NPPp = 11.56$ tonne C/ha/yr

Table 5.4: Mean annual precipitation (mm) and mean annual temperature in Khong Chiam, Ubon Ratchathani, Thailand over a 10 years period.

Year	Mean annual precipitation (mm)	Mean annual temperature (Celsius)
1988	1764	28.0
1989	2196	27.3
1990	2217	28.0
1991	2426	28.5
1992	2000	27.3
1993	1559	26.3
1994	2223	26.5
1995	1483	26.5
1996	2331	26.5
1997	2316	27.0
Mean	**2070**	**27.1**
±SD.	**361**	**0.9**

Leith (1975) suggests that NPP is best estimated by the minimum of the two functions (between Equation 5.11 and 5.12), which may be limiting productivity. Therefore, the best estimate of NPP in this study is from the mean annual precipitation rather than mean annual temperature (2312 $g/m^2/yr$ or 23.11 tonne/ha/yr or 11.56 tonne C/ha/yr. This is reasonable because of the study area is located in the tropical zone where the light intensity and temperature are unlikely to be the limiting factors for the net primary production. In contrast, the dry season obviously reduces plant production. Jordan (1983) confirms that water availability is an important factor limiting NPP, for example, the trees in the tropical dry forest are smaller, often scrubby, canopy cover is incomplete and productivity is lower than in the closed evergreen forest. In these forests, fire (an indirect effect of low rainfall), as well as seasonal rainfall, limits biomass and productivity.

Earlier field studies in Thailand by Kira et al. (1967) estimated NPP, and the ratio of NPP from Kira et al. to NPP from the Miami model is shown in Table 5.5. Esser et al. (1997) recorded the NPP field studies from all over the world including the study site by Kira et al. (1967) in Khao Chong, Southern Thailand measured the maximum above ground NPP was 2923 $g/m^2/yr$ and the maximum below ground NPP was 55 $g/m^2/yr$. The total NPP from Kira et al. (1967) was thus 2978 $g/m^2/yr$ (1415 g $C/m^2/yr$ or 14.15 tonne C/ha/yr). The Khao Chong forest is characterised as a tropical rain forest with annual temperature at 27.2 degree Celsius and annual precipitation at 2696 mm. When these climate data are run with the 'Miami model', the ratio of NPP from field data and the Miami model is 1.14 and 1.19 in relation to annual temperature and annual precipitation (Table 5.5). It can be interpreted that the Miami model underestimated or the field study overestimated plant production, but the results are reasonably close to each other. As the present study aims to quantify the NPP at the regional and global scale, the Miami model provides a simple and practicable model capable of generating information accurate enough for incorporating into ecosystem evaluation within the IA process.

Table 5.5: A comparison of NPP ($g/m^2/yr$) in tropical rain forest at Khao Chong, the South of Thailand, estimated from field data and from the Miami model, using climate data for that area.

Variables	NPPf (Kira et al., 1967)	NPPm (Miami model)	Ratio (NPPf:NPPm)
Annual temperature (27.2°C)	2978	2617	1.14
Annual precipitation (2696 mm)	2978	2499	1.19

Note: NPPf = NPP is measured from the field (Kira et al, 1967).
NPPm = NPP is estimated by Miami model.

The NPP of tropical rain forest at Khao Chong, estiamted by the Miami model from annual precipitation, at 12.5 tonne C/ha/yr is higher than the estimated NPP for the present study at 11.56 tonne C/ha/yr. This difference is reasonable because Khao Chong has a higher annual precipitation at 2696 mm than the Ban Koum project area at 2070 mm. The forest type is also different with Khao Chong classified as tropical

rainforest with high biomass density and Ban Koum mostly dry dipterocarp forest with low biomass density. This comparison supports the view that annual precipitation may be the limiting factor for NPP in these tropical terrestrial ecosystems.

During natural succession, terrestrial ecosystems tend to increase in biomass andthe Net Ecosystem Productivity (NEP) is greater than zero (Jordan, 1983). In this situation, ecosystems function as a carbon sink rather than a carbon source. Considering the results of biomass in the three forest types, it is possible that the forests are at different stages of succession and growing at different rates. The primary forest has probably nearly reached the climax stage in the dynamic equilibrium, but have not yet reached the declining or stable stage at which NEP would be negative or equal to zero, i.e. NPP equal to the rate of respiration of herbivores and decomposers. The study of Kobak (1995) indicates that mature forests have very low NEP with a maximum of 4 percent of NPP compared to young forests with a high NEP up to maximum of 20 percent of NPP.

Goudriaan (1995) estimated that with the major terrestrial carbon fluxes, by the plants and heterotrophic organisms, the NEP could be 10 percent of NPP before fire occurs. Apps and Raven (1995) emphasised that an increase in GPP and NPP does not necessarily result in an increase in NEP and hence of carbon storage capability, because NEP is also determined directly by ecosystem disturbances such as fire or insect-induced stand mortality and by changes in below ground compartments.

Therefore, based on published information and understanding of forest dynamics, the rate of NEP in terrestrial ecosystem is estimated at 10% in home garden systems and 20 percent of NPP in the secondary and riparian forests, but only 4 percent of NPP in the primary forest.

NPP of aquatic ecosystems were measured before and after dam construction by 'Dark-Light method', which recorded the net rate of photosynthesis and respiration over a defined period of time.

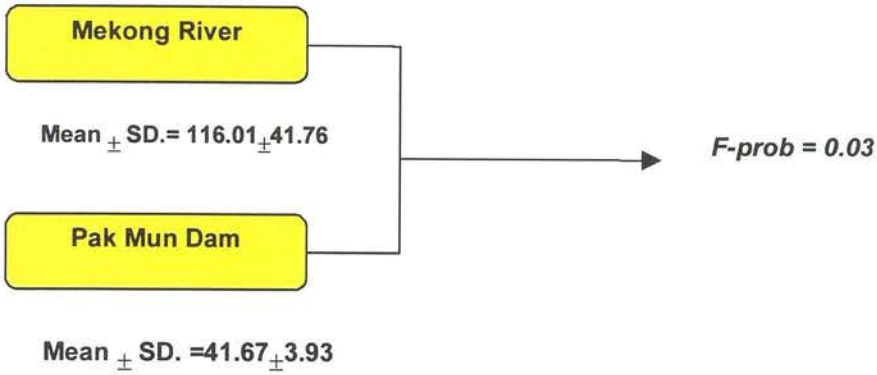


Figure 5.19: A comparison of aquatic net primary productivity (mgC/m^2/h) in the Mekong River and the Pak Mun Dam during the rainy season 1997.

The net primary productivity of the Mekong River and the Pak Mun Dam were significantly different (*F-prob = 0.03)* (Figure 5.19) with the Mekong River about three times higher than the Pak Mun Dam at 116 and 42 mgC/m^2/h. This is equivalent to 1.39 gC/m^2/d^3 (5.07 tonne C/ha/yr) in the Mekong River and 0.50 gC/m^2/d (1.83 tonne C/ha/yr) in the Pak Mun Dam

It can be interpreted that the Mekong River has high primary productivity, which provides the high nutrient supply to the wetland ecosystem in the Mekong Delta in Vietnam. As a consequence, Vietnam has become the major country to export rice in the world market with the rice production of 26.3 million tonne in 1996 related the high soil fertility in the delta (FAO, 1997). The rice production in Vietnam is 3.6 tonne/ha compared to Thailand at 2.4 tonne/ha, Lao PDR at 2.5 tonne/ha (FAO, 1997) and to the study area at 1.6 tonne/ha.

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[3] The conversion factor of NPP is 0.012 to convert from the unit of mg/m^2/h to g/m^2/d based on 12hrs of day light per day in tropical region.

Comparing the NPP of the Mekong River and the Pak Mun Dam to other rivers in Asia, the Mekong River with a range of 1.05-2.12 $gC/m^2/d$ is slightly higher than the average NPP of Tropical Asian rivers. However, its NPP is higher than the Ganges River in India and slightly lower than the Yangtze River in China (Table 5.6). The Mekong River has high productivity which provides the aquatic production to support people in this Indo-China Region. In contrast, the Pak Mun Dam with NPP at range of 0.45-0.54 $gC/m^2/d$ show a large reduction in productivity compared to the rivers in Asia.

Table 5.6: A comparison of NPP in the different rivers in Asia.

River/Resevoir	NPP ($gC/m^2/d$) (Minimum – Maximum)	Sources
Yangtze River (China)	1.15-3.61	Liang et al., 1988
Ganges River (India)	0.91-1.02	Natarajan, 1989
Tropical Asian Rivers	1.03-1.78	Dudgeon, 1995
Mekong River (Thailand & Lao PDR)	1.05-2.12	This study
Pak Mun Dam (Thailand)	0.45-0.54	This study

To achieve a highly productive aquatic ecosystems, the producer or phytoplankton must achieve a high rate of collection of light energy and an efficient utilisation of this absorbed energy by its photosynthetic system, followed by conversion of photsynthethate to new cell material (Kirk, 1994).

In tropical aquatic ecosystems, the photosynthesis takes place at, or close to, the surface, where there is an abundance of solar energy (Kellman and Tackaberry, 1997). In the Mekong River, although light penetration is limited to the surface 7 cm (Table 4.1), nutrients from upstream and high temperatures provide good conditions for primary productivity. The nutrient status of river water is largely a reflection of the geology of the watershed from which surfacewater runoff and nutrients drain into the river ecosystem. On the other hand, in the lentic system, nutrients are usually provided by mineralisation which takes place in bottom sediments, where organic detritus from the surface falls and is decomposed. As a consequence, the dam

system will depend on the nutrient input from the sediment turnover instead of the nutrients input from the surface runoff during rainy season. The reduction in NPP in the Pak Mun Dam after construction may be caused by reduced nutrient availability despite the increase in light penetration and temperature (Table 4.1).

Kirk (1994) reports that the natural aquatic ecosystems with the highest phytoplankton NPP are dominated by blue-green algae with a range of 300-1000 $gC/m^2/yr$ or 3.6-12.0 $gC/m^2/d$. The species dominant in Pak Mun Dam are blue-green algae (*Cyanophyta*) but NPP is in the range 0.45-0.54 $gC/m^2/d$, which is low productivity (Table 5.6). It is possible that the Pak Mun Dam is in an early stage of successionas its ecosystem has been developed for only five years. Thus it may not have reached it potential for NPP.

5.4.4 Carbon storage

Analysis of carbon storage in the terrestrial ecosystems is likely to be more useful and with fewer constraints than the aquatic ecosystems. Aquatic systems generally have high dynamics and continuum characteristics with are related to the rapid turnover of phytoplankton, to complexity of carbon allocation from water body to sediment and from water body to atmosphere. Therefore, further analysis is mainly focused on carbon storage in the terrestrial ecosystems, representing one of ecosystem services roles that sustain the whole system.

Data on carbon stored in the different land use types show that most carbon is stored in the biomass of primary forest at 102 tonne C/ha (Figure 5.20 and 5.21). The secondary and riparian forests have about half as much carbon stored as the primary forest, but they have greater potential for future sequestration if this is encouraged by management. The other land uses have much less capacity for storage because of their relatively small biomass and more rapid turnover.

According to TDRI (1993) reports that all the national parks in Thailand have an estimated average carbon storage at 171.2 tonne/ha. In the recent study by Centre of

Ecological Economics (1999), the result shows that the Kaeng Sue Tean (KST) of mixed deciduous forest (Teak forest) in the North of Thailand has an estimated carbon storage at 181.1 tonne/ha. Comparison of both sources of information in Thailand with the carbon storage in the present study, indicates that the carbon storage in Ban Koum hydropower project area is lower than the average carbon storage in the national parks and in KST forest, the North of Thailand. There are differences in the forest types especially in the national parks of Thailand such as the tropical rainforest in the South, the mixed deciduous forest in the North, the evergreen mixed with dry dipterocarp forest or the dry dipterocarp forest in the Northeast and the evergreen forest in the East and the West. It is understandable that there are variations in carbon storage between these studies what is important is to know the forest type and the ecological condition of the ecosystem.

However, the results of the carbon storage from the different land use types in the dry season are considered in the further step of analysis as the carbon storage at the initial stage (*time, t=0)* because of the update and complete data set, particularly the primary forest. The total carbon storage in the Ban Koum hydropower project will be estimated in relation to the total land area, the rate of human encroachment, the NPP and the NEP of each land use type in the next step of analysis.

Land use types	Carbon storage (tonneC/ha)
Primary forest	102.338
Secondary forest	48.729
Riparian forest	52.194
Riparian zone	0.9
Home-gardening	1.557
Grassland	4.638
Paddy rice field	1.56

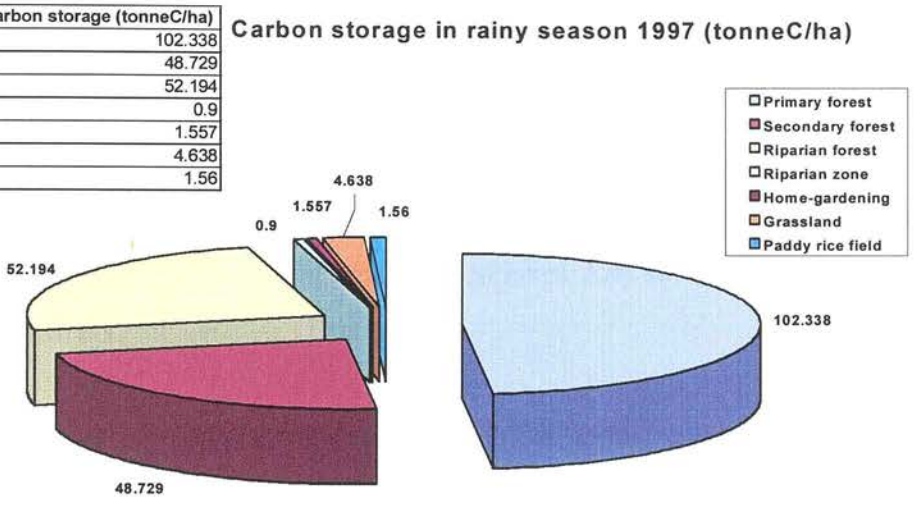


Figure5.20: A schematic of carbon storage (tonne C/ha) in the different land use types during the rainy season 1997. (Note that primary forest was not sampled in the rainy season and the C storage is assumed to be the same as in the dry season).

Land use types	Carbon storage (tonneC/ha)
Primary forest	102.338
Secondary forest	50.007
Riparian forest	60.107
Riparian zone	0.554
Home-gardening	2.785
Grassland	3.25
Paddy rice field	0

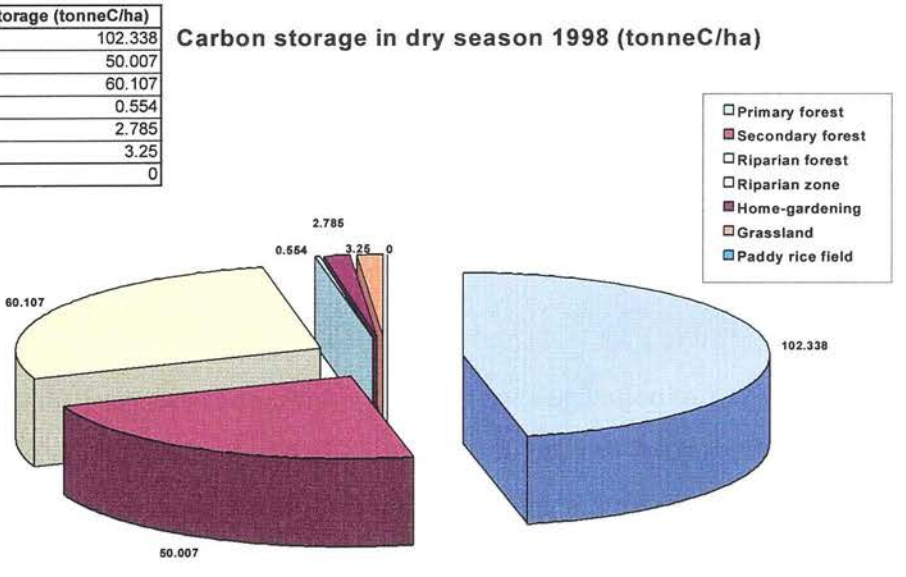


Figure 5.21: A schematic of carbon storage (tonne C/ha) in the different land use types during the dry season 1998.

5.4.5 Total carbon storage in flooded ecosystems

Total carbon storage can be calculated from the relationships of carbon storage per unit area and the total area flooded by the dam construction. However, it is important to compare the quantity of carbon storage per unit area from this study with other sources of data, particularly from the Southeast Asia forests, which may reflect the potential of carbon storage (Table 5.7).

Table 5.7: A schematic of carbon storage (tonne C/ha) in live vegetation in the different land use types between this study and South and Southeast Asian nations (Flint and Richards, 1996).

Land use types	Carbon storage[A] (tonne C/ha)	Carbon storage[B] (tonne C/ha)
Primary forest	102.3	98.1
Secondary forest	50.0	20.6
Riparian forest	60.1	84.2
Riparian zone	0.6	0.9
Grassland	3.3	5.4
Paddy rice field	1.6	5.1
Home gardening system	2.8	3.0
River	N.A	0.1

Note: A = The results of this study.
B = Source from Flint and Richards (1996).
N.A. = The data is not available.

Flint and Richards (1996) estimated the carbon content of live vegetation in 13 South and Southeast Asia Nations in 1980. Comparison in Table 5.7 shows the majority of carbon storage from this study is apparently lower than Flint and Richards's results but the primary and secondary forests indicate higher carbon storage, with the secondary forest almost double. Because Flint and Richards classified the secondary forest as interrupted woodland, it is calculated as one-fourth to one-third of the carbon storage in closed forest. The interrupted woodland is likely to have climatic and edaphic factors, which promote rapid growth of woody species after disturbances

and it is interpreted that the secondary forest in the study sites is in a successional stage with the high potential growth rate. In terms of carbon storage in paddy rice fields, the study sites store less carbon than Flint and Richards estimated because the Ban Koum paddy rice practices naturally depend on the annual rainfall during the rainy season and are limited by poor soil fertility. Moreover, the aquatic ecosystem shows very low carbon storage at 0.1 tonne C/ha when compared to the terrestrial ecosystems especially forests.

In the case of the Ban Koum hydropower project in the Lower Mekong River, if this is implemented, it will flood an estimated 94 sq. km (9400 ha), mainly composed of forest. The initial situation of the terrestrial ecosystem will result in the destruction forest, which is cut for valuable timber, bamboo and non-timber forest products utilised either for subsistence or commercially. The details of total area that will be flooded by the reservoir are given in Table 5.8.

Table 5.8: Land use in the area that will be flooded by the Ban Koum hydropower project (MRC, 1994).

Categories of flooded area	Area (km^2)
Area of existing water	39
Area of riverbank and island	18
Agricultural area	4
Forests	72
Total final reservoir area	**133**

The riparian forest and riparian zone of up to 18 sq. km are divided equally. The agricultural area contains both paddy rice fields and home gardening system. From the survey the paddy rice is estimated to be about 60 percent of total agricultural area (2.4 sq. km) with the rest (1.6 sq. km) classified as home gardening system. The grassland has not been identified in the flooded area according to the GIS forest cover information and it is assumed that small areas of grassland are mixed into the secondary. Thus, the grassland is estimated about 1 percent of secondary forest area

(0.25 sq. km). The area of primary forest in Lao PDR is estimated as 65 percent (46.80 sq. km), which has the highest forest cover of 61-82 percent (Parnwell and Bryant, 1996) and the secondary forest in Thailand as 35 percent (24.95 sq. km) based on topographic maps from MRC office, Bangkok.

Table 5.9: Total carbon storage in the different land use types in 1998.

Land use types	Carbon storage (tonne C/ha)	Flooded area (ha)[a]	Total carbon storage (tonne C)
Primary forest	102.34	4,680	478,951
Secondary forest	50.01	2,495	124,775
Riparian forest	60.11	900	54,099
Riparian zone	0.55	900	495
Grassland	3.25	25	81
Paddy rice field	1.56	240	374
Home gardening system	2.79	160	446
River	N.A.	3,900	N.A.
Total	-	**13,300**	**659,221**

Note: a = A hectare is equal to 0.01 km^2.
N.A. = The data is not available.

The carbon stored in different land use types, based on filed studies, is combined with the estimates of the area to be flooded to calculate the initial carbon store in the affected area (Table 5.9). The total amount of terrestrial carbon is calculated at 659,221 tonne C ($0.66x10^6$ tonne C), most of which is stored in the primary and secondary forests because of the large flooded forest area and the high biomass accumulation. Small amounts of carbon are stored in the riparian zone, the grassland and the agricultural land, which have perennial vegetation and no carbon accumulation from year to year. Townsend et al. (1996) explained that the agricultural areas have not contributed to carbon sequestration because most cultivation practices caused soil carbon reduction with time and crops were regularly harvested and consumed.

In addition to the flooded area affected by Ban Koum hydropower project, changes in stored carbon in the surrounding area must be taken into account in the ecosystem evaluation. Dam construction affects land use changes associated with human encroachment into the forest area near the dam. The rate of land use changes varies according to the poverty, the forest accessibility, the pressure of landless people affected by the dam project and the landless people from outside.

Panchamanon (1988) refers to deforestation and encroachment causing a loss of forest area after hydropower dam implementation in particular at Khao-lam Dam, Kanchanaburi, the West of Thailand. This dam was constructed in 1979 and started commissioning in 1984. The rate of forest lost is approximated at eight folds from the previous time during 5 year-period as follow:

- Before dam construction during 1974-1978, the deforestation in the area was 2,775 ha in 5 year-period or 555 ha/yr, affecting 1.73 percent of the forest per year.
- After dam construction from 1979 to 1986, the deforestation increased to 29,046 ha or 4,150 ha/yr, affecting 13 percent of the forest per year.

It is apparent that the hydropower dam projects have caused increasing rates of deforestation in the surrounding area. The rate of change, however, varies with the different conditions and pressures from the local people. Thus, the rate of deforestation from Panchamanon (1988) is very high when compared to FAO (1999) records which show the average rate of deforestation in Thailand is at 2.6 percent and in Lao PDR at 1.2 percent annually. Therefore, in the present study, the rate of land use change by encroachment that will affect the forest is assumed to be 2.6 percent per year.

To calculate the carbon storage change according to the hydropower dam project, it is necessary to formulate the relationships among the various biological factors in the terrestrial ecosystems. The set of factors defining the initial *(t=0)* carbon stored in the ecosystems, are described in the following equation.

$$TC(t) = a \sum_{landuse} \left(Bi(t) * Ai(t) \right) \qquad (t=0)$$

(Equation 5.14)

Where

$TC(t)$ = Total carbon at initial time $(t=0)$

a = Carbon content of biomass conversion factor as 0.5

$Bi(t)$ = Biomass of each land use type at time $t=0$

$Ai(t)$ = Land area of each land use type at time $t=0$

If for example the total land area at time $t=0$ is flooded by a hydropower dam project, the right hand side of equation 5.14 will be ***negative,*** indicating the loss of total carbon storage from the ecosystem.

Then, the equation of carbon storage over time can be defined as follows:

$$TC(t+1) = TC(t) + \sum_{landuse} \left(Ai(t) * NEPi * NPP \right) - C * En(t) * A(t)$$

(Equation 5.15)

Where

$TC(t+1)$ = Total carbon storage in terrestrial ecosystems at time $t+1$

$Ai(t)$ = Land area of each land use type at time t

$NEPi$ = Net ecosystem productivity of each land use type

NPP = Net primary productivity in the region at constant = 11.56 tonneC/ha/y.

C = Carbon storage in the primary forest as 102.3 tonne C/ha/y (assumed as the primary forest affected by encroachment)

$En(t)$ = Rate of land use change by encroachment at 2.6 percent per year (FAO, 1999) into the total area at time t

$A(t)$ = Land area of the whole system at time t

Equation 5.4 provides an estimate for the total carbon storage at $t=0$ for both without-project and with-project situation. Equation 5.15 is then used to predict the with-project loss of total carbon storage in relation to the flooding of ecosystems and encroachment. For the without-project situation the terrestrial ecosystems will continue growing and storing more carbon in the system. Thus, from the initial amount of total carbon storage at time zero, the change of total carbon storage from $t=0$ to $t=50$ can be defined by equation 5.15 under specific conditions.

To estimate the total carbon stored in the area flooded by Ban Koum hydropower project, it assumed that the total area has a rate of land use change equal to zero. This gives the initial total carbon storage in the affected area. The rate of land use change after hydropower project implementation is then considered at 2.6% of total flooded area per year according to the rate of deforestation in Thailand (FAO, 1999). This then calculates the total carbon loss after Ban Koum project implementation over a 50 year-period.

The assumptions to calculate changes in carbon storage without-project and with-project information are set up as follows:

I. Without-project implementation

Total carbon gain at ecosystem level in the area that would have been affected by the dam:

- For each different land use type in the total area of 9,500 ha, the carbon increment will depend on the appropriate rate of NEP. For example, the primary forest is classified as the mature forest so NEP is assumed as 4 percent of NPP (Kobak, 1995). The secondary and riparian forests are assumed to have NEP of 20 percent of NPP because of its status as young forest. The riparian zone and home garden system are assumed to have NEP of 10 percent of NPP. The grassland and the paddy rice field are assumed to have no carbon increments because both ecosystems are dominated by short-term perennial or annual vegetation.
- The other assumption is no encroachment *(En (t=0) = 0)* by people because

the land area is located in the National Park and is a protected area. Therefore, it is assumed that the total area of each land use will remain as at the initial time and the carbon storage will be directly associated to NPP and NEP.

II. With-project implementation

Total carbon loss at ecosystem level following the Ban Koum hydropower project implementation:

- It assumes when the dam is constructed in the site, the ecosystems will be changed, for example, the forest ecosystem will be flooded and the other land use types will be terminated. Consequently, the stored carbon will be lost from the system to the atmosphere or to the ocean. The total carbon storage loss is set at 0.66×10^6 tonne C, equal to the amount present at the initial time (Table 5.9).
- The other assumption under with-project implementation is the increment of land use change. Equation 5.15 is applied to the rate of land use change by human encroachment at 2.6 percent per year from the previous total land of 9,400 ha. People will encroach onto the primary forest and convert it agricultural lands. Therefore, there is a high tendency to impact change in the primary forest, which will reduce the carbon stored (102 tonne C/ha).

The effects of without-project and with-project implementation on storage of carbon are shown in Figure 5.22. With-project there is an initial loss of carbon from the terrestrial ecosystems at $t=0$, representing the carbon stored in the vegetation, which is flooded (0.66×10^6 tonne C). The subsequent carbon storage loss is associated with land use change by human encroachment of the forest at 2.6 percent per year. Thus the hydropower project causes an early loss of the carbon stored in tree biomass, followed by the encroachment of local people regarding to population growth and poverty, causing an indirect impact of the development of hydropower project. The hydropower project will provide an improved transportation system allowing access to the area that was previously inaccessible and followed by illegal logging.

If the project is not implemented there is a predicted increase in stored carbon by sequestration in the forest biomass due to its protection over the 50 years. From the initial $0.66x10^6$ tonne C in the area that would have been flooded, the accumulation of an additional $0.56x10^6$ tonne C, over an area of 9,400 ha, raises the biomass carbon to $1.22x10^6$ tonne C after 50 years (Figure 5.22).

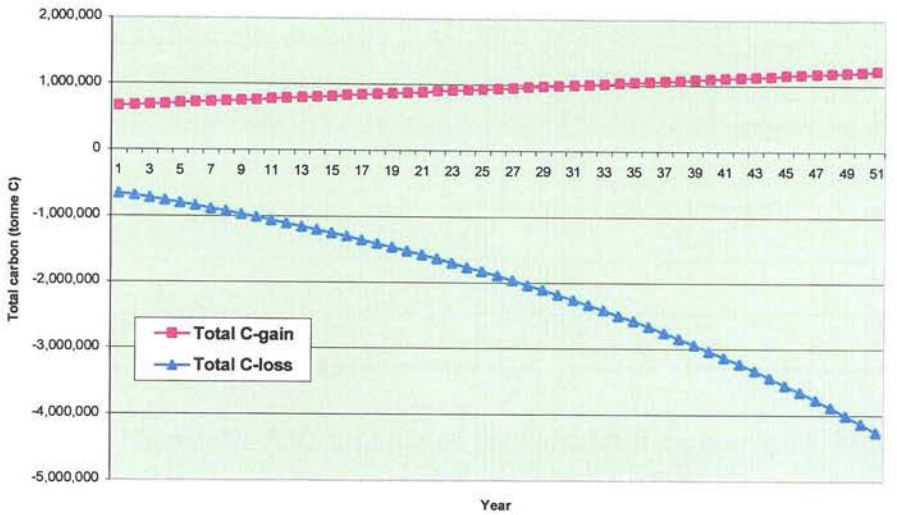


Figure 5.22: Total carbon storage gain (without-project) and loss (with-project) at the ecosystem level as the flooded area effected by Ban Koum hydropower project during 50 year-period (1998-2048).

Table 5.10: A summary of the potential carbon storage gain that would result from without-project implementation and the cumulative carbon loss (-) from with-project implementation over a 50 year-period.

Time period	Total carbon storage gain (million tonne C)	Total carbon storage loss (million tonne C)
Initial time *(t=0)*	0.66	-0.66
t=10	0.77	-1.06
t=20	0.88	-1.58
t=30	0.99	-2.26
t=40	1.11	-3.13
t=50	1.22	-4.26
Ratio of carbon storage change	**1.85**	**6.45**

Table 5.10 (Appendix 5.8) summaries the calculated carbon gain through without-project implementation and the carbon loss that could result from with-project implementation. It shows that over a 50-year period if the project is not implemented, the gain in carbon resulting from protection and growth of the forest could generate 1.85 times from the original amount. In contrast, the with-project implementation results in a major loss of carbon through encroachment, giving a total cumulative loss 6.45 times the initial amount in the reservoir area. With a human encroachment rate of 2.6 percent, about 24,500 ha or approximately 2.6 times of the total reservoir area in the period of 50 years (Appendix 5.8).

Within hydropower dam, decomposition of submerged vegetation will lead to a release of carbon stored biomass. Moreover, submerging may induce anoxic conditions at the bottom of reservoir favouring the production of methane and hydrogen sulfide and emission to the atmosphere (Galy-Lacaux et al., 1997). The results from a hydropower dam in French Guyana indicate that the total carbon loss after reservoir filling was $0.8\pm0.3\times10^{6}$ tonne C (27 tonne C/ha or 10% of the total carbon stock) for a flooded area of about 300 sq. km (Galy-Lacaux et al., 1997). The hydropower dams built in equatorial or tropical forest zones are expected to be

potentially important sources of greenhouse gases because of the high amount of flooded biomass (Frearnside, 1995).

The results illustrate that the hydropower project will cause a negative impact on the carbon balance with potential consequences for global climate changes. The terrestrial ecosystem will turn from its major role as the carbon sink become a carbon source, releasing carbon as greenhouse gases to the atmosphere and thus contributing to an increase global climate changes. On the other hand, if the hydropower project is not implemented, the area will remain as a carbon sink with further potential to store more carbon as tree biomass in the ecosystem. This provides an option to mitigate CO_2, and to conserve biodiversity, for future generations.

5.4.6 Carbon pricing

To provide a monetary value representing the ecosystem services as the unit of carbon storage and take into account the acceptable and applicable value, this study now explores carbon pricing according to the unit of carbon costs based on the objectives of CO_2 mitigation. Three scenarios are explored, based on a range of costs (see Table 3.6).

- Scenario I = Reforestation cost in Thailand at US$11/tonne C (TEI, 1998).
- Scenario II = Teak forest plantation cost in Thailand at US$56/tonne C (FIO, 1999).
- Scenarios III = Solar energy cost in developing countries at US$200/tonne C (Hall and House, 1994).

These three scenarios are applied to both the without-project and with-project situations. The evaluation is estimated from the amount of carbon stored and the justified carbon cost in the different scenarios at the year before hydropower dam project implementation. Traditionally, terrestrial ecosystems are valued through a shadow price or market based value. This study examines the monetary value of ecosystem services as carbon storage in the ecosystems without considering a discount rate (discount rate = zero). Because the discounting system is

inappropriately devaluing the ecosystem services and resulting the value received now is worth more than the future. It might cause the higher tendency of over utilisation of biodiversity at all levels. Based on equation 5.15, the monetary value is estimated as follows:

$$CV(t) = f(TC(t), P) \qquad 0 \leq t \leq T \qquad \text{(Equation 5.16)}$$

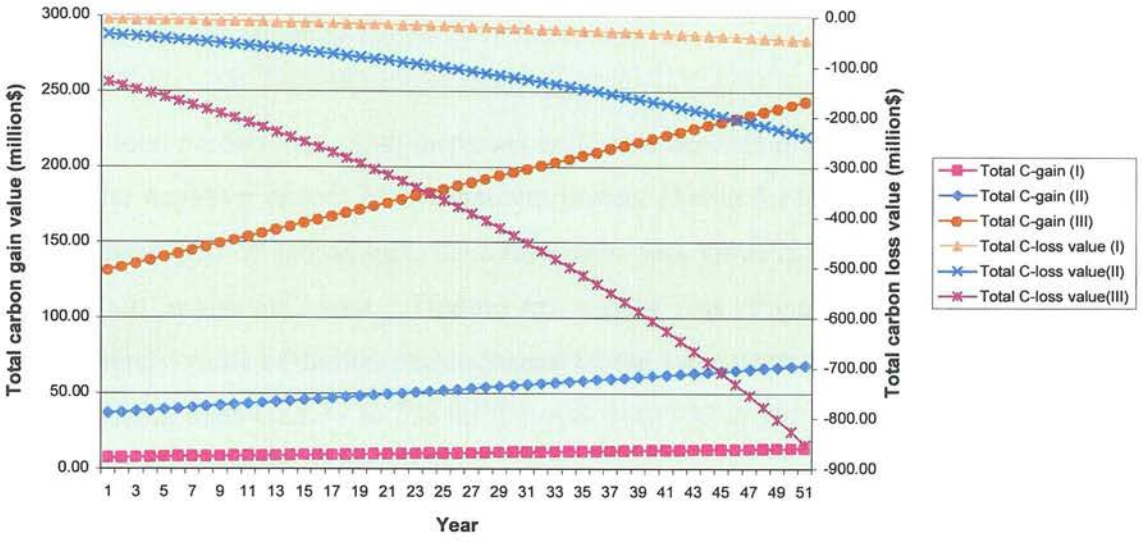
Where

$CV(t)$ = Carbon value in US$

$TC(t)$ = Total carbon storage in the ecosystem in tonne C at time t

P = The unit of carbon price in the different scenarios in US$/tonne C

The results in Figure 5.23 (Appendix 5.8) illustrate the monetary values for the total carbon gain (without-project condition) and total carbon loss (with-project condition) of the terrestrial ecosystem from t=*0-50*. They were generated from equation 5.16 in relation to the total carbon storage estimates without-project and with-project implementation under the carbon cost of three scenarios.



Note: Scenario I = The unit of carbon storage cost at $11/tonne C.
Scenario II = The unit of carbon storage cost at $56/tonne C.
Scenario III = The unit of carbon storage cost at $200/tonne C.

Figure 5.23: A comparison of total carbon gain (without-project) and total carbon loss (with-project) value (million US$) under three economic scenarios.

Without-project implementation the initial monetary value is the same as for with-project carbon loss in the three scenarios (US$ 7, 37 and 131 million). However, the accumulated value by the final year in the three scenarios (US$ 13, 68 and 244 million) is lower than the loss in the with-project scenarios because the rate of carbon accumulation is lower than the loss due to encroachment

Considering with-project value, Scenario III based on a 'Solar energy' option obviously gives the highest estimation of total carbon loss value during 50 year-period compared to Scenario I and II (Figure 5.23). The carbon cost of Scenario III is the cost of high technology dealing with a clean energy concept with a maximum cost of US$200 in the developing countries, aimed to reduce CO_2 emission from the energy end-user by changing from fossil fuels to solar energy. This option is focused on the problem of point source emission of greenhouse gases by providing an alternative energy source. In the respect, it can be considered as analogous to the

cost of hydropower generation. It is more expensive than Scenario I and II, which use more conventional and relatively low technology mitigation but which do not contribute significantly to energy replacement.

The total carbon loss value increases with time because of the human encroachment as the negative impact of hydropower project (Table 5.11). Under Scenario I, the cheapest cost of carbon unit, the total carbon loss value is slowly from US$ 7 to 18 million at the 50^{th} year. Trading the carbon loss (Figure 5.22, Table 5.10) the monetary value of carbon loss increases by the same proportions in Scenarios II and III, rising from US$ 37 to 238 million and from 132 to 851 million respectively over the 50 year-period (Table 5.11).

Table 5.11: A summary of carbon storage gain and carbon storage loss values under three scenarios during 50 year-period.

	Carbon storage gain value (million US$)			**Carbon storage loss value (million US$)**		
Scenarios	**I (US$11)**	**II (US$56)**	**III (US$200)**	**I (US$11)**	**II (US$56)**	**III (US$200)**
Time period						
Initial time *(t=0)*	7	37	132	7	37	132
t=10	8	43	154	12	59	212
t=20	10	49	176	17	89	317
t=30	11	56	199	25	126	452
t=40	12	62	221	34	175	626
t=50	13	68	244	47	238	851

The calculation presented in Table 5.11 show the difference between the value of carbon gained and lost in without-project and with-project implementation, for the three scenarios. This represents a ratio of total loss to gain of 4.5 (Table 5.12).

Table 5.12: The economic gain, loss and difference regarding to carbon pricing.

Scenario	Gain (million US$)	Loss (million US$)	Difference[a] (million US$)
I	+13	-47	60
II	+68	-238	306
III	+244	-851	1,095

Note: a = Difference is impacted by dam construction and human encroachment.

Nilsson and Schopfhauser (1995) reviewed the feasibility of forest plantation for carbon sequestration purposes. The concluded that plantation could be established globally on about 345 million hectares over a 60 year-period, giving a maximum annual rate of carbon sequestration of 1.48 Gt/yr. This is substantially lower than the amount of carbon required offsetting the current carbon emission at 3.8 Gt/y in order to stabilise the carbon content of the atmosphere. However, a wider range of forestry options are available for the mitigation of carbon buildup, including

- Slowing the rate of tropical deforestation
- Increasing the productivity of existing forest
- Increasing forest plantation

If the forest is considered as a natural resource that has to be sacrificed for the hydropower development project, the decisive information might be based on the total carbon value in the Scenario I and II. At the same time, the reforestation and forest plantation are sensible options for implementation, as suggested by Nilsson and Schopfhauser (1995). The decision-makers might negotiate for expansion after protection of forests to restore carbon in the other areas even if it takes a long time to store enough carbon to replace the carbon storage lost. A weakness of forest plantation, is that it is not a forest ecosystem like the original forest lost because the forest plantation technique employs monoculture or multiculture but the ecological structure and functions of the natural forest is irreversible, particularly the functions related to the components of biodiversity. Thus, although the reforestation is an ecological friendly strategy and tropical tree species can achieve remarkably high values of biomass within 40 years of planting under optimal conditions.(Flint and

Richards, 1996), it still does not replace the characteristics of the original forest. It might be similar to the original forest to the certain point according to the ecological succession but it takes a long time and protection to reach the mature stage of succession and many Asian-forest species continue to increase in volume and biomass for centuries (Lamprecht, 1989).

Therefore, there is a good argument to save the natural forest and allow forest trees to provide a carbon sink in order to contribute to the carbon balance in the global ecosystem (Beran, 1995). The forestry option is attractive to decision-makers but both reforestation and forest plantation options cannot completely solve the problem of global climate changes. There are some arguments which suggest that too much emphasis on the forestry options for CO_2 mitigation is likely to divert attention from or excuse the need to cut fossil fuel consumption (Cannell, 1999). On balance, the carbon storage approach and evaluation can contribute to a fair carbon trade off between the forestry management option in the developing countries and the industrial or developed countries.

5.5 CONCLUSIONS

Ecosystem evaluation is controversial because the ecosystem itself is very complex and it is difficult to quantify the value. The purpose of ecosystem evaluation is to elicit a measure of ecosystem services that sustain the whole ecosystem. *Carbon* is considered as a representative of ecosystem services for the ecosystem evaluation, because of its fundamental biological importance and its relevance to the issue of climate change. It can also be expressed in monetary terms to encourage economists, decision-makers, and policy-makers to take ecosystem value into their consideration of sustainable development. This study is designed to test the potential of carbon storage as an ecosystem value, through a case study of the Ban Koum hydropower project in the Lower Mekong River.

The study area is dominated by primary, secondary forest (75 percent), riparian (20 percent) and small areas of grassland, paddy rice field and home garden system.

Measurement of the biomass in each land use was used to calculate the total carbon storage (by multiplying conversion factor of 0.5), which shows (Table 5.13) that the primary forest has the highest capacity to store carbon, followed by the riparian and the secondary forests. The grassland, home garden system, paddy rice field and riparian zone have low potential to store carbon because the perennial pattern of vegetation has a short life cycle at annual time scale.

It is estimated, based on knowledge of NPP and NEP, that in the absence of dam development the carbon stored in the forest could increase by factor of 1.85 over a 50 year-period. In contrast, dam construction would result in a loss of carbon not only by directly flooding the land, but also through change in land use caused by human encroachment into the remaining forest, facilitated by improved access. Over 50 year-period, it is estimated that $4.3x10^6$ tonne of carbon would be lost through hydropower development, compared with a gain of 0.56 $x10^6$ tonne, without-project implementation, a ratio of carbon gain to carbon loss of 4.5.

In contrast, the interlinkage of carbon in aquatic ecosystems is clearly complicated with the low amount of carbon storage in primary producers and its very fast turn over rate. This, combined with the relatively small area of water, indicates that the aquatic systems are not major contributions to potential carbon sequestration. Therefore further analysis has concentrated on carbon storage in the terrestrial ecosystem. However, the study provides evidence that aquatic primary production is approximately halved after dam construction, and that dam construction upstream (China) may be affecting water flow and quality in the study area.

The forest can be considered as the major carbon store in the terrestrial ecosystems and it is possible to estimate the price of different land use types regarding this carbon storage potential. The price range provides value based on carbon storage value by various forestry and clean energy options. The price of primary forest seems to be the most expensive land use with a range from US$ 1,125 to US$ 20,460 per hectare (Table 5.13), which compares to the price of tropical forests from

US$1,000 to US$3,000 per hectare by Pearce (1994). These land use costs can be incorporated into the economic analysis of development project.

The next step has therefore been to attempt to convert carbon storage to the monetary value with regard to the carbon cost of CO_2 mitigation at the global scale of environmental problems. The three cost scenarios applied reflection the range of options for reducing CO_2 emission to the atmosphere such as the reforestation, the forest plantation and clean energy such as solar energy. Each scenario was applied to assess the carbon cost of gain (without-project) and the carbon cost of loss (with-project) from the terrestrial ecosystem in relation to the planned hydropower project. The results show that if the terrestrial ecosystem is destroyed by the project, more carbon will be lost over a 50 year-period than would be gained if construction did not proceed. The monetary value of the carbon gain or loss depends on the mitigation cost applied. Thus the lowest mitigation price (Scenario I) generates a loss of US$ 47 million compared to a gain of US$ 13 million; a difference of US$ 60 million. The highest mitigation price (Scenario III) values the carbon loss at US$ 851 million, compared to a gain of US$ 244 million; a difference of US$ 1,095 million.

Table 5.13: A summary of biomass, carbon storage and land use value in the different land use types.

Land use types	Biomass (tonne/ha)	Carbon storage (tonne C/ha)	Land use value[4] (US$/ha)
Primary forest	204.7	102.3	1,125-20,460
Secondary forest	100.0	50.0	550-10,000
Riparian forest	120.2	60.1	661-12,020
Riparian zone	1.1	0.6	7-120
Grassland	6.6	3.3	36-660
Paddy rice field	3.1	1.6	18-320
Home gardening system	5.6	2.8	31-560

[4] Land use value is estimated from the cost of carbon storage in ecosystems.

The terrestrial ecosystem had an initial carbon value estimated at US$ 7 and 132 million. If the value of carbon gained or lost over a 50 year-period is taken into account, the monetary value of the terrestrial ecosystems is increased to between US$ 60 and 1,095 million. These values are ecologically justified because they incorporate the carbon cost based on CO_2 mitigation management, the loss of carbon storage potential and also the carbon released by human encroachment to the natural forest as a consequence of project implementation.

Guo and Randel (1997) recommend the use of biomass and productivity data as the most approriate variables because they best represent per capita resource use and resource partitioning among organisms in competitive situations. They are obviously associated with the ecological functions, and also integrate the complex interlinkage of carbon storage in the terrestrial ecosystems. This chapter has provided a rational and practicable evaluation at the ecosystem diversity level, with emphasis on *carbon storage* as one representative of ecosystem services. The models used are simple and flexible and therefore allow alternative scenarios to be examined, as demonstrated. Carbon storage in the terrestrial ecosystem plays the important role in the global climate change but requires strategies to reduce CO_2 in the atmosphere by managing the natural ecosystem. If this approach is acceptable and applicable, it will guide the decision-makers or policy-makers or economists to take biodiversity at ecosystem level into their consideration based on sound ecological principles. The results from this chapter are later integrated with results from chapter four and six in order to test their application to the traditional and the alternative IA, and to improve the potential for sustainable development.

CHAPTER SIX
SOCIO-ECONOMIC EVALUATION

This chapter focuses on humans as a component of species diversity level. It is important to consider ***humans*** within a biodiversity evaluation as humans are major consumers of natural resources. In an economic perspective, humans' perceptions and interactions with other species, as well as other people, are always assumed to be rational, self-interested, and utility-maximising (Siebenhüner, 2000). This perception, particularly in the developed countries, permits enormous economic development and the extensive fulfillment of people's material needs for food, housing, security and physical health. Consequently, it posses a threat to biodiversity, which may be utilised by humans. The accelerated loss of biodiversity has become a major economic and environmental issue and has activated human motivation to achieve sustainable use of natural resources (Prato, 1998). To respond to the concept of sustainability, humans need to change their values and lifestyles towards less material consumption and collective environmental action (Siebenhüner, 2000).

This chapter is organised as follow:

- Overview of socio-economic scheme
- Scope of the study
- Background of the community situations
- Methodology (Data collection and data analysis)
- Results and discussion
- Conclusions

6.1 OVERVIEW OF SOCIO-ECONOMIC EVALUATION

The impacts of a project on socio-economy is termed a *'socio-economic assessment'*. It is 'the systematic advanced appraisal of the impacts on the day to day quality of life of people and communities when the environment is affected by development of policy change (Glasson, 1995). Marriot (1997) mentions that the impacts on

lifestyle, or the ways of life are often difficult to address and quantify. Some of the socio-economic concepts need to deal with the complexity of culture and history, where culture is an inter-subjective meaning constructed and communicated between people in and around economic interaction (Swedberg, 1991).

A wide range of impacts may occur after a hydropower development project, which include both ecological and socio-economic impacts. Generally, hydropower development projects in which the natural forest area is converted to a dam or a big reservoir have often failed to take into account the impacts on local people with traditional right to natural resources. The failure to adequately compensate or involve local people in the processes of fairness has resulted in poor performance of some projects. Further, the local people in rural communities are uprooted and forced to go elsewhere to take up unproductive land as the new residence or to probably change the pattern of living or to work in the cities.

The Pak Mun Dam in the northeastern of Thailand is a good example of the socio-economic impacts, which may be felt by local people after an environmental evaluation and impact assessment has taken place. This dam was selected for this study because it reflects the potential socio-economic impacts to local people from proposed dam projects in this region. The feasibility study of Ban Koum Hydropower Project in the Mekong River, estimated the cost of human impacts considering only the cost of a resettlement programme at US$5,500 per person (MRC, 1994).

A more balanced decision-making process may consider trade-offs between socio-economic and ecological costs and benefits. Equal importance should be given to both socio-economic and ecological schemes. Therefore, it is necessary to take both social and economic sectors into account so the decision-making process might consider natural resource utilization equally between humans and other living creatures. This study intends to explore socio-economic indicators from the basis of all social and economic variables and incorporate them into the methodology of impact assessment.

6.2 SCOPE OF THE STUDY

The overall study attempts to integrate socio-economic aspects within the IA (chapter seven). This chapter seeks to quantify the socio-economic impact for the without-project and the with-project situation. Figure 6.1 illustrates the scope of the study.

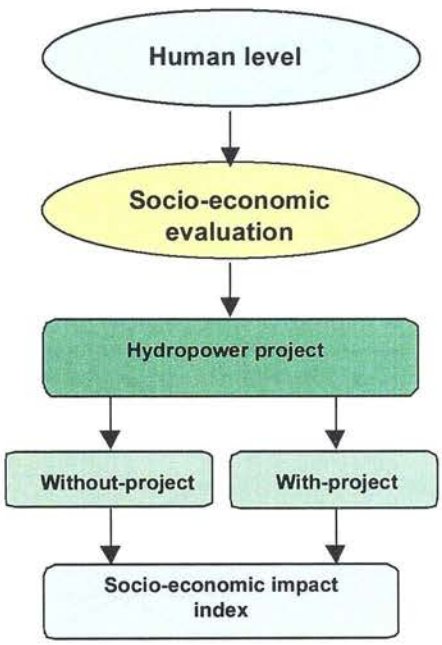


Figure 6.1: Scope of the socio-economic evaluation.

To understand the scope of study mention must be made of how the local governmental system functions. The Thai governmental system is classified into Regions, Provinces, Amphoes, Tumbons and Bans (villages) (Figure 6.2). This study will focus on the smallest local governmental administration level, the Ban.

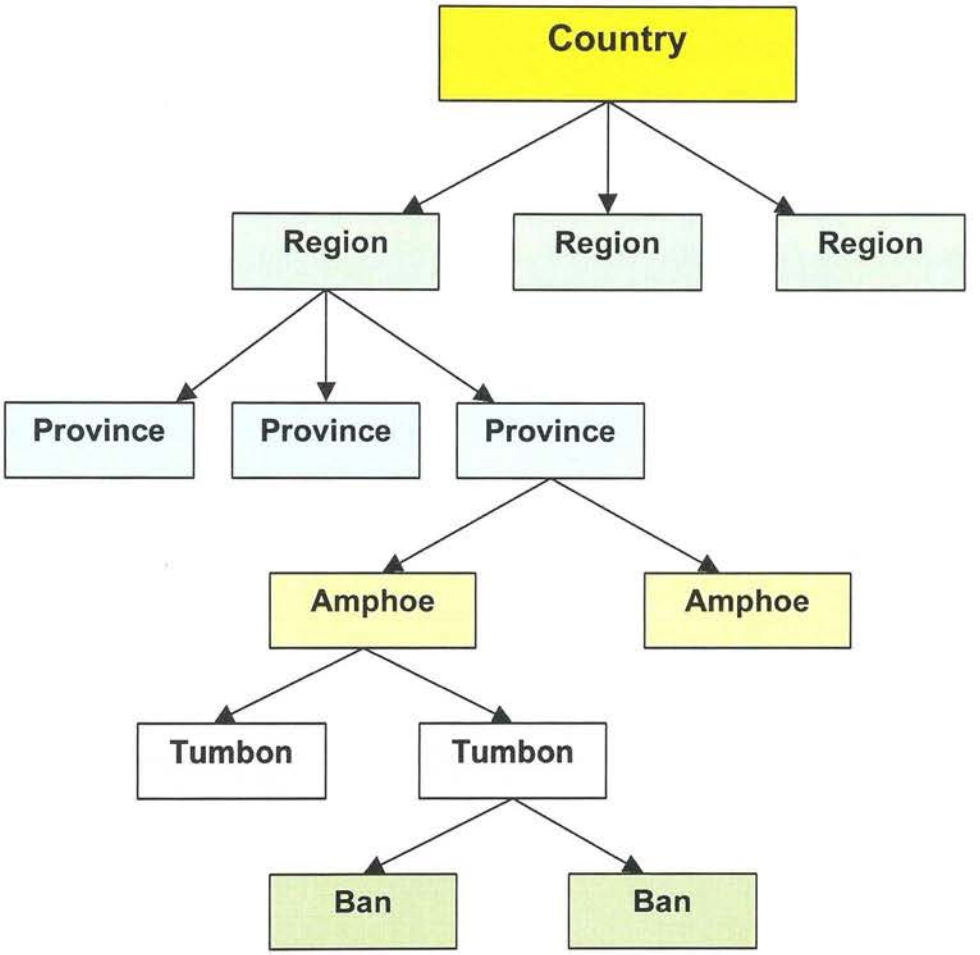


Figure 6.2: The organisation of governmental system in Thailand.

6.3 BACKGROUND OF THE COMMUNITY SITUATIONS

6.3.1 The without-project situation

The study will examine on how the local people normally live in the existing situation, before Ban Koum Hydropower Project implementation, in five villages along the Mekong River. This situation represents the before project

implementation, or the without-project. The without-project samples consist of Thai villages and Laotian village along the Mekong River. The Thai villages along the Mekong River are all Buddhist. Every village has a primary school, clean water and electricity supply provided from the local governmental authority units. A mobile medical team regularly visits each village at least once a month. Amphoe Khong Chiam's annual report (1997) indicates that the average income of local people in Amphoe Khong Chiam is 7,960 Baht per capita per year. This is equal to US$257 per capita per year according to exchange rate at US$1 per 31.4 Baht (World Bank, 1998a).

In the Laotian situation, all of the villagers are Buddhist and there is no school in each village, no clean water and no electricity, except a stand-alone generator in some households. To receive formal education, the children must take a boat for a 2-3 hours daily trip to the nearby city or move to a city with their relatives. There is no medical centre nearby the villages. Therefore, Laotians always take patients across the Mekong River to receive public health services from the Thai mobile medical team. They usually undertake illegal trading across the Mekong River in order to earn money for their family. The illegal products are marketable timber and fish, agricultural products and some wildlife. The Laotian language is quite similar to the Northeastern Thai language so communication is not difficult for the local people along the river. There is no reliable information about the average income of Laotians in this area.

6.3.2 The with-project situation

The selected dam (with-project situation) for the socio-economic study is Pak Mun Dam project. This project has been constructed in the same manner as Ban Koum hydropower project, and its engineering technique is a 'run-of-river' dam system. This dam is located on the Mekong's largest tributary in Thailand, and was built during the early 1990's by the Electricity Generating Authority of Thailand (EGAT). This dam was partially funded by the World Bank on the strength of cursory environmental impact assessments that did not study the seasonal fish migrations or

the relationship between the river and the local people (Brown et al, 1996). The cost of resettlement and compensation of this project was US$20 million (WCD, 1999). The Pak Mun Dam project has directly affected 241 households in eleven villages, including 136 households below 108m at mean sea level (maximum operating level), four households between 108.0 and 108.5m at mean sea level potentially affected by wave action and/or backwater effect. Another eleven households downstream of the dam near the construction site have also been affected. Furthermore, almost 6,000 families claimed to have lost fishing income since the dam construction. The conflict among local people, Thai government and the World Bank is still unsolved because about 3,000 households have been considered for compensation (30,000 Baht in cash, plus a 60,000 Baht contribution to a fund for occupational development of the fishermen), but the cases remained unresolved.

There are two Thai villages nearby Pak Mun Dam, Amphoe Khong Chiam, Ubon Ratchathani Province, which have been effected by the hydropower dam project since 1995. EGAT is the government authority for generating electricity and promoting the hydropower project. EGAT provided the community facilities and services for the resettlement of villages, such as roads, electricity, schools, temples and public health centres. EGAT also provided alternative compensation packages for resettled local families from one of the following options:

- The allocation of at least 0.08 ha (half a rai) of land for home plots and 1.6 ha (10 rai) of land for farm plots per family in the resettlement area. Assistance with the construction of houses out of compensation received by them for property is provided from them. For example, providing 30x20 m^2 land area with a basic house or providing land area and money of 135,000 Baht. It is equal to US$5,335 (exchange rate in 1995 at US$1 per 25.3 Baht) for their own house construction (Yahphrom, 1993).
- The reconstruction of their existing houses on new back-filled ground near the original site of such houses.

There are some conflicts between EGAT and villagers in relation to the compensation of land and the loss of fishery opportunity in natural waterway during

the construction. These problems have not yet been solved.

6.4 METHODOLOGY

6.4.1 Study sites

The without-project study sites

The target sample groups of the socio-economic study consist of a without-project sample and a with-project sample. The without-project sample consists of five Thai villages and one Laotian village along the Mekong River. The Thai villages were located in Pha Taem National Park, Amphoe Khong Chiam, Ubon Ratchathani Province, Thailand, which is opposite to Phou Xiang Thong Protected Area in Lao PDR. The typical infrastructure of Thai villages is displayed in Figure 6.3.

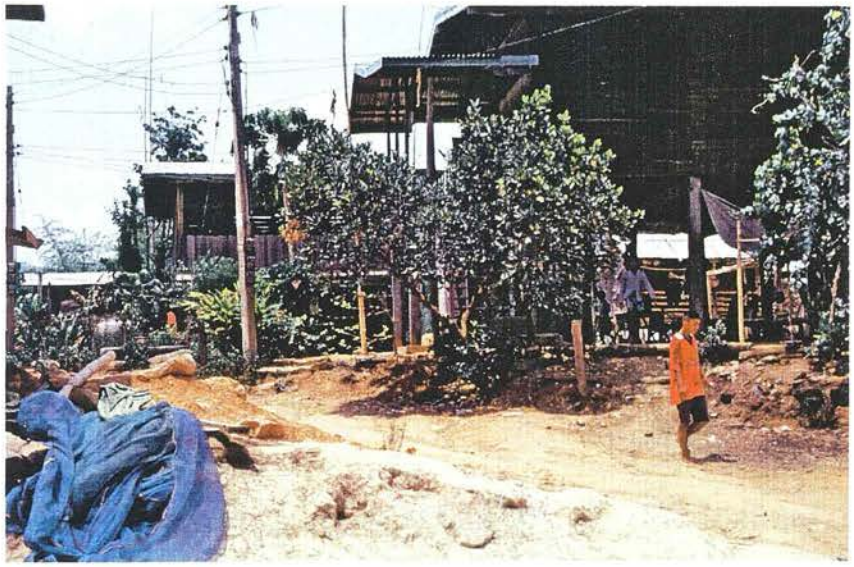


Figure 6.3: Infrastructure and households in the without-project sample.

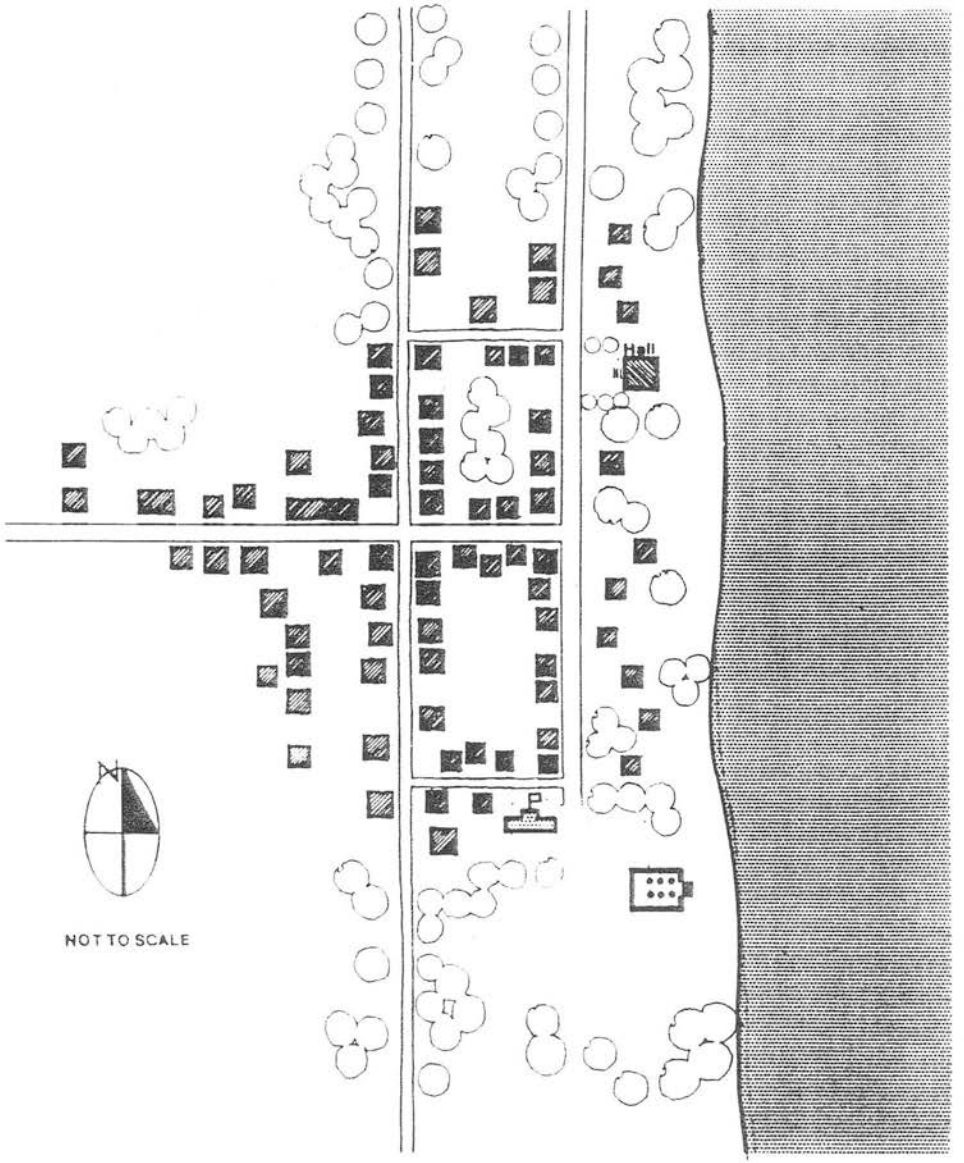
The Thai villages are:

1. Ban Kum (Tumbon Huai Phai, Amphoe Khong Chiam, Ubon Ratchathani Province)
   - This village has been located in this area for over 100 years. It consists of 93

households with a total of 377 inhabitants. Twelve households were selected for interview (Figure 6.4).

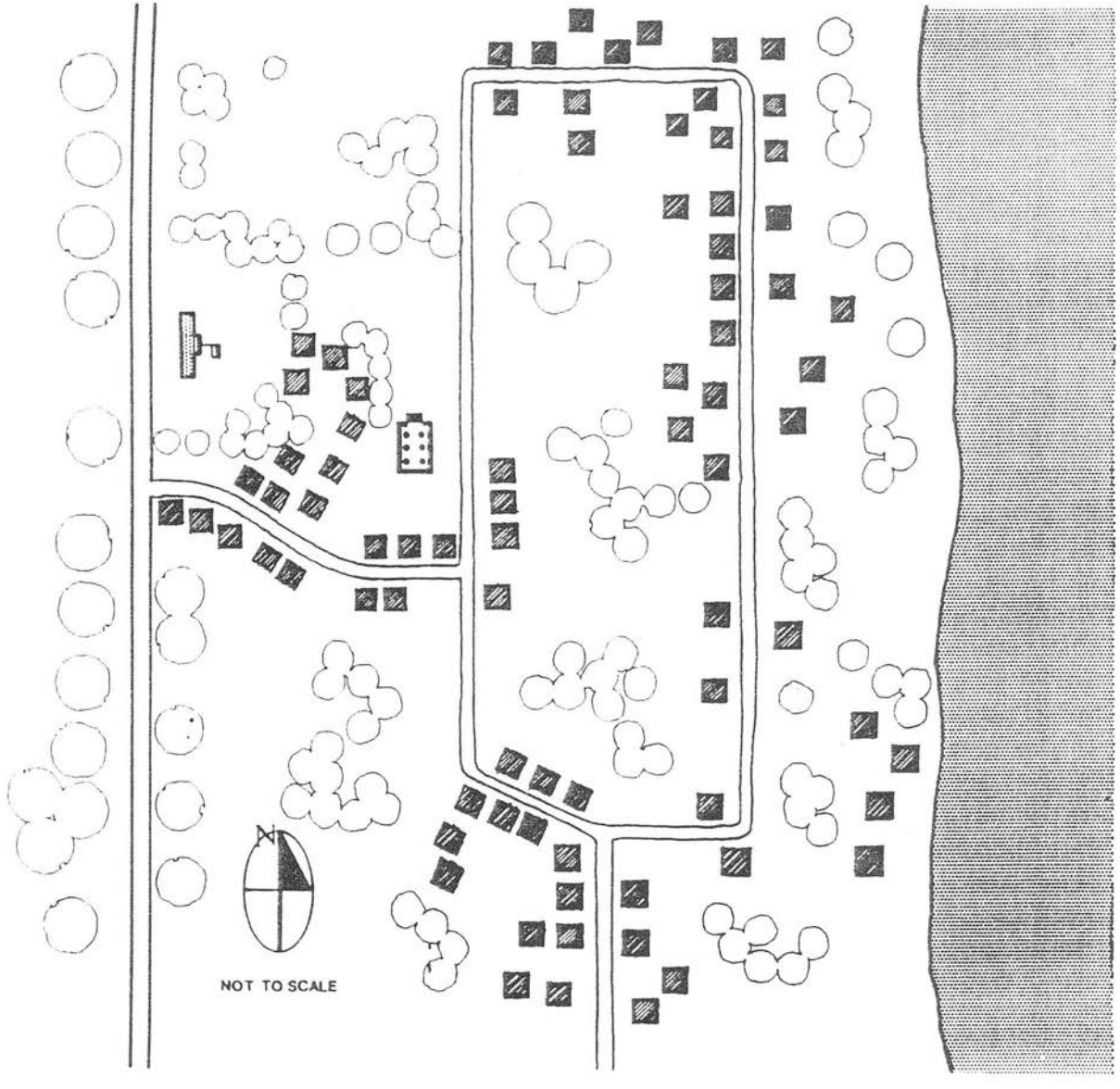
2. Ban Ta Mui (Tumbon Huai Phai, Amphoe Khong Chiam, Ubon Ratchathani Province)
   - It has existed for over 100 years. It consists of 82 households with a total of 486 inhabitants. Twelve households were interviewed (Figure 6.5).
3. Ban Tha Long (Tumbon Huai Phai, Amphoe Khong Chiam, Ubon Ratchathani Province)
   - It consists of 48 households with a total of 266 inhabitants. Eight households were interviewed. This village likely has long history as Ban Koum and Ban Ta Mui (Figure 6.6).
4. Ban Tung Na Mueng (Tumbon Na Pho Klang, Amphoe Khong Chiam, Ubon Ratchathani Province)
   - Consists of 166 households with a total of 692 inhabitants. Sixteen households were interviewed. This village was established over 35 years ago (Figure 6.7).
5. Ban Khan Tha Kwean (Tumbon Na Pho Klang, Amphoe Khong Chiam, Ubon Ratchathani Province)
   - It consists of 64 households with a total of 265 inhabitants. Eleven households were interviewed. This village was established over 100 years ago (Figure 6.8).

Laotian villages in the study site were located in the northern Champasak Province and the southwestern Saravan Province, the southern region of Lao PDR. There are three villages and one military camp. Because of political and military constraints, the survey could be conducted only at Ban Sura. Ban Sura, across the Mekong River from Ban Kum, was selected as the representative of Laotian villages. Thers are 88 households and eight households were interviewed. Since Lao PDR has been a socialist nation with strong centralisation, the assumption for this study is that all Laotian villages have homogenous socio-economic characteristics.



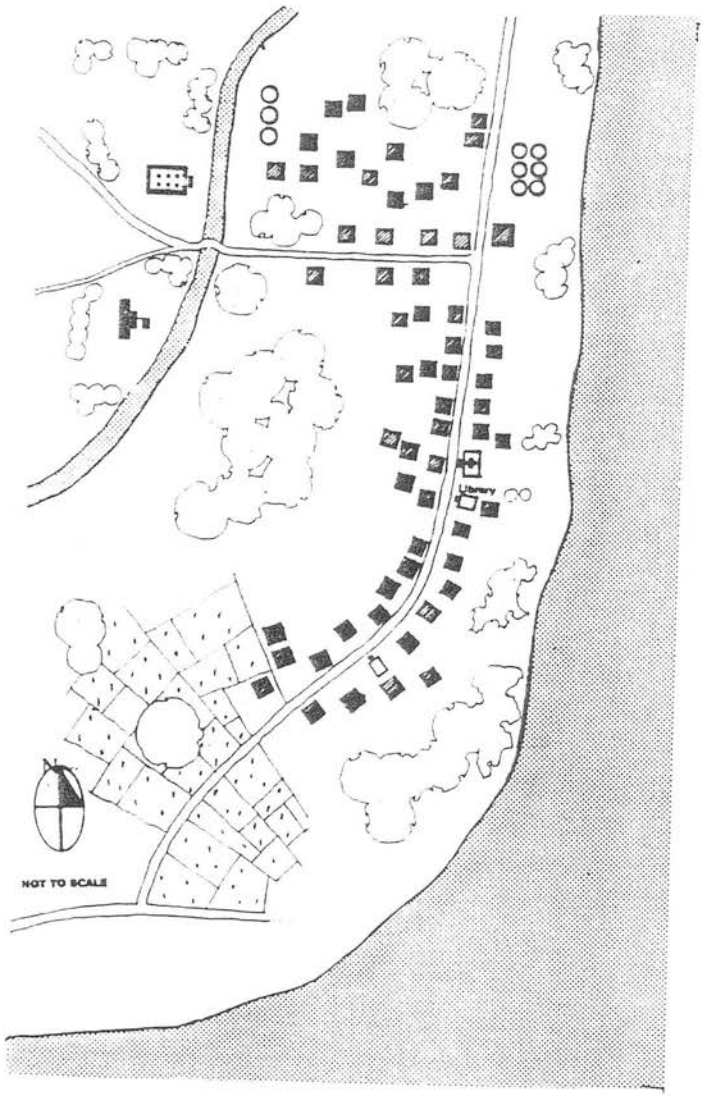
Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.4: A schematic map of Ban Kum.



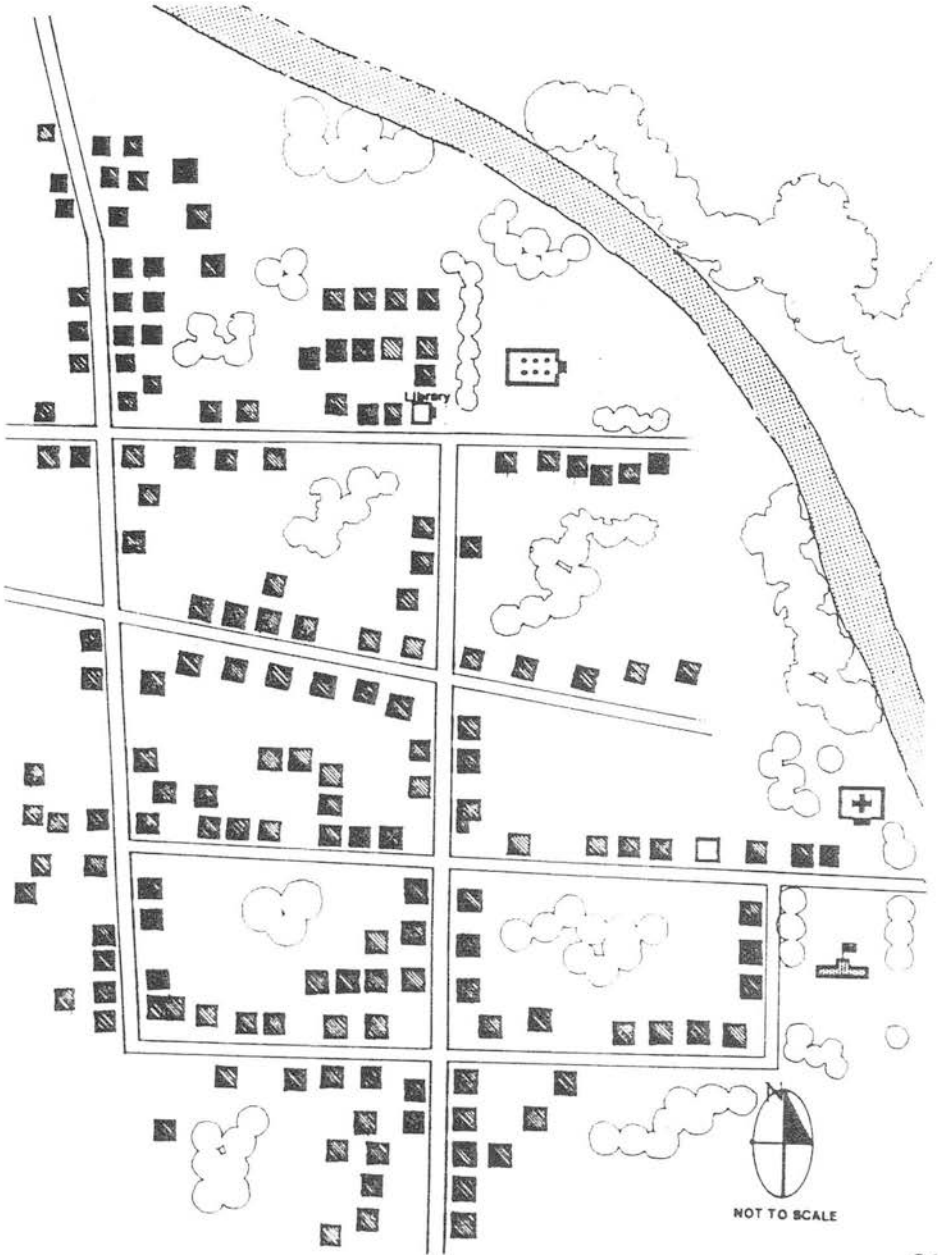
Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.5: A schematic map of Ban Ta Mui



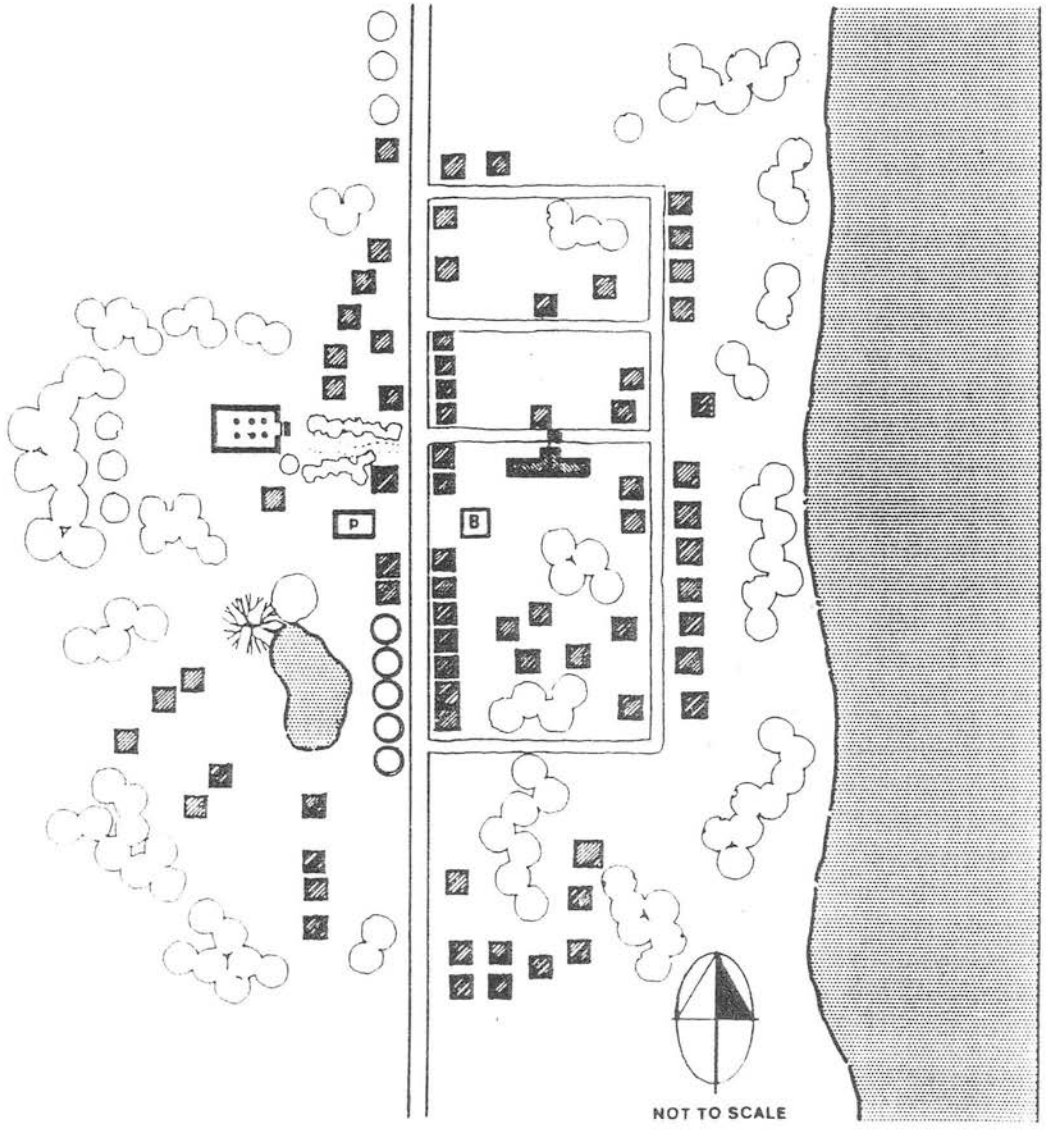
Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.6: A schematic map of Ban Tha Long.



Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.7: A schematic map of Ban Tung Na Mueng



Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.8: A schematic map of Ban Khan Tha Kwean

The with-project sample consists of two Thai villages, located nearby the Pak Mun Dam, Amphoe Khong Chiam, Ubon Ratchathani Province (Figure 6.9). These villages have been effected by the hydropower project since 1995 (Figure 6.10).

1. Ban Hua Hail Pattana
   - There are 92 households. Twelve households were interviewed (Figure 6.11).
2. Ban Hua Hail
   - There are 59 households. Ten households were interviewed (Figure 6.12).

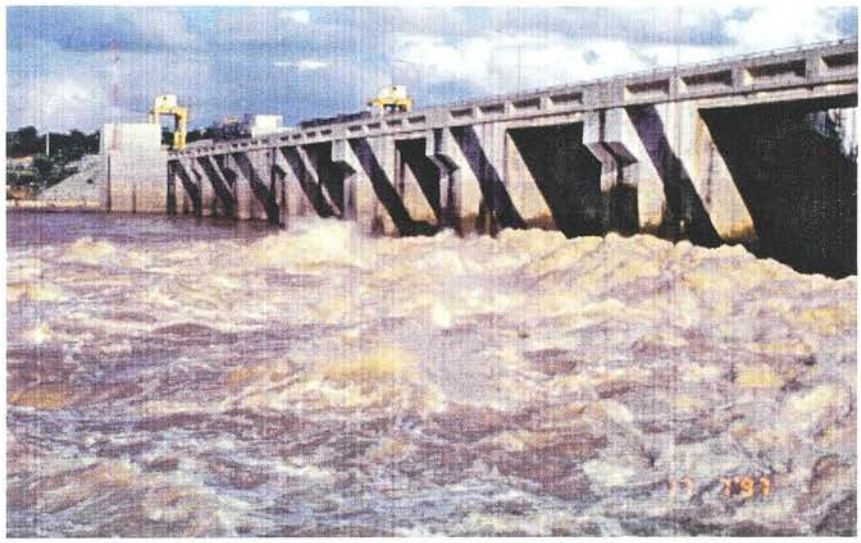
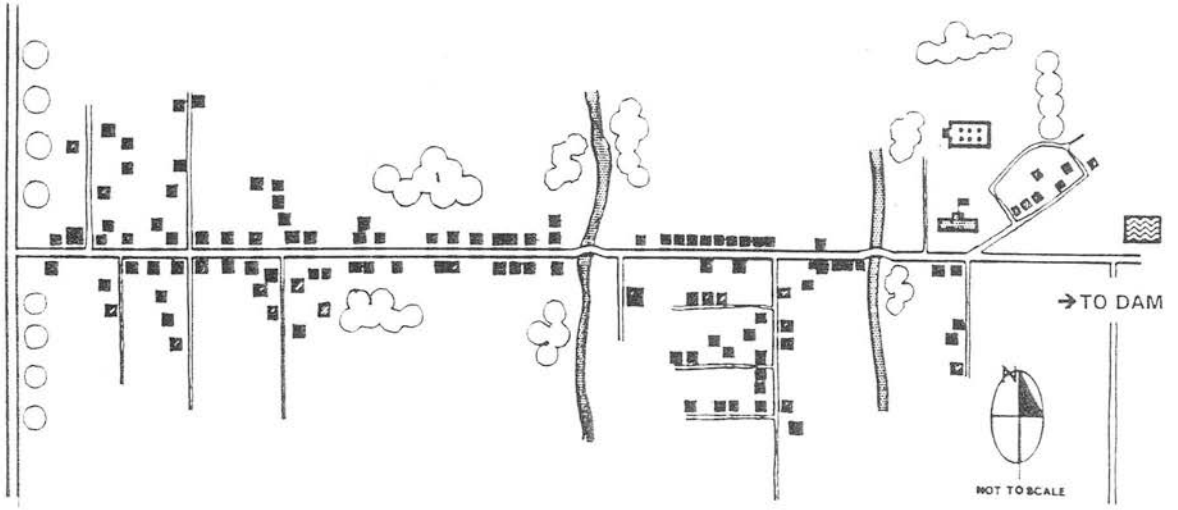


Figure 6.9: Pak Mun Dam in Amphoe Khong Chiam, Thailand.



Figure 6.10: Infrastructure and households in the with-project sample as the village nearby the Pak Mun Dam.



Description			
	Creek, River	P	Police station
	Dam		Pond
	Deep well		Rice field
Hall	Main hall		Road
B	Head village		School
	Health centre		Temple
	Household		Tree
Library	Library shelter		Groups of trees

Figure 6.11: A schematic map of Ban Hua Hail Pattana.

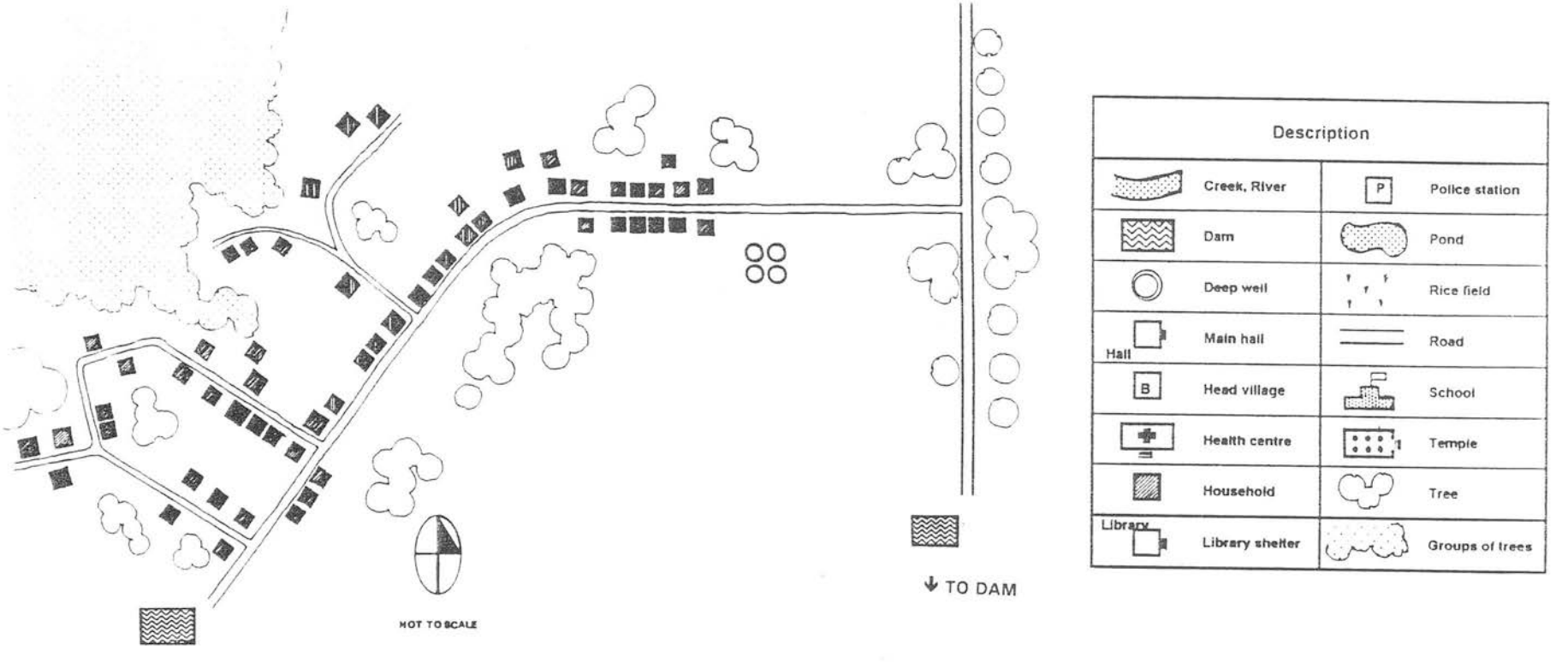


Figure 6.12: A schematic map of Ban Hua Hail

The natural resources were utilised by local people and classified into two categories - forest products (Figure 6.13, 6.14, 6.15 and 6.16) and fishery products (Figure 6.17). In term of the forest products the focus is on 'non-timber forest products' only, which are extracted from forest for human use. These include subsistence foods (bamboo shoot, mushroom, vegetable, etc.); small animal and insect; firewood; oil and resin; medicinal plants; and raw materials like small wood. Most of these products are used for subsistence or traded locally. Their economic value is therefore hard to monitor and easily overlooked (Jepma, 1995). However, the value of non-timber forest products, if they are properly assessed, may even outweigh that of timber (De Beer and McDermott, 1996).



Figure 6.13: Bamboo shoots are used as a subsistent food during rainy season.



Figure 6.14: Mushrooms trading in a village.



Figure 6.15: Firewood as a household energy source.



Figure 6.16: Resin from trees as a raw material for a household.

The fishery products are composed of fish, shrimp and crayfish. The fishery products are consumed and some traded to the middlemen from Amphoe or Province. The fishery value depends on the demand and supply in the market during the season.

Both of these natural resources were considered in this study. Data collected on natural resource use included: collector gender, the distance and time of collection, the frequency of collection, the percentage of trading to the market and the marketable value of products.







Figure 6.17: Fishery products from the Mekong River.

Marshall and Rossman (1999) suggest that the surveys are the preferred method if the researcher wishes to obtain a small amount of information from a large number of subjects. The questionnaires should be tested through administration to small groups to determine their usefulness and reliability. The aim of the survey method is to describe and explain statistically the variability of certain features of the population. Because of the strengths of the survey method, they possibly provide accuracy, generalisability, and convenience for extracting information to be amenable to rapid statistical analysis and are comparatively easy to administer and manage.

In this survey, the simple random sampling assumes that every household has an equal and independent chance of being chosen for survey. In theory, this simple random sampling requires selection with replacement, but samples in survey research will generally be comparatively small in contrast with the number of elements potentially available for sampling. Then the effect of non-replacement will be trivial and need not be considered further (Schofield, 1996).

Two sets of questionnaires were used, one designed for the villages along the river as the without-project implementation and the other for the villages nearby the Pak Mun Dam as the with-project implementation.

6.4.2 Data collection

The survey included a total of 89 households in eight villages including five Thai villages along the Mekong River, one Laotian village along the river and two Thai villages nearby the Pak Mun Dam. The sample size was approximately 15 percent of total households in each village. Thai and Laotian villages along the river lie about 30 km upstream from the proposed dam site, and represents the without-project implementation. The other two Thai villages nearby the Pak Mun Dam represent the resettlement villages in the with-project situation.

During the survey, the local governmental officers assisted in administering and introducing the reseacher to the head villagers in both the without-project sample and the with-project samples. The survey was undertaken following a reconnaissance visit to each village, and conversations with head villagers and old people. Interviews with the household respondents then followed. The survey was conducted in the Thai language with assistance from a local translator during all the interviews.

The questionnaires consisted of two sets – without project and with project - which are based on Kramer et al. (1995) and Gunawardena (1998). The questionnaire set A was designed for the without-project target sample that is located in the proposed dam area (Appendix 6.1). Another questionnaire set B was designed for with-project target sample (Appendix 6.2). This questionnaire set B included several more questions than set A. These focused on attitudes relating to natural resources and quality of life. The target respondent for the interview was either the head of household or their spouse in each household. The questionnaires focused on the socio-economic profile and included the following:

- Demographic information of household respondents
- Household size and household situation
- Occupation
- Income information
- Attitude to natural resources
- Natural resources accessibility and value
- Quality of life

The data collection was conducted between June 1997 and May 1998. Each interview took approximately 30-45 minutes. For the Laotian respondents, the interview was arranged in Ban Kum whenever the Laotians come across the Mekong River for social or trading activities with Thai villagers. In order to interview Laotians, it was necessary to clearly explain the objective of study and convince them. This was necessary that nothing in relation to political and military issues was

involved, because of the strong political and military influences in Lao PDR.

In order to aid data interpretation and analysis, the specific definition of some variables was clarified to the respondents during the survey. For instance, the household income generated from all kinds of activities to earn money included harvesting forest products for their livelihood or for trading, and fishery for subsistence food or for trading. Moreover, the time collecting, the gender of the collector and the collection distance is clearly identified. These data must be interpreted to show how much the local people rely on the natural resources. The attitude of local people to natural resources between forest and river is explored and compared. Finally, the rice consumption as kilogram per capita per year is measured and interpreted as one variable in the quality of life.

6.4.3 Data analysis

Data were analysed by non-parametric tests because these are compatible for nominal data, ordinal data as well as non-normal distribution of continuous data (Puri, 1996). Cramer (1994) recommends three conditions of data to fit with parametric test, if not these data should fit to non-parametric test. These conditions are:

- The variables are measured with an equal interval or ratio scale and the samples are drawn from populations.
- The variances are equal or homogenous.
- The distributions are normal.

Test the difference for unrelated data is the *Kruskal-Wallis test* equitable to one-way ANOVA because this test can be used to analyse ordinal data with more than two unrelated samples (Cramer, 1994). In the case of the nominal data, the Chi-square test can be used. Test of association for unrelated data fit is the *Spearman's rank order correlation*. Subsequent to correlation analysis, all the variables, which have different degree of correlation among those variables, are able to be included in specific factor analysis such as *Principle Component Analysis* (PCA) (Hair et al,

1998). With this factor analysis, a large number of variables can be grouped and reduced by defining a set of common underlying dimensions or factors. This PCA is used here to identify the underlying evaluative dimensions that become composites of specific variables. The advantage of PCA is that the reduction of dimensionality reduces the number of the independent variables without losing much of the information. As the result of PCA, the specific variables will be confirmatory as the statistical influencing factor to the dependent variable in the multiple regression equation. The data analysis will follow step by step the Figure 6.18. All these data from the questionnaires were interpreted and coded using the statistical programme SPSS WINDOW 6.1.3 (Norusis, 1993).

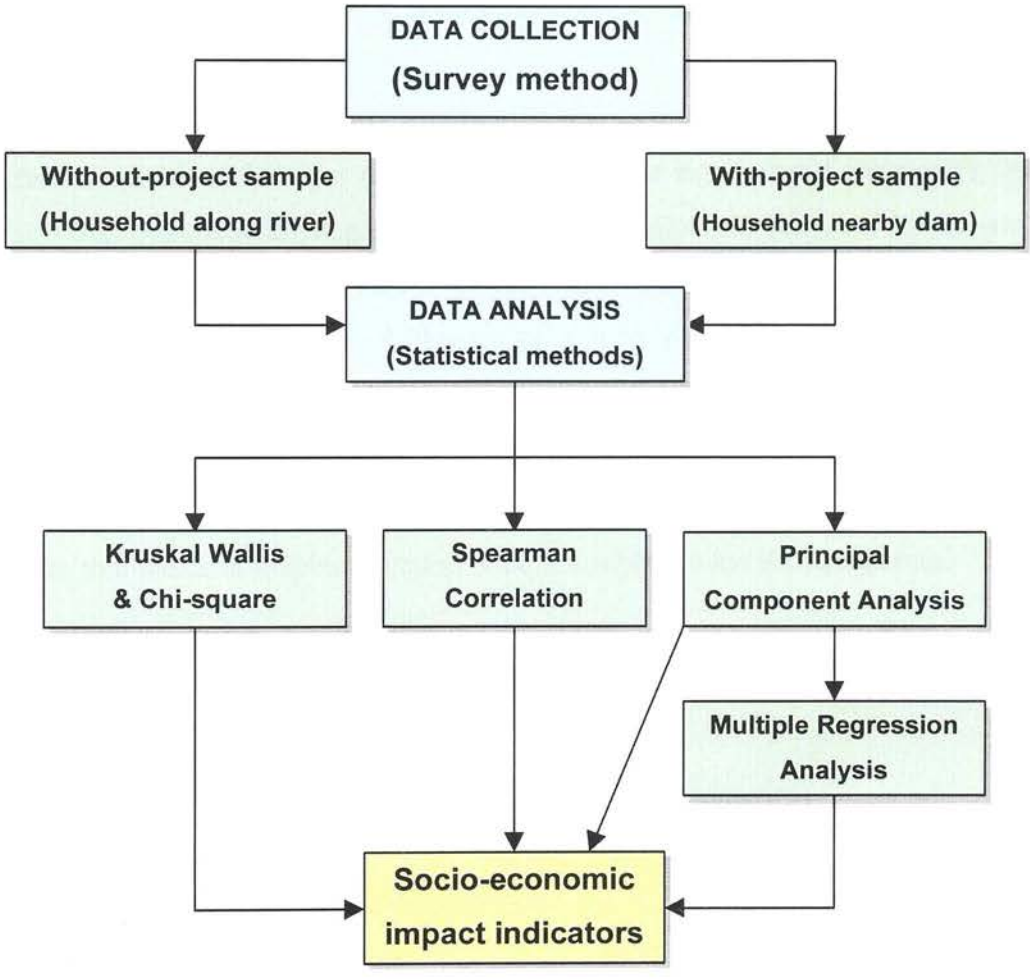


Figure 6.18: A flowchart of data collection and analysis for socio-economic impact indicators.

6.5 RESULTS & DISCUSSION

6.5.1 Test of the difference

The analysis of without-project and with-project samples were classified into seven characteristics of the socio-economic profile. Those socio-economic variables are analysed statistically for significant differences at $p=0.05$ by the *Kruskal-Wallis test* (One-way ANOVA) for non-parametric and non- categorical variables and *Chi-square test* for non-parametric and categorical variables (Cramer, 1994).

6.5.1.1 Demographic information of household respondents

There was no significant difference between the two samples (Table 6.1). The sex of household respondents between male and female has no significant difference (χ^2 = 1.11, p = 0.29). The mode of age group is in the range of 41-50 years old for sample set A as without-project sample and 31-40 years old for sample set B as with-project sample, which has no significant difference (χ^2 = 6.40, p = 0.17). The educational background shows the same mode as primary school level, which has no significant difference (χ^2 = 2.51, p = 0.64). Therefore, most respondents were educated to primary school level. That means they are capable of writing and reading. It clearly concludes that the demographic situation of both sample groups is homogenous.

Table 6.1: A comparison of demographic information between the without-project (A) and the with-project (B).

Variables	Without project (A)	With-project (B)	Chi-square (A&B)
Sex (Male %)	49.58	36.67	1.11
(Female %)	50.42	63.33	
Age (year)	41-50	31-40	6.40
Education	Primary school	Primary school	2.51

6.5.1.2 Household size and household situation

This category was analysed by *Kruskal-Wallis test* presenting the results between both samples. The average household size was five members per household in the without-project sample and four members per household in the with-project sample (Table 6.2) (KW = 3.96, p = 0.05). The household size in the with-project sample may have been reduced during the process of resettlement because the younger generation may be taken the opportunity to leave the family home and set up a new family or household. The average number of family member in school was only one in both samples (KW = 0.02, p = 0.88). Most of the children in the without-project sample attend the primary school in their village but some children in the with-project sample attended the school in Amphoe Khong Chiam.

There was no significant difference between the without and the with-project in the housing land area per household (KW = 3.03, p = 0.08) and land ownership (KW = 3.68, p = 0.05), respectively. The households in the with-project sample group had been provided housing land area of average 0.78 rai. While the households in the without-project mostly have various size of housing land area average 0.57 rai. This depends on the financial status of the village. The land ownership per household along the river averaged 2.77 rai while the majority of households nearby the dam had 2.24 rai. The household land utilisation is the traditional homegarden[1] system for subsistence food (e.g. fruit, vegetable) or livestock practices (e.g. chicken, pig). The number of boats and bicycles per household between samples had no significant difference (KW = 0.07, p = 0.79 and KW = 0.57, p = 0.44).

The number of motorcycle per household between both samples shows significant difference (KW = 4.69, p = 0.03). The hydropower development project should consider the changes of the transportation patterns within communities and from communities to nearby commercial and professional areas (Marriott, 1997). The

[1] Homegarden is a system of agricultural production conducted largely by household members at or near the residence. Produce from plants and animals in each garden, supplements the homegardeners' meal. Surplus may be exchanged, sold or shared beyond the household (Jepma, 1995)

respondents in the with-project sample obviously have motorcycles as the personal transportation to Amphoe or Province. In terms of social attitude, the local people are obviously changing their attitudes to become more materialistic than in the past. The motorcycle becomes a 'status symbol' reflecting socio-economic wellbeing in the rural society. For this reason, it might be understood that these respondents of the with-project sample are better off in terms of economic status than the without-project households.

People in this area usually consume sticky rice (*Oryza sativa* Linn.) as the carbohydrate-based for daily nutrition. The rice consumption is measured in kilograms per capita per year (kg/cap/year), which shows the average in the without-project sample and the with-project sample as 221.5 and 241.9 kg/cap/y, respectively. The result shows no significant difference (KW = 0.33, $p = 0.57$). The rice consumption quantity per household among both samples varied depending on the number of adults and children in the household. Households with smaller land area do not have enough land to follow paddy rice practices for their consumption needs so they need to buy the sticky rice from the market to support their family.

Table 6.2: A comparison of household size and household situation between the without-project (A) and the with-project (B).

Variables	Without-project (A)	With-project (B)	Kruskal-Wallis
	Mean ± SD	Mean ± SD	(A&B)
Household size (person)	5.13±1.95	4.38±2.18	3.96
Family members in School (person)	1.09±1.19	1.19±1.21	0.02
Land ownerships (rai)[a]	2.77±1.84	2.24±1.81	3.03
Housing land area (rai)	0.57±0.61	0.78±0.73	3.68
Boat	0.66±0.73	0.70±0.80	0.70
Bicycle	0.38±0.60	0.30±0.57	0.57
Motorcycle	0.34±0.56	0.55±0.51	**4.69***
Rice consumption (kg/cap/year)	221.49±96.53	241.90±85.54	0.33

Note: * = significant difference at $p = 0.05$
a = Rai is the traditional measurement unit for land, which is equal to 1,600 sq.m. (1 hectares equal to 6.25 rai).

6.5.1.3 Occupations of households

There was no significant difference in between samples in relation to occupation information in the households (Table 6.3) except the number of workers in households and main occupational type. The number of workers, who earn money in households, averages three in the without-project sample and two members per household in the with-project sample. The number of workers per household shows significant difference (KW = 10.27, $p = 0.001$). Each household had more than one occupation, because the major occupation does not earns enough money to support the whole family. Thus the additional occupation is necessary to increase household income. There was no significant difference in the number of additional occupations (KW = 0.00, $p = 0.99$). The major occupation type in households of the without-project sample is agricultural-based. The households along the river mostly have a piece of land to cultivate, while they also fish for their daily supplement and trade. Although the households near the dam apparently have some piece of land, it is not big enough to cultivate for trading. Therefore, each household usually has major

occupation as fishery in the with-project sample, fishery related occupations are the most frequent, with agriculture, labouring and trading being additional occupations of households in order to earn more money. The occupation type in both samples shows significant difference ($\chi^2 = 25.85, p = 0.02$).

Table 6.3: A comparison of occupations of households between the without-project (A) and the with-project (B).

Variables	Without-project (A)	With-project (B)	Kruskal-Wallis & Chi-square
	Mean ± SD	Mean ± SD	(A&B)
Number of additional occupation	1.52±0.66	1.55±0.91	0.00
Number of worker in household	2.78±1.31	1.81±0.98	**10.27****
Main occupation type (Mode)	Agricultural-based	Fishery-based	**25.85***

Note: * = significant difference at $p < 0.05$
** = significant difference at $p < 0.01$

6.5.1.4 Household income

In terms of income only horticultural income, showed a significant difference between the samples ($\chi^2 = 9.26$, $p = 0.01$) (Table 6.4). This means that some households along the river obviously earn money from horticultural practices while the households near the dam do not have enough land to permit horticulture. The income from horticultural practices is different from the income from agricultural product trading in relation to the same situation. Because there are fewer households in the without-project sample than the other to deal with this trading, it seems to show no significant difference with incomes in the without and with-project situations being.

The other income variables show no significant difference. These include household income, personal income, income from paddy rice, income from farming, income from consumer products trading, income from agricultural trading, income from catering and monthly wage from employment.

The majority of household income is earned mostly from agricultural and fishery products. The modal household income seems to be different at 2,001-3,000 and 3,001-4,000 Baht/month for the without-project and the with-project samples, respectively, but there are not statistical significant differences. While the mode of personal income shows no significant difference at the rate of 1,001-2,000 and 2,001-3,000 Baht/month for the without-project and the with-project samples, respectively. Their incomes are higher than the average income of local people in Amphoe Khong Chiam at about 660 Baht/month or 7,960 Baht/cap/y (Amphoe Khong Chiam, 1997). This indicates that they have better financial status or economic security than the local people who live further from the river. Moreover, it can explain why the household income rate in the hydropower development area is higher than in the villages along the river under the without-project implementation. The household income in the both samples also correlates to the number of workers in the households.

Table 6.4: A comparison of household income between the without-project (A) and the with-project (B).

Variables	Without-project (A)	With-project (B)	Chi-square
	Mode	Mode	(A&B)
Household income (Baht/month)	2,001-3,000	3,001-4,000	9.76
Personal income (Baht/month)	1,001-2,000	2,001-3,000	10.14
Rice income (Baht/month)	<1,000	<1,000	1.38
Farming income (Baht/month)	<1,000	<1,000	3.39
Horticultural income (Baht/month)	<1,000	None	**9.26***
Monthly wage (Baht/month)	2,001-3,000	3,001-4,000	12.61
Consumer products Trading (Baht/month)	1,001-2,000	1,001-2,000	7.12
Agricultural products Trading (Baht/month)	<1,000	None	1.31
Catering income (Baht/month)	1,001-2,000	1,001-2,000	4.03

Note: * = significant difference at $p < 0.05$

6.5.1.5 Natural resource attitudes in households

In the without-project sample (A) and the with-project sample (B), the majority of respondents have positive attitudes to natural resources, which show no significant difference ($\chi^2 = 0.07$, $p = 0.78$ and $\chi^2 = 1.56$, $p = 0.21$) (Table 6.5). They consider that forest and river are considerably beneficial to their livelihood in terms of food supplies, construction materials, as well as indigenous medicine. The respondents along the river consider the benefits they derive from the forest to be greater than the river. The respondents nearby the dam consider the benefit of the forest and the river to be equal.

Table 6.5: A comparison of natural resource attitudes in households between the without-project (A) and the with-project (B).
(Question number 22 and 24 in the questionnaires, Appendix 6.1 and 6.2)

Variables	With-project (A)	With-project (B)	Chi-aquare
	Mean ± SD	Mean ± SD	(A&B)
Forest benefit			
Yes (%)	97.10±0.18	94.45±0.23	0.07
No (%)	2.90±0.18	5.55±0.23	
River benefit			
Yes (%)	84.32±0.37	93.75±0.23	1.56
No (%)	15.66±0.37	6.25±0.23	

6.5.1.6 Natural resource accessibility and values

The two samples differ significantly in their distance from household to forest, and from household to river/dam (KW = 6.94, p = 0.008 and KW = 24.06, p = 0.000), respectively (Table 6.6). This means that the households along the river have more opportunities to access to the river than near the dam. The households nearby the dam, in contrast, are able to access to the forest more easily because they have been moved to the new resettlement area more inland, near the forest and farther from river.

There were significant differences in the marketable value of forest and fishery benefits between the samples (KW = 4.57, p = 0.03 and KW = 5.48, p = 0.02), respectively. This shows that the fishery marketable products provide more value than the non-timber forest marketable products.

The fishery products usually provide a mean income 3,106 Baht per month along the river, but provide households near the dam with 7,040 Baht per month (if they can fish every day). In fact the fisherman in the both samples go fishing every day but they are not able to catch fish every day. The fishery value is estimated and based on the possibility of catching fish every day, which is higher than the household income in the both samples (Figure 6.17). The household income was directly collected from the interviews. The fishing condition in the river is different near the dam and

on the main river because the fishing near the dam is under the control of EGAT. This means that there is irregular time schedule for the opening of the water gates of the dam. Fishing is possible whenever the water gates are closed. Mostly 60-80 percent of fishery products from the households is traded to the middlemen who control the fish price. The fishermen near the dam, close to Amphoe, seem to get higher price than along the river, because the price will depend on how far and difficult transportation, is from the source to the market.

For the non-timber forest marketable products, the households along the river are able to earn a mean of 814 Baht per month. The households near the dam earn a mean of 588 Baht per month from the non-timber forest products. These products are usually consumed in the household and the surplus is sold to the middlemen. The quantity of non-timber forest products is more or less dependent on the age of collector, the season, the village collection intensity and the demand from the market.

The households near the dam have easy access to the forest but they earn less money than the households along the river. The reason is that the households near the dam have more opportunities to earn money from other activities such as labouring or consumer products trading while the households along the river have not. This shows that the households in the without-project sample need to invest more effort in the search for the non-timber forest products, but they earn less money from it. Because the non-timber forest products e.g. bamboo shoots and mushrooms are usually consumed among the local people in Ubon Ratchathani Province, the market demand is limited. The market price is influenced by market demand and market supply. The non-timber forest products are collected seasonally and not all the year round, but this is different from the fishery products, which are harvested all the year round.

The persons who collect the non-timber forest marketable products for their household consumption are female except oil and resin. The male collectors are dominated in the without-project samples but the female collectors are dominated in the with-project with significant difference ($\chi^2 = 10.69$, $p = 0.005$). On the other

hand, males will fish in the river or dam. A task needs lots of skill and strength, there was significant difference between both samples (χ^2 = 13.18, p = 0.02), respectively. For small animal hunting and insect collection, the majority of hunters and collectors are male, which two samples show no significant. The activities of small animal hunting and the insect collection will do occasionally and depend on season and personal interest in each household.

Table 6.6: A comparison of the natural resources collected, and their values in households in the without-project (A) and the with-project (B).

Variables	With-project (A)	With-project (B)	Kruskal-Wallis & Chi-square
	Mean ± SD	Mean ± SD	(A&B)
Collection distance (house to forest)	1.25±1.45	0.56±1.07	**6.93****
Collection distance (house to river/dam)	0.69±1.10	2.43±1.09	**24.06****
Forest marketable Value (Baht/month)	815±2495	588±565	**4.57***
Fishery marketable value (Baht/month)	3106±2166	7040±7396	**5.48***
Subsistent food collector (Mode)	Female	Female	4.07
Firewood collector (Mode)	Female	Male & Female	2.79
Oil/resin collector (Mode)	Male	Female	**10.69****
Small animal hunter (Mode)	Male	Male	1.02
Insect collector (Mode)	Male & Female	Male	3.72
Fisherman (Mode)	Male	Male	**13.18***

Note: * = significant difference at $p < 0.05$
** = significant difference at $p < 0.01$

From the results of the statistical analysis, it seems that the comparison between the without-project sample (villages along the Mekong River) and the with-project sample (villages nearby Pak Mun Dam) have some statistically significant socio-economic variable differences (Table 6.7). These variables are the number of motorcycles per household, the number of workers, main occupation types, horticultural income, the distance from house to forest as well as distance from house

to river, forest value, fishery value, oil/resin collector and fisherman. This indicates that if the hydropower development project is introduced into this study area along the Mekong River, it will potentially effect the social life pattern and the financial situation of local people.

Table 6.7: The significantly different variables between the without-project (households along the Mekong River) and the with-project (households near the dam).

Variables	*Kruskal-Wallis* (1-way ANOVA) Without-project vs. With-project
1. Number of motorcycle per household	4.69*
2. Number of worker in household	10.27**
3. Main occupation type	25.85*
4. Horticultural income	9.26*
5. Distance from house to forest	6.94**
6. Distance from house to river or dam	24.06**
7. Forest marketable value (Baht/month)	4.57*
8. Fishery marketable value (Baht/month)	5.48*
9. Oil/resin collector	10.69**
10. Fisherman	13.18*

Note: * = significant difference at $p < 0.05$
** = significant difference at $p < 0.01$

6.5.1.7 Quality of life situation

In questionnaires set B, there were two questions related to the quality of life and the degree of importance attached to natural resources, which attempt to quantify the impact of the hydropower project on the local people. Figure 6.19 shows that 90 percent of respondents felt their quality of life were worse after being resettled to the new area by EGAT under the Pak Mun Dam project. Only 5 percent of respondents felt their quality of life got better, while another 5 percent feel they had the same quality of life. In terms of infrastructure (Figure 6.10), the authority organisations such as EGAT; the local educational authority; and the local governmental authority have provided all the community facilities and services. For instance, electricity, roads, schools, health center units and temples were provided for the people who were effected by the hydropower project. The quality of life changes can include income, type of work of residents, social patterns or daily activity patterns, and general perception of individual wellbeing. In conclusion, the resettled people had negative feelings towards the dam project. It has not provided them the benefit of a better quality of life, particularly since the potential for fishery based activies has changed.

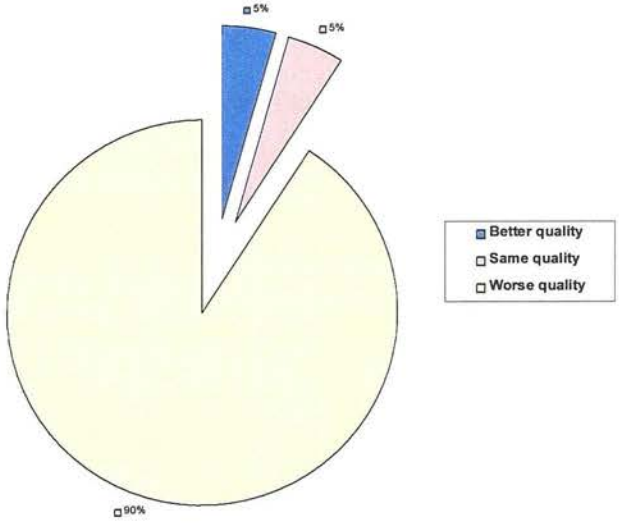


Figure 6.19: Relocated households attitude to quality of life situation after resettlement.

Figure 6.20 indicates the degree importance respondents nearby the dam attached to natural resources. The respondents mostly gave an equal weight of importance to forest and river, at 63 percent. The 23 percent of respondents believed the river was more important than the forest. Another 9 percent thought that the forest was more important than river, and only the 5 percent gave no response.

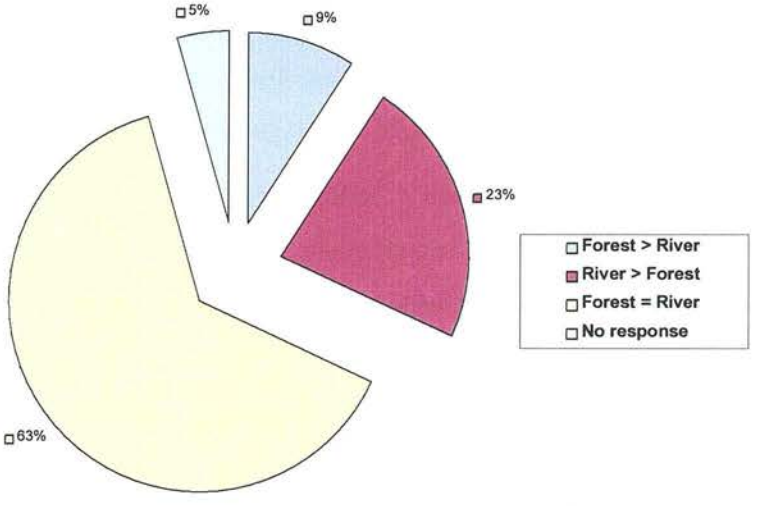


Figure 6.20: Relocated households attitude towards the forest and the river.
(The question is 'What do you think about the importance of forest and river/reservoirs to your life?

Forest is more important than river/reservoirs

River/reservoir is more important than forest

Forest and river/reservoir are equally important)

6.5.2 Measuring of association (*Spearman correlation*)

Analysis conducted thus for has been concerned with the test of difference between the without-project sample and the with-project sample, however, there needs to be a further test to measure association, e.g. *Spearman correlation coefficients*. This analysis can test the characteristics of respondents from both samples having the association among variables without sample separation. The reason is to reduce bias

that both samples are justified to have the same background because they have been in the same Amphoe. Background information and some personal experience with the local people, provided justification for selection of variables for measuring association. There were 35 variables to be measured in the analysis. Five of these variables (boat ownership, fisherman, household size, number of occupations and location) correlated significantly with between twelve and nine other variables. These analysis show a positive significant correlation between personal income and education, household income, monthly payment and forest marketable value (Table 6.8).

These five variables have significant association to each other, which are associated to the fishery practice and the way of sustaining a family. So it supports the judgement to select all variables, justifies further analysis such as the factor analysis (PCA) can group and screen the strong influent variables for the identification the factors related to the without and with-project situations (by location).

Table 6.8: The Spearman correlation coefficients arising from an analysis of socio-economic data of without-project samples (households along the river) and with-project samples (households nearby the dam).

	River/dam	Sex	Age	Education	Family member	Children inschool	Land area	housing(area/house)	Boat	Bicycle	Motorcycle	Rice consumption	No.of occupation	Worker	Occupation type	Household income	Personal income	Rice income	Farm. income	Horti. income	Monthly wage	Consummer product inc.	Agricultural trading	Catering income	Forest benefit	Aqua.benefit	Forest distance	River distance.	Subsist. food collector	Firewood collector	Oil/resin collector	Small animal hunter	Fisherman	Fishery value(Baht/m)	Forest value(Baht/m)
River/dam	1.0000																																		
Sex	0.1116	1.0000																																	
Age	-0.1175	-0.1080	1.0000																																
Education	0.0997	-0.1373	**-0.4043**	1.0000																															
Fam-mem.	**-0.2121**	-0.0698	-0.0836	0.0187	1.0000																														
Inschool	0.0160	0.1117	**-0.2451**	0.0900	**0.3316**	1.0000																													
Land area	-0.1878	-0.0726	0.1814	0.0867	**0.2065**	-0.0224	1.0000																												
housing	**0.2612**	-0.0713	0.1453	-0.0464	-0.0181	0.0866	**0.3229**	1.0000																											
Boat	0.0283	-0.0955	-0.1842	-0.0307	**0.2195**	0.0141	-0.1123	-0.0787	1.0000																										
Bicycle	-0.0813	0.1091	-0.1392	0.1603	-0.0267	**0.2086**	0.1966	0.2060	-0.1806	1.0000																									
Motorcycle	**0.2321**	-0.0522	0.0298	0.0811	0.0287	0.0714	0.1517	0.3411	0.0645	0.0877	1.0000																								
Rice consu.	0.0764	-0.0421	**0.2581**	-0.2437	-0.1206	-0.1409	0.1649	-0.0179	-0.1211	**-0.3058**	0.1197	1.0000																							
No.occup.	0.0011	-0.1789	-0.1304	0.1078	**0.3259**	0.1721	**0.2362**	0.1324	**0.2134**	0.0930	0.0252	-0.1820	1.0000																						
Worker	**-0.3605**	0.0337	-0.0452	0.0929	**0.4230**	-0.0381	0.1174	**-0.2942**	**0.2289**	0.0300	-0.1433	-0.1588	**0.2375**	1.0000																					
Occupation	0.0303	-0.0800	-0.1376	0.0974	**0.2133**	0.0577	0.1677	0.0076	**0.3332**	0.0516	0.1207	-0.2442	**0.6524**	**0.3078**	1.0000																				
Hincome	0.1539	-0.0404	-0.2207	**0.3548**	0.0778	0.1983	0.1441	0.1951	-0.0759	0.1525	0.1241	-0.0768	0.2321	0.1673	**0.2797**	1.0000																			
Pincome	0.1973	-0.1156	**-0.2957**	0.3375	0.1202	0.1345	0.0890	0.2390	0.1388	0.2569	0.2420	0.0131	0.2282	0.0432	0.1786	**0.7500**	1.0000																		
Rice inc.	-0.0348	0.1198	0.0666	0.0300	**0.3308**	0.1127	**0.4695**	**0.3049**	0.0093	0.0722	0.0199	0.0810	0.2126	0.0889	0.1653	0.1031	0.2493	1.0000																	
Farm. inc.	0.0889	0.1429	0.1320	-0.1839	-0.0543	-0.0080	0.0360	**0.3193**	-0.1628	0.0510	0.0422	0.0379	-0.1371	-0.1502	-0.1556	0.0147	-0.1832	-0.0866	1.0000																
Horti. inc.	**-0.3374**	0.0454	0.0699	-0.0570	0.0219	-0.0738	**0.2765**	0.0515	-0.0893	**0.3691**	-0.1201	-0.1288	-0.1955	0.1296	-0.1072	-0.0061	-0.0345	**0.3038**	-0.0905	1.0000															
M-wage	0.0890	-0.1047	-0.1608	**0.3366**	-0.0587	0.1977	-0.0314	0.1388	**-0.2449**	0.1246	0.0610	0.0796	0.0980	-0.1833	-0.0520	**0.3896**	**0.3965**	-0.0462	0.1337	-0.0708	1.0000														
Consum inc.	-0.0883	0.0657	-0.0071	0.2033	-0.0377	0.1558	-0.0033	0.0164	-0.0141	0.0720	0.0326	0.0175	0.0730	0.1049	-0.0150	0.2262	0.1166	-0.0431	0.1439	-0.0526	-0.0027	1.0000													
Agri. Trading	-0.1221	**-0.2336**	0.0947	0.1217	-0.0464	-0.0241	0.0233	-0.2270	-0.1324	-0.1457	0.0683	0.1295	0.1408	0.0748	0.0780	**0.2880**	0.0385	0.0176	-0.0349	0.0067	0.0072	0.1986	1.0000												
Catering inc.	0.0056	-0.0122	-0.1148	0.1124	0.1325	**0.2810**	-0.0371	-0.1176	-0.0368	0.0822	-0.0465	-0.2375	**0.2307**	-0.0203	0.1790	0.2290	0.2267	0.0508	-0.0345	0.0083	0.2260	0.1937	0.2024	1.0000											
Forest ben.	-0.0300	0.0861	0.1492	-0.1571	0.1508	0.0764	0.1422	0.1076	0.2042	-0.0086	0.1466	-0.2102	0.0461	0.1466	**0.2392**	-0.1514	-0.2037	0.1038	0.0225	-0.0497	**-0.2544**	0.0793	0.0441	0.0436	1.0000									
Aqua.ben.	0.1371	-0.1636	-0.0745	0.0755	0.1331	-0.0673	0.0910	-0.2050	**0.3516**	-0.0953	0.0835	0.0300	0.1672	-0.0117	**0.3340**	-0.0102	-0.0251	0.0176	0.0431	-0.0860	-0.0173	-0.0787	0.0891	0.0879	**0.3221**	1.0000								
Forest dis.	**-0.3021**	**-0.2791**	0.1061	0.0548	-0.0023	0.0004	0.1288	-0.0444	-0.1736	-0.0297	0.1968	0.0309	0.1789	-0.0037	0.1001	0.0942	0.1281	-0.0757	0.0069	**-0.2348**	**0.2239**	0.0026	**0.2458**	0.0169	-0.1360	-0.0808	1.0000							
River dis.	**0.5484**	-0.0549	-0.0246	**0.2202**	-0.0516	0.1276	0.1189	**0.3127**	**-0.2538**	0.1406	**0.2566**	-0.0773	0.0671	-0.1328	-0.0065	0.1962	0.1387	0.0451	0.1357	-0.2199	0.1191	-0.0948	-0.0640	-0.0198	-0.0792	-0.1443	0.1627	1.0000						
Subs. Coll.	-0.0247	0.0442	0.0721	-0.0586	-0.1395	0.0270	-0.1296	0.1874	0.1086	0.0186	0.0212	-0.0279	**-0.2604**	-0.0713	-0.1592	**-0.4097**	-0.1259	-0.0825	-0.0453	0.0721	**-0.2303**	-0.0231	**-0.2847**	**-0.2847**	0.1270	-0.0125	-0.1108	-0.0876	1.0000					
Firewood coll.	0.1084	0.0594	0.0577	-0.0828	0.1730	-0.0469	0.0944	-0.0130	**0.2601**	-0.1058	-0.1452	-0.0801	0.1226	-0.0565	0.1672	-0.2233	0.1099	0.1922	0.0098	-0.1612	-0.1828	-0.0908	**-0.2189**	-0.0955	0.0637	0.1231	-0.2249	-0.1008	**0.3184**	1.0000			
Oil/resin coll.	0.1414	0.0238	-0.1163	0.0836	0.0152	-0.1087	0.0506	0.0979	**0.2489**	-0.1125	0.0426	-0.1632	0.0393	0.0921	0.1731	**0.3500**	0.1849	0.2194	-0.0476	0.1212	-0.0565	-0.0172	0.1529	0.1528	0.0554	0.1136	-0.1543	-0.0614	-0.0303	-0.0063	1.0000		
Small ani. Hunt.	0.0338	-0.0201	-0.0671	-0.0269	**0.3049**	0.0199	0.0890	0.0246	**0.2755**	-0.1631	-0.1235	0.0343	0.0708	0.0861	0.1592	0.0210	0.1489	0.1711	-0.0644	0.0206	-0.0570	-0.1011	-0.0971	**-0.0959**	0.0844	0.1807	-0.1826	**-0.2217**	-0.0079	**0.2981**	0.0110	1.0000		
Fisherman	0.0662	**-0.2861**	-0.1061	0.0158	**0.3867**	0.0719	0.1162	0.2074	**0.4589**	-0.1539	**0.1484**	-0.1410	**0.4428**	**0.2831**	**0.4579**	0.0364	-0.0054	0.0307	-0.1835	-0.2102	-0.1588	-0.1796	-0.0599	0.0151	**0.2231**	**0.4313**	-0.1765	0.0270	0.0343	**0.2467**	0.0666	**0.3368**	1.0000		
Fishery value	**0.3378**	0.0192	-0.1110	0.0220	-0.0912	0.1646	-0.0682	**0.3609**	0.2680	0.0283	0.0584	0.0058	-0.0482	-0.1997	0.0472	**0.4034**	**0.4941**	-0.0018	.	0.2050	-0.1208	-0.0348	-0.0006	-0.0220	.	0.0507	-0.2538	0.1227	0.1608	0.1872	0.1766	0.1488	0.0482	1.0000	
Forest value	**0.2652**	-0.0526	-0.1755	0.2440	0.2364	0.1856	-0.0710	0.1783	**0.4248**	-0.1376	0.0535	0.0816	**0.2397**	0.1237	0.1799	0.1570	**0.5914**	0.0224	0.0823	**-0.3953**	0.2117	0.1278	-0.1741	0.1726	0.0532	0.2328	-0.0952	-0.0212	-0.0523	**0.3452**	0.1862	**0.3854**	**0.3008**	0.1127	1.00

6.5.3 Factor analysis (*Principal Component Analysis, PCA)*

Responses from questionnaires were coded into 172 variables. This gives lots of variables to be interpreted. Hair et al. (1998) recommend factor analysis as a method for reducing variables without losing information. This method can be utilised to examine the underlying patterns or relationships for a large number of variables and to determine whether or not the information can be condensed or summarised in a smaller set of factors or components. From a statistical standpoint, the appropriateness of factor analysis and the measurement to quantify the degree of inter-correlation among the variables is the measure of sampling adequacy (MSA). This MSA index will be above 0.50 for either the entire matrix or an individual indicator of appropriateness of applying factor analysis. Basically, the factor analysis is based on the criteria for the number of factors to be extracted, for example, latent roots or eigenvalues, percentage of variance criterion and scree test criterion (Hair et al., 1998).

In this study the analysis incorporated both the latent roots (eigenvalues) at greater than 1.0 and the percentage of variance approximately at 70 of cumulative percentage, which provided the MSA index at 0.6045 from 39 variables and extracted them into eleven factors. In the social sciences, where information may be less precise, researchers may possibly consider 60 percent of the total variance explained as being a satisfactory solution (Hair et al., 1998). The extracted factors were rotated by Quartimax rotation, which is one of the major orthogonal approaches to simplify the rows of a factor matrix. This rotation focuses on rotating the initial factor so that a variable loads high on one factor and as low as possible on all other factors. The purpose of rotation was to make the result of factor analysis more interpretable. The factors were then be renamed to characterise the grouped variables. Factors were processed as independent variables instead of implementing the original variable in the multiple regression analysis.

Table 6.9 shows the rotated factor matrix analysed by PCA. There are eleven factors to be grouped, ranked and renamed as follow:

- Factor 1 = Fishery potential
- Factor 2 = Employment pressure
- Factor 3 = Non-timber forest collection effort
- Factor 4 = Settlement background
- Factor 5 = Agricultural potential
- Factor 6 = Farming support
- Factor 7 = Forest accessibility
- Factor 8 = Fishery value
- Factor 9 = Educational background
- Factor 10 = Basic consumption
- Factor 11 = Personal earnings

Factor loading was sorted in order and grouped indicating the weight of each variable that contributes to each factor. The high loading variables were highlighted and the low loading variables were ignored. As a result (Table 6.9), 'fishery potential' has the highest eigenvalue at 5.6050. That indicates the highest degree of interrelation among variables. 'Personal earnings' has the lowest eigenvalue at 1.0664. That indicates the lowest degree of interrelation among variables. The percentage of variance is equal to 71 of cumulative percentage, which is acceptable according to convention at 60 percent (Hair et al., 1998).

Having identified the eleven factors, which represent the social and economic conditions, the sequence of analysis was done as following:

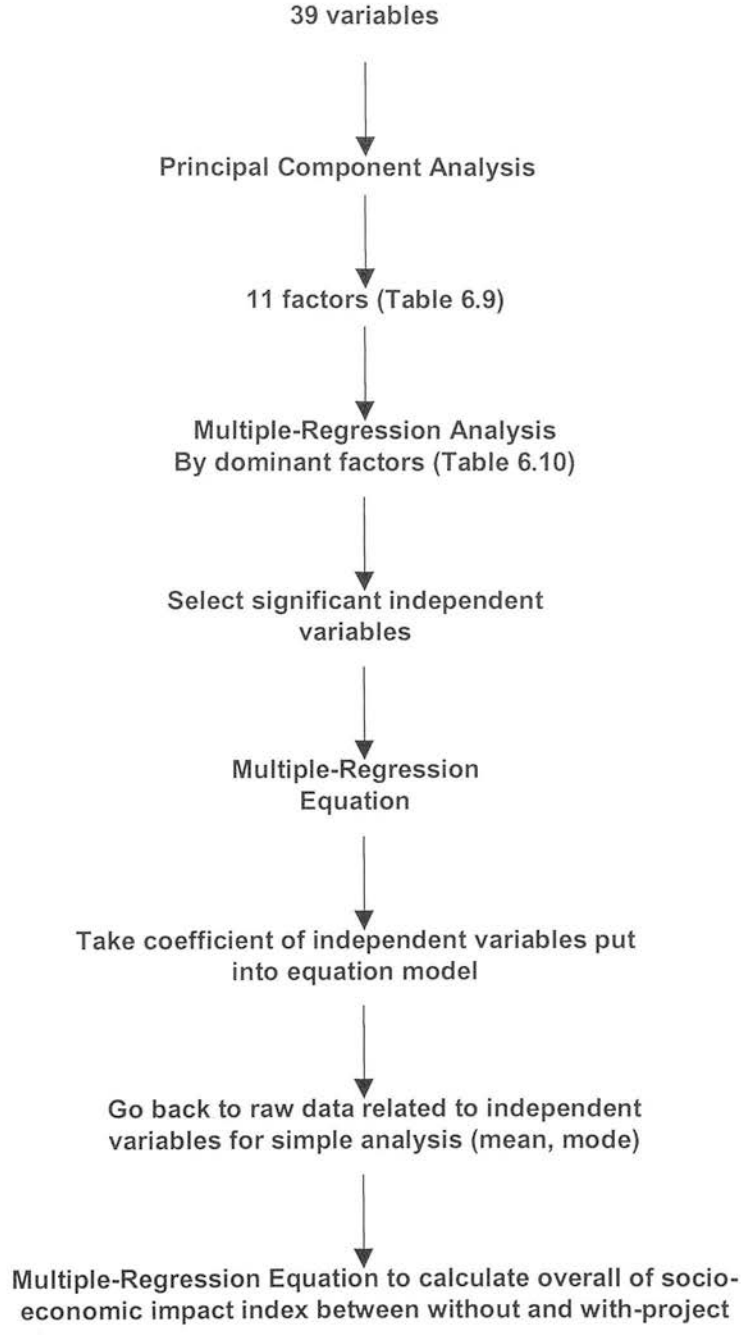


Table 6.9: The rotated factor matrix analysing by PCA for the extracted factors as independent variables for the socio-economic indicators.

Factor Name	Variables	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Factor10	Factor11
1.Fishery potential	Fishery frequency/year	0.85206	-0.07120	0.04552	-0.00059	-0.07243	-0.07050	0.00542	-0.10058	-0.03077	0.11688	0.00110
	% fish trading	0.85119	-0.02865	0.08565	-0.00322	-0.06210	0.02520	0.08123	0.19074	-0.00502	-0.00619	0.14216
	Fishery hour/trip	0.80540	0.00859	0.18712	-0.00918	0.00966	0.09958	-0.06013	-0.02051	0.02831	-0.09706	0.00109
	Fishery quantity/trip	0.78939	0.01957	0.04470	-0.20205	0.12251	0.14885	-0.10478	0.22113	-0.02320	0.00158	0.08448
	Fishery distance/trip	0.74423	-0.13653	-0.11292	0.16613	0.01208	-0.03654	0.06102	-0.18350	0.18586	0.06951	-0.00834
	Boat	0.64649	-0.14565	0.09716	0.00616	-0.17023	-0.05804	0.03044	0.05514	-0.19335	-0.14948	0.31173
	Occupation type	0.60312	0.02130	-0.03536	0.17258	0.17803	-0.14929	0.24372	0.34939	0.03964	-0.14513	-0.24300
	No. of occupation	0.56303	0.18410	-0.03515	0.14347	0.41638	-0.06573	0.24931	-0.05556	-0.01091	-0.14746	-0.21534
	No. of family member	0.44230	0.11891	0.18970	0.08948	0.40560	-0.05003	-0.16315	-0.38708	0.01110	-0.03062	0.02816
2.Employment pressure	Full-time employed	-0.15386	0.90325	-0.02683	-0.06294	0.00336	0.05550	0.06602	-0.06089	0.07829	0.08826	0.05021
	Monthly wage	-0.20511	0.87473	-0.06499	-0.06519	-0.12376	0.15635	0.11571	0.02125	0.11572	0.02268	0.09610
	Employment	0.03910	0.80325	0.01655	0.03926	0.03741	0.02183	-0.05792	0.15549	-0.10742	-0.09410	-0.10999
	Household income	0.18333	0.49325	-0.32676	0.10936	0.14112	0.11449	0.10529	0.46713	0.17551	-0.06212	0.10779
3.Forest collection effort	Forest quantity/trip	0.02429	0.13462	0.82092	0.13487	0.07900	-0.02361	0.10718	-0.15424	0.01071	0.06044	0.01901
	Forest hour/trip	0.10806	-0.19638	0.79211	0.00626	-0.00735	-0.06439	-0.17541	0.05565	0.10042	0.01377	-0.08826
	Forest distance/trip	0.05600	-0.07501	0.78919	0.06475	-0.01981	-0.03155	-0.04350	0.07755	0.06437	-0.01452	-0.07084
	% forest product trading	0.20110	0.02211	0.74052	0.11492	-0.01936	0.02788	0.23258	-0.10951	-0.23317	-0.07709	0.09132
4.Settlement background	Time of settlement	0.12206	-0.14845	0.13972	0.83876	-0.02253	0.11332	-0.10960	-0.08790	0.03722	0.15671	0.01465
	Address	-0.00926	0.00041	-0.23061	-0.79908	-0.01915	0.07432	-0.33670	0.15418	-0.04057	-0.00908	0.09237
	River-home distance	-0.13953	0.04410	-0.24075	-0.62485	0.23229	0.07869	0.06796	-0.07707	0.39763	0.04307	-0.08546
	Forest frequency/year	0.01930	-0.24935	0.23231	-0.52452	-0.29997	0.26856	0.07703	0.08749	-0.07656	0.01272	-0.04768
5.Agriculatural potential	Rice income	-0.01696	-0.13861	-0.00455	-0.03293	0.77453	0.00640	0.06873	0.05456	0.01172	0.10421	0.07182
	No. of children in school	0.10455	0.31101	0.01257	-0.07716	0.49165	0.03570	-0.08060	-0.11170	-0.22808	-0.37734	-0.10750

	Landowner ship	0.09916	-0.01128	0.00101	0.12743	0.48400	0.13635	0.15913	-0.04082	0.44515	0.37769	0.00477
6.Farming support	Housing land area	0.10039	0.06444	-0.00907	-0.14085	0.22639	0.82317	0.03704	0.16144	-0.07693	-0.04570	0.16247
	Farming income	-0.11852	0.19285	-0.11756	0.02698	-0.14663	0.82308	0.02153	-0.10853	0.02638	0.02276	-0.08020
7.Forest accessibility	Motorcycle	0.07490	-0.01882	0.11356	-0.12971	0.06814	0.17508	0.74580	0.06786	0.08126	0.09072	0.03059
	Forest-home distance	0.02608	0.22299	-0.09793	0.32706	0.05207	-0.14970	0.63010	-0.04050	-0.01843	0.15171	-0.08071
	Horticultural income	-0.21832	-0.27301	0.06433	0.34329	0.15822	0.07873	-0.35571	0.29315	0.30741	-0.02339	0.10853
8.Fishery value	Monthly fishery value	0.11394	0.08830	-0.02880	-0.22672	-0.05455	0.01710	-0.04563	0.77377	-0.12261	0.12428	0.08039
9.Educational background	Education	0.01799	0.31115	0.02498	-0.21732	-0.09462	-0.18908	0.10413	-0.06736	0.65473	-0.16693	0.08861
	No. of worker	0.44115	-0.12868	-0.02311	0.24218	-0.03662	-0.15203	-0.15858	-0.12635	0.52407	-0.08436	-0.03229
10.Basic consumption	Rice consumption	-0.11751	0.14649	0.08470	-0.01154	0.06579	-0.13690	0.24829	0.06599	-0.08336	0.71859	0.07082
	Age	-0.15126	-0.24546	-0.08266	0.20704	0.06046	0.23162	-0.04787	0.07501	0.07941	0.61450	-0.19374
	Bicycle	-0.20286	-0.02516	0.11751	0.05123	0.37863	0.24262	0.04253	0.21380	0.44729	-0.46241	-0.09395
11.Personal earnings	Monthly forest value	0.14291	-0.04016	-0.07710	0.05772	-0.04706	0.06392	-0.09951	-0.00855	-0.00334	0.04151	0.85859
	Personal income	0.14164	0.31084	-0.03640	-0.12691	0.26551	-0.03921	0.17150	0.34798	0.10523	-0.14056	0.60362
Eigenvalue		**5.60495**	**4.05314**	**3.06155**	**2.49677**	**2.14957**	**1.99626**	**1.71626**	**1.57617**	**1.33571**	**1.22481**	**1.06638**
% of Variance		**15.1**	**11.0**	**8.3**	**6.7**	**5.8**	**5.4**	**4.6**	**4.3**	**3.6**	**3.3**	**2.9**
Cumulative %		**15.1**	**26.1**	**34.4**	**41.1**	**46.9**	**52.3**	**57.0**	**61.2**	**64.8**	**68.1**	**71.0**

6.5.4 Multiple regression analysis

Results of the multiple regression analysis are displayed in Table 6.10 (Appendix 6.3). These show that the overall regression equation explains (R^2 = 0.7585) 75.9 percent of total variance and multiple R as 0.8709, a result that F value is statistically significant at $p<0.00001$. The dependent variable (Y) was '*location*', which was categorised as villages along the river representing without-project condition and villages near the dam representing with-project condition. This dependent variable finally represented the indicator of socio-economic impact between without and with-project. Therefore, the dependent variable was analysed together with eleven factors from PCA.

Table 6.10: Multiple regression of socio-economic impact index between the without-project and the with-project sample.

Multiple R = 0.8709 R^2 = 0.7585

Independent variables	Coefficient	F-value	Significance
1.Fishery potential	0.0003	1.996	**0.0495***
2.Employment pressure	0.1422	1.968	**0.0527***
3.Non-timber forest collection efforts	-0.0200	-2.236	**0.0282***
4.Settlement background	-0.1614	-12.664	**0.0000***
5.Agricultural potential	0.0083	0.207	0.8368
6.Farming support	0.0572	1.107	0.2716
7.Forest accessibility	0.0439	0.926	0.3575
8.Fishery value	0.0000	1.026	0.3080
9.Educational background	-0.0966	-2.058	**0.0430***
10.Basic consumption	0.0003	0.848	0.3993
11.Personal earned	-0.000004	-0.305	0.7611
Constant	1.8183	14.472	0.0000*
Overall F = 21.9844	Significance =0.0000*		Adjusted R^2 = 0.7240

Note: * = significant difference at p = 0.05

Multiple regression equation using the relevant significant coefficient from Table 6.10:

Socio-economic impact index = *1.8183 + 0.0003Fishery potential + 0.1422Employment pressure – 0.0200Non-timber forest collection efforts – 0.1614Settlement background – 0.0966Educational background*

(Equation 6.1)

From the statistical significance of the F-value, there are five independent variables showing significantly affected by the development project. These variables (and the unit of measurement) are derived from the survey data (Appendice 6.4):

1. Fishery potential (number of days fished per year)
2. Employment pressure (proportion of adults in full time employment)
3. Non-timber forest collection efforts (mean of weight (kg) collected per trip)
4. Settlement background (period of years of residence by household)
5. Educational background (proportion of adults with education level)

It includes fishery potential, employment pressure, non-timber forest collection efforts, settlement background and educational background.

For the without-project situation, the socio-economic impact index was calculated by the multiple regression equation regarding to the flow chart on page 247. The values of independent variables are extracted from the raw data based on the percentage. The result is as follow:

Socio-economic impact index

*= 1.8183 + 0.0003(0.5*365) + 0.1422(0.123*1) -0.0200(0.275*2)*

*– 0.1614(0.646*6) – 0.0966(0.797*1)*

(Equation 6.2)

Without-project index *= 1.1770*

For with-project situation, the result of socio-economic impact index was calculated as follow:

Socio-economic impact index

$$= 1.8183 + 0.0003(0.421*365) + 0.1422(0.318*1) - 0.0200(0.2*1) - 0.1614(1*1) - 0.0966(0.818*1)$$

(Equation 6.3)

With-project index = 1.6652

Under without-project condition, the local people have a peaceful life with socio-economic impact index of 1.18 but the people were changed their socio-economic condition after the project implementation with socio-economic impact index of 1.67. It can interpret that the hydropower project caused the socio-economic impacts to the local people who were directly affected by resettlement programme and environmental changes.

Table 6.11: A comparison of socio-economic indicators, from within the multiple regression equations, as one measure of biodiversity evaluation between the without-project and the with-project sample.

Biodiversity evaluation (based on human system)	Without-project sample	With-project sample	Impacts
Socio-economic indicators			
1. Fishery potential[1]	0.0548	0.0461	Negative
2. Employment pressure[3]	0.0175*	0.0452*	Positive
3. Non-timber forest collection efforts[2]	0.0110*	0.0040*	Negative
4. Settlement background[2]	0.6256**	0.1614**	Negative
5. Educational background[1]	0.0770	0.0790	Positive

Note: 1 = Equal opportunity
2 = Quality of life
3 = Economic security
* = Significant at <0.05
** = Significant at <0.00

Wilson (1991) mentions that the socio-economic outputs are associated with social values (e.g. individual happiness and economic justice) and social goods (e.g. quality of life, participation, equity, fairness and so on). This study also indicates that the results relate to the vision of equal opportunities, quality of life and economic security.

In Table 6.11, the socio-economic indicators are compared between the without-project and the with-project, which are the independent variables are directly impacted by the hydropower development project. It can be assumed that the socio-economic impact indicator is 1.18 in the proposed area of Ban Koum Dam representing the present situation at zero dam impact while the socio-economic impact indicator of 1.67 can reflect the actual impact of the Pak Mun Dam on the local people.

This indicates that the with-project implementation can cause the negative impacts in relation to fishery potential (equal opportunity), non-timber forest collection efforts and settlement background (quality of life). On the other hand, the with-project can also cause the positive impacts to the local people according to employment pressure (economic security) and educational background (equal opportunity). Therefore, there is a trend of socio-economic impacts in particular to equal opportunity and quality of life to get worse off situation. Even though after the project they might be better off situation in terms of having more economic security by getting more jobs and better education opportunity for their children, they still feel unhappy and unsatisfied with the new pattern of living.

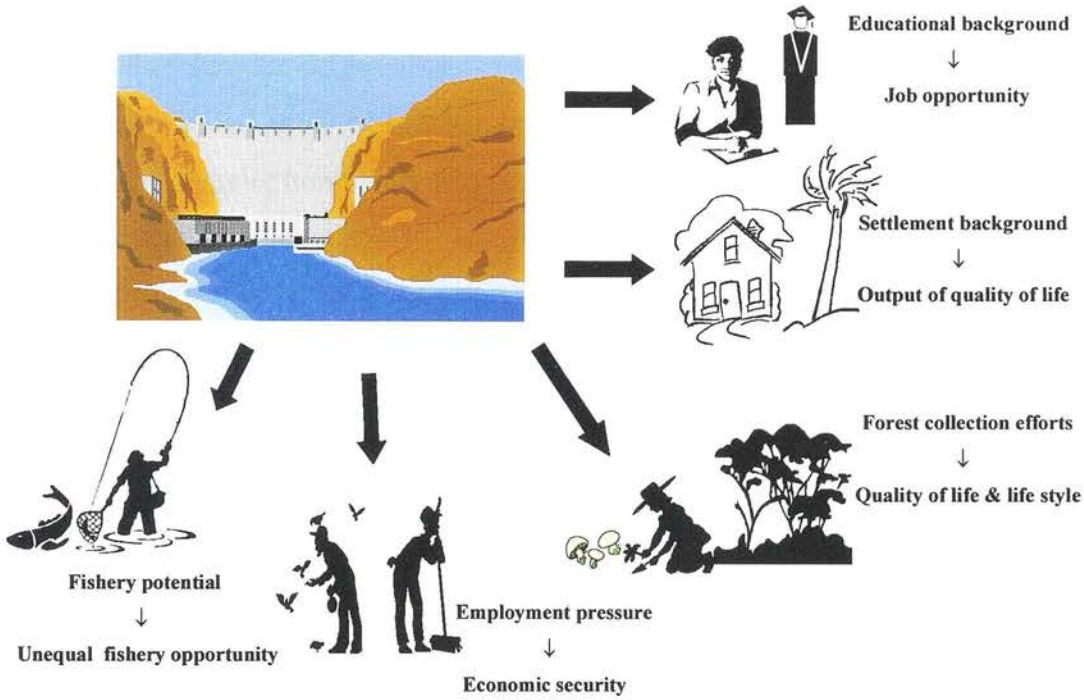


Figure 6.21: The socio-economic impacts according to the dam development project.

Figure 6.21 represents the impacts of the dam on the socio-economic factors in the villages. These include fishery potential, which deteriorates due to the ecological changes, as habitat is lost, productivity declines, and so on. The dam would also invariably lead to a significant reduction in food for the people whose lives are intertwined with the cycle of the river ecosystem. The dam will impact the river in a number of ways: fish migration routes will be blocked, cutting off spawning and feeding habitat; the sediment will be trapped behind the dam and reduced seasonal flows will result in a loss of nutrients (Rothert, 1994). Even though the Pak Mun Dam project proposed to minimise impacts on fish migration through the installation of fish ladders, the fish ladders failed. This has shown how inefficient ladders can be in a tropical river (Rothert, 1994). The people not only nearby the dam but also along the river will probably lose fishery opportunity because of the dam development project. On the other hand, the fishery potential, as a socio-economic indicator, justifies the problem of unequal opportunity for harvesting because the

dam authority firmly controls the irregular time of opening the water gate. Therefore, the people have to invest more time in waiting for the fishery opportunity than do the people who live along the river.

Employment pressure will influence local people's lives after reallocation, insufficient income of households and increasing pressure for additional occupations in the household. This is able to represent the economic security, which the local people nearby the dam under the 'with-project implementation' will have. As the amount of agricultural land is effected by the dam project, they have no opportunity to continue their traditional practices such as farming, horticulture, etc. Consequently, the local people suffer increased pressure for employment. This may be provided by the dam project but may also force them to leave home in search of work. As a result they can have higher personal incomes than the people along the river and other local people too.

When collecting non-timber forest products, the people will need to invest more effort and time to access the forest because they will be resettled far from the forest and also because of the effect of deforestation following dam construction. This means that the socio-economic impacts will change the way of life of traditional forest dwellers. Then the forest people will be irretrievably lost from the traditional culture. Hence the quality of life and style of local people nearby the dam will certainly change. They will become more like people in towns, who can not sustain their life style based on their level of income. While the people along the river still sustain their daily family livelihood based on the non-timber forest products, they certainly earn some money as well. Thus the people under 'without-project implementation' still continue their traditional life style and have less economic pressures than those relocated due to dam development.

The settlement background will be worse because the local people are moved from the productive area near the river and other natural resources to unproductive area far away from natural resources. They have difficulty sustaining their livelihood in the resettlement areas. This socio-economic indicator represents the output of quality of

life, how these people struggle due to the dam project. Consequently, the resettlement of local people from the old settlement to the new settlements might cause loss of their indigenous culture, which is very important to their heritage.

Educational background relates to the positive impact of the development project because the project provides a better road transportation to town. Therefore, the children can have good opportunities to go to secondary schools in town, which in turn may lead to better job property in the future. For the educational background of adults, most are at the primary school level. Less educated people earn money from their traditional occupations, because they do not have the educational background to upgrade their own careers for new potential job opportunities. Thus, some local people seem to gain little benefits in terms of job opportunity in relation to the dam project.

In the case of 'without-project' implementation, the local people possibly have either unchanged or stable socio-economic situations. Because the five independent variables change systematically with respect to the natural condition, so the change is different from the impact of 'with-project' implementation. Hence, these local people still have the traditional life style based on the natural resources utilisation and agricultural practices with mostly sustain their needs.

The socio-economic impacts from the Ban Koum Project are predicted to impact the local people to at least the same degree as the Pak Mun Dam Project. Because the environmental mitigation and resettlement and compensation costs of the Pak Mun Dam were equivalent to 14 percent of total cost of the dam impacts, while the Ban Koum Project will invest only 3 percent of the capital cost or 1.8 percent of the total cost (MRC, 1994). It can interpret this study that the proposed Ban Koum Project is focused on the economic benefit more than the environmental and socio-economic impacts.

6.6 CONCLUSION

This study concludes that if the hydropower development project is implemented in the Mekong River, it will certainly impact on the local people and communities in terms of the socio-economic situation. The diagrammatic conclusion (Figure 6.22) indicates that the socio-economic comparison between 'location' or 'sample' has an significant difference for ten variables. These variables are the number of workers, main occupation types, the number of motorcycles per household, horticultural income, the distance from house to forest as well as distance from house to river, forest value, fishery value, oil/resin collector and fisherman.

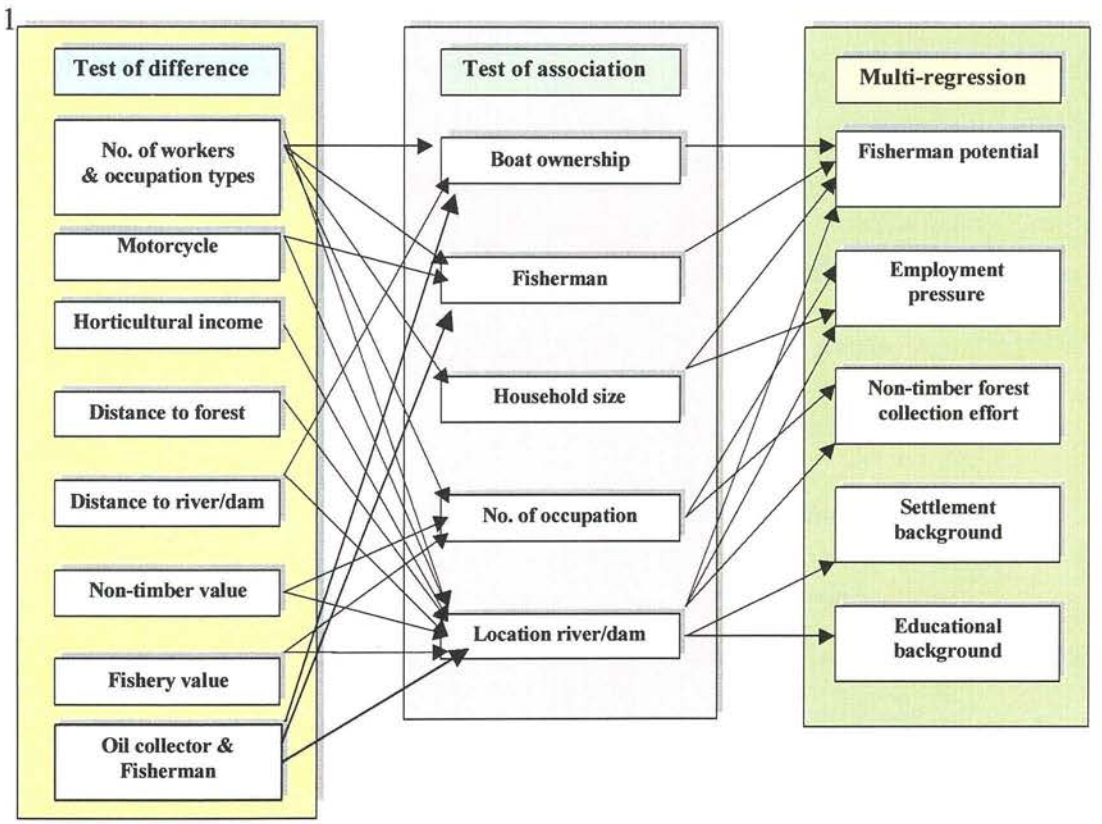


Figure 6.22: A diagram of socio-economic indicators and socio-economic impacts from the dam development project.

The difference between the without-project sample and the with-project sample with regard to 'location' also associates to the boat ownership, fisherman, household size

and the number of occupations in the household. Hence the variables show the inter-relationship to the final five independent variables utilised in 'Multiple regression analysis'. These independent variables are fishery potential, employment pressure, non-timber forest collection efforts, settlement background and educational background. All five variables were classified with regard to three different contexts of 'equal opportunity' including the fishery potential and educational background. The second is 'quality of life' including the non-timber forest collection efforts and the settlement background. The third is 'economic security' including the employment pressure.

These socio-economic indicators are reliable for quantification in terms of parametric information, which clearly express the socio-economic impacts of the dam development project.

Socio-economic indicators	*Socio-economic impacts*	*Socio-economic contexts*
1. Fishery potential	*(–)*	• **Unequal fishery opportunity**
2. Employment pressure	*(+)*	• **Economic security**
3. Forest collection efforts	*(–)*	• **Change of quality of life & life style**
4. Settlement background	*(–)*	• **Change of quality of life**
5. Educational background	*(+)*	• **Equal opportunity**

Figure 6.23: Socio-economic indicators, impacts and contexts according to the dam development project.

In conclusion, the dam development project can have considerable impacts in terms of (Figure 6.23) providing unequal fishery potential and change of quality of life and life style.

First, the 'fishery potential' shows the negative impact that provides the 'unequal

opportunity of fishery'. The fishery opportunity is changed and controlled by the project management system that the local people have to depend on.

Second, the 'employment pressure' shows the positive impact that creates the pressure on 'economic security' in the households. The economic situation of the households is unstable because the increasing consumption puts more pressure on the household members. Therefore, it is necessary to search for the additional occupations to earn enough money to support their new life styles. It seems that the households apparently earn more money but they need to put more efforts than usual into income generation.

Third, the 'forest collection efforts' shows the negative impact on the 'change of quality of life' and the positive impact on the 'change of life style'. The change of quality of life is from depending on the natural resources to the external resources. They also change their consumption behaviours and attitudes. Therefore, they are under pressure of over consumption based on luxury things e.g. refrigerators, colour television, motorcycle. The local people seem to improve the life style from the rural cultural community to become the city community but they consume more resources than in the past.

Fourth, the 'settlement background' shows the negative impact from the dam development project in relation to the 'change of quality of life'. They are resettled in the unproductive area, which they can not cultivate enough foods for their family. They are moved far away from the natural resources. This might cause loss of their indigenous culture, which is very important to social diversity and heritage.

Finally, the 'educational background' shows the positive impact in relation to the 'equal opportunity'. It seems that the dam development project does provide the local people with a better opportunity to give their children a higher education. Their children can transport daily to school in town because of the better transportation systems and better financial of their parents. From the other point of view, their parents with less educational background still have less opportunity to get the better

job from the dam project. Apparently, there are some constraints in terms of job opportunity based on the educational background, which the dam project might provide little benefits to the minority of local people.

In terms of fishery products and non-timber forest marketable products, the households along the river earn money different from the households near the dam. The households along the river earn more money from non-timber forest products around 814 Baht per month but the other earns only 588 Baht per month. For the fishery products, the households near the dam obviously earn more money at 7,040 Baht per month when compare to the money of households along the river earn around 3,106 Baht per month. It seems that the hydropower project provides better opportunity for earning from fishery but the fisherman find it more difficult to sustain their pattern of living in relation to the fishery.



Figure 6.24: Quality of life of local people along the Mekong River (Ban Kum).

Prior to such a dam development project, the local people should be taken into the serious consideration (Figure 6.24). Moreover, it should be recognised that human quality of life depends on living within the tolerances of the environment, and using its living resources sustainably (Maltby, 1999). Thus, the project should provide an equal benefit to the local people as much as to the city people who usually gain a lot of advantage from consuming the natural resources in the remote. The natural

resources are always transferred or processed in order to supply to people with high consumption and sustain their lifestyle in the city, particularly energy consumption. The process of decision-making should be shared by all stakeholders among the local people, the local authorities, the developers, the non-government organisations and the government authorities without any bias. Moreover, the methods of socio-economic assessment should be improved and include the pattern of living, the cultural constraints, the quality of life and attitudes into the process of assessment for the better decision-making.

CHAPTER SEVEN
AN ALTERNATIVE APPROACH: RESULTS AND DISCUSSION

Over the past two decades several approaches have been introduced to better integrate environmental considerations into the decision-making process. Because the environment is highly complex, the exact details of project impacts have not been completely estimated and quantified within decision processes. Impact Assessment (IA) is a process to improve decision-making and ensure that the project/programme/policy options under consideration are environmentally and socially sound and sustainable (Roe et al., 1995). IA tends to produce large and comprehensive reports that may not be readily useful to decision-makers (Walthern, 1992). The purpose of these reports (so called Environmental Impact Statements, EIS) is to help decision-makers decide whether a project that will affect society or the environment should be undertaken. The EIS should be able to express a global, social judgement summarising the main strengths and weakness of the project. Mc. Killop and Brown (1999) also discuss how IA usually occurs too late in the development process and does not allow the equal consideration of environmental and social factors with economic and technical factors, thereby limiting options for making decision.

Traditional IA was designed to fulfill a more limited scope, and that is how it has been standardised and improved. Nardini (1997) suggests that IA techniques have been developed to value environmental goods and services for which a market does not exist and to internalise externalities. Environmental issues are generally recognised to be important not only because of human utility, but also for conservation of natural systems. In the past humans generally considered themselves unique, and not as a component of the environment. Nowadays humans must be accounted as a component of biodiversity and should be included in IA evaluation alongside other form of life.

Convention on Biological Diversity[1] (CBD) negotiated at the Earth Summit and the Ramsar[2] Convention on Wetlands of International Importance, which both identify impact assessment as a key tool in helping to deliver conservation objectives. It seeks to ensure conservation of biodiversity and sustainable use of its components. It also promotes a fair and equitable sharing of the benefits that can be drawn from genetic resources. Consequently, the International Association for Impact Assessment (IAIA) aims to respond to the CBD and to promote the effective practice of environmental impact assessment, consistent with the institutional and process arrangements that are in force in the different countries (IAIA, 1999). Therefore, IAIA plays a leading and proactive role in the improvement and dissemination of concepts and practices becoming the best practice. One of the objectives in the best practice is to protect the productivity and capacity of natural systems and the ecological processes, which maintain their ecosystem functions.

To help meet these objectives, IAIA (1999) set up guidelines for practitioners and decision-makers on the incorporation of biodiversity into impact assessment. These guidelines aim to enable more informed decision making about the impacts of policies, programmes and projects:

- To ensure that biodiversity is addressed as early in the decision-making process as possible.
- To put biodiversity in place at the impact assessment or project level.
- To widen biodiversity from its current narrow ecological focus to the ecological economic value of the natural systems and their ecosystem services,

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[1] The Convention on Biological Diversity was adopted on May 22, 1992 in Nairobi, Kenya. On June 5, 1992, during the United Nation Conference on Environment and Development (UNCED-the Earth Summit) in Rio de Janeiro, more than 150 States signed the Convention, and on December 29, 1993 it entered into force. By May 20, 1997 a total of 169 States had ratified the Convention, making it one of the most widely adapted environmental treaties. The CBD has three interdependent objectives: conservation of biodiversiy (genes, species and ecosystems); sustainable use of its components (no long term decline of biodiversity); and fair and equitable benefit-sharing (WRI, 1997).

[2] The Ramsar Convention has played an important role in promoting awareness of wetlands and providing technical support to governments for conservation, wise use of biological diversity and management of these ecosystems on a sound ecological basis. The Ramsar Convention's work will become more closely related to the broader concerns of the Convention on Biological Diversity and the UN Commission on Sustainable Development (Ramsar, 1997).

and the social dimension of biodiversity.

The concurrent aim of IAIA (1999) is focusing on impact assessment of dams and water resource development. These are major projects, which need improved impact assessment to better address sustainability, regional and global impacts, and the integrated analysis of environmental, social and economic aspects.

The aim of this study also corresponds to the objectives of new dimensions of environmental assessment practice such as to facilitate the sustainability concept, process strengthening, and contribution of IA to decision-making (Sadler and Verheem, 1996 and 1999). In the process strengthening focuses on integrated approaches to IA, which considers as follows (Sadler and Verheem, 1996):

- 'Best guess' science paradigms and practices
- Traditional knowledge
- User-friendly tools, techniques and information technologies
- Relationship of socio-economic, bio-physical, health and risk components

Economic thinking, in the form of extended cost-benefit analysis, can contribute to a more comprehensive and integrated approach to IA, but does not make rigorous links between ecosystem processes and functions and related anthropocentric values. Largely for this reason, this study explores the potential for integrating a wide array of scientific information and conservation within decision-making. Previous chapters have examined the quantification and evaluation of species, ecosystems and socio-economic systems. The present chapter attempt to integrate this information into, not only an alternative IA, but also the decision-making process in general. This chapter consists of:

- Overview of impact assessment.
- Problems of traditional biodiversity evaluation in the impact assessment.
- Overview of the decision-making process.
- Scope of the study.
- Results and discussion: Part I A comparison between traditional and alternative impact assessment.

- Results and discussion: Part II Rational decision-making for sustainable natural resource use.
- Conclusion: A conceptual model for alternative impact assessment and the decision-making process.

7.1 OVERVIEW OF IMPACT ASSESSMENT

Impact assessment is used as an umbrella term for a range of techniques including (Roe et al., 1995):

- Environmental impact assessment (EIA)
- Cumulative effects assessment
- Health impact assessment (HIA)
- Risk assessment
- Social impact assessment (SIA)
- Strategic environmental assessment (SEA)
- Technology assessment

Impact assessment relates to a process rather than a particular activity. It provides information on the environmental, social and economic effects of proposed activities and is a mechanism by which information can be presented clearly and systematically to decision-makers. To achieve these objectives, impact assessment needs to be process-oriented, multidisciplinary and have inter-linkages among ecological, social, economic and political systems (Roe et al., 1995). On the other hand, impact assessment is an important management tool for improving the long-term viability of many projects or policies and its use can help to avoid mistakes that can be expensive and damaging in environmental, social and/or economic terms.

Technical methods in IA are composed of many steps. Basically, it involves analysing the impact of development on environmental components. The first step is

preliminary assessment (screening and scoping[3]) followed by selection of environmental parameters, collection of existing information, description and evaluation of environmental system, and prediction and evaluation of impacts. The final tasks are concerned with monitoring and mitigation of the development impact.

Ecological assessment is incorporated as part of this overall process and normally involves three phases in terms of intensity of study and the details of information needed. These are as follows (Morris and Therivel, 1995):

- Phase I is habitat survey to provide a general description of ecosystems, habitat or vegetation type within a study area.
- Phase II involves the collection of quantitative vegetation data and abundance data on selected animal species and/or groups.
- Phase III involves detailed quantitative information on species populations and/or communities.

Each step of a traditional ecosystem evaluation may use many measures that aim to increase the objectivity of the process and/or increase comparability by the use of numerical values e.g. species diversity, species richness, indicator species, composite indices and priority ranking that.

Another approach in ecological evaluation emphasises economic value of natural resources for the economic growth. Economic value is focused on the human needs while the other organisms are considered less in relation to human benefit. Consequently, it tends to increase the rate of utilisation and exploitation and also encourages the inefficient use of natural resources.

However, some economists have attempted to measure the total economic value of

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[3] Scoping is used to define the proposed action; request cooperating agencies; identify what's important or not important; set time limit on studies; determine staff requirements of the study team; collect background information; identify required permits; identify other regulatory requirements and determine the range of alternatives (Marriott, 1997).

biodiversity as part of ecological valuation. Consideration of the ecosystem within such an analysis requires information on ecosystem structure and function (including goods and services) and its contribution to the sustainability of the whole biosphere. Consequently, the ecosystem structure and function should be fully taken into account during biodiversity evaluation. This alternative biodiversity evaluation approach will ensure the incorporation of some intrinsic functional values within the IA, which hitherto have had limited incorporation in the decision-making process. The adoption of the above framework in any development project, plan or policy relating to natural resource use should result in a more reliable, realistic and holistic environmental decision-making process.

7.2 TRADITIONAL BIODIVERSITY EVALUATION IN THE IMPACT ASSESSMENT

'The ability of choose policy paths that are sustainable requires that the ecological dimension of policy be considered at the same time as economic (...) and other dimensions – on the same agendas and in the same institutions'

World Commission on Environmental and Development, 1987.

IA is now established in most countries, but it is recognised that IA, as typically institutionalised, is constrained by certain limitations and weakness. These include structural weakness centered on the circumscribed role of IA in decision-making and relatively late stage at which it is applied (Sadler, 1986). In the case of the World Bank's role it is primarily to advise on and monitor the quality of IA reports and outputs at project level. However, the IA is recognised as an *insufficient method* to provide a systematic, integrated analysis of alternatives or to guide broader lending strategies (Sadler, 1996). The World Bank has also sought to define operational policies to promote sustainable development and to strengthen and integrate economic, environmental and social assessment of its lending activities. It is also developing methods of defining sustainable development in terms of maintenance of three types of capital stock: economic, natural and social.

However, the recent reviews of the IA process for the development projects indicate a number of weaknesses. These include (World Bank, 1997):

- Inadequate determination of the spatial context of the project
- Poor or insufficient baseline information and treatment of biodiversity as simple 'lists' of species found in a project area
- Lack of rigor in the cost-benefit analysis
- Insufficient attention to implementation and monitoring of mitigation measures and environment management plans including institutional arrangement.

To improve the IA performance as a means to protect biodiversity, it is necessary to be systematically assessed and evaluated, and the ecological, social and economic value of such functions quantified as part of the cost-benefit analysis of projects (World Bank, 1997). Traditionally, biodiversity has not been addressed and concerned in the IA (World Bank, 1997) until the institutional agreements among international organisations (CBN, Ramsar, UNDP) have been accepted and focused on integration of biodiversity concerns into IA. It has some constrains because the IA method still considers the contribution of biodiversity to national, regional and local economies by measuring in monetary terms. However, the economic evaluation of the existence of biodiversity may not accurately reflect their inherent ecological value.

Within a holistic approach to biodiversity evaluation, there is an emphasis on ecosystem structures and functions even. However, these attributes may be difficult to express in monetary terms.

Thus, the ability to characterise and estimate monetary values of ecosystems and in particular ecosystem services, still faces several problems, as recognised by Bingham et al. (1995):

- The ecosystem valuation could be improved if currently available tools for monetary valuation could be competently applied more often. It is challenging to define what sorts of valuation information are likely to be

decisive and needed to make a decision.

- Good valuation studies depend on ecological results being adequately appreciated. Ecosystem services can be valued in monetary terms only after those services are well understood, yet predicting how ecosystem service flows will change, as a result of human intervention, is often difficult.
- Even if ecosystem services were perfectly understood and evaluated in monetary units it will be most important to clarify where conventional economic values are sufficient for decisions and where broader human values - including non-monetary values - and criteria for decision-making are more appropriate.

IA should be carried out simultaneously for all the considered alternatives. The most important consideration involves the identification of the impacts not only on the group of people who are affected, but also the values that they attach to the various impacted components. Such determinations must be made explicit in term of 'good-bad value judgement' (Nardini, 1997). Keenly (1992) suggests that a 'value-focused' approach[4] should be considered in the evaluation of impacts. Although the measurement of biodiversity is likely to 'undervalue' based on a variety of economic and social reasons, it should be described in qualitative terms (World Bank, 1997). The problems of estimated biodiversity value or in terms of environmental value can be proved impossible to estimate using any of the available techniques, either because of lack of data or the difficulty of extracting the desired information or unquantifiable benefits of biodiversity (World Bank, 1998b). To this extent, any estimates of value will still underestimate the total value.

Therefore, it is necessary to seek for an alternative of biodiversity value by focusing the biodiversity benefits (carbon storage) large enough to justify this integrated alternative IA for providing the sustainable development to decision-makers.

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[4] There are a multiplicity of methods of ecological evaluation, but most appear to be based on market prices; subjective-oriented as with willingness-to-pay or willingness-to-accept by contingent valuation method; and so on.

7.3 OVERVIEW OF THE DECISION-MAKING PROCESS

Decision-making is the process of making a decision, which is an irrevocable allocation of resources (Merkhofer, 1999). There are several tools for helping decision-makers to make good decisions. These rely on underlying assumptions to evaluate and compare alternatives. There are three major tools for assessing, refining and narrowing options for the good decision characterised by Merkhofer (1999) as Probabilistic risk assessment, Cost-benefit analysis and Decision analysis.

- ***Probabilistic risk assessment (PRA)*** provides a systematic, logical process for exploring, understanding and quantifying risk. When performed well, it enables managers to identify threats that pose the greatest dangers and to document reasons for the conclusion in terms of quantified uncertainty. This tool is the product of probability and the consequence of events and indicates the type and nature of all possible outcomes, the magnitude of these outcomes, their probabilities, and their timing. PRA uses data and analysis that are similar to the standard impact assessment, but includes additional tools that allow for statistical and probabilistic analysis of uncertainty. There are some weaknesses such as:
  - It is difficult to do well.
  - Errors occur when models are too simple, data do not reflect recent changes, or underlying assumptions do not hold.
  - It is hampered by limited availability of measures for human health and ecological stress.
  - It can be expensive and time-consuming and generally requires a multidisciplinary team including experts in probabilistic methods.

- ***Cost-benefit analysis (CBA)*** looks only at the direct project benefits and direct project costs although an expanded approach will include the external and environmental improvement benefits as well as the costs of external and/or environmental control measures. CBA seeks to determine not only if a project can be expected to provide a satisfactory return to the economy, but also if there is an alternative way of achieving a project's objectives. It would offer a

higher return by the project. Shadow prices are used to reflect the value of cost and benefit, which also reflect the true willingness-to-pay by individuals in order to have access to certain goods and services rather than from the existence of intrinsic value. The typical CBA calculates measured benefits and costs and converts them into an economic rate of return. In practice, most applications of cost-benefit analysis omit non-marketable values and therefore can lead to misleading results (Tilden and Frehs, 1997). The non-market costs and benefits could be estimated in common units comparable to monetary value. *Cost-effectiveness analysis (CEA)* is a modified form of CBA that focuses on finding the least-cost alternative for achieving a specified goal. CEA avoids the need to estimate non-economic impacts and to value benefits. Using cost-effectiveness analysis as the rationale on which to make a decision, is based on the assumption that the important factors can be expressed in numerical form and that a correct judgment of the situation can be a realistic assumption. Despite a number of weaknesses, CEA puts increasing stress on ecosystem or natural systems and on environmental quality. Important problems outlined by Nardini (1997) are:

- The economic valuation of environmental, social-cultural and health effects is often difficult, sometimes impossible, and questionable concerning biodiversity.
- The appropriate discount rate and the necessity to aggregate the stream of future benefits and costs, are intricate points and basically unclear. Discounting is commonly used to express future costs and benefits in terms of present monetary value, assuming that a value received now is worth more than the same value provided at some future date. Some critics regard discounting as inappropriately devaluing those ecosystem services that take a long time to be realised. Some experts have advocated using lower or negative discount rates that place a higher value on the future benefits and weigh the future costs of biodiversity/environment heavily. Thus, discounting can result in greater ecosystem or biodiversity exploitation or use of natural capital now at the expense of future ecosystem health or availability of natural capital (Bingham et al., 1995).

- Efficiency, the criterion underlying cost-benefit analysis, is not theoretically incompatible with the sustainable concept. This is because of the existence of exhaustible natural resources for which it is practically impossible to find real substitutes. The cost-benefit analysis is incomplete because many costs and benefits are difficult to quantify and, even if quantifiable, may be difficult to represent in monetary terms (Bingham et al, 1995).
- The cost-benefit analysis is weak in generating public participation and negotiation. Several methods already exist for assessing the monetary value of ecosystem attributes. These methods fall into two categories, one relying on observable choices and the other on the response people make to the proposed choices. Even the contingent valuation does little to bring people into the negotiation process necessary for conflict resolution.

- ***Decision analysis (DA)*** is a theoretically sound megatool for comparing decision options. Decision theory derives from a set of axioms for what it means to be rational. In practice, DA is concerned with identifying the alternatives to a decision, estimating outcomes and assigning probabilities and establishing the utility function. At the simplest level, DA may be applied by encouraging a decision-maker to identify multiple decision alternatives, to specify the range of likely consequence of each alternative, and to apply consistent value judgments when deciding how desirable or undesirable each possibility is. The DA cycle is composed of four phases, framing[5], deterministic[6], probabilistic[7] and evaluation, all of which contribute to a

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[5] Framing phase defines the decision problem in a way that allows the alternatives to be evaluated with DA. For example, the objective hierarchies facilitate the definition of performance measures, which are the consequences of an alternative to how good or bad things turn out (Merkhofer, 1999).

[6]Deterministic phase is to translate the graphic presentations of the decision model into a mathematical model. For example, multiattribute utility analysis (MUA) is a set of tools for constructing a value model (Merkhofer, 1999). This is a diversified multicriteria analysis, which involves weights and scaling functions for supporting collaborative decision-making processes involving multiple stakeholders with diverse interests.

[7] Probabilistic phase is developed for those uncertainties that have a large impact on the resulting utility for one or more alternatives or cause the preferred alternative to change as the variable is moved from high to low settings, for example, the decision tree analysis (Merkhofer, 1999).

decision. Each phase of the DA cycle has a specific tool to measure the performance to meet the final decision. Some of the features of DA are as follows:

- It typically requires significant time and involvement from decision-makers. For instance, since the calculations are extensive and complex, the experienced people in positions of management responsibility do not have the time or the detailed understanding to review them. Judgment as to the weight given to various factors is left to the analyst instead of to the judgment of people who have experience in the field that is being analysed. However, the considerations relative to the complexity, which cannot be quantified, are necessarily left out of the calculation.
- It makes explicit potentially controversial judgements and viewpoints. There are some debates where the decision analysis requires the explicit articulation of a thought process. Thus the decision-maker is forced to give a verbal description of the thought processes, even though it may be a simplification of the real practices.
- It has to integrate in a single model the different beliefs and value judgements of multiple individuals. Decision analysis tends to be concerned with putting numbers on everything, especially in dollars, which might bias a study against other human and aesthetic qualities.
- It is the best application in high-stake, complex decisions when time for deliberation is available.

Each of the major tools has strengths and weaknesses or limitations; however, they have common characteristics of repeatable quantification of information (Dale and O'Neill, 1999). The sophisticated tools may lead to inappropriate confidence in the data, especially when the measures are not well understood. Therefore, a simple, repeatable and quantitative approach is most appropriate to provide understandable results for better decisions-making.

In the real world situation, solutions to problems are reached as a compromise, resulting from trade-offs between various conflicting objectives of the stakeholders

through negotiation to reach a consensus. In such situations the approach is not to maximise all the objectives, but to optimise, that is to find an acceptable balance between the requirements of stakeholders. Different kinds of objectives can be included, expressing not only economic values of products (eg. electricity) but also addressing goals which can not always be expressed in monetary terms such as biodiversity, people's preferences, equity, or minimising risk and uncertainty.

The present study examines the decision-making technique involving multiple criteria that is *'Multi-Criteria Analysis (MCA)'*. This technique measures objective achievements on a range of scales from simple quantities to purpose-built indices. Theoretically, MCA can define a separate objective for each criterion in a single function. Criteria are defined as measurable features of the planning environment, which either singly or together indicate the levels of objective achievement.

Sadler (1996) suggests that some methods for IA are aggregation methods to aim to make the total amount of environmental information more manageable. In this process, results are often weighted against each other and 'trade-offs' choices are made. Therefore, the index method is used in this study by aggregation of valuation and weighted summation. Prioritisation can be achieved either through relative weighting, or through ordering. In a weighting procedure, each objective is assigned some fractional level of importance, with the total fractional weights assigned adding up to unity. The overall value of an option is considered to be the sum of the values assigned to the different criteria. The resulting evaluation provides two distinct features:

- It directly combines different criteria scores and finds the best resultant combination score either algebraically or graphically.
- It relies on building up out-ranking relationships between criteria, keeping criteria distinct.

The various criteria scores must be standardised, with all factors on the same scale (Rossiter, 1995). To standardise to the same scale, a simple linear stretch can be applied:

$$V_i = (x_i - x_{\min})/(x_{\max} - x_{\min})new_range \qquad \text{(Equation 7.1)}$$

Where

V_i = The standardised weight of individual indicator

x_i = The raw scores in the original units of measure

new_range = The range to which all factors will be standardised either 1 or 100 i.e. normalised.

Hruby (1999) recommends the simple formulation of a decision rule for continuous criteria as the *weighted linear combination formula* for the composite score:

$$S = (V_1 + V_2 + V_3 ..... + V_n)/n \qquad \text{(Equation 7.2)}$$

Where

S = The composite suitability score usually sum to 1

V = The standardised weight of each biodiversity indicator

Thus, the decision-makers may choose the option with the highest cumulative value. This flexibility in data analysis is a major advantage of the MCA technique, particularly in environmental planning situations where impacts may be scored on a number of different measurement scales. In general, MCA presents the following aspects:

- There is no solution, which optimises all the criteria at the same time and therefore the decision-maker has to find compromise solutions.
- When an action is best for some criteria, it is usually worse for the others, so that many pairs of actions remain incomparable with respect to a dominance relation.

7.4 SCOPE OF THE STUDY

The scope of this final chapter consists of two parts, which apply the results of observations on hydropower schemes on the Lower Mekong River:

- The first part is focused on the test between the traditional and an alternative approach of the IA process, which is presented in the flow chart in Figure 7.1. This new approach initiates and incorporates the evaluation of species, ecosystem and human components into IA and explores the rationality of the alternative IA by comparing it to the traditional IA. Carbon storage is considered as a monetary value of the ecosystem services and is followed by species composition, richness and diversity. Moreover, humans, as biodiversity components, need to be included into the evaluation, as they should be considered along with other levels of biodiversity.

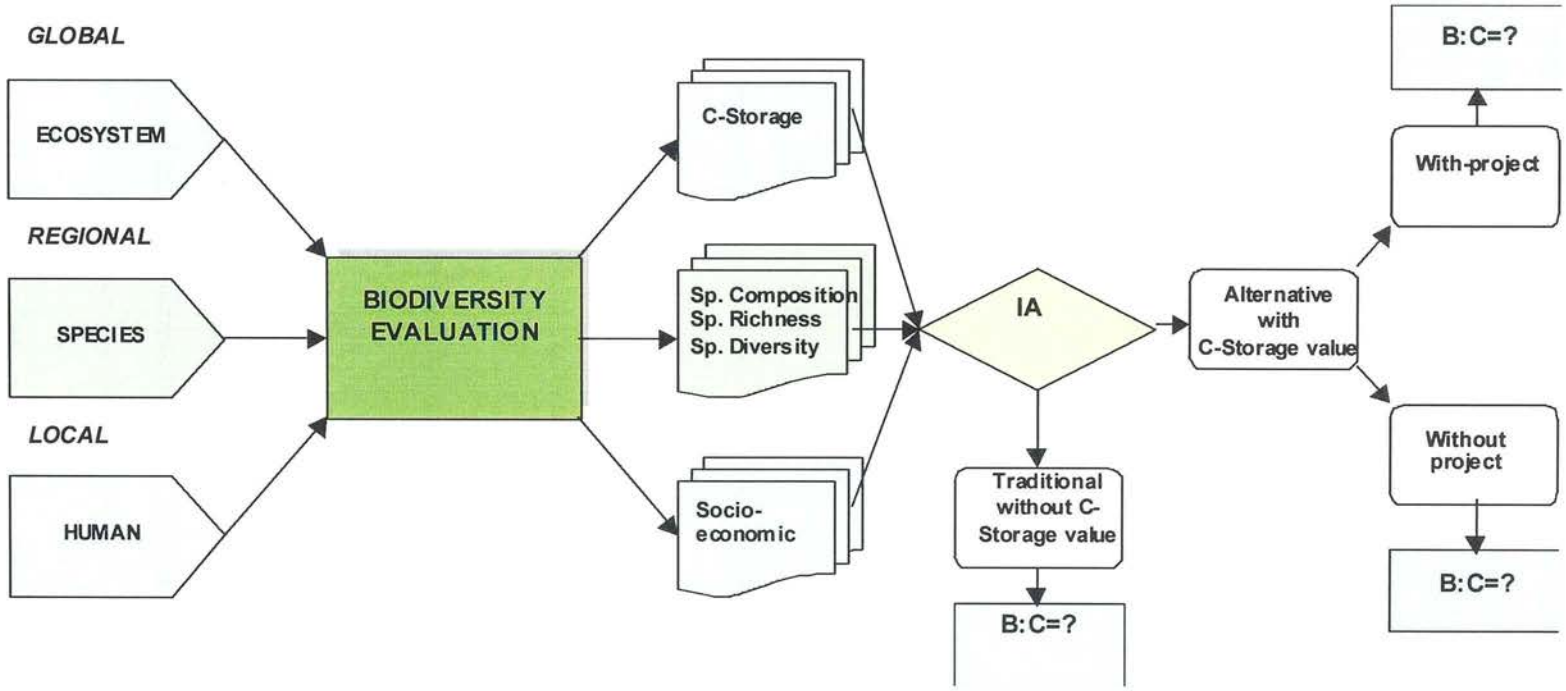


Figure 7.1: A flowchart of the biodiversity evaluation incorporated into the alternative IA.

- The second part focuses on the decision-making process, presenting the integration of three sectors, which reflect concerns of decision-makers/policy-makers and the public, environmental, social and economic sectors (Figure 7.2). It explores the effective resource uses for the development projects.

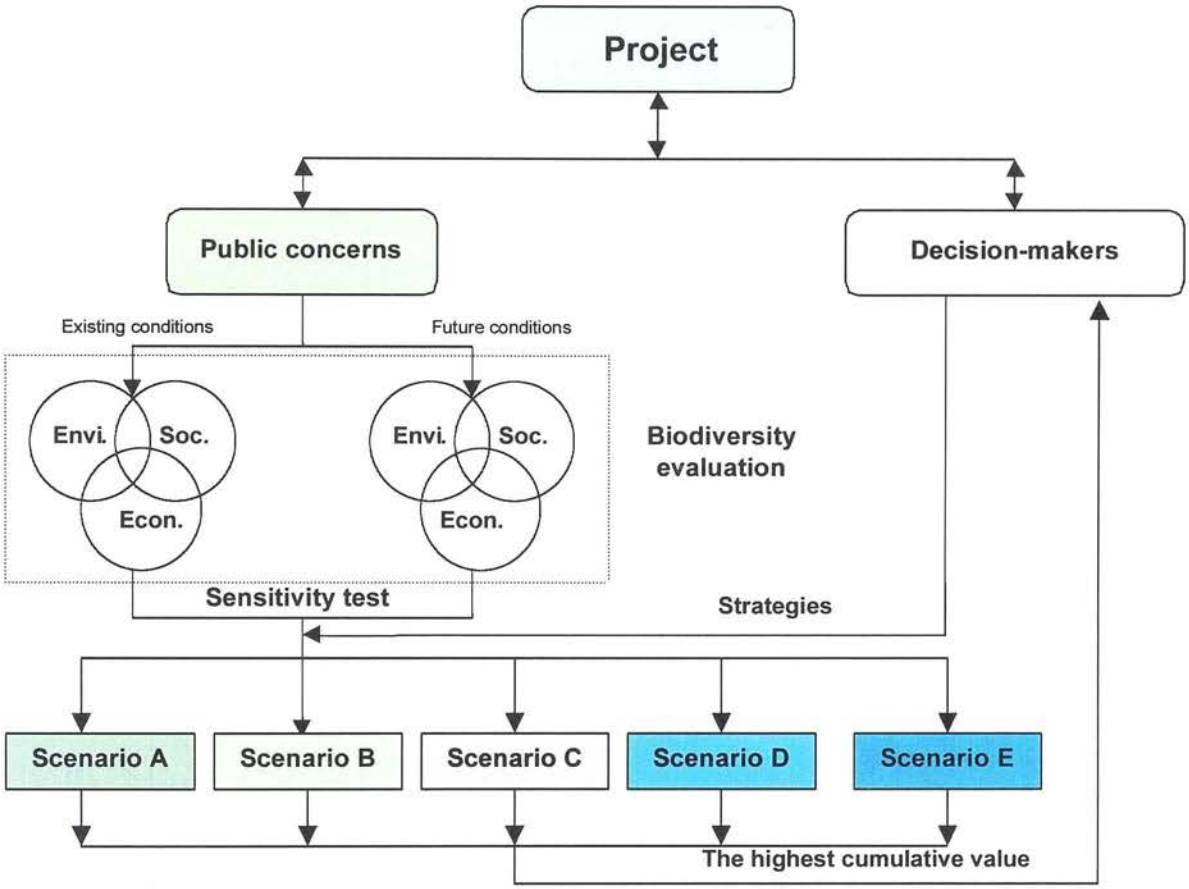


Figure 7.2: A flowchart of decision-making model.

Biodiversity should be considered in relation to the different spatial scales of impact (Table 7.1). At a global scale, the ecosystems are representative of biodiversity in relation to major ecosystem services, and carbon storage in ecosystems is examined as a rationally decisive biodiversity index. The monetary value of carbon storage is based on different scenarios, which represent CO_2 mitigation options. At a regional scale, the focus is on the species level consisting of species composition, richness and diversity in ecosystems. The species composition represents a qualitative value of the types of species present. The species richness is the number of species

existing in ecosystems but a species diversity index ranging from 0 to 5, represents the abundance of different species. Local scale analysis is concentrated on human society, with the indices related to quality of life, economic security and equal opportunity in relation to the socio-economic scheme, expressed by numeric values. Therefore, all of biodiversity indices can be incorporated into the alternative IA, bringing more environmental costs into the traditional cost-benefit analysis in the decision-making process.

Table 7.1: The relationships of scale, biodiversity level, indices and evaluation value.

Scale	Level	Indices	Unit of evaluation
Global	Ecosystem	Carbon storage	Monetary value ($)
Regional	Species	Species composition	Numeric value
		Species richness	Numeric value
		Species diversity index	Numeric value (0-5)
Local	Human	Quality of life	Numeric value
		Economic security	Numeric value
		Equal opportunity	Numeric value

7.5 RESULTS AND DISCUSSION: PART I A COMPARISON BETWEEN TRADITIONAL AND ALTERNATIVE IMPACT ASSESSMENT

Generally, the traditional impact assessment is not strong enough in terms of realistic economic valuation of biodiversity. Therefore, this study aims to improve the method of biodiversity evaluation within IA (Figure 7.1). An alternative IA provides a more reliable and fairer evaluation of biodiversity in the decision-making process. The results from the Mekong illustrate a comparison between the traditional and the alternative IA, based on an improved ecological and socio-economic perception (Table 7.2).

Table 7.2 indicates options to expand and merge the ecological concepts into the procedure of evaluation. It provides a broader perception of multi scales of benefits and costs from the development project. Benefits of the hydropower dam project should be considered at different levels including the direct benefit from electricity production, the direct benefit from the aquaculture and fishery in the dam and finally the indirect benefit from the recreation and ecotourism. However, the costs also need to include the environmental evaluation to justify the cost of damaging ecological structure and functions based on the principles of sustainable development. There are still some constraints in relation to ecosystem services because some services are difficult and complicated to measure at this moment.

Table 7.2 identifies six important and varied ecosystem services, which are capable of quantitative expression in expanded IA. Changes in the state and distribution of ecosystems within the catchment affect the hydrological cycle and, in addition to affecting water supply to the reservoir, can influence crop production, ecosystem development and supply to the people. Other services are indirectly affected by dam construction but can have medium to long-term consequences for the development of the natural resources and human use. These, and probably other ecosystem services, deserve to be explored in future research and considered within IA along with improved socio-economic assessment. However, as indicated in Table 7.2, this study is focusing on the species diversity, ecosystem and human level as the components of biodiversity, with carbon storage being selected to represent the role of ecosystem services.

Table 7.2: A comparison of the evaluation in traditional and alternative IA.

	Traditional IA	Alternative IA
Benefits of hydropower dams		
1. Electricity	+	+
2. Aquatic productivity	+	+
3. Recreation and ecotourism	+	+
Costs of hydropower dams		
1. Direct costs	+	+
2. Operation & maintenance	+	+
3. Services (transmission lines & system)	+	+
4. Environmental aspects		
4.1 Environmental mitigation	+	+
4.2 Changes in ecosystem services		
- climatic regulation (c-storage)	0	+*
- erosion control	0	+
- soil formation	0	+
- nutrient cycling	0	+
- food production	+	+
- pharmaceutical products	0	+
- genetic resources/ species diversity	0	+*
- water regulation	+	+
- water supply	+	+
5. Social aspects		
5.1 Resettlement	+	+*
5.2 Socio-economic impacts		
- equal opportunity	0	+*
- quality of life	0	+*
- economic security	0	+*

Note: + variables, which should be considered for inclusion in future IA.
0 variables not considered in traditional IA.
* indicates variables explored in the present study.

7.5.1 Economic analysis through the addition of carbon value

Ban Koum Hydropower Project has been ranked as the first priority of the proposed projects for the maintream of Mekong River based on economic analysis and the options of BKC20 (MRC, 1994). Benefits and costs of this project are presented in the MRC report and are summarised in Table 7.3. At this stage, the species diversity levels are not integrated into the economic analysis. It should be noted that the combined costs of environmental mitigation (4.1) and resettlement (5.1) are only 2.6 percent of the capital cost and 1.8 percent of the total cost of the project estimated by the traditional IA. MRC (1994) reports the environmental cost to be about 3 percent of the capital cost. Emphasis is placed here on the development of an alternative IA through the inclusion of an economic evaluation of carbon storage as an ecosystem service. The economic value of carbon stored in the terrestrial ecosystems was calculated on the basis of various published costs of replacement (Table 5.3). These are presented in Table 7.3 as three scenarios of increasing costs with the alternative IA:

- Scenario I. Reforestation of community forests in Thailand (US$11/tonne C)
- Scenario II. Plantation with high value teak in Thailand (US$56/tonne C)
- Scenario III. Solar energy replacement in developing countries, upper level (US$200/tonneC)

For the Ban Koum project the different cost of CO_2 mitigation management raises the total cost of the project from between US$3,212 million to US$4,016 million compared with the traditional IA estimate of US$3,165 million. The highest total cost was based on the value of carbon storage lost from the affected area, including the impact of human encroachment, with the carbon pricing based on the cost of the solar energy option to mitigate atmospheric carbon.

Table 7.3: A comparison of the traditional and alternative IA based on the Ban Koum Hydropower Project (million US$).

Description	Traditional IA[a]	Alternative IA		
		Scenario I	Scenario II	Scenario III
Benefits of Ban Koum Hydropower Dam				
1. Total energy (9102 GWh)	4,526	4,526	4,526	4,526
Capital costs of Ban Koum Hydropower Dam				
1. Direct costs	1,640	1,640	1,640	1,640
2. Services (transmission lines & system)	366	366	366	366
3. Management, administration and engineering	128	128	128	128
4. Environmental aspects				
4.1 Environmental mitigation[b]	49	49	49	49
4.2 Species diversity aspects:				
Species composition	0	+	+	+
Species richness	0	+	+	+
Species diversity	0	+	+	+
4.3 Ecosystem services (Carbon storage lost value)	0	47	238	851
5. Social aspects				
5.1 Resettlement[c]	8	8	8	8
5.2 Socio-economic impacts				
- equal opportunity	0	+	+	+
- quality of life	0	+	+	+
- economic security	0	+	+	+
6. Total capital cost (million US$)	2,191	2,238	2,429	3,042
7. Total cost : plus operating cost & interim replacement (50 year-period)	3,165	3,212	3,403	4,016

Note: a = Details in Appendix 7.1 (MRC, 1994).
b = Environmental mitigation includes the costs of mitigation measures such as erosion protection, flood protection dykes, creation of managed wetlands, and the cost of local community development.
c = The resettlement cost includes compensation, resettlement and new facilities for the displaced population. The cost is US$5,500/displaced person.

Table 7.4: Economic analyses of benefit to cost ratio of Ban Koum Hydropower Dam, under traditional and alternative IA methodologies.

	Traditional IA (million US$)	Alternative IA (million US$)		
		Scenario I	Scenario II	Scenario III
Benefits of Ban Koum Hydropower Dam[a]	4,529	4,529	4,529	4,529
Total costs of Ban Koum Hydropower Dam	3,165	3,212	3,403	4,016
Benefit to cost ratio	1.43	1.41	1.33	1.13

Note: a = Benefit discount rate at 10 percent.

A comparison of the economic analysis of the traditional and alternative IA in terms of a benefit to cost ratio is shown in Table 7.4 (Appendix 7.2). The benefit to cost ratio of Ban Koum project was estimated at 1.43 by the traditional IA (MRC, 1994), but fell to 1.41, 1.33 and 1.13 with the three Scenarios in the alternative IA. This illustrates that Scenario III, in relation to the clean energy as solar energy use, would provide the least economic benefit to this hydropower project, because the cost of the environmental damage under Scenario III (US$49 + US$851 + US$8 million). It was estimated at about sixteen times higher than the environmental cost of the project (US$49 + US$8 million) in the traditional IA. This Scenario III focused on the most effective atmospheric CO_2 mitigation among three scenarios because the clean energy approach for the replacement of fossil fuels utilisation would be an adequate ecosystem value to incorporation in the alternative IA.

Scenarios I and II are associated with the forest management to mitigate carbon loss, at apparently lower cost than Scenario III. The results of benefit to cost ratio indicate the high potential of economic benefit from the Ban Koum project even if the carbon storage value was included in the economic analysis. The implication of forestry management is not efficiency and adequate enough for atmospheric CO_2 mitigation

because the forest plantation or reforestation can gradually store carbon over long time periods while the loss of carbon storage from ecosystems by dam construction occurs suddenly. On the other hand, Scenario I and II have not considered at the point source of global climate change problems, which are caused by fossil fuel use.

It is understandable that if the estimated carbon storage cost of natural ecosystems (particularly terrestrial ecosystems) is low with high economic benefit from the project, the tendency of natural resource utilisation will increase. To trade off the loss of the carbon sink system and the increase of emission from the forest during the dam construction, it is necessary to bare in mind with either a more efficiency alternative for electricity production or the consideration of the highest carbon storage value into the IA.

Considering the time scales of the impacts, the results of cost-benefit analysis show the breakeven point for the traditional IA is approximately in the 10th year of a 50 year-period. Scenarios I and II meet a similar breakeven point in the 11th year, while the scenario III meets the breakeven point in the 14th year of the project's life (Figure 7.3 and Appendix 7.2).

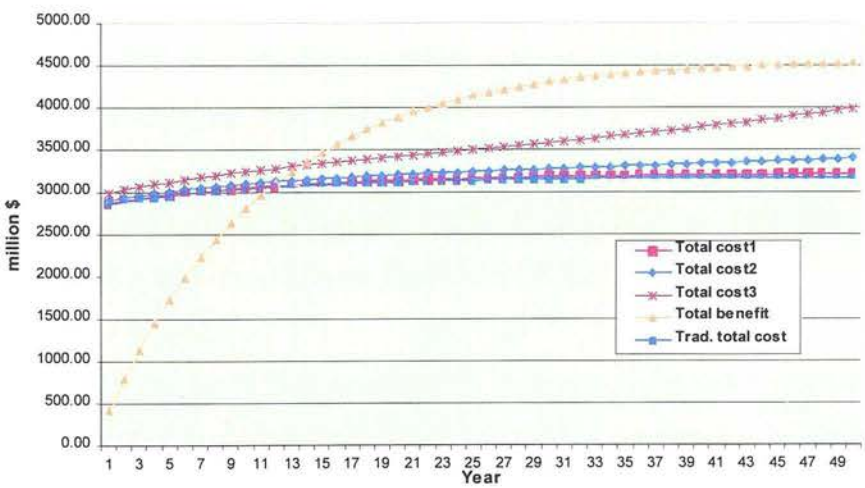


Figure 7.3: A comparison of total cost under different scenarios and total benefit of Ban Koum Hydropower Project.

Given the complex nature of biological systems, and the only recently recognised importance of ecosystem services like carbon storage, it is understandable why biodiversity has been poorly handled within IA. It is fair to say that traditional IA has attempted to evaluate some aspects of environmental mitigation such as immediate and obvious aspects such as the cost of erosion protection, flood protection dykes, the creation of managed wetland, and so on. However, the environmental mitigation cost of the Ban Koum project has largely ignored the wider consequences of biodiversity loss by the dam construction. The economic analysis of traditional IA indicates the high benefit (B:C = 1.43) from the Ban Koum project, while the alternative IA gives less relative benefit, depending upon the different carbon values used. The alternative IA described here has at least shown that other values of ecosystem services, such as carbon storage, can be integrated into the ecological evaluation in IA procedure.

It is impossible to ignore the development projects of the Mekong River Basin, but any projects in the area should utilise appropriate and rational tools for planning and management. The alternative IA suggested here might broaden the vision of environmental planners, especially to the global climate change objectives of sustainable resource use. This economic analysis should help to convince the decision-makers or policy-makers to give more serious consideration to sustainable environmental development. The example also provides a strong example of the principle *'Think global, act local'* (Maltby et al., 1999).

7.6 RESULTS AND DISCUSSION: PART II RATIONAL DECISION-MAKING FOR SUSTAINABLE NATURAL RESOURCE USE

A further step in this study is to integrate all biodiversity indicators (species, ecosystem and human aspect) with economic indicators to predict the impacts on biodiversity of the Ban Koum project. This analysis is based on the scientific information from chapters four, five and six, which describe the conditions before and after dam construction.

Theoretically, Multi-Criteria Analysis (MCA) is an appropriate method to apply to conditions of single-objective and multi-criteria. It includes the following steps (Rossiter, 1995; Maxwell, 1999):

- Identifying public issues and relevant concerns
- Translating public issues and concerns into quantitative evaluation
- Crafting options into strategies
- Identifying possible future conditions (uncertainties)
- Constructing scenarios (combinations of strategies and future conditions)
- Using cumulative scores to find the best strategies for the future

The generalised flowchart of the decision making process (Figure 7.2) shows the three key sectors as environmental, social and economics. Each sector needs to be quantified on an equivalent basis but not necessarily having the same units. MCA is the current method by which the analysis of decision-makers involvies sets of scenarios based on the different criteria.

The present study is focused on the key problem of setting up criteria for weighting these variables. Thus, the single objective is to provide the equal sharing of energy consumption in the region. It is assumed that the dam project is implemented in the Mekong River. Therefore, the different scenarios are based on the with-project implementation condition. The multiple criteria need to justify the different environmental, social and economic concerns through a combination of these three sectors (See Figure 7.2).

As a result, the decision-making model is a simple numeric representation of hypothesised relationships for each level of biodiversity, which performs as both structure and function. The quantitative and qualitative measurements of performances are used to assign a score in the model equation. Most indicators are fixed characteristics that describe the structure of the ecosystem or physical, chemical and geologic properites (Brinson, 1995). These indicators are time independent conditions

(on a scale of ecological processes), and thus cannot reflect actual rates of performances. The present model scores based on indicators, therefore, did not reflect the levels at which a system may actually perform. Instead, it estimates the potential or probable system performance, expressing healthiness or sustainability.

The final part of the study explores the sensitivity of the model (Figure 7.2) under different scenarios corresponding. Each scenario represents a combination of different proportions of the biodiversity indicator values. Each biodiversity indicator has a different unit of measure, therefore, it is necessary to make some assumptions to generate a standardised system of weighting. The proposed weighting system is based on the equation 7.1 by Rossiter (1995). Each indicator is standardised into a percentage unit and is transformed into maximum, mean and minimum categories. The maximum and the minimum value of biodiversity indicators are represented as the maximum and the minimum value in the Equation 7.1 (Table 7.5) and are compiled from the results of the field studies.

Table 7.5: The condition of biodiversity and economic indicators at maximum, minimum and mean value.

Indicators	Maximum	Minimum	Mean
Carbon storage unit (million tonne C)	1.22	-1.22	NA.
Species composition[a]	67	38	55.67
Species richness[a]	76	20	54.33
Species diversity index	3.14	2.91	3.03
Socio-economic impact index	1.67	1.18	NA.
Economic indicator (Benefit to cost ratio)	1.43	1.0	NA.

Note: NA. = The data is not applicable.
a = Species composition shows the observed number of plant species. Species richness is the predicted number (see chapter four).

The way in which the values given in Table 7.5 were derived is as follows. These

results are then applied to a series of scenarios regarding to the vertical scale including global, regional and local scales (See Table 7.1).

1. Global scale

- ***Carbon storage*** is estimated in chapter five in terms of the amount of carbon stored, which is valued under certain circumstances. Measures of carbon stored and loss are taken into account in exploring the impact of various scenarios because the effect of different forest management options and economic valuations may need to be separated. The possibility of a carbon storage loss of 1.22 million tonne is estimated from the proposed reservoir area during a 50-year period without human disturbance. This represents a minimum value. This means that the proposed area would directly release carbon at the initial stage of dam construction, the opportunity to store more carbon in the system would also be lost. The result of carbon storage estimation from chapter five is used as the maximum value under ideal condition when the terrestrial ecosystem in the reservoir area is kept naturally with the carbon stored at 1.22 million tonne over a period of 50 years. The ideal scenario focuses on the management aspects in order to replace more stored carbon (1.22 million tonne C) in the ecosystem relative to the estimate for the 50-year period. However, the estimates of carbon storage loss from the area assumed different situations, these were based on the whole catchment area at the assumed human encroachment rate of 2.0, 1.5 and 0 percent per year in Scenario C, D and E, respectively (Appendix 7.3). The loss of carbon was presented as negative value in the equation. The more details are explained in the footnote of Appendix 7.4.

2. Regional scale

- ***Species composition***: the results from the primary, the secondary and the riparian forests were used to provide estimates of maximum, minimum and mean values. The mean value of tree species in the three forest types was the existing value of species composition (x_i = *62).* The maximum value (x_{max} = 67) represents the

secondary forest, which is probably in the process of succession and therefore a minimum value ($x_{min} = 38$) is from the riparian forest. The values of x_{max}, and x_{min} were applied in equation 7.1 to generate standardised values.

- ***Species richness*** is based on the results in chapter four, which showed a range from 76 to 20 species over the three forest types. The maximum number of species existed in the primary forest and the minimum number in the riparian forest. The mean of the number of species across all forest types was used to represent the current condition (existing value). This indicator was standardised and quantified to generate the normalised score for the final estimation of each scenario. When the dam was constructed, the riparian forest will be most affected, some species will disappear and species richness of the study area will probably decline. Species richness usually indicates strong correlation with available energy in the ecosystem. Greater species richness might occur in systems with higher productivity where the energy is sufficient to support the higher total number of individuals of all species (DeAngelis, 1995). Greater species richness may also occur in ecosystems that have long evolutionary histories, an increase in available energy may open the possibility for organisms to develop mechanisms to conserve or more efficiently acquire any of the other limiting resources. It means that the higher species richness may assure ecosystem health and stability.
- ***Species diversity*** index is maximal at 3.14 in the primary forest, and minimal at 2.91 in the secondary forest, with a mean value of 3.03 representing the existing condition for the three forest types. After dam construction, it is expected that the human encroachment will cause deforestation and change of land use in the surrounding area. Thus, the primary forest will be changed to secondary forest (or agricultural land), with a reduced species diversity index representing a negative trend. The high species diversity can exist in the spatially heterogeneous environment where the disturbances influence to the species in the different degree. In the case of extreme disturbances, or no disturbances, the trends of species diversity may be decreased as only specialist species can persist, and less

species coexist overall. Therefore, the dam construction will disturb and change the heterogeneity of environment and the species diversity will be decreased by these impacts.

3. Local scale

- ***Human context*** is represented as the *socio-economic impact index*, which was calculated from the survey data in chapter six. It assumes that the present socio-economic situation, with an index of 1.18 is the minimum value of the zero impact from the dam project. The ideal condition (Scenario B) represents the socio-economic impact at zero change under the situation of acceptable target with an index of 1.18 as well. The result from the local people of Pak Mun Dam, who have already been affected by dam construction under the situation of with-project, generated a socio-economic impact index of 1.67 as the condition of Scenario C, which is taken to represent acceptable maximum change at the rate of 100 percent. In the different scenarios, it is necessary to set up the different degrees of socio-economic impact based on the acceptable rate of socio-economic change at 75 and 50 percent in Scenario D and E, respectively (Table 7.6).

Table 7.6: A summary of weight of indicators under different scenarios.

Scenario	Weight of indicators					
	Ecosystem level (Carbon storage)	Species level			Human level	
		I	II	III	Socio-eco.	Econ.
A = existing condition	23	61	61	52	0	100
B = Ideal condition (0% encroachment rate with C-replacement value, maximum of primary forest condition and zero socio-economic impact)	100	100	100	100	0	77
C = (2% encroachment rate with C-replacement value, 20% reduction of species indicator value and maximum socio-economic impact)	-81	23	42	-174	100	81
D = 1.5% encroachment rate with C-replacement value, 10% reduction of species indicator value and 75% change of socio-economic impact relative to with-project condition)	-53	41	52	-78	75	53
E = 0% encroachment rate with C-replacement value, 5% reduction of species indicator value and 50% change of socio-economic impact)	23	95	56	-13	51	86

Note: I = Species composition
II = Species richness
III = Species diversity index
Socio-eco. = Socio-economic impact index
Econ. = Economic indicator

- ***Economic context*** is applied *Benefit to cost ratio* and used as an overall economic measure of the with-project condition under different scenarios (Table 7.7). The maximum ratio of the Mekong River Commission's report at 1.43 not including the value of carbon storage as defined by Scenario A (present condition). The ideal condition is considered with a carbon storage value at US$200/tonne C

under the condition of carbon replacement of 1.22 million tonne C. This had a B:C ratio of 1.33. The minimum value was assumed to be a ratio equal 1.0 that means the benefit and cost of the project are equal. To explore different scenarios, carbon storage was changed according different encroachment rates and price of carbon mitigation relative to the carbon storage in ecosystem indicator. In three impact scenarios, economic indicators were calculated at 1.35, 1.23 and 1.37 in Scenario C, D and E, respectively. They represent different conditions of encroachment and mitigation price, which were included in the alternative IA.

Table 7.7: A summary of economic analysis (B:C ratio) under different scenarios for normalising scores.

Scenario	Total C[a] (million tonne C)	Total C-value[b] (million US$)	Total cost[c] (million US$)	Total benefit (million US$)	B:C
A = existing condition with carbon storage loss by traditional IA	-0.66	None	3,165	4,529	1.43
B = 0% of encroachment rate with C-replacement value	1.22	244 (US$200/tonneC)	3,409	4,529	1.33
C = 2% of encroachment rate with C-replacement value	-3.20	179 (US$56/tonneC)	3,344	4,529	1.35
D = 1.5% of encroachment rate witht C-replacement value	-2.52	504 (US$200/tonneC)	3,669	4,529	1.23
E = 0% of encroachment rate with C-replacement value	-0.66	132 (US$200/tonneC)	3,297	4,529	1.37

In the final step, the individual indicator scores for each biodiversity level were normalised to 1 through Equation 7.2 to generate the *composite score (cumulative value)*. This represents a single, dimensionless index, which reflects the net impacts of alternative management scenarios. It integrates all the factors and gives them equal weighting within agreed ranges, thus allowing the overall consequences of a change in one factor to be apparent.

Finally, the composite score of each scenario was derived from different combination as a summary indicator. As a result (Table 7.8 and Appendix 7.4), the numeric composite scores have been linked to different measured quantitative and qualitative data, relative to different sectors under the decision-making model (See Figure 7.2) as follows:

1. Environmental sector:

- Species level – species composition (number and type of tree species), species richness (number of tree species from calculation) and species diversity index.
- Ecosystem level – carbon storage (million tonne C).

2. Social sector:

- Human level – socio-economic impact indicator-involving quality of life, economic security and equal opportunity.

3. Economic sector:

- Economic indicator – benefit to cost ratio was calculated under different scenarios regarding to the rate of encroachment and the carbon value (Table 7.6, Appendix 7.2 and 7.3).

Table 7.8: A summary of the normalised scores of indicators and the final composite scores under the without and the with project scenarios.

Indicators	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Species	0.58	1.00	-0.36	0.05	0.46
Ecosystem (carbon storage)	0.23	1.00	-0.81	-0.53	0.23
Socio-economic impact	0.00	0.00	1.00	0.76	0.51
Economic (Benefit to cost ratio)	1.00	0.77	0.81	0.53	0.86
Composite score	**0.45**	**0.69**	**0.16**	**0.20**	**0.52**

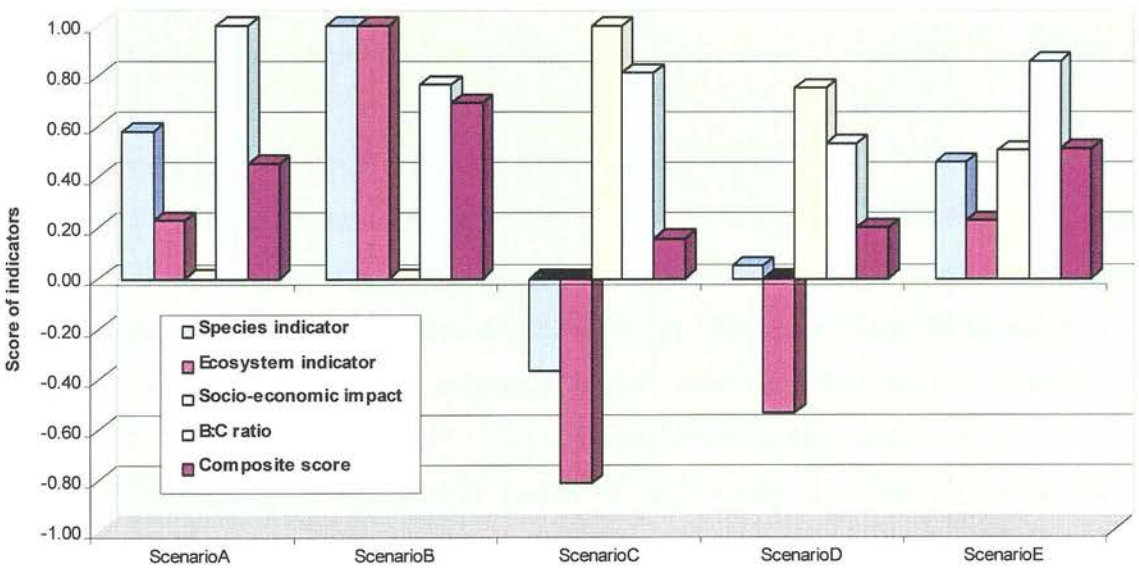


Figure 7.4: A summary of sensitivity test of normalised score based on the biodiversity indicators under the different scenarios.

These measures, or indicators, of the different sectors of concerns can be varied objectively to represent management options and to identify particularly sensitive factors. This provides a mechanism for negotiation between different internal groups by expressing options as scenarios.

- Scenario A: Present condition. This is the representation of biodiversity sustainability at the existing condition with zero socio-economic impact and the highest economic benefit without incorporating carbon value.
- Scenario B: Ideal condition. This is the representation of its sustainability at the climax or ideal condition with zero socio-economic impact and the acceptable carbon value in economic analysis.
- Scenarios C, D and E: They are simulated to represent conditions affected by the dam, reflect the change of biodiversity and economic indicator values relative to the present condition (A) integrated by carbon values.

The results for the five scenarios are summarised in Figure 7.4:

- Scenario A represented the existing condition regarding to the field data, with a moderate benefit to cost ratio and a composite score of 0.45. It was also scaled at zero impact on socio-economic conditions. This reflects that the socio-economic condition is considered according to MRC report and the economic indicator was taken into account at 1.43. This scenario gave the composite scores of 0.45.
- Scenario B was an ideal condition speculating the best condition for all biodiversity indicators with carbon storage gain under natural condition, with the maximum economic benefit, and no socio-economic change, generating a composite score of 0.69, which was higher than the scenario A. This scenario aims to integrate the carbon value of replacement into the cost of project that economic analysis reflects the lower economic score than Scenario A. This emphasies on the concerns of environmental changes, socio-economic stability and economic benefit of the Ban Koum Project.
- Scenario C simulated the worst case for biodiversity. It reflected species loss at 20% of total species mainly through removal of the riparian zone, 100 percent

carbon storage loss including human encroachment pressure at rate of 2.0% and a replacement carbon value of US$56/tonne C. Because of the worst case situation, the replacement carbon value was considered at the cheap price with the simple forestry option of forest plantation technique. The highest impacts on socio-economic conditions, the normalised score was equal to 1.0, represents the analysis from the completed Pak Mun Dam community. The economic analysis was considered as the benefit to cost ratio, it estimates at 1.35, which gave the high score of 0.81. The composite score of 0.16 reflects a poor environmental condition.

- Scenario D simulated a moderate impact on biodiversity and economic indicators. The species indicator was reduced by only 10 percent of the total species loss from the present condition. The carbon storage loss was assumed at the human encroachment rate of 1.5 percent to the primary forest and also placeed the carbon value at US$200/tonne C. The socio-economic impact was less than in scenario C but it is assumed at 75 percent of the maximum impact. The economic indicator shows the benefit to cost ratio of 1.23. This was calculated in relation to the encroachment rate and the carbon storage loss value that was normalised score at 0.53. Finally, the composite score of this scenario shows the positive score at 0.20.
- Scenario E reflected a combination of low impact on biodiversity with moderate economic benefit. The species indicator was assumed to reduce only 5 percent from the present condition, while the carbon storage and carbon storage loss value were assumed at zero percent of the encroachment rate and placed carbon value at US$200/tonne C without replacement, respectively. This scenario gave the socio-economic impact is also assumed at 50 percent of the maximum impact, which has occurred at Pak Mun Dam. Thus, the composite score was estimated at the positive result of 0.52 may be considered as a negotiable compromise with acceptable biodiversity impact and moderate economic benefit from the project.

A comparison of five scenarios showed that, if the main objective were *'energy production'* for the regional demands, then Scenario E reflects the best scenario relative to optimising the impacts from the dam, with moderate impact on the species diversity and human levels. The impact on carbon storage is low, if the human encroachment is controlled to a rate of zero percent and the carbon value is considered at the US$200/tonne C. This scenario, with acceptable biodiversity impact and moderate economic benefit from the project, limits the loss of stored carbon from the terrestrial ecosystems and effectively gives a positive overall score.

If the terrestrial ecosystems retain their potential to sequester carbon in biomass as well as in soils, the non-human species and humans can be sustained through contained circulation of energy and matter for biological and social consumption. Due to a holistic approach including the combination of biodiversity conservation, sustainable use of biodiversity and equitable sharing of benefit (Maltby et al., 1999), which the aim of this study has already followed the concept of sustainability by integrating the indicators of biodiversity evaluation from global to local scale. This study also placed emphasis on the fairness of criteria among environmental, social and economic sectors to be satisfied. It should be more successful if the decision-making processes provide all information to the public participation. These include (Wood, 1996):

- All interested parties (stakeholders) have equal opportunity to influence the decision before it is made.
- People directly affected by the development projects have equal access to compensation.

Finally, This can provide the equal opportunity to all stakeholders and the environment to gain benefit.

7.7 CONCLUSION: A CONCEPTUAL MODEL FOR ALTERNATIVE IMPACT ASSESSMENT AND DECISION-MAKING PROCESS

The new alternative approach to IA was tested in the first part of the model by introducing field observations of biodiversity into the IA process. The second part involved integrating the different information onto common scales, then exploring different scenarios within the decision-making process. The two stages are represented in Figure 7.5. The conceptual model of this study was designed to explore rational and practical methods to generate biodiversity at different levels (species, humans and ecosystem) and different units of measurement in the impact assessment process. Nevertheless, the decision-making process is also important, and requires methods to deal with the weighting criteria of these indicators and to produce comparable scores for each variable. It is necessary to set up the weighting system and normalise scores of biodiversity indicators with comparable criteria even though each indicator may have different units of measurement. When these biodiversity and economic indicators have the same standard of scoring, the final composite score reflects the performance of the system as a whole in relation to the development project.

The application of multi-criteria analysis to dam proposals on the Mekong River illustrates how sensitivity analysis, represented as different scenarios, can provide summaries of variation of economic benefit and biodiversity impacts from the development project. Species diversity and social factors can be recognised in the IA and the decision-making process, even though they are usually measured as qualitative variables or non-economic quantitative variables. It is important that biodiversity evaluation is improved and is taken into account in the IA and decision-making process. Even though they may not be measurable in monetary units, they should be *'given full recognition'* without depending on the market prices.

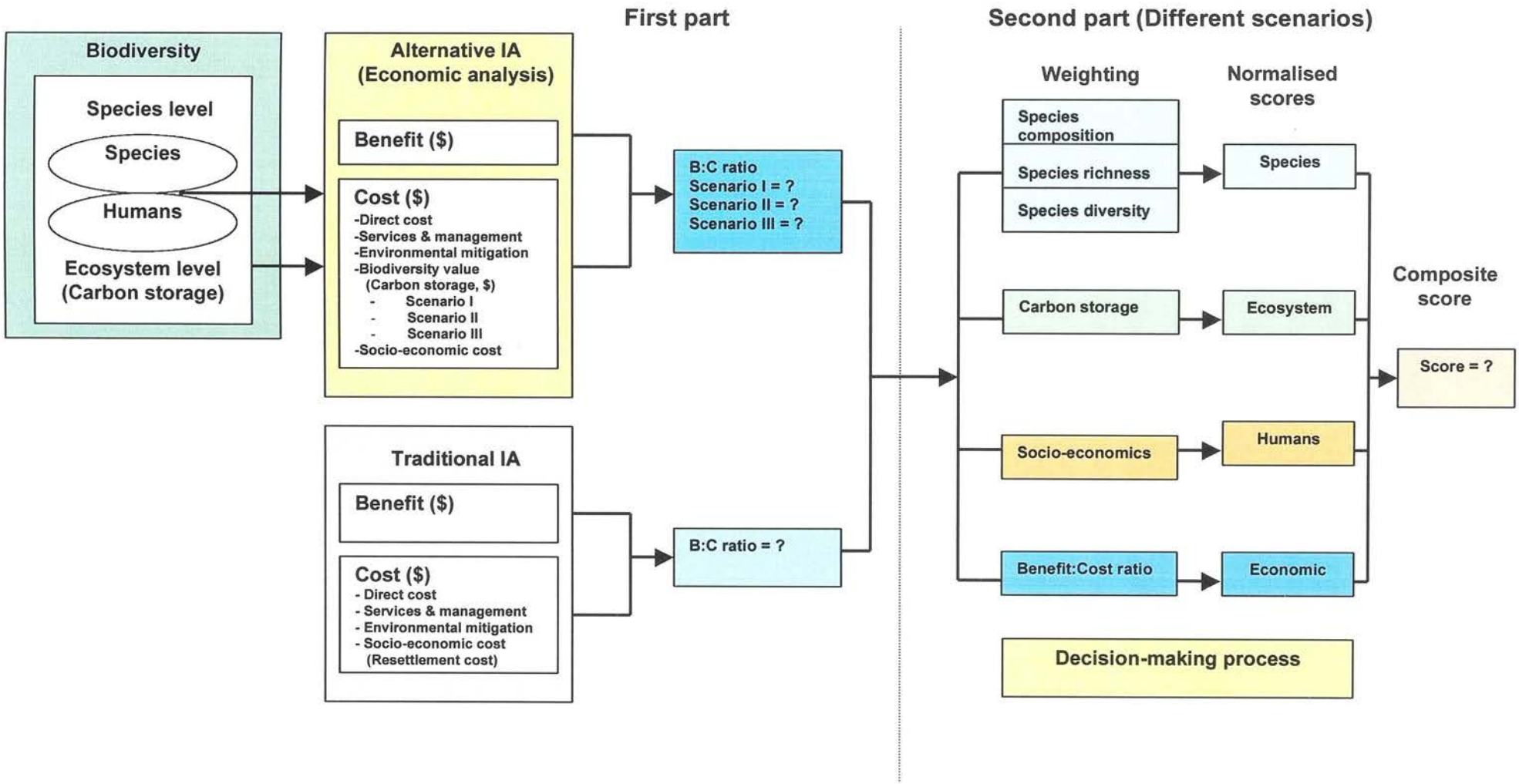


Figure 7.5: A conceptual model of alternative IA and decision-making process.

It is clear that carbon has a key role in the nutrient cycle and supports organisms in the ecosphere. The alternative of representing carbon value in monetary units can be varied depending on the management objectives and options. This representation of carbon relative to CO_2 mitigation also serves to represent ecosystem level services. Thus biodiversity in its many forms can be recognised and expressed in more ways than the conventional monetary valuation, reflecting anthropocentric perspectives.

CHAPTER EIGHT
CONCLUSIONS AND RECOMMENDATIONS

This study is based on evidence from the past experiences of impact assessment procedure in Thailand, particularly biodiversity evaluation, which is usually given less weight than the economic aspects. The study has explored biodiversity evaluation, at different levels, with the aim of incorporating such information into the impact assessment and decision-making processes. The role of biodiversity is important to human society, and must be considered not only at genetic, species and ecosystem levels but must also recognise that people are a component of biodiversity. When the study searched the literature in relation to the topic of biodiversity, impact assessment and decision-making process, it became clear that all four aspects of biodiversity were linked together in the idea of environmental problem-solving. Basically, the environmental problems include natural resource scarcity, habitat loss, species extinction, pollution and the quality of people's lives. These problems need urgent solutions, with special emphasis on the concept of a holistic approach to conservation, sustainable resource use and equitable sharing of the benefits.

The topic of biodiversity evaluation has become interesting not only to scientists (ecologists) but also to economists and decision-makers. Biodiversity is now considered as a priority for conservation including the use of biodiversity as biological resources, the role in maintenance and support the human society and other living species, and the potential resource use for future generations. However, the complexity of biodiversity, which is a multidimensional concept, render it difficult to define in an operational sense and difficult to measure. Measurements of biodiversity in terms of monetary and non-monetary value encounter strengths and weaknesses across all methods. Economists have attempted to capture all biodiversity value in the concept of *'Total Economic Value (TEV)'*, but this has its limitations. It is mainly based on the contribution of biodiversity to human society. It is subjective to the individual with little understanding of the wider role in structure and functions of the whole system. However, Pearce (1993) comments

that

'Valuation may be imperfect but, invariably, some valuation is better than none'.

The purpose of this study was to attempt to provide more constructive biodiversity evaluation at various spatial and temporal scales, focusing on the different levels of biodiversity, mainly the species and ecosystem levels, and with emphasis on human at social and economic aspects. The human level is important at the local scale while the species and ecosystem levels reflect the regional and the global scales, respectively. In addition to the complexity of ecosystem processes, the ecosystem services, which provide and support the whole ecosphere are complex and difficult to measure and evaluate. *'Carbon storage'* is proposed as one tangible indicator of ecosystem services based on the monetary value estimated by CO_2 mitigation cost. There is much evidence to support the idea of carbon storage as an ecosystem indicator, reflecting the ecosystem services not only to people but also to other life. This is particularly relevant in light of the current debate over climate change.

A biodiversity evaluation exploring alternative impact assessment was developed and a simple model of the impacts was developed. The case study to test these ideas was the planned Ban Koum Hydropower Project on the mainstream of Mekong River, and the existing Pak Mun Dam Project. These were selected for this study as the experimental case and the reference case, respectively. They have been the subject of conventional impact assessment with emphasis on economic analysis and with little consideration of biodiversity. They provide a specific example of major developments, which are increasingly common in the region.

8.1 CONCLUSIONS

This study has described and characterised biodiversity at the genetic, species and ecosystem levels, but focused on the species and the ecosystem levels because the genetic level is assumed to vary within a species or population. Therefore, although

genetic diversity is not recognised in this study, it can be considered in the future research of biodiveristy valuation. In addition, the hypotheses of this study will modify the new horizon of biodiversity evaluation, with emphasis on biodiversity as sustainable resource use, not only for human society, but also for members in other living communities. The conclusions from the study generally support the three original hypotheses as follows:

Species diversity and socio-economic evaluation

Biodiversity at the species level is traditionally included as the typical ecological indicators for evaluation in IA. In the present study species diversity evaluation is based on three indicators.

- First, the composition of tree species in terrestrial ecosystems or phylum of phytoplankton in aquatic ecosystems.
- Second, the species richness reflecting the number of species expected in the ecosystem.
- Third, the species diversity index representing the relative abundance of individual species in the ecosystem.

These species indicators measured from the area of Ban Koum and Pak Mun Dams indicated the potential impacts of the dam on species diversity in both terrestrial and aquatic ecosystems. These indicators are the relative measurements to reflect as follows:

- The quality and state of the ecosystem through the evolutionary process of individual species.
- The heterogeneity of the ecosystem in relation to available niches for species.
- The functional groups of species regarding to linkage between each other (e.g. food web), energy and nutrients or materials, which sustain ecosystem functions.

These indicators can be related to the extent to which the natural system has been modified by human factors. It is necessary for the indicators to be interpreted through

deep ecological knowledge. The species indicators are quantified in terms of numeric value, which can be interpreted in terms of their ecological importance such as the presence of keystone or rare species. Their value may be accredited in relation to anthropocentric concerns, but there are still many species not considered of importance to humans, which may be ecologically important. Consequently, the individual species value should be weighted equally with regard to other levels of biodiversity.

It can be concluded that species diversity can be represented by various indicators. It can provide qualitative and quantitative information for the IA and the decision-making process. It also provides the prediction of dam impacts highlights a number of key changes in biodiversiy. As the environment changes, the species can respond to change in compostion as new species enter and the species previously present no longer persist. This means that species composition can change while some species can be dispersed through other sites or habitats. Therefore, species distribution generally are determined by their environmental tolerances and/or requirements and the degree of environmental impact will lead to changes in species diversity as follows:

- Destruction of the riparian ecosystems, especially the riparian forest, which is a unique and specialised ecosystem containing many endemic species. If Ban Koum dam is constructed in the Lower Mekong River Basin, it will cause a reduction of about 20% of tree species, richness and relative abundance in the area. The species will also cause a loss (unspecified) of the community of fauna associated with riparian ecosystem. Nevertheless, the loss of riparian ecosystems will affect the interaction between the aquatic and the terrestrial community, especially its role as a breeding ground and nutrient trap from the flooding, which can reduce the aquatic productivity in the Mekong River Basin.
- Human encroachment following dam construction will reduce the diversity in primary and secondary forests, probably resulting in the presence of fewer species characteristic of climax ecosystems. The secondary forest exhibit reduced regeneration and may be prevented from reaching the climax stage of ecological succession because of continuing human disturbances.

- Phytoplankton species composition and density after dam construction will be affected by the change of environmental conditions. Primary productivity will decrease in relation to the change of phytoplankton population, and the fishery productivity may be reduced by unproductive condition.

The reduction of species diversity will affect not only the extinction of rare species but also the loss of intraspecific genetic diversity. The genetic diverstiy plays in enabling species to occupy in a different range of environmental conditions if it is lost significant proportion in the population causing possibly close to extinction. Thus, it is necessary to be concentrated on the species diversity level as one of biodiversity evaluation.

In terms of biodiversity evaluation at human level, it cannot treat species and ecosystems in isolation from people, because people are basically one component of biodiversity and always interact with the environment through harvest of wild species, control of the practices of agriculture, forestry and fishery, and regulation of water and waste. Therefore, it is necessary to consider the ways of sustainable living among people in society and among people and other biodiversity. To reach this goal, it needs to take not only ecological but also social and economic sectors into account. Socio-economic impacts are usually associated to lifestyle, or the way of life, which are difficult to quantify. Some socio-economic concepts need to deal with the complexity of culture and history of people, where culture is an inter-subjective meaning constructed and communicated between people inside and outside the economic community.

This study selected the Thai and Laotian villages along the Mekong River as the sample of without-project condition and the villages near the Pak Mun Dam as the sample of with-project condition. The survey method with interview was used to collect the data. This study also indicated the classification of socio-economic indicators with association to social values such as economic security and social goods such as quality of life and equal opportunity. The socio-economic indicators reflected the socio-economic impact index as the final result. As a result, the without-project implementation indicated a

socio-economic impact at 1.18 which is less than the with-project implementation at 1.67. This meant that there was an impact on the local people after the dam construction. There is a tendency for socio-economic impacts relating in particular to equal opportunity and quality of life, to have a negative impact, leading local people to be worse off. Although the local people might become better off in terms of having more economic security, by getting more jobs and better education for their children, they still feel unhappy and unsatisfied with the new pattern of living and also the difficulty of fishing. Because of the ecological changes and the impacts of modernisation, social and economic changes occur. The local people in the without-project condition probably have stable socio-economic situations. These local people will have the traditional life style based on the natural resource utilisation and agricultural practices which mostly sustain their needs.

In conclusion, at the human level, socio-economic evaluation can provide the rational indicator in particular to such a dam development project. If this socio-econmic indicator is integrated with other biodiversity indicators, adequate information would be given to the decision-makers. Thus, the project should provide benefit to the local people as much as to the city people who usually gain a lot of advantage from consuming the natural resources with minimal negative impacts to the environment. Nevertheless, the process of decision-making should be shared between the local people, the local authority, the developer and the government without any bias. Moreover, the methods of socio-economic assessment should be improved and include the pattern of living, the cultural constraints, the quality of life and attitudes towards the process of assessment for the better decision-making.

Thus there is general support for Hypothesis I, ***'Each biodiversity level can be quantified and evaluated to provide a holistic approach including environmental, social and economic aspects'***.

Ecosystem diversity evaluation

A considertion of the ecosystem level of biodivesity requires information on ecosystem structure and function, including goods and services. An emphasis on the holistic rather than the reductionistic approach can enable representation of ecosystem functions, which are the result of the complex interactions among the organisms and their environment. The ecosystem services provide environmental stocks such as natural capital (e.g. soil fertility, nutrient store, water holding capacity) and the flow of ecosystem goods (e.g. fuel, food, medicine) can provide natural income to the human society. Many approaches exist to identify and compare the value of ecosystems particularly for environmental decision-making but they are priced in relation to human use and attitude.

The problem is that the ecosystem services are not fully captured or adequately quantified in the commercial market. They are often given little weight in evaluation and decision-making. In this study an estimate of one ecosystem service value, based on *'Carbon storage'*, is estimated as an indicator of indirect use value of biodiversity at the ecosystem level. Nevertheless, the carbon still plays an important role in the ecological process by functioning and conserving life-support systems. Its balance can ensure the planet is kept fit for life. The carbon storage for biodiversity evaluation is a quantity value only. It does not reflect the quality value because the individual organic compound released (carbon dioxide, methane or other gases), or their value if they are retained, would have different turnover times. Much more sophisticated calculations are however possible and have been used in some models.

The initial carbon storage in above-ground biomass in the study area of the Ban Koum project was estimated at 0.66 million tonne C and would be lost from the terrestrial ecosystem through felling and destruction of the forest and the establishment of the reservoir. The loss from the ecosystem does not take account of the proportion that would remain in long-lived wood products, but this would be small. The calculations represent potential loss of existing stored carbon, which would be released to the

atmosphere. They do not include the loss of the future potential carbon storage.

The prediction of dam impacts also includes the following:

- The forest ecosystem, particularly primary forest, will be encroached by local people after the dam construction because a transport system will be constructed and provide increased access to the forest.
- Illegal logging will be a secondary impact because the access to the primary forest will encourage felling of the commercial timber. This will accelerate the rate of deforestation and the rate of carbon loss from the terrestrial ecosystem.
- The land use pattern will be changed by the poor people as a tertiary impact from the dam project. After the illegal logging practices, the abandoned or disturbed forest will be left for the poor people to convert into agricultural land.
- A long-term impact, with increased access and following encroachment by poor people, may be land transfer to the rich people to develop the area as a resort. This will introduce some tourism revenue to the area but a contradictory effect may be increased pressure of encroachment because the poor people will get money from selling the land and then migrate or expand their invasion of the forest. The cycle of deforestation will be continued with further illegal logging to change woodland to agricultural land again.
- Carbon stored in soils will be released through forest clearing before and immediately after the inundation. The amount of soil carbon loss has not been accounted in this study but it is a recognised carbon source to the atmosphere, which could be subject to research to improve estimates of the carbon dynamics of the terrestrial ecosystem following dam construction.

Carbon is a useful ecosystem indicator and it is an urgent issue of environmental concern because of its role in global climate change. Converting carbon storage to a monetary value is a considerable advantage in economic analysis in IA and decision-making. Different scenarios of valuing carbon loss can use the CO_2 mitigation costs of different options of management. Scenarios have been based on the mitigation cost by

community reforestation (US$11/tonne C), teak forest plantation (US$56/tonne C) and clean energy by solar technology (US$200/tonne C). The results show that:

- The lowest price of carbon unit (US$11/tonne C) has least effect on the benefit to cost ratio (1.41) with a total carbon loss value of US$47 million. This lowest price of carbon is based on the cost of reforestation without including the land price and the opportunity loss of carbon storage in the biomass. Therefore, this price does not reflect the true value of carbon and the decision-maker should recognise this weakness.
- The price of carbon unit (US$56/tonne C) for the teak forest plantation is higher than the reforestation option because the carbon price is calculated to include the discount rate and land cost. The land cost is very cheap and the majority of the carbon price is on direct cost, management and administration. The resulting benefit to cost ratio is still high at 1.33 with a carbon cost of US$238 million. This forest plantation option might add some value to the biodiversity based on the carbon storage but it is probably a small addition to the overall benefit of the project.
- The highest price of carbon, based on the solar energy technology option, provides the benefit to cost ratio of 1.13 and a carbon loss value of US$851 million. This price reasonably reflects the role of carbon in the ecosystem close to the role of carbon in industry, as well as dealing with global climate change problems. If the developers attempt to utilise the natural resource as the Mekong River for hydropower generating to serve the industrial demands, it is necessary to fairly take this price of carbon relative to the cost of high technology in the industrial sectors into their decision-making process.
- The price of primary forest seems to be the most expensive range from US$1,125 to US$20,460 per hectare and the least expensive range from US$18-560 per hectare based on carbon storage value. These land use prices will be useful for the economic analysis based on the cost of carbon storage replacement.

The economic analysis provides additional information to decision-makers and allows

them to consider what emphasis should be placed on the local, the regional or the global scale of benefit. The information also shows how the costs may be considered over time scales, which are important in relation to trade-off strategies in industrial emission permissions. For instance, with the reforestation option it is necessary to consider the time scale of the increment of carbon storage in the biomass, which is so important in terms of the trade off strategy with the industrial emission permission. The scenarios raise the questions of social benefits, which might be achieved through land management options and would may advantages for local people. This study suggests that the highest price of carbon unit should be taken into the consideration of biodiversity evaluation in the IA process in order to deal with the fair trade-off between the industrial emission permission and the loss of potential carbon storage of the nations.

It can conclude that the ecosystem value based on carbon storage, whilst providing a contribution to solving global climate change, can also contribute to conservation by slowing the rate of tropical deforestation, increasing the productivity of existing forest, and benefiting local people. From the ecological point of views, the disturbances may cause the loss of some characteristic species but the ecosystems still function satisfactorily. Although the species are the vulnerable entities, the ecosystems are more permanent. Thus, it is important to consider both species and ecosystem diversity in aspect of conservation and management together in order to meet the goal of sustainable resource use.

This holistic, integrated approach should provide a more rational and practicable evaluation for ecosystem diversity level illustrated by *carbon storage* as one representative of ecosystem services. If this approach is acceptable and applicable, it will help to guide the decision-makers, policy-makers, and economists to take biodiversity value at ecosystem level into their consideration.

Thus there is general support for Hypothesis 2, ***'Carbon storage represents an indicator of ecosystem services, represented in terms of monetary value regarding to the CO_2***

mitigation objectives and integrated into the economic analysis in IA process based on sustainable use'.

Implication of biodiversity evaluation for impact assessment and the decision-making process

International obligations on biodiversity conservation under the international organisations including, CBD, Ramsar and IAIA, identify impact assessment as a key tool in delivering the biodiversity conservation objective. To incorporate biodiversity into impact assessment for impact practitioners and decision-makers, it is necessary to tap into resources of information on biodiversity for the benefit of conservation and wider goals of sustainability.

Therefore, the biodiversity should be taken into account in relation to the different scales of judgement. Priorities are thus not all or none, but are built up at successive levels to reflect locally, nationally, regionally and globally perceived biodiversity conservation on the purpose of evaluation:

- At the global scale, the ecosystem services of carbon storage.
- At the regional scale, the qualitative and quantitative values of species.
- At the local scale, the quality of life, equal opportunity and economic security of the human community.

These biodiversity indices are incorporated into the alternative IA, which is compared with the traditional IA based on economic analysis. The improved perception of multi scale benefits and costs from the dam project indicate that the carbon storage loss monetary value was compatible with conventional economic analysis of IA. The other biodiversity indices were not adequately converted into monetary units, and were not represented in carbon storage value. The comparison of the alternative and the traditional IA, based on the economic analysis of benefit to cost ratio, showed that incorporating carbon storage loss value can significantly affect the economic benefit of

the project. This alternative IA also adopted the concept of biodiversity conservation at the species level. Although not measured in monetary terms, the gain or loss of species can certainly be quantified and can be integrated into the decision process.

A second area of interest concerns the integration of all biodiversity indicators at species, ecosystem and human level to improve decision-making for the dam project implementation. What is needed, in addition to the environmental or ecosystem management principles, is to integrate scientific information and knowledge, to link ecosystem functions as goods and services to socio-economics, and to create a cross-sectoral balance.

A simple model for decision-making, incorporating all biodiversity and economic indicators is based on the single objective and multi-criteria scenarios. The single objective of the model is to provide approaches to equitable sharing of the benefits and costs. The conceptual model facilitates exploring the sensitivity of different scenarios, representing the combination of different proportions of biodiversity indicator values. The problems are the different units of measure and it is necessary to make some assumption for standardisation into a simple weighting system. The indicators are standardised into the percentage unit of weight with each category of biodiversity normalised to score from 0 to 1. When these biodiversity and economic indicators have the same standard of scoring, the final composite score reflects the performance of the system regarding to the development project. Testing this decision model on the Mekong suggested that:

- The worst scenario was associated with the high reduction of species, the maximum carbon storage loss from the terrestrial ecosystem and the high socio-economic impact to the local people, where the composite score was 0.16.
- The best scenario was associated with the low reduction of species, the zero rate of encroachment with minimum carbon storage loss at maximum carbon unit price (US$200/tonne C) and the medium socio-economic impact at 50 percent of the worst situation. The composite score was 0.52.

Finally, it can conclude that this model indicates that the integration of bioidiversity indicators at different levels and economic indicators can improve information for making decisions and provides more holistic and sustainable concepts.

Thus there is general support for Hypothesis 3, ***'Integrating all biodiversity and economic values can improve the scenarios for the decision-making process'.***

This research study corresponds to the environmental or ecosystem approach, which can be stated as:

'There is no single or unique indicator that represent biodiversity value as a whole, but it is feasible, meaningful and useful to incorporate wider range of biodiversity indicators into impact evaluation and decision-making'.

Finally, the development needs to be guided and strengthened, so that it can contribute to the sharing of benefits among people and other biodiversity and to improve the social welfare to be ecologically sustainable.

8.2 RECOMMENDATIONS

This study can present the recommendations with regard to the evaluation of biodiversity and the implication of alternative impact assessment as follows:

Species diversity evaluation

- Species composition and richness can reflect the interrelationships between species and physical conditions. It is possible to study the eco-physiology of the dominant species group and also the interaction between tree with herbivores in order to understand the intrinsic value of dominant species to respond to their role in the ecosystem.
- Species can reflect the evolutionary history of ecosystems and the quality of

biodiversity performance according to ecosystem health, ecosystem resilience and ecosystem stability. However, the species need to be studied in depth. They must be measured at each trophic level in order to understand the interrelationships and their role in sustaining the systems. This might be exposed in terms of quantitative values that can be incorporated into the IA and decision-making process.

Ecosystem diversity evaluation

- Carbon storage is an adequate indicator of ecosystem services in the terrestrial ecosystem. The carbon storage cannot be applied to the aquatic ecosystem because the carbon cycle of aquatic ecosystem is so complex. The carbon is associated with dynamic mechanisms not only between atmosphere - water body and water body - sediment in relation to microorganisms activities but also related to the chemical components and reaction in water itself.
- Carbon storage loss value is strongly recommended as a strategic indicator enabling decision-makers, policy-makers or politicians to consider trade-offs between carbon emissions and carbon mitigation reduction. The carbon unit price must be considered in relation to the economic value based on the technology option because the environmental damage cost is usually crated from the result of technology. It is unfair to take the carbon unit price from the capital cost of reforestation or forest plantation, which is impacted by the source of carbon emission.
- The developing countries in the tropical zone can have a power of bargaining in order to conserve their forests with regard to the international commitments. They can sell their legal right of conserving and preserving forest to the industrial countries in order to correspond to the carbon mitigation objective. It will be the equitable sharing of benefit of carbon storage in their forests with the industrial countries which are the source of carbon emission.

Socio-economic evaluation

- Socio-economic evaluation must be considered as being of equally importance to species or ecosystem evaluation. The socio-economic analysis should be studied more in comparison to culture and ancestor background of each household in order to understand the perceptions of local people.
- The technique of interview should be combined with participatory approach in order to provide robust data whilst maintaining good relationships between the interviewee and respondents.

Implication of biodiversity evaluation to impact assessment and decision-making process

- Biodiversity evaluation can support sustainable development concepts as a simple, practicable and rational method for improving IA and decision-making.
- Biodiversity evaluation can respond on different scales of environmental concerns such as carbon storage representing the global scale, species representing the regional scale and socio-economics representing the local scale. Carbon storage can be a representative of the ecosystem indicator based on the global scale of environmental concerns.
- To implement the biodivesity evaluation within IA, it is necessary to gear towards scientific and policy consultations and other consultative mechanisms, which will promote this alternative IA approach.
- The alternative IA improves the weight of biodiversity in the decision-making process and the public, through the socio-economic indicator of local people, can have power to participate in the decision-making process.
- Biodiversity indicators can be related to the same standardised score as economic indicator, which describe the possibility of equitable weight in decision-making.

To extract the recommendations focused on the target organisations at different levels, there are three levels as follows:

- Global level: International organisations such as
  - World Bank
  - Asian Development Bank (ADB)
  - United Nations Environmental Programme (UNEP)
  - The World Conservation Union (IUCN)

  In the global level, it is necessary to have the broad perception and the rational and practical processes towards to global communities.

  1. To promote carbon storage as an indicator representing ecosystem services is a simple, rational and applicable indicator for biodiversity evaluation at a certain level. Therefore, carbon storage needs to be agreed and integrated into impact assessment as one of the regulation processes.
  2. To integrate biodiversity and carbon storage as a potential linkage with important roles, it is necessary to consider global actions regarding the international rivers, in order to achieve equitable natural resource sharing benefits among environmental, social and economic sectors.
  3. To create a sincere commitment between developed and developing countries to utilise natural resources based on sustainable concepts over certain time scales. Allocation of natural resource under governance concepts rather than the concept of the right to use resources to one which see capacity to use them as a privilege.
  4. To establish institutions involving the fair trade of carbon controlled between developing and developed countries aiming to mitigate atmospheric carbon and to reduce fossil fuels consumption.

- Regional level: International/Intergovernment organisations such as
  - National government
  - International organisation

  This level should adopt and implement biodiversity evaluation particularly

carbon storage towards achieving sustainable development by harmonising the various sectoral environmental, social and economic policies and plans into the national operation.

1. To review the environmental law and reform the institutional mechanisms for implementation regarding the importance and linkage of biodiversity and carbon storage in the ecosystem for reducing CO_2 emission.
2. To ensure socially responsible national economic development while protecting the biodiversity for the future generations.
3. To apply the environmental policy in relation to the zero discount rate of biodiversity value, especially the carbon storage value, as it will reduced the discriminate in favour of projects with low capital cost and high operating cost.
4. To recommend the strategy of carbon storage benefits, it is justified that carbon storage can be tradable as a carbon emission permits system in the international market.
5. To develop the interrelationship among developing countries in the region to accept liability for the performance of the carbon storage in the high quality forestry based offsets. Carbon trading is a clear strategic role as market catalyst for reducing carbon emission, which the industrial countries have to decide whether or not to invest into clean energy with less emission.

- Local level: Local authorities/Stakeholders such as
  - Local people
  - Private sector
  - Government officers
  - Non-governmental organisation (NGO)
  - Local authorities
  - Politicians

At this local level, it is necessary to target the three sectors, government, community and private sectors, to respond to their biodiversity in the local community. A given recommendation is the following:

1. To improve and provide the environmental education to all stakeholders in the communities for understanding the linkage between biodiversity and carbon storage for solving the natural resource loss at local scale and the reduction of atmospheric carbon at regional and global scale.
2. To ensure stakeholders are comitted to social sustainability as a prerequisite by relieving the poverty and distinguish the understanding of biodiversity value and carbon benefits for trading in the future.
3. To share responsibility for biodiversity among stakeholders across sectoral activities and contribute the effective bargaining power with the government regarding to the development projects or policies.
4. To create a sense of environmental awareness and efficient utilisation of biodiversity within the communities.

8.3 CONSTRAINTS AND FUTURE RESEARCH AREA

Constraints:

- The lack of biodiversity data in the Laotian forest in particular, needed to estimate the carbon storage situation and also the data on species need to be collected and analysed for the accuracy of results.
- With species diversity evaluation, there are some constraints since species cannot be valued in monetary units because not every species can be contributed or utilised by humans.
- The lack of high technology instruments for the measurement of carbon storage in the aquatic ecosystem in both river and reservoir. Therefore, data from the aquatic ecosystem could not provide results for carbon storage in the aquatic

ecosystem. However, carbon storage seems to be an inadequate indicator according to the complicated mechanisms and the complexity of aquatic ecosystems.

- One of the constraints to ecosystem evaluation is that it is extremely difficult to measure ecosystem functions and processes and to predict the certain impacts of disturbance from the development project/policy to the complex systems.

Future research area:

- Improving the carbon storage equation of terrestrial ecosystems enabling it to become more reliable including the soil carbon storage in the ecosystem evaluation in order to improve IA process.
- Initiating the process of carbon storage management for carbon trading.
- Introducing the research on the carbon trade-off aspects in relation to promoting biodiversity conservation in the tropical forest.
- The MCA should be studied in future research because it is important to understand and to extract more functional and mechanical relationships between each biodiversity indicator and the pure economic aspect.
- Developing the decision-making model is the theme of future research area because the model can be improved by the integration of other biodiversity indicators into the model and also adopted the *'Multi-Criteria Analysis'* to test the new approach.

REFERENCES

Akbay, N., N. Anul, S. Yerli, S. Soyupak and C. Yurteri (1999) Seasonal distribution of large phyplankton in the Keban Dam Reservoir. *Journal of Plankton Research,* **21(4):** 771-787.

Allaby, M. (1996) *The Concise Oxford Dictionary of Ecology.* Oxford University Press, Oxford.

Amphoe Khong Chiam (1997) *Database of Amphoe Khong Chiam 1996.* Ubon Ratchathani, Thailand.

Amthor, J.S. and G.W. Koch (1996) Biota growth factor β: stimulation of terrestrial ecosystem net primary production by elevated atmospheric CO_2. In *Carbon Dioxide and Terrestrial Ecosystems,* G.W. Koch and H.A. Mooney (Eds.). Academic Press, San Diego, pp.399-414.

Australian Mekong Research Center (AMRC) (1999) Mekong Report. University of Sydney, Sydney.

Apps, M. and J. Raven (1995) Carbon fixation and allocation. In *Carbon Sequestration in the Biosphere,* M.A. Beran (Ed.). Springer-Verlag, Berlin, pp.183-192.

Armengol, J., J.Toja and A. Vidal (1994) Seasonal rhythm and secular changes in Spanish reservoirs. In *Limnology Now: A Paradigm of Planetary Problems,* R. Margalef (Ed.). Elsevier, Amsterdam, pp.237-253.

Atjay, G.L., P. Ketner and P. Duvigneaud (1979) Terrestrial primary production and phytomass. In *The Global Carbon Cycle,* B. Bolin, (Ed.). John Wiley and Sons, Chichester, pp.129-181.

Bacon, P.R. (1997) Wetland and biodiversity. In *Wetlands, Biodiversity and the Ramsar Convention,* A.J. Hails (Ed.). Ramsar Convention Bureau, India, Chapter 1.

Barbier, E.B. (1995) *Paradise Lost? The ecological economics of biodiversity.* Earthscan Publications, London, 265pp.

Barbier, E.B., M. Acreman and D. Knowler (1997a) *Economic Valuation of Wetlands.* IUCN, Cambridge,

Barbier, E.B., M. Acreman and D. Knowler (1997b) *Economic Valuation of Wetlands: A Guide for Policy makers and Planners.* Ramsar Convention Bureau, Gland, Chapter 7.

Beaufort, L.F. de (1951) *Zoogeography of the Land and Inland Waters.* Sidgwick and Jackson, London, pp.60-90.

Beran, M.A. (1995) *Carbon Sequestration in the Bioshere: Processes and Prospect.* Springer-Verlag, Berlin, 305pp.

Bernard, G. and L. Kristoferson (1985) *Agricultural Residuals as Fuel in the Third World, Technical Report No. 4.* Earthscan Energy Information Programme, International Institute for Environment and Development, London.

Bingham, G., R.. Bishop, M. Brody, D. Bromley, E. Clark, W. Cooper, R. Costanza, T. Hale, G. Hayden, S. Kellert, R. Norgaard, B. Norton, J. Payne, C. Russell and G. Suter (1995) Issues in ecosystems valuation: improving information for decision making. *Ecological Economics,* **14:** 73-90.

Bolin, B., E.T. Degens, S. Kempe and P. Ketner (1977) *The global carbon cycle. Scope 13.* John Wiley, New York.

Boonkerd, S., J. Sadakorn and T. Sadakorn (1982) *Flora in Thailand.* Faculty of Forestry, Kasetsart University, Bangkok, 657pp.

Bormans, M.and I.T. Webster (1999) Modelling the spatial and temporal variability of diatoms in the River Murray. *Journal of Plankton Research,* **21(3):** 581-598.

Brinson, M.M. (1995) The HGM approach explained. *National Wetlands Newsletter,* November-December: 7-13.

Brown, S. (1984) Biomass of tropical forests: a new estimate based on forest volumes. *Science,* **223:** 1290-1293.

Brown, S. (1990) Tropical secondary forests. *Journal of Tropical Ecology,* **6:** 1-32.

Brown, S., A.J.R. Gillespie and A.E. Lugo (1989) Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science,* **35:** 881-902.

Brown, S. and L.R. Iverson (1992) Biomass estimation for tropical forests. *World Resource Review,* **4(3):** 366-384.

Brown, S., L.R. Iverson, A. Prasad, and D. Liu (1993) Geographical distribution of carbon in biomass and soils of tropical Asian forests. *Geocarto International,* **4:** 45-59.

Brown, S., J. Sathaye, M.G.R. Cannell and P. Kauppi (1996) Management of forests for mitigation of greenhouse gas emissions. In *Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the IPCC, R.T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken, (Eds.). Cambridge University Press, pp.775-797.

Brunig, E.F. (1983) Vegetation structure and growth. In *Ecosystems of the World 14A: Tropical Rain Forest Ecosystem,* F.B. Golley (Ed.). Elsevier, Amsterdam, pp. 49-75.

Cannell, M.G.R. (1999) Growing tree to sequester carbon in the UK: answers to some common questions. *Forestry,* **72(3):** 237-247.

Cannell, M.G.R. and R. Milne (1995) Carbon pools and sequestration in forest ecosystems in Britain. *Forestry,* **68(4):** 361-378.

Centre of Ecological Economics (1999) *An Economic Valuation of A Natural Forest: The Case of the Teak Forest in Mae Yom National Park with Particular Reference to Ecological Costs of the Kaeng Sua Ten Water Resources Development Project (Part 2).* Center of Ecological Economics, Chulalongkorn University, Bangkok, 251pp.

Changprai, C. and A. Chotimon (1971) *Soil Survey of Chawat Ubon Ratchathani.* Soil Survey Division, Land Development Department, Bangkok, 48pp.

Cline, W.R. (1992) *Optimal Carbon Emission over Times: Experiments with the Nordhaus DICE Model.* Mimeo, Institute for International Economics, Washington DC.

Community Aid Abroad (CAA) (1999) *Mekong Hydrodevelopment: Mekong Profile.* http://www.caa.org.au/publications/briefing/mekong_hydro/profile.html

Costanza, R. and L. Comwell (1992) The 4P approach to dealing with scientific uncertainty. *Environment,* **34:** 12-20.

Costanza, R. and H.E. Daly (1992) Natural capital and sustainable development. *Conservation Biology,* **6:** 37-46.

Costanza, R., R. d' Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt (1997) The value of the world's ecosystem services and natural capital. *Nature,* **387:** 253-260.

Costanza, R., R. d' Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt (1998) Special section: forum on valuation of ecosystem services, the value of ecosystem services: putting the issues in perspective. *Ecological Economics,* **25:** 67-72.

Cramer, D. (1994) *Introducing Statistics for Social Research.* Routeledge, London. pp.55-56.

Dale, V.H. and R.V. O' Neill (1999) Tools to characterize the environmental setting. In *Tools to Aid Environmental Decision Making,* V.H. Dale and M.R. English, (Eds.). Springer-Verlag, New York, pp.62-93.

Daly, G.C. and P.R. Ehrlich (1995) Population extinction and the biodiversity crisis. In *Biodiversity Conservation,* C.A. Perrings, K.G. Maler, C. Folke, C.S. Holling and B.O. Jansson, (Eds.). Kluwer Academic Publishers, Dordrecht, pp.45-56.

Daly, H.E. (1999) *Ecological Economics and the Ecology of Economics.* Edward Elgar, Cheltenham, pp.119-121.

Dean, J.D. (1999) Unpublished data, Institute of Terrestrial Ecology, Edinburgh.

DeAngelis, L. D (1995) Relationships between the energetics of species and large-scale species richness. In *Linking Species and Ecosystems,* C.G. Jones and J.H. Lawton (Eds.). Chapman and Hall, New York, pp.263-272.

De Beer, J.H. and M.J. McDermott (1996) *The Economic Value of Non-Timber Forest Products in Southeast Asia.* The Netherlands Committee for IUCN, Amsterdam, 200pp.

Dixon, R.K., P. Schroeder and J. Winjum (1991) *Assessment of Promising Forest Management Practices and Technologies for Enchancing the Conservation and Sequestration of Atmospheric and Their Cost at the Site Land.* Report of the US. Environmental Protection Agency, No. EPA/600/3-91/067.

Dixon, R.K., A.R. Brown, A.M. Houghton, A.M. Solomon, M.C. Trexler and J. Wisniewski (1994a) Carbon pools and flux of global forest ecosystems. *Science,* **263:** 185-190.

Dixon, R.K., J.K. Winjum, K.J. Andraska. J.J. Lee and P.E. Schroeder (1994b) Integrated systems: assessment of promising agroforest and alternative land-use practices to enchance carbon conservation and sequestration. *Climatic Change,* **30:** 1-23.

Doi, A. and Y. Taki (1994) First record of the Cyprinid, *Cyclocheilichthys heteronema*, from Lake Tonle-Sap of the Mekong River System. *Japanese Journal of Ichthyology,* **41(1):** 84-85.

Drew, W.B., S. Aksornkoae and W. Kaitpraneet (1978) An assessment of productivity in successional stages from abandoned swidden (Rai) to dry evergreen forest in Northeastern Thailand. *Forest Research Bull.* No.56. Kasetsart University, Bangkok.

Dudgeon, D. (1995) The ecology of rivers and streams in Tropical Asia. In *Rivers and Stream Ecosystems,* C.E. Cushing, K.W. Cummins and G.W. Minshall (Eds.). Elsevier, Amsterdam, pp.615-657.

Eade, J.D.O. and D. Moran (1996) Special economic valuation: benefits transfer using Geographical Information System. *Journal of Environmental Management,* **48:** 97-110.

Englin, J. and J.M. Callaway (1995) Environment impacts of sequestering carbon through forestation. *Climatic Change,* **31:** 67-78.

Esser, G., I. Aselman and H.F.H. Leith (1982) *Modelling the Carbon Reservoir in the System Compartment 'Litter'.* Mitt. Geo-Palaeontol., Inst. Univ. Hamburg, SCOPE/UNEP Sonderband, Heft, **52:** 39-58.

Esser, G. (1991) Osnabrück biosphere model: structure, construction, results. In *Modern Ecology: Basic and Applied Aspects,* G. Esser and D. Overdieck (Eds.), Elsevier, Amsterdam, pp.679-709.

Esser, G., J. Hoffstadt, F. Mack and U. Wittenberg (1994) *High Resolution Biosphere Model, Documentation, Model Version 3.00.00. Heft 2,* Mitteilungen aus dem Institut fuer Pflanzenoekologie der Justus-Liebeg-Universitaet Giessen.

Esser, G., H.F.H. Leith, J.M.O. Scurlock and R.J. Olson (1997) *Worldwide Estimates and Bibliography of Net Primary Productivity Derived from Pre-1982 Publications.* Environmental Sciences Division, Oak Ridge National Laboratory, 15pp.

Faeth, P., C. Cort and R. Livernash (1994) *Evaluating the Carbon sequestration Benefit of Forestry Projects in Developing Countries.* World Resource Institute, Washington DC., pp.33-36.

Fankhauser, S. (1994) The social costs of greenhouse gas emissions: an expected value approach. *The Energy Journal,* **15(2):** 157-184.

Fankhauser, S. (1995) *Valuing Climate Change.* Earthscan Publications Limited, London, 180pp.

Fankhauser, S. (1997) *Economic Estimates of Climate Change Impacts.* Sustainable Development and Global Climate Change Conference, Global Environment Facility, Washington, DC.

Fearnside, M.P. (1995) Hydroelectric dams as sources of greenhouse gases. *Environmental Conservation,* **22(1):** 7-19.

Fearnside, M.P. (1997) Environmental services as a strategy for sustainable development in rural Amazonia. *Ecological Economics,* **20:** 53-70.

Ferreira, L.V. and Stohlgren, T.J. (1999) Effect of river level fluctuation on plant species richness, diversity, and distribution in a floodplain forest in Central Amazonia. *Oecologia,* **120(4):** 582-587.

Flint, P.E. and J.F. Richards (1996) Trends in carbon content of vegetation in South and Southeast Asia associated with change in land use. In *Effects of Land-Use Change on Atmospheric CO2 Concentrations, South and Southeast Asia as a Case Study,* V.H. Dale, (Ed.). Springer-Verlag, Berlin, pp.201-300.

Foley, J.A. (1994) Net primary productivity in the terrestrial biosphere – the application of a global model. *Journal of Geophysical Research - Atmosphere,* **99:** 20773-20783.

Folke, C., C.S. Holling and C. Perrings (1996) Biological diversity, ecosystems and the human scale. *Ecological Applications,* **6(4):** 1018-1024.

Food and Agriculture Organisation (FAO) (1997) *State of the World's Forest 1997.* FAO, Rome, pp.173-174.

Food and Agriculture Organisation (FAO) (1999) *State of the World's Forest 1999.* FAO, Rome, 132pp.

Forest Industry Organisation (FIO) (1997) *Eucalyptus Forest Plantation Project.* Forest Industry Organisation, Ministry of Agriculture, Bangkok, Thailand, 58pp.

Forest Industry Organisation (FIO) (1999) *Teak Forest Plantation Project.* Forestry Indust Organisation, Ministry of Agriculture, Bangkok, Thailand, 39pp.

Forest Information Service (FIS) (1998) Definition of forest, deforestation, afforestation and reforestation. http://www.home.att.net/~gkland/DEF paper.html

Freeman, M.A. (1993) *The Measurement of Environmental and Resource Values.* Resource for the Future, Washington DC., pp.165-198.

Gajaseni, J. (1997) *Man and Environment.* Chulalongkorn University Press, Bangkok, 137pp. (in Thai).

Gajaseni, J. and C.F. Jordan (1990) Decline of teak yield in northern Thailand: effects of selective logging on forest structure. *Biotropica,* **22(2):** 114-118.

Galy-Lacaux, C., R. Delmans, C. Jambert, J. Dumestre, L. Labroue, S. Richard and P. Gosse (1997) Gaseous emissions and oxygen consumption in hydroelectric dams: A case study in French Guyana. *Global Biogeochemical Cycles,* **11(4):** 471-483.

Gilbertson, D.D., M. Kent and F.B. Pyatt (1985) *Practical Ecology.* Unwin Hyman, London, 320pp.

Gilpin, A. (1995) *Environmental Impact Assessment (EIA).* Cambridge University Press, Cambridge, 182pp.

Glasson, J. (1995) Socio-economic impacts1: Overview and economic impacts. In *Methods of Environmental Impact Assessment,* P. Morris and R. Therivel, (Eds.). University College London, London, pp.49-68.

Goldewijk, K.K. and R. Leemans (1995) Systems models of terrestrial carbon cycling. In *Carbon Sequestration in the Biosphere,* M.A. Beran (Ed.). Springer-Verlag, Berlin, pp.129-152.

Golley, F.B. (1983) Abundance of energy and chemical elements. In *Tropical Rain Forest Ecosystems: Structure and Function,* F.B. Golley (Ed.). Elsevier Scientific Publishing Company, Amsterdam, pp.101-115.

Goudriaan, J. (1995) Global carbon cycle and carbon sequestration. In *Carbon Sequestration in the Biosphere,* M.A. Beran, (Ed.). Springer-Verlag, Berlin, pp.3-18.

Graae, B.J. and V.S. Heskjær (1997) A comparison of understorey vegetation between untouched and managed deciduous forest in Denmark. *Forest Ecology and Management,* **96(1-2):** 111-124.

Grainger, A. (1993) *Controlling Tropical Deforestation.* Earthscan Publications, London, pp.49-68, 146-175.

Gregory, R. (1999) Identifying environmental value. In *Tools To Aid Environmental Decision Making,* V.H. Dale and M.R. English (Eds.). Sringer-Verlag, New York, pp.32-61.

Gunawardena, U.A.D.P. (1998) *Economic Evaluation of Conservation Benefits: A Case Study of Sinharaja Rain Forest Reserve in Sri Lanka.* A Ph.D. thesis, Institute of Ecology and Resource Management, the University of Edinburgh.

Guo, Q. and P.W. Randel (1997) Measuring dominance and diversity in ecological communities: choosing the right variables. *Journal of Vegetation Science,* **8:** 405-408.

Hair, J.F., E.A. Rolph, L.T. Ronald and C.B. William (1998) *Multivariate Data Analysis.* Prentice Hall, New Jersey, pp.364-404.

Hall, D.O. and J.I. House (1994) Trees and biomass energy: carbon storage and/or fossil fuel substitution? *Biomass and Bioenergy,* **6(1/2):** 11-30.

Hanley, N., J.F. Shogen and B. White (1997) *Environmental Economics in Theory and Practice.* Macmillan Press, London, pp.383-424.

Heal, O.W. and S.F. Maclean Jr. (1975) Comparative productivity in ecosystems secondary productivity. In *Unifying Concepts in Ecology,* W.H. van Dobben and R.H. Lowe-McConnell, (Eds.). Centre for agricultural publishing and documentation,Wageningen, pp.89-108.

Herendeen, R.A. (1998) Monetary-costing environmental services: nothing is lost, something is gained. *Ecological Economics,* **25(1):** 29-30.

Hirsch, P. and G. Cheong (1996) *Natural Resource Management in the Mekong River Basin: Perspective for Australian Development Cooperation.* University of Sydney, 90pp.

Hourcade, J.C, K. Halsnaes, M. Jaccard. W.D. Montgomery, R. Richels, J. Robinson, R.R. Shukla and P. Sturm (1996) A review of mitigation cost studies. In *Climate Change 1995. Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses.* Contribution of Working Group II to the Second Assessment Report of the IPCC R.T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken, (Eds.). Cambridge University Press, pp.300-366.

Hruby, T. (1999) Assessment of wetland functions: what they are and what they are not. *Environmental Management,* **23(1):** 75-85.

Huston, M. and L.E. Gilbert (1996) Consumer diversity and secondary production. In *Biodiversity and Ecosystem Processes in Tropical Forests,* G.H. Orians, R. Dirzo and J.H. Cushman, (Eds.). Springer-Verlag, Berlin, pp.33-47.

International Association for Impact Assessment (IAIA) (1999) Impact assessment and the biodiversity agenda. In *Proceeding IAIA conference 1999*, Glasgow, Scotland, pp.1.

IGBP (1994) *IGBP Global Modelling and Data Activities 1994-1998.* Report 30. International Geosphere-Biosphere Programme, Stockholm.

Intergovernmental Panel on Climate Change (IPCC) (1991) *Formulation of Response Strategies.* Report prepared for IPCC Working Group III. Island Press, Washington DC.

Intergovernmental Panel on Climate Change (IPCC) (1992) *Climate Change: The IPCC Response Strategies.* WMO/UNEP. Island Press, Covelo, 273pp.

International Rivers Network (IRN) (1999) *Power Struggle: The Impacts of Hydro-Development in Laos.* International Rivers Network, 68 pp.

International Rice Research Institute (IRRI) (1993) *IRRI Rice Almanac.* International Rice Research Institute, Manila.

International Rice Research Institute (IRRI) (1995) *World Rice Statistics, 1993-1994.* International Rice Research Institute, Manila.

International Rice Research Institute (IRRI) (1999) *Information about Agriculture in Asia.* http://www.cgiar.org/irri/Riceweb/agrinfoasia.htm.

Imhof, A. (1998) Economic crisis casts further doubt on viability of Lao dams. *World Rivers Review,* **13(4):** 1-2.

IUCN-The World Conservation Union (1989) *Directory of Asian Wetlands.* IUCN, Gland, Switzerland.

Iverson, L.R., S. Brown, A. Prasad, H. Mitasova, A.J.R. Gillespie and A.E. Lugo (1992) Use of GIS for estimating potential and actual biomass for continental South and Southeast Asia. In *Effects of Land Use Change on Atmospheric Carbon Dioxide Concentrations: Southeast Asia as a Case Study,* V.H. Dale, (Ed.). Springer-Verlag, New York, Chapter 3.

Jarvis, P.G. (1993) Prospects for bottom-up models. In *Scaling Physiological Processes Leaf to Globe,* J.R. Ehleringer and C.B. Field, (Eds.), Academic Press, New York, pp.115-126.

Jepma, C.J. (1995) *Tropical Deforestation: A Socio-Economic Approach.* Earthscan Publications, London, pp.22-47, 85-157.

Johns, A.D. (1988) Effects of 'selective' timber extraction on rain forest structure and composition and some consequences for frugivores and folivores. *Biotropica,* **20:** 31-37.

Johns, A.D. (1992) Species conservation in managed tropical forests. In *Tropical Deforestation and Species Extinction,* T.C. Whitmore and J.A. Sayer, (Eds.). Chapman and Hall, London, pp.15-53.

Jordan, C.F. (1983) Productivity of tropical rain forest ecosystems and the implications for their use as future wood and energy sources. In *Tropical Rain Forest Ecosystems (Ecosystems of the World No. 14),* F.B. Golley (Ed.). Elsevier, Amsterdam, pp.117-135.

Jordan, C.F. (1985) *Nutrient Cycling in Tropical Forest Ecosystems.* Wiley, New York.

Keenly, K. (1992) *Value Focused Thinking.* Harvard University Press, Cambridge.

Keeratiwiriyaporn, S. (1999) *An Energy Model for Thailand.* A Ph.D. thesis, Department of Electrical Engineering, the University of Edinburgh, pp.75, 80

Kellman, M. and R. Tackaberry (1997) *Tropical Environments.* Routledge, London, pp.55-90.

Kira, T. et al. (1967) Comparative ecological studies on three main types of forest vegetation in Thailand, IV: Dry matter production, with special reference to the Khao Chong rainforest. *Nature and Life in Southeast Asia, Vol. V,* Fauna and Flora Research Society, Kyoto, Japan, pp.148-174.

Kiratiprayoon, S., J. Luangjame, P. Damrongthai and M. Tarumatsawas (1995) Species diversity of second growth at Ngao demonstration forest, Lampang Province, Thailand. In *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests,* T.J.B. Boyle and B. Boontawee (Eds.) Center for International Forestry Research (CIFOR), Bangor, pp.237-245.

Kirk, T.O. John (1994) *Light and Photosynthesis in Aquatic Ecosystems.* Cambridge University Press, Cambridge, pp.1-25, 360-431.

Kobak, K.I. (1995) Net ecosystem productivity in forests.
http://www.metla.fi/conf/iufro95abs/d4pos8.htm

Koch, G.W. and H.A. Mooney (1996) Response to terrestrial ecosystems to elevated CO_2: a synthesis and summary. In *Carbon Dioxide and Terrestrial Ecosystems,* G.W. Koch and H.A. Mooney (Eds.). Academic Press, San Diego, pp.415-430.

Kramer,R.A., N. Sharma and M. Munasinghe (1995) *Valuing Tropical Forests.* World Bank Environment Paper No. 13, Washington DC., 66pp.

Krebs, C.J. (1989) *Ecological Methodology.* Harper Collins Publishers, New York, 654pp.

Ladale, M. and D.F. Westlake (1995) River and stream ecosystems of Great Britain. In *River and Stream Ecosystems,* C.E. Cushing, K.W. Cummins and G.W. Minshall (Eds.). Elsevier, Amsterdam, pp.343-388.

Lamprecht, J (1989) *Silviculture in the Tropics: Tropical Forest Ecosystems and Their Tree Species, Possibilities and Methods for the Long-Term Utilisation.* Deutsche Gesellschaft fuer Technische Zusammenarbeit, Eschborn, Germany.

Lao-Swedish Forestry Co-operation Programme (1992) *Forest inventory manual: Field manual national forest inventory , Sawannaketh.* Vientiane, Lao PDR.

Leith, H.F.H. (1972) *Modelling the Primary Productivity of the World.* Deciduous Forest Biome Memo Rep. 72-9, pp10.

Leith, H.F.H. (1973) Primary production: terrestrial ecosystems. *Human Ecology* **1:** 303-332.

Leith, H.F.H. (1975) Primary productivity in ecosystems: comparative analysis of globalpatterns. In *Unifying Concepts in Ecology,* W.H. Van Dobben and R.H. McConnell, (Eds.). The Huge, Wageningen, pp.67-87.

Liang, Y., J. Wang and C. Hu (1988) Hydrobiology of a flooding ecosystem, Lake Chenhu in Hanyang, Hubei, with preliminary estimation of its potential fishery production capacity. *Chin. J. Oceanol. Limnol.,* **6:** 1-14.

Liao, G.Z., R.X. Lu and X.Z. Xiao (1989) Fisheries resources of the Pearl River and their exploitation. *Can. Spec. Publ. Fish. Aquat. Sci,* **106:** 561-568.

Lincoln, R., G. Boxshall and P. Clark (1998) *A Dictionary of Ecology, Evolution and Systematics.* Cambridge University Press, Cambridge, 361pp.

Madison, D. (1993) *The Shadow Price of Greenhouse Gases and Aerosols.* Miemo, Centre for Social and Economic Research on the Global Environment, University College London and University of East Anglia, Norwich.

Maltby, E., C.P. Immirzi and D.P. McLaren (1992) *Do Not Disturb: Peatbogs and the Greenhouse Effect.* Friends of the Earth, London, 55pp.

Maltby, E. (1999) Wetland ecosystem functioning: An expert-type approach to support decision-making. In *Ecosystem Management: Questions for Science and Society,* E. Maltby, M. Holdgate, M. Acreman and A. Weir, (Eds.). College Hill Press, pp.131-140.

Maltby, E., M. Holdgate, M. Acreman and A. Weir (1999) *Ecosystem Management: Questions for Science and Society.* College Hill Press, pp.1-42.

Map of Thailand and Lao PDR (1998)
http://www.lib.utexas.edu/Libs/PLC/Map_collection/middle_east_and_asia/Thailand.jpg

Marriott, B.B. (1997) *Environmental Impact Assessment: A Practical Guide.* McGraw-Hill, New York, pp.39-48, 75-88, 283-298.

Marshall, C. and G.B. Rossman (1999) *Designing Qualitative Research.* SAGE Publications, London, 224pp.

Maxwell, L.C. (1999) Decision-maker response. In *Tools to Aid Environmental Decision Making,* V.H. Dale and M.R. English (Eds.). Springer-Verlag, New York, pp.282-284.

McAlice, B.J. (1971) Phytoplankton sampling with the Sedgwick-Rafter cell. *Limnol. Oceanogr.*, **16:** 19-28.

McKillop, J. and A.L. Brown (1999) Mismatch between project development and environmental assessment. 19th Annual Meeting of the International Association for Impact Assessment, Glasgow, pp.125.

Mekong Fisheries Network Newsletter (MFNN) (1996a) 1,200 different fish species in the Mekong Basin. *Mekong Fish Catch and Culture* **2(1):** 4-5.

Mekong Fisheries Network Newsletter (MFNN) (1996b) 1,000,000 tonnes of fish from the Mekong. *Mekong Fish Catch and Culture* **2(1):** 1.

Mekong River Commission (MRC) (1994) *Mekong Mainstream Run-of-River Hydropower: Main report.* The Mekong River Commission Secretariat, Bangkok.

Mekong River Commission (MRC) (1995) *Pre-feasibility Study on Ban Koum Run-of-River Hydropower Project (Basinwide).* The Mekong River Commission Secretariat, Bangkok, pp.6.

Mekong River Commission (MRC) (1996) *Mekong River Basin Diagnosis Study* (Draft final report). The Mekong River Commission Secretariat, Bangkok.

Mellilo, J.M, A.D. McGuire, D.W. Kicklighter, B. Moore, C.J. Vorosmarty and A.L. Schloss (1993) Global climate change and terrestrial net primary production. *Nature,* **363:** 234-240.

Merkhofer, M.W. (1999) Assessment, refinement, and narrowing of options. In *Tools to Aid Environmental Decision Making,* V.H. Dale and M.R. English (Eds.). Springer Verlag, New York, pp.231-284.

Morris, P. and R. Therivel (1995) *Methods of Environmental Impact Assessment.* University College London Press, London, pp.197-226.

Moulton, R.J. and K.R. Richards (1990) *Cost of Sequestration Carbon through Tree Planting and Forest Management in the United States.* General Technical Report WO-58, USDA Forest Service, Washington, DC, 48pp.

MRC/GTZ (1997) *Technical Note 2: Interpretation and delineation from satellite images.* Forest Cover Monitoring Project MRC/GTZ, 24pp.

MRC/GTZ (1998) Unpublished GIS data on forest cover TM 12649 (Lao PDR).

Myers, W.L., G.P. Patil and C. Taillie (1995) Comparative paradigms for biodiversity assessment. In *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests,* T.J.B. Boyle and B. Boontawee (Eds.). Center for International Forestry Research (CIFOR), Bogor, Indonesia, pp.67-85.

Nardini, A. (1997) A proposal for integrating environmental impact assessment, cost-benefit analysis and multicriteria analysis in decision making. *Project Appraisal,* **12(3):** 173-184.

Natarajan, A.V. (1989) Environmental impact of Ganga Basin development on gene-pool and fisheries of Ganga River system. *Can. Spec. Publ. Fish. Aquat. Sci.,* **106:** 545-560.

National Resource Canada (NRC) (1999) Glossary.
http://www.nrcan.gc.ca/cfs/proj/sci-tech/arena/gloss e.html

Nilsson, S. and W. Schopfhauser (1995) The carbon-sequestration potential of a global afforestation program. *Climatic Change,* **30(3):** 267-293.

Nordhaus, W.D. (1991) The cost of slowing climate change: a survey. *The Energy Journal,* **12(1):** 37-65.

Norman, M.J.T., C.J. Pearson and P.G.E. Searle (1995) *The Ecology of Tropical Food Crops.* Cambridge University Press, Cambridge.

Norton, B. (1989) Commodity, amenity, and morality: the limits of quantification in valuing biodiversity. *In: Biodiversity,* E. O. Wilson (Ed.). National Academy Press, Washington DC., pp.200-205.

Norusis, M.J. (1993) *SPSS for Windows: Advanced Statistics, release 6.0.* SPSS Inc., 578pp.

Ogawa, H., et al. (1965) Comparative ecological studies on three main types of forest vegetation in Thailand. I. Structure and floristic composition; II. Plant biomass. *Nature and Life in Southeast Asia*, **4:** 13-80.

Orians, G.H., R. Dirzo and J.H. Cushman (1996) Impact of biodiversity on tropical forest ecosystem processes. In *Functional Roles of Biodiversity: A Global Perspective,* H.A. Mooney, J.H. Cushman, E. Medina, O.E. Sala and E. Schulze, (Eds). Jone Wiley & Sons, Chicester, pp.213-244.

Panchamanon, W. (1988) Unpublished data. Wildlife Sanctuary Subdivision, Wildlife Conservation Division, Royal Forestry Department, Thailand. (March).

Pantulu, V.R. (1986) The Mekong River system. In: *The Ecology of River Systems,* B.R. Davies and K.F. Walker (Eds). Dr W. Junk Publishers, Dordrecht, pp.695-720.

Parks, P.J. (1996) Economic reasons for forest land-use change: Relevance to tropical deforestation and the carbon cycle. In *Effects of Land-Use Change on Atmospheric CO2 Concentrations, South and Southeast Asia as a Case Study,* V.H. Dale, (Ed.). Springer-Verlag, Berlin, pp.329-365.

Parnwell, J.G. and R.L. Bryant (1996) *Environmental Change in South-East Asia: People, Politics and Sustainable Development.* Routledge, London, pp.124-162.

Parry, M.L., M.B. de Rozari, A.L. Chong, and S. Panich (1991) *The Potential Socio-economic Effects of Climate Change in South-East Asia.* United Nations Environmental Programme, Nairobi.

Pearce, D.W. (1993) *Economic values and the Natural World.* Earthscan Publications, London, 129pp.

Pearce, D.W. (1994) *Global Environmental Value of Tropical Forests.* University College, London

Pearce, D.W. and R.K. Turner (1990) *Economics of Natural Resources and the Environment.* Harvester Wheatsheaf, Hertfordshire, 378pp.

Pearce, D.W. and D. Moran (1994) *The Economic Value of Biodiversity.* Earthscan Publications, London, 172pp.

Pearce, D.W., W.R. Cline, A.N. Achanta, S. Fankhauser, R.K. Pachauri, R.S. Tol and P. Vellinga (1996) The social costs of climate change: greenhouse damage and the benefits of control. In *Climate Change 1995,* P. Bruce, H. Lee and E.F. Haites, (Eds). IPCC. Cambridge University Press, Cambridge, pp.183-224.

Peck, S.C. and T.J. Teiberg (1992) CETA: a model for carbon emissions trajectory assessment. *The Energy Journal,* **13(1):** 55-77.

Perrings, C.A. (1995) Ecological and economic values. In *Environmental Valuation New Perspectives,* K.G. Willis and J.T. Corkindale, (Eds.). CAB International, Wallingford, pp.56-66.

Perrings, C.A., K.G. Maler, C. Folke, C.S. Holling and B.O. Jansson (1995a) *Biodiversity Loss: Ecological and Economic Issues.* Cambridge University Press, Cambridge, 332pp.

Perrings, C.A., K-G Maler, C. Folke, C.S. Holling and B-O Jansson (1995b) Introduction: framing the problem of biodiversity loss. In *Biodiversity Loss Economic and Ecological Issues,* C.A. Perrings, K-G Maler, C. Folke, C.S. Holling and B-O Jansson, (Eds.). Cambridge University Press, Cambridge, pp.1-17.

Philip, M.S. (1994) *Measuring Trees and Forests.* CAB International, Wallingford, 310pp.

Pielou, E.C. (1995) Biodiversity versus old-style diversity measuring biodiversity for conservation. In *Measuring and Monitoring Biodiversity in Tropical and Temperate Forests,* T.J.B. Boyle and B. Boontawee (Eds.). Center for International Forestry Research (CIFOR), Bogor, Indonesia, pp.5-17.

Pimm, S.L. (1984) The complexity and stability of ecosystems. *Nature,* **307:** 321-326.

Pimm, S.L. (1994) Biodiversity and the balance of nature. In *Biodiversity and Ecosystem Function,* E.D. Schulze and H.A. Mooney, (Eds). Springer-Verlag, Berlin, pp.349-359.

Power, M.E. and L.S. Mills (1995) The keystone cops meet in Hilo. *Trends in Ecology and Evolution,* **10:** 182-184.

Prat, N. and J.V. Ward (1994) The tamed river. In *Limnology Now: A Paradigm of Planetary Problems,* R. Margalef (Ed.). Elsevier, Amsterdam, pp.219-236.

Prato, T. (1998) *Natural Resource and Environmental Economics.* Iowa State University Press, Ames, pp.3-26.

Prescott, G.W. (1982) *How to know the freshwater algae.* Wm. C. Brown Company Publishers, Iowa, 293pp.

Prugh, T., R. Costanza, J.H. Cumberland, H. Daly, R. Goodland and R.B. Norgaard (1995) *Natural Capital and Human Economic Survival.* International Society for Ecological Economics, Solomon, MD, 198pp.

Puri, K.B. (1996) *Statistical Practice.* Arnold, London, 134pp.

Raich, J.W., E.B. Rastetter, J.M. Mellilo, D.W. Kicklilghter, P.A. Steudler, B.J. Peterson, A.L. Grace, B.I. Moore and C.J. Vörösmarty (1991) Potential net primary productivity in South America: application of global model. *Ecological Applications,* **1(4):** 399-429.

Ramsar (1997) *Wetlands, Biodiversity and the Ramsar Convention.* Ramsar Convention Bureau, Gland, Switzerland. http://ramsar.org/lib_bio_1.htm

Reichle,D.E., R.V. O' Neill and W.F. Harris (1975) Principles of energy and material exchange in ecosystems. In *Unifying Concepts in Ecology,* W.H. Van Dobben and R.H. Lowe-Mcconnell (Eds.). Centre for Agricultural Publishing and Documentation, Wageningen, pp.27-43.

Ricklefs, R.E. (1990) *Ecology.* W.H. Freeman and Company, New York, pp.210-227.

Rigg, J. and R. Jerndal (1996) Plenty in the context of scarcity: Forest management in Laos, In *Environmrntal Change in South-East Asia: People, Politics and Sustainable Development*, J.G. Michael and Raymond L. Bryant, eds. Routledge, London, pp.145-162.

Roberts, T.R. (1995) *Botia splendida*, a new species of Loach (Pisces, *Cobitidae*) from the Mekong Basin in Laos. *Ruffles Bulletin of Zoology,* **43(2):** 463-467.

Roe, D., B. Dala-Clayton and R. Huges (1995) *A Directory of Impact Assessment Guidelines.* Environmental Planning Group, International Institute for Environment and Development, London, pp.1-20 and 41.

Rossiter, D.G. (1995) *Land Evaluation, Part 4: Economic Land Evaluation* . College of Soil, Crop and Atmospheric Science, Cornell University.

Rothert, S. (1994) The Gift of the sea of Laos. *World Rivers Review,* **9(4):** 1-5.

Royal Forestry Department (RFD) (1972) *Economic Tree of Thailand Vol. 1.* Royal Forest Department, Bangkok, Thailand, 249 pp.

Royal Forestry Department (RFD) (1975) *Economic Tree of Thailand Vol. 2.* Royal Forest Department, Bangkok, Thailand, 266 pp.

Royal Forestry Department (RFD) (1983) *Economic Tree of Thailand Vol. 3.* Royal Forest Department, Bangkok, Thailand, 258pp.

Royal Forestry Department (RFD) (1998) Unpublished data of forest cover on Thai boundary TM 12649. (Dr. S. Ongsomwang).

Sadler, B. (1986) Impact assessment in transition: A framework for redeployment. In *Integrated Approach to Resource Planning and Management,* R. Lang (Ed.). University of Calgary Press, Calgary, pp.99-129.

Sadler, B. and R. Verheem (1996) *Status, Challenges and Future Directions.* Ministry of Housing, Spatial Planning and the Environment, The Netherlands, 188pp.

Sadler, B. and R. Verheem (1999) *Country Status Reports on Environmental Impact Assessment.* The Netherlands Commission for Environmental Impact Assessment, The Netherlands, 289pp.

Salathe', T. (1993) Towards integrated management of coastal wetlands of Mediterranean type. In *Towards the Wise Use of Wetlands,* T.J. Davis (Ed.). Ramsar Convention Bureau, Gland, Switzerland. http://ramsar.org/lib_wise_1.htm

Schlesinger, W.H. (1991) Climate, environment and ecology. In *Climate Change: Science, Impacts and Policy,* J. Jager and H.L. Ferguson (Eds.). Cambridge University Press, Cambridge.

Schneider, R.R. (1994) Government and the economy on the Amazon frontier. *Latin America and the Caribbean Technical Department Regional Studies, ProgramReport No. 34.* The World Bank, Washington D.C., 86pp.

Schneider, E., and J.J. Kay (1994) Complexity and thermodynamics: towards a new ecology. *Futures,* **24:** 626-647.

Schofield, W. (1996) Survey sampling. In *Data Collection and Analysis,* R.Sapsford and V. Jupp (Eds). SAGE Publications, London, pp.25-55.

Schroeder, P. (1996) A carbon budget for Brazil: influence of future land-use change. *Climatic Change,* **33(3):** 369-383.

Sedjo, R. and A M. Solomon (1989) Climate and forest. *In: Greenhouse Warming: Abatement and Adaptation,* N.J. Rosenberg, W.E. Easterling, P.R. Crosson and J. Darmstadter (Eds). Resources for the Future, Washington D.C., pp.105-120.

Siebenhüner, B. (2000) Homo sustinens – towards a new conception of humans for the science of sustainability. *Ecological Economics,* **32(1):** 15-25.

Smith, F. (1996) Biological diversity, ecosystem stability and economic development. *Ecological Economics,* **16:** 191-203.

Smitinand, T. (1980) *Flora of Thailand.* Royal Forest Department, Bangkok, Thailand, 379pp.

Sriburi, T. (1995) *Environmental Impact Assessment.* Mind Publishing, Bangkok, 260pp. (In Thai)

Swedberg, R.M. (1991) The battle of the methods: Toward a paradigm shift. In *Socio-Economics Toward a New Synthesis,* A. Etzioni and P.R. Laurence (Eds.) M.E. Sharpe, Inc., pp.13-33.

Taki, Y. and A. Doi. (1995) Two new species of the Cobotid Genus *Botia* from the Lai-Mekong Basin. *Japanese Journal of Ichthyology,* **42(2):** 147-155.

Tilden, D. and J. Frehs (1997) Environmental assessment decisions using the environmental assessment valuation reference inventory TM(EVRITM). The 17th Annual Meeting of the International Association of Impact Assessment, New Orleans, pp.430-469.

Thailand Development Research Institute (TDRI) (1993) Preparation of A National Strategy on Global Climate Change: Thailand (Draft Final Report). TDRI, Bangkok, 330pp.

Thailand Environment Institute (TEI) (1996) *Thailand's Role in a Global Context.* Thailand Environment Institute 1996 Annual Conference Volume 1. Thailand Environment Institute, Bangkok, pp.1-24, (6-1)-(6-21).

Thailand Environment Institute (TEI) (1998) *Asia Least-Cost Greenhouse Gas Abatement Strategy: Thailand Third Draft Final Report submitted to Office of*

Environmental Policy and Planning, The Government of Thailand. Thailand Environment Institute, Bangkok.

The National History Museum (1998) *Measuring Biodiversity Value.* http://www.nhm.ac.uk/science/projects/worldmap/diversity/index.html

Townsend, A.R., B.H. Braswell, E.A. Holland and J.E. Penner (1996) Spatial and temporal patterns in terrestrial carbon storage due to deposition of fossil fuel nitrogen. *Ecological Applications,* **6(3):** 806-814.

Trexler and Haugen (1994) *Keeping It Green: Evaluating tropical forestry strategies to slow global warming.* World Resource Institute, Washington DC.

Turner, R.K., D. Pearce and I. Bateman (1994) *Environmental Economics.* Harvester Wheatsheaf, Hertfordshire, pp.108-128, 267-298.

Turner, R.K., W.N. Adger and R. Brouwer (1998) Ecosystem services, research needs, and policy relevance: a commentary. *Ecological Economics,* **25:** 61-65.

United Nations Environment Programme (UNEP) (1994) *UNEP greenhouse gas abatement costing studies, Phase II Report, Part 1: Main Report.* UNEP Collaborating Centre on Energy and Environment, Risø National Laboratory, Denmark.

Verburg, P.S.J., D.van Dam, J.C.Y., R. Westerhof and N.van Breemem (1995) The role of decomposition in carbon sequestration in ecosystems. In *Carbon Sequestration in the Biosphere,* M.A. Beran, (Ed.). Springer-Verlag, Berlin, pp.85-112.

Vidthayanon, C. and M. Kottelat (1995) First record of *Abbottina rivularis (Cyprinidae, Gobioninae)* from the Mekong Basin. *Japanese Journal of Ichthyology,* **41(4):** 463-465.

Vidthayanon, C. and et al. (1996) *Nandus oxyrhynchus,* A new species of leaf fish *(Teleostei, Nandidae). Raffles Bulletin of Zoology,* **44(1):** 11-19.

Vitousek, P.M. (1993) Global dynamics and ecosystem processes: scaling up or scaling down? In *Scaling Physiological Processes Leaf to Globe,* J.R. Ehleringer and C.B. Field, (Eds.), Academic Press, New York, pp.169-177.

Wangwacharakul, V. and R. Bowanwiwat (1995) Economic evaluation of carbon dioxide response options in forestry sector: Thailand. *Biomass and Bioenergy,* **8(5):** 293-307.

Washington, H.G. (1984) Diversity, biotic and similarity indices: a view with special relevance to aquatic ecosystems. *Water Res.,* **18:** 653-694.

Ward, J.V. (1994) The structure and dynamics of lotic ecosystems. In *Limnology Now: A Paradigm of Planetary Problems,* R. Margalef (Ed.). Elsevier Science B.V., Amsterdam, pp.195-218.

Wathern, P. (1992) *Environmental Impact Assessment, Theory and Practice.* Routledge, New York.

Welcomme, R.L. (1979) *Fisheries Ecology of Floodplain Rivers.* Longmans, London, 317pp.

Wetzel, R.G. and G.E. Likens (1991) *Limnological Analyses.* Springer-Verlag New York, Inc., New York, 391pp.

Whittaker, R.H. (1975) *Communities and Ecosystem.* Macmillan, Toronto, 385pp.

Whittaker, R.H. and G.E. Likens (1975) The biosphere and man. In *Primary Productivity of the Biosphere, Ecological Studies 14,* H. Leith and R.H. Whittaker, (Eds.). Springer-Verlag, Berlin, pp.305-328.

Wilson, J.O. (1991) Human value and economic behavior. In *Socio-Economic Toward a New Synthesis,* A. Etzioni and P.R. Laurence (Eds.) M.E. Sharpe, Inc., New York, pp.233-262.

Winjum, J.K. R.K. Dixon and P.E. Schroeder (1993) Forest management and carbon storage: an analysis of 12 keys forest nations. *Water, Air, and Soil Pollution,* **70:** 239-257.

Wood, C. (1996) *Environmental Impact Assessment: A Comparative Review.* Addison Wesley Longman, Essex, pp. 1-14, 289-298.

World Bank (1997) *Biodiversity and Environmental Assessment.* Environmental Assessment Sourcebook Update No.20. The World Bank, Washington DC., 10pp.

World Bank (1998a) *Country Data: Lao PDR and Thailand.*
http://www.worldbank.org/cgi_bin/sendoff_cgi

World Bank (1998b) *Economic Analysis and Environmental Assessment.* Environmental Assessment Sourcebook No.23. The World Bank, Washington DC., 14pp.

World Commission on Dams (WCD) (1999) *Mekong River Basin/Pak Mun Dam (Case Study: Scoping Paper).* World Commission on Dams, Cape Town, 34pp.

World Commission on Environment and Development (1987) *Our Common Future.* Oxford University Press, Oxford, 398pp.

World Resources Institute (WRI) (1992) The diversity of life. World Resources Institute, Washington DC. http://www.wri.org/wri/biodiv/b01-gbs.html

World Resources Institute (WRI) (1997) *Global Biodiversity Forum 1997.* IUCN, Gland, Switzerland, pp.7-15.

Xu, Zhi, D., P. Bradley and P.J. Jakes (1995) Measuring forest ecosystem sustainability: A resource accounting approach. *Environmental Management,* **19(5):** 685-692.

Yahphrom, P. (1993) *Preliminary Socio-economic Changes of the Pak Mun Project's Resettlers* (Master's Thesis). NIDA, Bangkok, Thailand, 102pp.

APPENDICES

APPENDIX I: CHAPTER FOUR

APPENDIX II: CHAPTER FIVE

APPENDIX III: CHAPTER SIX

APPENDIX IV: CHAPTER SEVEN

APPENDIX V: ABSTRACT

APPENDIX I: CHAPTER FOUR

4.1 Scene TM 12649 of the study area

4.2 Co-ordination of sampling plots

4.3 Species composition of tree and sapling species in the different forest types during the dry season 1998

4.4 Species composition of phytoplankton in the Mekong River and the Pak Mun Dam

4.5(a) Quadrat sampling data in primary forest in a form of needed for the Jack-knife estimate of species richness during the dry season (April-May 1998)

4.5(b) Quadrat sampling data in secondary forest in a form of needed for the Jack-knife estimate of species richness during the dry season (April-May 1998)

4.5(c) Quadrat sampling data in riparian forest in a form of needed for the Jack-knife estimate of species richness during the dry season (April-May,1998)

4.6 Jack-knife estimate of species richness of phytoplankton in the Mekong River and the Pak Mun Dam during the rainy season 1997

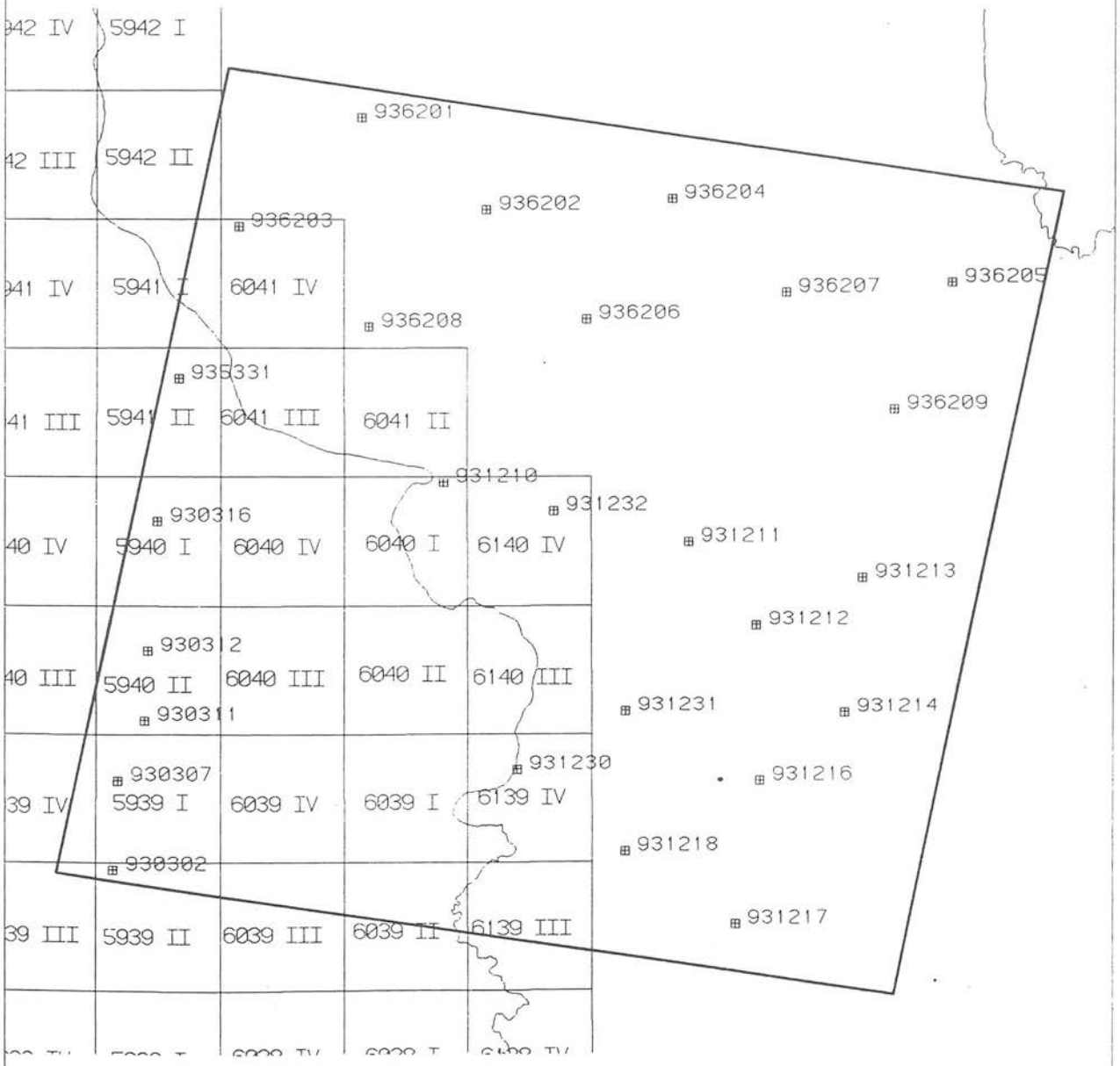
4.7(a) Shanon-Wiener index of species diversity of tree in primary forest during the dry season (May 1998)

4.7(b) Shanon-Wiener index of species diversity of tree in secondary forest during the dry season (May 1998)

4.7(c) Shanon-Wiener index of species diversity of tree in riparian forest during the dry season (May 1998)

4.8 Shanon-Wiener index of species diversity of phytoplankton in the Mekong River and the Pak Mun Dam during the rainy season 1997

Appendix 4.1: Scene TM 12649 of the study area (6039I, 6139IV, 6040II and 6140III)



Appendix 4.2:

1. Co-ordinations of sampling plots (size 25x25 m^2) in Thai study site are as follow:

Plot 1.	15° 22.319 N	105 ° 28.508 E
Plot 2.	15° 22.332N	105 ° 28.489 E
Plot 3.	15° 23.297 N	105 ° 29.563 E
Plot 4.	15° 23.366 N	105 ° 30.050 E
Plot 5.	15° 23.345 N	105 ° 30.382 E
Plot 6.	15° 23.368 N	105 ° 30.424 E
Plot 7.	15° 23.404 N	105 ° 31.235 E
Plot 8.	15° 23.545 N	105 ° 31.381 E
Plot 9.	15° 24.018 N	105 ° 31.334 E
Plot 10.	15° 24.089 N	105 ° 31.327 E
Plot 11.	15° 23.448 N	105 ° 31.477 E
Plot 12.	15° 23.445 N	105 ° 31.582 E
Plot 13.	15° 23.460 N	105 ° 31.590 E
Plot 14.	15° 24.163 N	105 ° 33.093 E
Plot 15.	15° 24.237 N	105 ° 33.113 E
Plot 16.	15° 24.075 N	105 ° 33.157 E
Plot 17.	15° 24.150 N	105 ° 33.216 E
Plot 18.	15° 24.224 N	105 ° 33.292 E
Plot 19.	15° 24.287 N	105 ° 34.023 E
Plot 20.	15° 24.210 N	105 ° 34.078 E
Plot 21.	15° 24.351 N	105 ° 34.275 E
Plot 22.	15° 24.497 N	105 ° 34.363 E
Plot 23.	15° 25.043 N	105 ° 34.496 E
Plot 24.	15° 25.102 N	105 ° 34.565 E
Plot 25.	15° 27.547 N	105 ° 35.391 E
Plot 26.	15° 28.060 N	105 ° 35.459 E
Plot 27.	15° 28.143 N	105 ° 35.507 E
Plot 28.	15° 28.397 N	105 ° 35.590 E
Plot 29.	15° 28.230 N	105 ° 35.491 E
Plot 30.	15° 28.120 N	105 ° 35.439 E

2. The representative of Laotian forest is located at Ban Hung Luang, Amphoe Sri Mueang Mai, Ubon Ratchathani Province at co-ordinate 15° 42.178 N 105 ° 34.148 E.

3. The distance is 24.8 km along the river from the first station upstream as follow:

1. Station Ban Kum (MekA.) (15° 23.431N 105° 29.781E; 104MSL)
2. Station Ban Ta Mui (MekB.) (15° 23.803N 105° 32.902E: 110MSL)
3. Station Ban Kan Tha Khwian (MekC.)(15° 31.996N 105° 36.007E: 110MSL)
4. Station Kaeng Soi (MekD.) (15° 27.078N 105° 35.755E; 114MSL)

4. Co-ordination of sampling station in Pak Mun Dam is 15° 16.398N 105° 27.593E.

Appendix 4.3: Species composition of tree and sapling species in the primary forest as Laotian study sites, the secondary and riparian forest during dry season in April-May 1998.

No.	Local name	Scientific name	Primary forest		Secondary forest		Riparian forest	
			Tree (62 species) Co-species =33	Sapling (37 species)	Tree (67 species) Co-species =31	Sapling (39 species)	Tree (38 species) Co-species =14	Sapling (21 species)
1	Hnaam han	*Acacia comosa* Gagnep.	√					
2	Hnaam pla duk	*Acacia sp.*			√	√		
3	Mueat	*Adinandra integerrima* T. Andres. Ex Dyer	√					
4	Kang hung	*Albizia chinensis* Merr.	√					
5	Ma rum paa	*Albizia lebbeck* (L.) Benth.			√		√	
6	Kha min ton	*Alseodaphne birmanica* Korsterm.		√				
7	Kra bak	*Anisoptera costata* Korth.	√					
8	Ehn mon	*Anogeissus acuminata* Wall.			√			√
9	Hard	*Artocarpus lakoocha* Roxb.	√	√				
10	Phai chot	*Arundinaria ciliata* A. Camus			√		√	
11	Hnaam khee had	*Azima sarmentosa* (Bl.) Benth & Hook	√					
12	Som sieow/Chong ko	*Bauhinia acuminata* Linn.			√			
13	Nguei phaa	*Bombax anceps* Pierre	√	√	√			
14	Ma muang hua malang wan	*Buchanania reticulata* Hance			√	√		
15	Pha uung	*Calophyllum saigonense* Pierre	√					
16	Ngueng suem	*Calycopteris floribunda* Lamk	√					
17	Ma lueam/Kok kan	*Canarium subulatum* Grill.	√	√	√	√	√	√
18	Kra don	*Careya sphaerica* Roxb.			√	√	√	
19	Kuun	*Cassia fistula* Linn.	√	√	√		√	
20	Kor kun	*Castanopsis brevispinula* Heckel & A. Camus	√	√				
21	Kor hin	*Castanopsis piriformis* Hickel & A. Camus	√	√				

22	Po daeng	*Colona ebolata* Craib.	√			√			√	√
23	Kan jong	*Colubrina asiatica* (L.) Brongn.								√
24	Tiu khaao	*Cratoxylum formosum* (jacj) Dyer	√	√			√			
25	Tao	*Cratoxylum maingayi* Dyer					√			
26	Tiu daeng	*Cratoxylum pruniflorum* Gogel.					√		√	√
27	Pha yung	*Dalbergia cochinchinensis* Pierre	√			√			√	√
28	Kaeng	*Dialium cochinchinense* Pierre	√	√						
29	Saan	*Dillenia obovata* (Bl.) Hoogl.	√	√		√				
30	Taa nok krot	*Dillenia ovata* Wall.ex Hook.f.& Thomas	√	√						√
31	Phaeng/San chaang	*Dillenia pentagyna* Roxb.							√	
32	Huean kwang/Tub tao	*Diospyros ehretioides* Wall.				√	√		√	√
33	Saat/Hiang	*Dipterocarpus obtusidolius* Teysm. ex Miq.				√	√			
34	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.				√	√			
35	Ma kok nam	*Eleocarpus hygrophilus* Kurz.							√	
36	Saan	*Erythrophleum succirubrum* Gagnep.				√				
37	Sa baeng/Chaad	*Erythrophleum teysmannii* Craib		√		√	√		√	
38	Hwaar	*Eugenia cumini* (L.) Druce	√	√						
39	Mee	*Eugenia euneura* Craib				√			√	
40	Mao	*Eugenia grandis* Wight	√	√		√				
41	Sai	*Ficus sp.*				√				
42	See da paa	*Gardenia coronaria* Ham.				√				
43	Phai rai	*Gigantochloa albocilata* Munro	√						√	
44	Muei daeng	*Gracinia erythroclada* Kurz	√	√						
45	Sa long kong	*Grewia asiatica* Linn.	√				√		√	
46	Khee taeo	*Grewia elatostemoides* Coll. Et Hemsl.	√	√						√
47	Kon som	*Grewia microcos* Linn.	√							
48	Khaao	*Haldina cordifolia* Ridsd.	√			√	√		√	
49	Mueat bai khon	*Helicia petiolaris* Benn.	√	√		√	√		√	√
50	Mueat bai kliang	*Helicia robusta* (Roxb.) R. Br.ex Wall.	√	√		√	√			
51	Khan naang/Khaa naang	*Homalium tomentosum* Benth.				√	√		√	

52	Kan hin	*Hopea ferrea* Pierre	√									
53	Lueat nok	*Horsfieldia amygdaing* Warb.	√									
54	Som kop	*Hymenodictyon excelsum* Wall.	√		√		√		√		√	√
54	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	√		√		√				√	
55	Pluei khaao	*Lagerstroemia calyculata* Kurz.					√					
56	Pluei see daa	*Lagerstroemia duperreana* Pierre					√		√			
57	Pluei kra daeng/Pluei nam	*Lagerstroemia floribunda* Jack	√		√							√
58	Ka ka lao	*Lagerstroemia macrocarpa* Wall.					√					
59	Pluei	*Lagerstroemia spp.*							√			
60	Ooy chaang	*Lennea coromandelica* (Houtt.) Merr.					√					
61	Kor	*Livistona speciosa*					√		√		√	√
62	Ma muang paa	*Mangifera longipetiolata* King					√					
63	Nam kliang	*Melanorrhoea laccifera* Pierre					√					
64	Lum duen	*Melodorum fruticosum* Lour.	√		√							
65	Mueat ae	*Memecylon scutellatum* Naud.					√		√			
66	Sa thon	*Milletoa leucantha* Kurz					√		√			
67	Chak chan	*Millettia pubinervis* Kurz.					√					√
68	Khang hua moo	*Miluisa velutina* Hook.f. Thorn					√					
69	Thom	*Mitragyna javanica* Koord. & Val	√		√		√		√			
70	Yor paa/Sa lak paa	*Morinda coreia* Ham	√		√		√		√		√	
71	Pok	*Parinaria anamense* Hance	√				√					
72	Liang	*Parkia timoriana* (DC.) Merr.					√		√			
73	Ee tok	*Passiflora foetida* Linn.					√		√		√	
74	Rang haeng	*Pectacme sauvis*					√					
75	Ma kham pom	*Phyllanthus emblica* Linn.	√		√		√		√			
76	Yang don	*Polyalthia asteriella* Ridl.	√									
77	Saai den	*Polyalthia cerasoides* Benth. ex Bedd.	√		√		√		√			
78	Duk phee	*Prismatomeris griffithii* Ridl.	√		√							
79	Pra duu	*Pterocarpus macrocarpus* Kurz	√		√		√		√		√	
80	Kor khee muu	*Quercus helferiana* A. DC.	√		√							

81	Hnaam taeng	*Randia dasycarpa* Barkh.f.	√	√	√	√	√	√
82	Kaay sue	*Schima wallichii* (DC.) Korth.	√	√				
83	Pha yom	*Shorea floribunda* Kurz	√	√	√		√	√
84	Chig/Teng	*Shorea obtusa* Wall.			√	√	√	√
85	Rang	*Shorea siamensis*		√	√			
86	See	*Shorea thorellii* Pierre ex Laness.	√		√			
87	Tae	*Sindora siamensis* Teijsm. Ex Miq.		√	√			
88	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forman			√			
89	Po daan	*Sterculia guttata* Roxb.	√					
90	Khee kaa	*Strychnow rupicola* Pierre ex Dop.					√	
91	Rok faah/Chueak	*Terminalia alata*			√			
92	Haen	*Terminalia bellerica* Roxb.			√			
93	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness.	√		√	√	√	√
94	Hean	*Terminalia glaucifolia* Craib				√		
95	Saan kum	*Terminalia nigrovenulosa* Pierre ex Laness.	√	√	√	√	√	
96	Khai naao	*Vitex glabrata R. Br.*			√	√		
97	Teen nok	*Vitex pinnate* Linn.	√		√		√	
98	Sa kang	*Vitex tripinnate* Merr.	√		√			
99	Mok	*Wrightia pubescens* R. Br.	√	√	√	√	√	√
100	Daeng	*Xylia xylocarpa* Taub.			√	√	√	√
101	Kra tang	Xylopia vielana Pierre.	√					
102	Ee hen						√	
103	Hmor		√					
104	Khee kra thoe				√	√	√	
105	Ma lung		√					
106	Mueat bai luaem		√	√				
107	Mueat ta baeng		√					
108	Pha lin				√			
109	Phai hlai kliang						√	
110	Pluei nam phueng					√		√

111	Pung muu	√		
112	Rang sean	√		
113	Teui	√		
114	Unidentified 1		√	
115	Unidentified 2			√
116	Unidentified 3			√

Appendix 4.4: Species composition of phytoplankton in the Mekong River and the Pak Mun Dam.

	Scientific name (Genera)	With-out project Mekong River				With project Pak Mun Dam		
No.		A	B	C	D	P1	P2	P3
	Chlorophyta:							
1	*Ankistrodesmus*							√
2	*Askenasyella*	√				√		
3	*Brachiomonas*		√	√				
4	*Cerasterias*		√					
5	*Chlamydomonas.*	√						
6	*Chlorangiella*		√					
7	*Chlorococcum*					√		
8	*Chloromonas*	√						
9	*Closteriopsis*	√	√					
10	*Closterium*	√	√		√			
11	*Conochaete*			√				
12	*Coronastrum*				√			
13	*Corone*				√			
14	*Cosmocladium*					√	√	
15	*Dactylothece.*		√					
16	*Dictyosphaerium*				√	√		
17	*Dimoorphococcus*			√				
18	*Diogenes*	√						
19	*Dispora*				√			
20	*Euastridium*	√	√		√			
21	*Euastropsis*	√						
22	*Euastridium*			√				√
23	*Euastrum*	√	√	√			√	
24	*Geminella*		√					
25	*Genicularia*			√				
26	*Gloeoactinium*				√			
27	*Gloeocystis*	√		√	√			√
28	*Hazenia*				√			
29	*Hormidiopsis.*	√	√	√	√	√	√	
30	*Keriochlamys*							√
31	*Kirchneriella.*	√						
32	*Mesotaenium*			√				
33	*Micrasterias*			√				
34	*Mycanthococcus*	√						
35	*Nautococcus*	√	√				√	
36	*Netrium*	√						
37	*Oocystis*			√				
38	*Palmodictyon*			√				
39	*Pediastrum*	√						

40	*Platydorina*				√	√			
41	*Pleodorina*						√		√
42	*Polyedriopsis*	√							
43	*Polytoma*	√							
44	*Quadrigula*				√				
45	*Radiofilum*							√	
46	*Scenedesmus*			√	√		√	√	√
47	*Schroederia*						√	√	
48	*Selenastrum*				√				
49	*Sphaerellocystis.*	√							
50	*Sphaerellopsis.*	√			√				
51	*Stephanondphaera*				√				
52	*Straurastrum.*	√		√	√	√			
53	*Temnogametum*							√	√
54	*Tetradesmus*	√							
55	*Tetraedron*	√		√	√				
56	*Triploceras*				√				
57	*Trochiscia*			√					
58	*Volvox*					√			
	Cyanophyta:								
59	*Aphanocapsa*				√				
60	*Aphanizomenon*	√							
61	*Anabaena*							√	
62	*Arthrospira*							√	√
63	*Bozia*				√	√			
64	*Capsosira*					√	√		
65	*Chamaesiphon*					√			
66	*Chroococcus*			√					√
67	*Coelosphaerium*			√	√		√	√	√
68	*Cylindrospermum*	√			√		√		
69	*Dactylococcopsis*	√					√	√	√
70	*Diplocolon*	√		√	√	√	√		
71	*Eucapsis*	√		√	√	√	√		√
72	*Gloeocapsa*	√		√	√	√	√	√	√
73	*Gloeothece*	√		√	√	√	√	√	√
74	*Gomphosphaeria*	√		√		√	√	√	√
75	*Hapalosiphon*							√	
76	*Heterohormogonium*	√		√	√	√			√
77	*Holopedium*					√			
78	*Marssoniella*	√			√				
79	*Merismopedia*			√	√		√	√	√
80	*Microchaete*			√					
81	*Microcystis*	√		√	√	√	√		
82	*Myxosarcina*	√							
83	*Nodularia*	√			√				
84	*Raphidiopsis*				√	√			
85	*Stichosiphon*				√	√		√	
86	*Stigonema*	√		√					
87	*Symploca*								√

88	*Trichodesmium*				√								
	Chrysophyta:												
89	*Chlorameoba*						√						
90	*Chlorocloster*						√						
91	*Chlorogibba*	√		√	√								
92	*Chrysamoeba*								√				
93	*Chrysochromulina*			√					√		√		
94	*Chrysococcus*	√					√						
95	*Dichotomococcus*						√						
96	*Dinobryon*			√									
97	*Heterogloea*				√								
98	*Hydrurus*								√				
99	*Goniochloris*			√									
100	*Mischococcus*												√
101	*Pseudostaurastrum*	√							√		√		
102	*Tetraedriella*	√		√	√		√						
103	*Trachychloron*				√		√						
	Bacillariophyta:												
104	*Achnanthes*	√			√								
105	*Actinocyclus*								√				
106	*Amphicampa*	√		√	√								
107	*Amphipora*			√									
108	*Amphora*	√		√	√								
109	*Aneumastis*				√								
110	*Bacillaria*	√											
111	*Biddulphia.*			√									
112	*Brebissona*	√											
113	*Campylodiscus*				√								
114	*Cyclotella*				√								
115	*Cymbella*			√	√								
116	*Denticula*	√		√									
117	*Diadesmus*			√	√								
118	*Diatomella*	√											
119	*Encyonema*			√									
120	*Eunotia*				√								
121	*Fragillaria*	√		√									
122	*Gomphoneis*	√											
123	*Gyrosigma*	√		√									
124	*Hydrosera*	√		√	√		√		√		√		√
125	*Mastogloia*			√									
126	*Meridion*				√								
127	*Navicula*	√		√									
128	*Opephora*	√		√									
129	*Rhopalodia*			√									
130	*Scoliopleura*				√								
131	*Stauroneis*	√											
132	*Surirella*	√		√	√								
133	*Tabellaria*	√		√									
	Euglenophyta:												

134	*Euglena*	√	√	√	√			
135	*Euglenomorpha*	√	√					
136	*Phacus*	√	√	√	√		√	√
	Chloromonadophyta:							
137	*Gonyostomum*	√	√	√	√			
138	*Merotrichia sp.*	√						
139	*Vacuolaria*				√			
	Pyrrhophyta:							
140	*Cystodinium*				√			
141	*Glenodinium*	√			√			
142	*Gloeodinium*	√	√	√		√	√	
143	*Gymnodinium*	√						
144	*Hypnodinium*	√						
145	*Perinidium*				√			
146	*Urococcus*	√						
	Cryptophyta:							
147	*Chroomonas*		√					
148	*Cryptomonas*	√	√					
149	*Rhodomonas*	√	√					
150	*Tetragonidium*	√	√	√	√			

Appendix 4.5a: Quadrat sampling data in primary forest in a form of needed for the Jackknife estimate of species richness during dry season (April-May 1998).

		Plot																Row
No.	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Sum
1	*Anisoptera costata* Korth.	1	1	1	0	0	1	1	1	1	0	0	0	1	1	0	0	9
2	*Vitex pinnate* Linn.	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
3	*Terminalia nigrovenulosa* Pierre ex Laness.	1	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	5
4	*Quercus helferiana* A. DC.	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	3
5	*Eugenia cumini* (L.) Druce	1	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1	6
6	*Prismatomeris griffithii* Ridl.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
7	*Shorea floribunda* G. Don	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
8	*Dillenia obovata* (Bl.) Hoogl.	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	13
9	*Cratoxylum formosum Dyer*	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
10	*Dalbergia cochinchinensis* Pierre	1	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1	9
11	*Grewia elatostemoides* Coll. Et Hemsl.	1	0	1	1	0	1	1	0	0	1	0	0	1	1	1	0	9
12	*Hymenodictyon excelsum* Wall.	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
13	*Polyalthia cerasoides* Benth.ex Bedd.	1	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0	6
14	*Grewia asiatica* Linn.	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	3
15	*Pterocarpus macrocarpus* Kurz	1	0	0	1	1	0	1	0	1	0	1	1	1	1	1	1	11
16	*Lagerstroemia floribunda* Jack	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	4
17	*Hmor*	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	3
18	*Morinda coreia* Ham	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	*Melodorum fruticosum* Lour.	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	4
20	*Shorea thorellii* Pierre ex Laness	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	*Dialium cochinchinense* Pierre	0	1	1	0	0	1	1	0	0	0	1	0	0	1	1	0	7
22	Malung	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
23	*Adinandra integerrima* T. Andres. ex Dyer	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24	*Canarium subulatum* Grill.	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	0	6
25	*Xylopia vielana* Pierre.	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	3
26	*Hopea ferrea* Pierre	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
27	*Schima wallichii* (DC.) Korth.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	*Parinari anamense* Hance	0	0	1	0	0	0	1	0	0	1	1	0	1	1	1	0	7
29	*Wrightia pubescens* R. Br.	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	3
30	*Polyalthia asteriella* Ridl.	0	0	1	0	0	0	1	1	0	1	0	0	1	1	0	0	6
31	*Cassia fistula* Linn.*	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	2
32	*Gigantochloa albociliata Munro*	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
33	*Helicia petiolaris* Benn.	0	0	0	1	1	1	1	0	0	1	1	0	0	1	1	0	8
34	*Randia dasycarpa* Barkh.f.	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	3
35	*Irvingia malayana* Oliv.ex A. Benn.	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	3
36	*Colona ebolata* Craib	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2
37	*Castanopsis brevispinula* Hickel & A. Camus	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2
38	*Eugenia grandis* Wight	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	3
39	*Calycopteris floribunda* Lamk	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	3
40	*Albizia chinensis* Merr.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
41	*Bombax anceps* Pierre	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	1	5
42	*Gracinia erythroclada* Kurz	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
43	*Helicia robusta* (Roxb.) R. Br.ex Wall.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	3
44	*Acacia comosa* Gagnep.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
45	*Mitragyna javanica* Koors. & Val.	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	4

46	*Phyllanthus emblica* Linn.	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	3
47	*Calophyllum saigonense* Pierre	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
48	*Artocarpus lakoocha* Roxb.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2
49	*Prismatomeris griffithii* Ridl.	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
50	Rang sean	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	5
51	*Grewia microcos* Linn.	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
52	Mueat ta baeng	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
53	*Vitex tripinnate* Merr.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
54	Tuei	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
55	*Castanopsis piriformis* Hickel & A. Camus	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	6
56	*Terminalia corticorsa* Pierre ex Laness.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	3
57	Mueat bai lueam	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2
58	Pung muu	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
59	*Azima sarmentosa* (Bl.) Benth & Hook	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
60	*Schima wallichii* (DC.) Korth.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
61	*Horsfieldia amygdaing* Warb.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
62	*Haldina cordifolia Ridsd.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Total = 62 species

Unique species(*k*) = 17 (Unique species defined as one species occur in only one quadrat.)

Jackknife estimate of species richness

S=s+((n-1)/n)^k

S =Jackknife estimate of species richness

s = Observed total number of species presene in n quadrats

n = Total number of quadrats sampled

k = Number of unique species

62.3338195

Jackknife estimate of species richness = 62.3338195 species

Variance*(S)=(n-1/n)*[sum((j^2)*fj)-k^2/n]*

n-1/n=	0.938
[sum((j^2)*fj)-k^2/n] =	28.938
27.12890625	

Variance of *(S) = 27.12890625*

No. of unique species (*j*)	**No. of quadrat containing *j* unique species, *fj***	***j^2*fj***
1	1 (quadrat no.= 7)	1
2	3 (quadrat no. = 2,6,15)	12
3	2 (quadrat no. = 3,13)	18
4	1 (quadrat no. = 10)	16
SUM =		47
k^2/n=		**18.1**

Jackknife estimator of species richness obtains confidence limit as follows: *t(alpha) = Student's t value for n-1 degree of freedom for the appropriate value of alpha*

t (alpha) = 2.131 (at df. = 15)

Upper limit S = S + *t*Variance^0.5 = 62.334 + 2.131*(27.129^0.5)* 73.433

Lower limit S = S - *t*Variance^0.5 = 62.334 - 2.131*(27.129^0.5)* 51.235

Jackknife estimator of species richness will possibly occur from 73 species to 51 species in primary forest.

Appendix 4.5b: Quadrat sampling data in secondary forest in a form of needed for the Jackknife estimate of species richness during dry season (April-May 1998).

		Plot																		Row
No.	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Sum
1	*Irvingia malayana* Oliv. wx A. Benn.	0	1	0	1	1	1	0	0	1	1	0	1	0	0	0	0	1	0	8
2	*Shorea obtusa* Wall.	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	16
3	*Vitex pinnate* Linn.	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
4	*Erythrophleum teysmannii* Craib	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3
5	*Randia dasycarpa* Bakh.f.	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3
6	*Shorea floribunda* Kurz	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
7	*Dalbergia cochinchinensis* Pierre	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8	*Ptercarpus macrocarpus* Kurz	0	1	1	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0	6
9	*Terminalia corticorsa* Pierre ex Laness.	0	1	0	1	1	0	1	0	0	0	1	1	0	0	0	0	0	0	6
10	*Morinda coreia* Ham	1	0	1	1	1	1	0	0	0	1	1	1	1	1	0	1	0	1	12
11	*Canarium subulatum* Grill.	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	3
12	*Memecylon scutellatum* Naud.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
13	*Polyalthia cerasoides* Benth. ex Bedd.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
14	*Arundinaria ciliata* A. Camus	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	5
15	*Xylia xylocarpa* Taub.	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	16
16	*Lagerstroemia duperreana* Pierre	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	*Wrightia pubescens* R. Br.	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	3
18	*Terminalia bellerica* Roxb.	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	4
19	*Terminalia nigrovenulosa* Pierre ex Laness.	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	5
20	*Helicia robusta* (Roxb.)	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	4
21	*Milletoa leucantha* Kurz	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	10
22	*Lagerstroemia calyculata* Kurz.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
23	*Helicia peteolaris* Benn.	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	1	1	10
24	Pha lin	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
25	*Sindora siamensis* Teijsm. ex Miq.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26	*Buchanania reticulatata* Hance	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	4
27	*Erythrophleum succirubrum* Gagnep.	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
28	*Shorea siamensis*	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
29	*Vitex glabrata R. Br.*	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
30	*Dipterocarpus tuberculatus* Roxb.	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	3
31	*Parinaria anamense* Hance	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
32	*Passiflora foetida* Linn.	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
33	*Shorea thorellii* Pierre ex Laness.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	2
34	*Phyllanthus emblica* Linn.	1	0	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	1	7

35	*Melanorrhoea laccifera* Pierre	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
36	*Dipterocarpus obtusidolius* Teysm. ex Miq.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	3
37	*Diospyros ehretioides* Wall.	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	1	7
38	*Careya sphaerica* Roxb.	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	3
39	*Homalium tomentosum* Benth.	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	3
40	*Spondias bipinnata* Airy Shaw & Forman	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	4
41	*Lennea coromandelica* (Houtt.) Merr.	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
42	*Hymenodictyon excelsum* Wall.	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	4
43	*Dillenia ovata* Wall ex Hoook.f. & Thomas	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
44	*Colona ebolata* Craib.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	2
45	*Haldina cordifolia* Ridsd.	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	6
46	*Lagerstroemia macrocarpa* Wall.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
47	*Bauhinia acuminata* Linn.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
48	*Acacia sp.*	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
49	*Eugenia euneura* Craib	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2
50	Khee kra thoe?	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	4
51	*Livistona speciosa*	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	3
52	*Parkia timoriana* (DC.) Merr.	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	3
53	*Bombax anceps* Pierre	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	3
54	*Mangifera longipetiolata* King	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
55	*Terminalia alata*	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	4
56	*Ficus sp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
57	*Mitragyna javanica* Koord. & Val	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	3
58	Unidentified 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
59	*Anogeissus acuminata* Wall.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
60	*Albizia lebbeck* (L.) Benth.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
61	*Cassia fistula* Linn.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
62	*Miluisa velutina* Hook.f. Thom	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
63	*Pectacme sauvis*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
64	*Millettia pubinervis* Kurz.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
65	*Gardenia coronaria* Ham.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
66	*Vitex tripinnate* Merr.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
67	*Eugenia grandis* Wight.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Total species = 67 species	**16**	**12**	**12**	**10**	**12**	**12**	**11**	**8**	**8**	**21**	**17**	**19**	**16**	**10**	**4**	**21**	**9**	**11**	**229**
	Unique species = 20																			
	Jackknife estimate of species richness																			
	S=s+((n-1)/n)^k																			

S =Jackknife estimate of species richness				
s = Observed total number of species presene in n quadrats				
n = Total number of quadrats sampled				
k = Number of unique species				
67.31880735				
Jackknife estimate of species richness = 67.32 species				
Variance*(S)=(n-1/n)*[sum(j^ 2*fj)-k^ 2/n]*				
n-1/n=	0.94			
[sum((j^2)*fj)-k^2/n] =	19.8			
18.67901235				
Variance of *(S) = 18.68*				
No. of unique species (*j*)	**No. of quadrat containing *j* unique species, *fj***		***j^2*fj***	
0	5 (quadrat no.=6,7,11,14,17)		0	
1	9 (quadrat no. = 3,5,8,9,10,12,13,15,18)		9	
2	2 (quadrat no. = 2,4)		8	
3	1 (quadrat no.16)		9	
4	1(quadrat no. 1)		16	
Sum =			**42**	
k^2/n =			**22.2**	
Jackknife estimator of species richness obtains confidence limit as follows: *t(alpha) = Student's t value for n-1 degree of freedom for the appropriate value of alpha*				
t(alpha) = 2.11 (at df.=17)				
Upper limit S = S + *t*Variance^0.5 = 67.32 + 2.11*(18.68^0.5)*				**76**
Lower limit S = S - *t*Variance^0.5 = 67.32 -2.11*(18.68^0.5)*				**58.2**
Jackknife estimator of species richness will possibly occur from76species to 58 species in the secondary forest.				

Appendix 4.5c: Quadrat sampling data in riparian forest in a form of needed for the Jackknife estimate of species richness during dry season (April-May 1998).

		Plot no.				
No.	Species	2	5	7	20	Total
1	*Irvingia malayana* Oliv. wx A. Benn.	0	1	0	0	1
2	*Shorea obtusa* Wall.	0	1	0	0	1
3	*Vitex pinnate* Linn.	0	0	0	1	1
4	*Erythrophleum teysmannii* Craib	0	1	0	0	1
5	*Randia dasycarpa* Bakh.f.	0	1	0	0	1
6	*Shorea floribunda* Kurz	0	1	0	0	1
7	*Dalbergia cochinchinensis* Pierre	0	1	0	0	1
8	*Grewia asiatica* Linn.	0	1	0	0	1
9	*Ptercarpus macrocarpus* Kurz	0	1	0	0	1
10	*Terminalia corticorsa* Pierre ex Laness.	0	1	0	0	1
11	*Morinda coreia* Ham	1	0	1	0	2
12	*Canarium subulatum* Grill.	0	1	0	1	2
13	*Helicia petiolaris* Benn.*	0	1	0	0	1
14	*Arundinaria ciliata* A. Camus	1	0	0	0	1
15	*Xylia xylocarpa* Taub.	1	0	1	0	2
16	*Wrightia pubescens R. Br.*	1	0	1	1	3
17	*Terminalia nigrovenulosa* Pierre ex Laness.	0	0	0	1	1
18	*Cartoxylum pruniflorum* Gogel.	0	0	1	0	1
19	*Careya sphaerica* Roxb.	0	0	1	0	1
20	*Homalium tomentosum* Benth.	1	0	1	0	2
21	*Hymendictyon excelsum* Wall.	1	0	0	1	2
22	*Haldina cordifolia* Ridsd.	1	0	1	0	2
23	*Eugenia euneura* Craib	0	0	1	0	1
24	Khee kra thoe?	0	0	1	1	2
25	*Livistona speciosa*	1	0	1	1	3
26	Unidentified 1*	0	0	0	1	1
27	Unidentified 2	0	0	0	1	1
28	*Albizia lebbeck* (L.) Benth.*	0	0	1	0	1
29	*Cassia fistula* Linn.*	0	0	0	1	1
30	*Gigantochloa albocilata* Munro	0	0	1	0	1
31	Phai hlai kliang	0	0	0	1	1
32	*Dillenia pentagyna* Roxb.	1	0	1	0	2
33	*Colona ebolata* Craib.	1	0	0	0	1
34	*Passiflora foetida* Linn.	0	1	0	0	1
35	Ee hen	0	1	0	0	1
36	*Strychnow rupicola* Pierre ex Dop.	0	0	1	0	1
37	Tub tao	0	0	1	0	1
38	*Elaeocarpus hygrophilus* Kurz	0	0	1	0	1

					50								
Total species = 38													
Unique species (k) = 27		(Unique species defined as one species occur in only one quadrat.)											
Jackknife estimate of species richness													
S=s+((n-1)/n)^k													
S =Jackknife estimate of species richness													
s = Observed total number of species presene in n quadrats													
n = Total number of quadrats sampled													
k = Number of unique species													
38.00042													
Jackknife estimate of species richness = 38 species													
Variance*(S)=(n-1/n)*[sum((j^2)*fj)-k^2/n]*													
	n-1/n=	0.750											
[sum((j^2)*fj)-k^2/n] =		42.750											
Variance*(S)=(n-1/n)*[sum((j^2)*fj)-k^2/n]*		32.0625											
Variance of *(S)* =		32.06											
No. of unique species (*j*)		No. of quadrat containing *j* unique species, *fj*							*j^2*fj*				
	2	1 (quadrat no.= 2)							4				
	6	1 (quadrat no. = 20)							36				
	8	1 (quadrat no. = 7)							64				
	11	1 (quadrat no. = 5)							121				
SUM =	225								225				
k^2/n=	182.3												
Jackknife estimator of species richness obtains confidence limit as follows: *t(alpha) = Student's t value for n-1 degree of freedom for the appropriate value of alpha*													
t(alpha) = 3.182 (at df. = 3, p=0.975)													
Upper limit S = S + *t*Variance^0.5 = 38.00+ 3.182*(32.06^0.5)*			56.02										
Lower limit S = S - *t*Variance^0.5 = 38.00 - 3.182*(32.06^0.5)*			19.98										
Jackknife estimator of sapling species richness will possibly occur from 56 species to 20 species in riparian forest.													

Appendix 4.6: Jackknife estimate of species richness of phytoplankton in the Mekong River (Mek) and the Pak Mun Dam (Mun) during rainy season 1997.

No.	Scientific name	MekA.	MekB.	MekC.	MekD.	TOTAL(Mek.)	MunA.	MunB.	MunC.	TOTAL(Mun)
1	*Ankistrodesmus*	0	0	0	0	0	0	0	1	1
2	*Askenasyella*	1	0	0	0	1	1	0	0	1
3	*Brachiomonas*	0	1	1	0	2	0	0	0	0
4	*Cerasterias*	0	1	0	0	1	0	0	0	0
5	*Chlamydomonas.*	1	0	0	0	1	0	0	0	0
6	*Chlorangiella*	0	1	0	0	1	0	0	0	0
7	*Chlorococcum*	0	0	0	0	0	1	0	0	1
8	*Chloromonas*	1	0	0	0	1	0	0	0	0
9	*Closteriopsis*	1	1	0	0	2	0	0	0	0
10	*Closterium*	1	1	0	1	3	0	0	0	0
11	*Conochaete*	0	0	1	0	1	0	0	0	0
12	*Coronastrum*	0	0	0	1	1	0	0	0	0
13	*Corone*	0	0	0	1	1	0	0	0	0
14	*Cosmocladium*	0	0	0	0	0	1	1	0	2
15	*Dactylothece.*	0	1	0	0	1	0	0	0	0
16	*Dictyosphaerium*	0	0	0	1	1	1	0	0	1
17	*Dimoorphococcus*	0	0	1	0	1	0	0	0	0
18	*Diogenes*	1	0	0	0	1	0	0	0	0
19	*Dispora*	0	0	0	1	1	0	0	0	0
20	*Euastridium*	1	1	0	1	3	0	0	0	0
21	*Euastropsis*	1		0	0	1	0	0	0	0
22	*Euastridium*	0	0	1	0	1	0	0	1	1
23	*Euastrum*	1	1	1	0	3	0	1	0	1
24	*Geminella*	0	1	0	0	1	0	0	0	0
25	*Genicularia*	0	0	1	0	1	0	0	0	0
26	*Gloeoactinium*	0	0	0	1	1	0	0	0	0
27	*Gloeocystis*	1	0	1	1	3	0	0	1	1
28	*Hazenia*	0	0	0	1	1	0	0	0	0
29	*Hormidiopsis.*	1	1	1	1	4	1	1	0	2
30	*Keriochlamys*	0	0	0	0	0	0	0	1	1
31	*Kirchneriella.*	1	0	0	0	1	0	0	0	0
32	*Mesotaenium*	0	0	1	0	1	0	0	0	0
33	*Micrasterias*	0	0	1	0	1	0	0	0	0
34	*Mycanthococcus*	1	0	0	0	1	0	0	0	0
35	*Nautococcus*	1	1	0	0	2	0	1	0	1
36	*Netrium*	1	0	0	0	1	0	0	0	0
37	*Oocystis*	0	0	1	0	1	0	0	0	0
38	*Palmodictyon*	0	0	1	0	1	0	0	0	0
39	*Pediastrum*	1	0	0	0	1	0	0	0	0
40	*Platydorina*	0	0	1	1	2	0	0	0	0
41	*Pleodorina*	0	0	0	0	0	1	0	1	2
42	*Polyedriopsis*	1	0	0	0	1	0	0	0	0
43	*Polytoma*	1	0	0	0	1	0	0	0	0
44	*Quadrigula*	0	0	1	0	1	0	0	0	0
45	*Radiofilum*	0	0	0	0	0	0	1	0	1
46	*Scenedesmus*	0	1	1	0	2	1	1	1	3
47	*Schroederia*	0	0	0	0	0	1	1	0	2
48	*Selenastrum*	0	0	1	0	1	0	0	0	0
49	*Sphaerellocystis.*	1	0	0	0	1	0	0	0	0

50	*Sphaerellopsis.*	1	0	1	0	2	0	0	0	0
51	*Stephanondphaera*	0	0	1	0	1	0	0	0	0
52	*Straurastrum.*	1	1	1	1	4	0	0	0	0
53	*Temnogametum*	0	0	0	0	0	0	1	1	2
54	*Tetradesmus*	1	0	0	0	1	0	0	0	0
55	*Tetraedron*	1	1	1	0	3	0	0	0	0
56	*Triploceras*	0	0	1	0	1	0	0	0	0
57	*Trochiscia*	0	1	0	0	1	0	0	0	0
58	*Volvox*	0	0	0	1	1	0	0	0	0
59	*Aphanocapsa*	0	0	1	0	1	0	0	0	0
60	*Aphanizomenon*	1	0	0	0	1	0	0	0	0
61	*Anabaena*	0	0	0	0	0	0	1	0	1
62	*Arthrospira*	0	0	0	0	0	0	1	1	2
63	*Bozia*	0	0	1	1	2	0	0	0	0
64	*Capsosira*	0	0	0	1	1	1	0	0	1
65	*Chamaesiphon*	0	0	0	1	1	0	0	0	0
66	*Chroococcus*	0	1	0	0	1	0	0	1	1
67	*Coelosphaerium*	0	1	1	0	2	1	1	1	3
68	*Cylindrospermum*	1	0	1	0	2	1	0	0	1
69	*Dactylococcopsis*	1	0	0	0	1	1	1	1	3
70	*Diplocolon*	1	1	1	1	4	1	0	0	1
71	*Eucapsis*	1	1	1	1	4	1	0	1	2
72	*Gloeocapsa*	1	1	1	1	4	1	1	1	3
73	*Gloeothece*	1	1	1	1	4	1	1	1	3
74	*Gomphosphaeria*	1	1	0	1	3	1	1	1	3
75	*Hapalosiphon*	0	0	0	0	0	0	1	0	1
76	*Heterohormogonium*	1	1	1	1	4	0	0	1	1
77	*Holopedium*	0	0	0	1	1	0	0	0	0
78	*Marssoniella*	1	0	1	0	2	0	0	0	0
79	*Merismopedia*	0	1	1	0	2	1	1	1	3
80	*Microchaete*	0	1	0	0	1	0	0	0	0
81	*Microcystis*	1	1	1	1	4	1	0	0	1
82	*Myxosarcina*	1	0	0	0	1	0	0	0	0
83	*Nodularia*	1	0	1	0	2	0	0	0	0
84	*Raphidiopsis*	0	0	1	1	2	0	0	0	0
85	*Stichosiphon*	0	0	1	1	2	0	1	0	1
86	*Stigonema*	1	1	0	0	2	0	0	0	0
87	*Symploca*	0	0	0	0	0	0	0	1	1
88	*Trichodesmium*	0	0	1	0	1	0	0	0	0
89	*Chlorameoba*	0	0	0	1	1	0	0	0	0
90	*Chlorocloster*	0	0	0	1	1	0	0	0	0
91	*Chlorogibba*	1	1	1	0	3	0	0	0	0
92	*Chrysamoeba*	0	0	0	0	0	1	0	0	1
93	*Chrysochromulina*	0	1	0	0	1	1	1	0	2
94	*Chrysococcus*	1	0	0	1	2	0	0	0	0
95	*Dichotomococcus*	0	0	0	1	1	0	0	0	0
96	*Dinobryon*	0	1	0	0	1	0	0	0	0
97	*Heterogloea*	0	0	1	0	1	0	0	0	0
98	*Hydrurus*	0	0	0	0	0	1	0	0	1
99	*Goniochloris*	0	1	0	0	1	0	0	0	0
100	*Mischococcus*	0	0	0	0	0	0	0	1	1

101	*Pseudostaurastrum*	1	0	0	0	1	1	1	0	2
102	*Tetraedriella*	1	1	1	1	4	0	0	0	0
103	*Trachychloron*	0	0	1	1	2	0	0	0	0
104	*Achnanthes*	1	0	1	0	2	0	0	0	0
105	*Actinocyclus*	0	0	0	0	0	1	0	0	1
106	*Amphicampa*	1	1	1	0	3	0	0	0	0
107	*Amphipora*	0	1	0	0	1	0	0	0	0
108	*Amphora*	1	1	1	0	3	0	0	0	0
109	*Aneumastis*	0	0	1	0	1	0	0	0	0
110	*Bacillaria*	1	0	0	0	1	0	0	0	0
111	*Biddulphia.*	0	1	0	0	1	0	0	0	0
112	*Brebissona*	1	0	0	0	1	0	0	0	0
113	*Campylodiscus*	0	0	1	0	1	0	0	0	0
114	*Cyclotella*	0	0	1	0	1	0	0	0	0
115	*Cymbella*	0	1	1	0	2	0	0	0	0
116	*Denticula*	1	1	0	0	2	0	0	0	0
117	*Diadesmus*	0	1	1	0	2	0	0	0	0
118	*Diatomella*	1	0	0	0	1	0	0	0	0
119	*Encyonema*	0	1	0	0	1	0	0	0	0
120	*Eunotia*	0	0	1	0	1	0	0	0	0
121	*Fragillaria*	1	1	0	0	2	0	0	0	0
122	*Gomphoneis*	1	0	0	0	1	0	0	0	0
123	*Gyrosigma*	1	1	0	0	2	0	0	0	0
124	*Hydrosera*	1	1	1	1	4	1	1	1	3
125	*Mastogloia*	0	1	0	0	1	0	0	0	0
126	*Meridion*	0	0	1	0	1	0	0	0	0
127	*Navicula*	1	1	0	0	2	0	0	0	0
128	*Opephora*	1	1	0	0	2	0	0	0	0
129	*Rhopalodia*	0	1	0	0	1	0	0	0	0
130	*Scoliopleura*	0	0	1	0	1	0	0	0	0
131	*Stauroneis*	1	0	0	0	1	0	0	0	0
132	*Surirella*	1	1	1	0	3	0	0	0	0
133	*Tabellaria*	1	1	0	0	2	0	0	0	0
134	*Euglena*	1	1	1	1	4	0	0	0	0
135	*Euglenomorpha*	1	1	0	0	2	0	0	0	0
136	*Phacus*	1	1	1	1	4	0	1	1	2
137	*Gonyostomum*	1	1	1	1	4	0	0	0	0
138	*Merotrichia sp.*	1	0	0	0	1	0	0	0	0
139	*Vacuolaria*	0	0	0	1	1	0	0	0	0
140	*Cystodinium*	0	0	0	1	1	0	0	0	0
141	*Glenodinium*	1	0	0	1	2	0	0	0	0
142	*Gloeodinium*	1	1	1	0	3	1	1	0	2
143	*Gymnodinium*	1	0	0	0	1	0	0	0	0
144	*Hypnodinium*	1	0	0	0	1	0	0	0	0
145	*Perinidium*	0	0	0	1	1	0	0	0	0
146	*Urococcus*	1	0	0	0	1	0	0	0	0
147	*Chroomonas*	0	1	0	0	1	0	0	0	0
148	*Cryptomonas*	1	1	0	0	2	0	0	0	0
149	*Rhodomonas*	1	1	0	0	2	0	0	0	0
150	*Tetragonidium*	1	1	1	1	4	0	0	0	0
	TOTAL	70	58	59	41	228	26	23	21	70

Mekong River has total species =134 species
Unique species = 79

Pak Mun Dam has total species =43 species
Unique species = 24

Jackknife estimate of species richness

S=s+((n-1)/n)^k

S =Jackknife estimate of species richness
s = Observed total number of species presene in n quadrats
n = Total number of quadrats sampled
k = Number of unique species

134

Jackknife estimate of species richness = 134 species

43

Jackknife estimate of species richness = 43 species

Variance(S)=(n-1/n)*[sum(j^2·fj)-k^2/n] 91.3125

5.33

n-1/n= 0.75

[sum((j^2)*fj)-k^2/n] 121.75

Variance of *(S) = 91.31*

Variance of *(S) = 5.33*

No. of unique spec	No. of quadrat containing *j* unique species, *fj*	*j^2*fj*
16	2 (samplr no.=B,D)	512
21	1 (sample no. = C)	441
27	1 (sample no. =A)	729
Sum =		**1682**
k^2/n =		**1560.25**

	*j^2*fj*
6	36
8	64
10	100
	200
	192

Jackknife estimator of species richness obtains confidence limit as follows: *t(alpha) = Student's t value for n-1 degree of freedom for the appropriate value.*

t(alpha) =3.182 (at df.=3, p=0.975)

Upper limit S = S + *t*Variance^0.5 =134 + 3.182*(91.31^0.5)* **164**

Lower limit S = S - *t*Variance^0.5 = 134 -3.182*(91.31^0.5)* **103.594**

Jackknife estimator of species richness will possibly occur from 164 species to 104 species in the Mekong River during rainy season 1997.

t(alpha) = 4.303 (at df.=2, p=0.975)

Upper limit S = S + *t*Variance^0.5 =43 + 4.303*(5.33^0.5)* **52.93**

Lower limit S = S - *t*Variance^0.5 = 43 -4.303*(5.33^0.5)* **33.07**

Jackknife estimator of species richness will possibly occur from 53 species to 33 species in the Pak Mun Dam during rainy season 1997.

Appendix 4.7a:Shanon-Wiener index of species diversity in primary forest (dring dry season, May 1998)

			Plot																	
No.	Local name	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	IVI
1	Kra bak	*Anisoptera costata* Korth.	6	9	1			2	6	11	9				7	1			52	11.30%
2	Teen nok	*Vitex pinnate* Linn.	1													2			3	0.65%
3	Saan kum	*Terminalia nigrovenulosa* Pierre ex Laness	1		2			1				1			1				6	1.30%
4	Kor khee muu	*Quercus helferiana* A. DC.	2									7				5			14	3.04%
5	Hwaar	*Eugenia cumini* (L.) Druce	1					1			1	1			1			1	6	1.30%
6	Duk phee	*Prismatomeris griffithii* Ridl.	1	2								1				2			6	1.30%
7	Pha yom	*Shorea floribunda* Kurz.	2		1	2	6	4	6	1	1	2	7	11	1	7	13	5	69	15.00%
8	Saan	*Dillenia obovata* (Bl.) Hoogl.	1	1	1	2	1	2	2	1	1		2		1	1	2		18	3.91%
9	Tiu khaao	*Cratoxylum formosum* (jacj) Dyer	1									1							2	0.43%
10	Pha yung	*Dalbergia cochinchinensis* Pierre	3					3				7	2	1	2	2	1	1	22	4.78%
11	Khee taeo	*Grewia elatostemoides* Coll. Et Hemsl.	1		2			1	1			1			2	2	3		13	2.83%
12	Som kop	*Hymennodictyon excelsum* Wall.	1			1						1							3	0.65%
13	Saai den	*Polyalthia cerasoides* Benth.ex Bedd.	1					5	1			2			1	2			12	2.61%
14	Sa long kong	*Grewia asiatica* Linn.	1							1					2				4	0.87%
15	Pra duu	*Pterocarpus macrocarpus* Kurz	1			1	1		1		2		1	2	1	3	2	5	20	4.35%
16	Pluei kra daeng	*Lagerstroemia floribunda* Jack	1					2								1		1	5	1.09%
17	Hmor		1		1							1							3	0.65%
18	Yor	*Morinda coreia* Ham.		1															1	0.22%
19	Lum duen	*Melodorum fruticosum* Lour.		1	2										2		3		8	1.74%
20	See	*Shorea thorellii* Pierre ex Laness.		4															4	0.87%
21	Kaeng	*Dialium cochinchinense* Pierre		3	4			1	1				1			1	1		12	2.61%
22	Ma lung				3						1								4	0.87%
23	Mueat	*Adinandra integerrima* T. Andres. Ex Dyer			1														1	0.22%
24	Ma lueam	*Canarium subulatum* Grill.			2	5	1	3								5	3		19	4.13%
25	Kra tang	*Xylopia vielana* Pierre			2			1	1										4	0.87%
26	Kan hin	*Hopea ferrea* Pierre			1														1	0.22%
27	Kaay sue	*Schima wallichii* (DC.) Korth.			3										1				4	0.87%
28	Pok	*Parinari anamense* Hance			1				1			1	1		2	3	1		10	2.17%
29	Mok	*Wrightia pubescens* R. Br.			1				1						1				3	0.65%
30	Yang don	*Polyalthia asteriella* Ridl.			1				1	1		1			2	1			7	1.52%
31	Kuun	*Cassia fistula* Linn.			1			1											2	0.43%
32	Phai rai khon	*Gigantochloa albociliata* Munro			1														1	0.22%
33	Mueat bai khon	*Hellicia petiolaris* Benn.				2	4	3	1			2	3			4	4		23	5.00%
34	Hnaam taeng	*Randia dasycarpa* Barkh.f.				1		1						3					5	1.09%
35	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.					1			1		1							3	0.65%
36	Po daeng	*Colona ebolata* Craib					1										5		6	1.30%
37	Kor hin	*Castanopsis piriformis* Hickel & A. Camus					4				1		2	1	1	2	6		17	3.70%
38	Kor kun	*Castanopsis brevispinula* Heckel & A. Camus						1				1							2	0.43%
39	Mao	*Eugenia grandis* Wight						1									1		2	0.43%
40	Kang hung	*Albizia chinensis* Merr.						2											2	0.43%
41	Nguei phaa	*Bombax anceps* Pierre						2		1						1	1	1	6	1.30%
42	Muei daeng	*Gracinia erythroclada* Kurz						1											1	0.22%
43	Ngueng suem	*Calycopteris floribunda* Lamk						2	2							1			5	1.09%

44	Thom	*Mitragyna javanica* Koord. & Val							2			1			1	5			9	1.96%	
45	Hnaam han	*Acacia comosa* Gagnep.							1										1	0.22%	
46	Ma kam pom	*Phyllanthus emblica* Linn.							1		1				1				3	0.65%	
47	Sa kang	*Vitex tripinnate* Merr.										1							1	0.22%	
48	Mueat ta baeng											1							1	0.22%	
49	Kon som	*Grewia microcos* Linn.										1				1			2	0.43%	
50	Hard	*Artocarpus lakoocha* Roxb.										1					1		2	0.43%	
51	Rang sean											1		1		1	2	1	6	1.30%	
52	Teui											1							1	0.22%	
53	Pha uung	*Calophyllum saigonense* Pierre										1							1	0.22%	
54	Pluei lueat	*Terminalia corticorsa* Pierre ex Laness.												2			1	2	5	1.09%	
55	Mueat bai luaem													1		1			2	0.43%	
56	Pung muu														1				1	0.22%	
57	Hnaam khee had	*Azima sarmentosa* (Bl.) Benth & Hook													1				1	0.22%	
58	Mao	*Eugenia grandis* Wight														1			1	0.22%	
59	Taa nok krot	*Dillenia ovata* Wall.ex Hook.f.& Thomas														1			1	0.22%	
60	Mueat bai kliang	*Helicia robusta* (Roxb.) R. Br.ex Wall.						4	3								2		9	1.96%	
61	Lueat nok	*Horsfieldia amygdaing* Warb.															1		1	0.22%	
62	Khaao	*Haldina cordifolia* Ridsd.															1		1	0.22%	
	TOTAL		26	21	31	14	19	44	32	17	17	39	19	22	32	56	54	17	460	100.00%	SD.
	Shannon-Wiener index of diversity		2.777	2.331	4.067	2.550	2.590	4.235	3.695	1.849	2.292	4.124	2.648	2.332	4.011	4.308	3.801	2.604	Mean=	3.138	0.852
	$H'_{max}=\log_2 S$		4.087	2.807	4.248	2.807	3.000	4.459	4.087	2.807	3.000	4.585	3.000	3.000	4.322	4.644	4.322	3.000	Mean=	3.636	0.748
	Evenness $(J')=H'/H'_{max}$		0.679	0.830	0.957	0.908	0.863	0.950	0.904	0.659	0.764	0.899	0.883	0.777	0.928	0.928	0.880	0.868	Mean=	0.855	0.091
	Simpson 's index of diversity(1-D)		0.929	0.744	0.932	0.796	0.798	0.939	0.898	0.561	0.685	0.915	0.798	0.707	0.916	0.938	0.898	0.796	Mean=	0.828	0.112
	Simpson's index (D)		0.071	0.256	0.068	0.204	0.202	0.061	0.102	0.439	0.315	0.085	0.202	0.293	0.084	0.062	0.102	0.204	Mean=	0.172	0.112
	Maximum index of diversity(D_{max})		0.941	0.857	0.947	0.857	0.875	0.955	0.941	0.857	0.875	0.958	0.875	0.875	0.950	0.960	0.950	0.875	Mean=	0.909	0.043
	Evenness (Index of diversity/D_{max})		0.987	0.868	0.984	0.929	0.912	0.984	0.955	0.654	0.783	0.955	0.912	0.808	0.964	0.977	0.945	0.909	Mean=	0.908	0.091
	No. of species (Tree)		17	7	19	7	8	22	17	7	8	24	8	8	20	25	20	8	Mean=	14.063	6.962
	No. of species (Sapling)		1	2	6	4	1	1	2	0	3	7	1	0	5	17	11	0	Mean=	3.813	4.651

Appendix 4.7b: Shanon-Wiener index of species diversity in Thai secondary forest (dring dry season, April-May 1998)																				
		Plot																		
No.	Species	4	6	8	9	10	14	15	17	18	21	22	23	24	26	27	28	29	30	Total	IVI
1	*Irvingia malayana* Oliv. wx A. Benn.		11		4	3	4			7	1		1					3		34	4.28%
2	*Shorea obtusa* Wall.	4	2		8	17	8	9	13	9	2	4	3	14	7	15		24	14	153	19.27%
3	*Vitex pinnate* Linn.		1									1			1					3	0.38%
4	*Erythrophleum teysmannii* Craib		10						11	7										28	3.53%
5	*Randia dasycarpa* Bakh.f.	2										1	1							4	0.50%
6	*Shorea floribunda* Kurz														1				2	3	0.38%
7	*Dalbergia cochinchinensis* Pierre		2																	2	0.25%
8	*Ptercarpus macrocarpus* Kurz		5	1		1					1		1				1			10	1.26%
9	*Terminalia corticorsa* Pierre ex Laness.		1		3	2		3				3	1							13	1.64%
10	*Morinda coreia* Ham	3		4	1	1	1				5	1	2	1	3		1		5	28	3.53%
11	*Canarium subulatum* Grill.			1									3	2						6	0.76%
12	*Memecylon scutellatum* Naud.						1	15												16	2.02%
13	*Polyalthia cerasoides* Benth. ex Bedd.			8													1			9	1.13%
14	*Arundinaria ciliata* A. Camus			2		1								1	19		4			27	3.40%
15	*Xylia xylocarpa* Taub.	1	1	1	9	6	2	10		1	7	11	7	11	3		5	1	13	89	11.21%
16	*Lagerstroemia duperreana* Pierre			5																5	0.63%
17	*Wrightia pubescens* R. Br.			2							1	3								6	0.76%
18	*Terminalia bellerica* Roxb.			4	1									1			1			7	0.88%
19	*Terminalia nigrovenulosa* Pierre ex Laness.			1							2			1	1		4			9	1.13%
20	*Helicia robusta* (Roxb.)						1	1			2	1								5	0.63%
21	*Milletoa leucantha* Kurz		1	1							1	1	1	3	1	1		2	9	21	2.64%
22	*Lagerstroemia calyculata* Kurz.			3													3			6	0.76%
23	*Helicial petiolaris* Benn.		1		1	16	6	18	1	5		6						2	1	57	7.18%
24	Pha lin				2															2	0.25%
25	*Sindora siamensis* Teijsm. ex Miq.				1															1	0.13%
26	*Buchanania reticulatata* Hance				1	9		3			1									14	1.76%
27	*Erythrophleum succirubrum* Gagnep.					2	1													3	0.38%
28	*Shorea siamensis*					2														2	0.25%
29	*Vitex glabrata R. Br.*					1		1												2	0.25%
30	*Dipterocarpus tuberculatus* Roxb.						11	10	4											25	3.15%
31	*Parinaria anamense* Hance						1		1											2	0.25%
32	*Passiflora foetida* Linn.						4			1										5	0.63%
33	*Shorea thorellii* Pierre ex Laness.								1									5		6	0.76%
34	*Phyllanthus emblica* Linn.	1						3			4	1	1	1					2	13	1.64%
35	*Melanorrhoea laccifera* Pierre								2											2	0.25%
36	*Dipterocarpus obtusidolius* Teysm. ex Miq.								10							2		1		13	1.64%
37	*Diospyros ehretioides* Wall.	2									1		1	4	2			1	1	12	1.51%
38	*Careya sphaerica* Roxb.									1			1					1		3	0.38%
39	*Homalium tomentosum* Benth.										7	3	12							22	2.77%
40	*Spondias bipinnata* Airy Shaw & Forman										2	1		1			2			6	0.76%
41	*Lennea coromandelica* (Houtt.) Merr.										2	11								13	1.64%
42	*Hymenodictyon excelsum* Wall.	1	1								5						5			12	1.51%
43	*Dillenia ovata* Wall ex Hoook.f. & Thomas										1									1	0.13%
44	*Colona ebolata* Craib.										1						1			2	0.25%
45	*Haldina cordifolia* Ridsd.	5									1	6	3	4			1			20	2.52%
46	*Lagerstroemia macrocarpa* Wall.		1																	1	0.13%
47	*Bauhinia acuminata* Linn.	1																		1	0.13%

48	*Acacia sp.*	2												1						3	0.38%
49	*Eugenia euneura* Craib										2		1							3	0.38%
50	Khee kra thoe?										4		5				1		1	11	1.39%
51	*Livistona speciosa*											1	1				7			9	1.13%
52	*Parkia timoriana* (DC.) Merr.	1										1					1			3	0.38%
53	*Bombax anceps* Pierre												1	1			1			3	0.38%
54	*Mangifera longipetiolata* King													1						1	0.13%
55	*Terminalia alata*	4					1	1						3						9	1.13%
56	*Ficus sp.*															1				1	0.13%
57	*Mitragyna javanica* Koord. & Val														2		4		3	9	1.13%
58	Unidentified 1	1															3			4	0.50%
59	*Anogeissus acuminata* Wall.																2			2	0.25%
60	*Albizia lebbeck* (L.) Benth.																1			1	0.13%
61	*Cassia fistula* Linn.																1			1	0.13%
62	*Miluisa velutina* Hook.f. Thorn	3																		3	0.38%
63	*Pectacme sauvis*	2																		2	0.25%
64	*Millettia pubinervis* Kurz.	1																		1	0.13%
65	*Gardenia coronaria* Ham.									1										1	0.13%
66	*Vitex tripinnate* Merr.												2							2	0.25%
67	*Eugenia grandis* Wight.																		1	1	0.13%
	Total number of individual plots	34	37	33	31	61	41	74	43	32	53	56	48	50	40	19	50	40	52	794	100.00%
																				MEAN	SD.
	Shannon-Wiener index of diversity	2.771	2.861	3.215	2.784	2.844	3.027	2.927	2.418	2.517	4.020	3.497	3.657	3.267	2.475	1.058	4.036	2.062	2.810	2.903	0.704
	$H'_{max}=\log_2 S$	4.000	3.585	3.585	3.322	3.585	3.585	3.459	3.000	3.000	4.392	4.087	4.248	4.000	3.322	2.000	4.392	3.170	3.459	3.566	0.588
	Evenness $(J')=H'/H'_{max}$	0.693	0.798	0.897	0.838	0.793	0.844	0.846	0.806	0.839	0.915	0.856	0.861	0.817	0.745	0.529	0.919	0.650	0.812	0.803	0.097
	Simpson 's index of diversity(1-D)	0.937	0.809	0.869	0.815	0.815	0.844	0.843	0.777	0.797	0.9	0.	0.	0.	0.7	0. 0	0.9	0.	0.	0. 0	0.
		0.0	0. 9	0.	0.	0.	0.	0. 7	0.	0. 0	0.07	0. 7	0.	0.	0. 0	0.07	0. 9	0.	0.	0. 90	0.
		0.9 7	0.9 7	0.9 7	0.900	0.9 7	0.9 7	0.909	0. 7	0. 7	0.9	0.9	0.9 7	0.9	0.900	0.7 0	0.9	0. 9	0.909	0.90	0.0
		0.999	0.	0.9	0.90	0. 9	0.9	0.9 7	0.	0.9	0.970	0.9	0.9	0.90	0. 0	0. 0	0.97	0. 7	0.900	0.	0.
	.				0							7	9		0			9		.7	.

Appendix 4.7c: Shanon-Wiener index of species diversity in Thai riparian forest (dring dry season, April-May 1998

No.	Species	2	5	7	20	Total	IVI		
1	*Irvingia malayana* Oliv. wx A. Benn.		2			2	1.20%		
2	*Shorea obtusa* Wall.		8			8	4.79%		
3	*Vitex pinnate* Linn.				1	1	0.60%		
4	*Erythrophleum teysmannii* Craib		2			2	1.20%		
5	*Randia dasycarpa* Bakh.f.		3			3	1.80%		
6	*Shorea floribunda* Kurz		1			1	0.60%		
7	*Dalbergia cochinchinensis* Pierre		2			2	1.20%		
8	*Grewia asiatica* Linn.		4			4	2.40%		
9	*Ptercarpus macrocarpus* Kurz		2			2	1.20%		
10	*Terminalia corticorsa* Pierre ex Laness.		1			1	0.60%		
11	*Morinda coreia* Ham	1		2		3	1.80%		
12	*Canarium subulatum* Grill.		1		1	2	1.20%		
13	*Helicia petiolaris* Benn.*		1			1	0.60%		
14	*Arundinaria ciliata* A. Camus	10				10	5.99%		
15	*Xylia xylocarpa* Taub.	2		18		20	11.98%		
16	*Wrightia pubescens R. Br.*	5		1	3	9	5.39%		
17	*Terminalia nigrovenulosa* Pierre ex Laness.				1	1	0.60%		
18	*Cratoxylum pruniflorum* Gogel.			2		2	1.20%		
19	*Careya sphaerica* Roxb.			3		3	1.80%		
20	*Homalium tomentosum* Benth.	18		1		19	11.38%		
21	*Hymenodictyon excelsum* Wall.	7			2	9	5.39%		
22	*Haldina cordifolia* Ridsd.	4		5		9	5.39%		
23	*Eugenia euneura* Craib			1		1	0.60%		
24	Khee kra thoe?			2	1	3	1.80%		
25	*Livistona speciosa*	5		2	4	11	6.59%		
26	Unidentified 1*				1	1	0.60%		
27	Unidentified 2				1	1	0.60%		
28	*Albizia lebbeck* (L.) Benth.*			1		1	0.60%		
29	*Cassia fistula* Linn.*				1	1	0.60%		
30	*Gigantochloa albocilata* Munro			2		2	1.20%		
31	Phai hlai kliang				1	1	0.60%		
32	*Dillenia pentagyna* Roxb.	2		17		19	11.38%		
33	*Colona ebolata* Craib.	1				1	0.60%		
34	*Passiflora foetida* Linn.		1			1	0.60%		
35	Ee hen		2			2	1.20%		
36	*Strychnow rupicola* Pierre ex Dop.			4		4	2.40%		
37	Tub tao			3		3	1.80%		
38	*Elaeocarpus hygrophilus* Kurz			1		1	0.60%		
	Total number of individual plots	55	30	65	17	167	100.00%		
								SD.	
	Shannon-Wiener index of diversity	2.375	3.348	3.197	3.220	MEAN=	3.035	0.445	
	$H'_{max}=\log_2 S$	3.322	3.700	4.000	3.459	MEAN=	3.620	0.297	
	Evenness $(J')=H'/H'_{max}$	0.715	0.905	0.799	0.931	MEAN=	0.837	0.100	
	Simpson 's index of diversity(1-D)	0.905	0.873	0.835	0.872	MEAN=	0.871	0.029	
	Simpson's index (D)	0.095	0.127	0.165	0.128	MEAN=	0.129	0.029	
	Maximum index of diversity(D_{max})	0.900	0.923	0.938	0.909	MEAN=	0.917	0.016	
	Evenness (Index of diversity/D_{max})	1.006	0.946	0.891	0.959	MEAN=	0.950	0.047	
	No. of species (Tree)	10	13	16	11	MEAN=	12.500	2.646	

Appendix 4.8: Shanon-Wiener index of phytoplankton species diversity in Mekong River (Mek) and Pak Mun Dam (Mun) during rainy season 1997.

No.	Scientific name	MekA.	MekB.	MekC.	MekD.	TOTAL(Mek.)	MunA.	MunB.	MunC.	TOTAL(Mun)
1	*Ankistrodesmus*	0	0	0	0	0	0	0	1	1
2	*Askenasyella*	1	0	0	0	1	1	0	0	1
3	*Brachiomonas*	0	1	1	0	2	0	0	0	0
4	*Cerasterias*	0	1	0	0	1	0	0	0	0
5	*Chlamydomonas.*	1	0	0	0	1	0	0	0	0
6	*Chlorangiella*	0	1	0	0	1	0	0	0	0
7	*Chlorococcum*	0	0	0	0	0	1	0	0	1
8	*Chloromonas*	1	0	0	0	1	0	0	0	0
9	*Closteriopsis*	1	1	0	0	2	0	0	0	0
10	*Closterium*	1	1	0	1	3	0	0	0	0
11	*Conochaete*	0	0	1	0	1	0	0	0	0
12	*Coronastrum*	0	0	0	1	1	0	0	0	0
13	*Corone*	0	0	0	1	1	0	0	0	0
14	*Cosmocladium*	0	0	0	0	0	1	1	0	2
15	*Dactylothece.*	0	1	0	0	1	0	0	0	0
16	*Dictyosphaerium*	0	0	0	1	1	1	0	0	1
17	*Dimoorphococcus*	0	0	1	0	1	0	0	0	0
18	*Diogenes*	1	0	0	0	1	0	0	0	0
19	*Dispora*	0	0	0	1	1	0	0	0	0
20	*Euastridium*	1	1	0	1	3	0	0	0	0
21	*Euastropsis*	1		0	0	1	0	0	0	0
22	*Euastridium*	0	0	1	0	1	0	0	1	1
23	*Euastrum*	1	1	1	0	3	0	1	0	1
24	*Geminella*	0	1	0	0	1	0	0	0	0
25	*Genicularia*	0	0	1	0	1	0	0	0	0
26	*Gloeoactinium*	0	0	0	1	1	0	0	0	0
27	*Gloeocystis*	1	0	1	1	3	0	0	1	1
28	*Hazenia*	0	0	0	1	1	0	0	0	0
29	*Hormidiopsis.*	1	1	1	1	4	1	1	0	2
30	*Keriochlamys*	0	0	0	0	0	0	0	1	1
31	*Kirchneriella.*	1	0	0	0	1	0	0	0	0
32	*Mesotaenium*	0	0	1	0	1	0	0	0	0
33	*Micrasterias*	0	0	1	0	1	0	0	0	0
34	*Mycanthococcus*	1	0	0	0	1	0	0	0	0
35	*Nautococcus*	1	1	0	0	2	0	1	0	1
36	*Netrium*	1	0	0	0	1	0	0	0	0
37	*Oocystis*	0	0	1	0	1	0	0	0	0
38	*Palmodictyon*	0	0	1	0	1	0	0	0	0
39	*Pediastrum*	1	0	0	0	1	0	0	0	0
40	*Platydorina*	0	0	1	1	2	0	0	0	0
41	*Pleodorina*	0	0	0	0	0	1	0	1	2
42	*Polyedriopsis*	1	0	0	0	1	0	0	0	0
43	*Polytoma*	1	0	0	0	1	0	0	0	0
44	*Quadrigula*	0	0	1	0	1	0	0	0	0
45	*Radiofilum*	0	0	0	0	0	0	1	0	1
46	*Scenedesmus*	0	1	1	0	2	1	1	1	3
47	*Schroederia*	0	0	0	0	0	1	1	0	2

48	*Selenastrum*	0	0	1	0	1	0	0	0	0			
49	*Sphaerellocystis.*	1	0	0	0	1	0	0	0	0			
50	*Sphaerellopsis.*	1	0	1	0	2	0	0	0	0			
51	*Stephanondphaera*	0	0	1	0	1	0	0	0	0			
52	*Straurastrum.*	1	1	1	1	4	0	0	0	0			
53	*Temnogametum*	0	0	0	0	0	0	1	1	2			
54	*Tetradesmus*	1	0	0	0	1	0	0	0	0			
55	*Tetraedron*	1	1	1	0	3	0	0	0	0			
56	*Triploceras*	0	0	1	0	1	0	0	0	0			
57	*Trochiscia*	0	1	0	0	1	0	0	0	0			
58	*Volvox*	0	0	0	1	1	0	0	0	0			
59	*Aphanocapsa*	0	0	1	0	1	0	0	0	0			
60	*Aphanizomenon*	1	0	0	0	1	0	0	0	0			
61	*Anabaena*	0	0	0	0	0	0	1	0	1			
62	*Arthrospira*	0	0	0	0	0	0	1	1	2			
63	*Bozia*	0	0	1	1	2	0	0	0	0			
64	*Capsosira*	0	0	0	1	1	1	0	0	1			
65	*Chamaesiphon*	0	0	0	1	1	0	0	0	0			
66	*Chroococcus*	0	1	0	0	1	0	0	1	1			
67	*Coelosphaerium*	0	1	1	0	2	1	1	1	3			
68	*Cylindrospermum*	1	0	1	0	2	1	0	0	1			
69	*Dactylococcopsis*	1	0	0	0	1	1	1	1	3			
70	*Diplocolon*	1	1	1	1	4	1	0	0	1			
71	*Eucapsis*	1	1	1	1	4	1	0	1	2			
72	*Gloeocapsa*	1	1	1	1	4	1	1	1	3			
73	*Gloeothece*	1	1	1	1	4	1	1	1	3			
74	*Gomphosphaeria*	1	1	0	1	3	1	1	1	3			
75	*Hapalosiphon*	0	0	0	0	0	0	1	0	1			
76	*Heterohormogonium*	1	1	1	1	4	0	0	1	1			
77	*Holopedium*	0	0	0	1	1	0	0	0	0			
78	*Marssoniella*	1	0	1	0	2	0	0	0	0			
79	*Merismopedia*	0	1	1	0	2	1	1	1	3			
80	*Microchaete*	0	1	0	0	1	0	0	0	0			
81	*Microcystis*	1	1	1	1	4	1	0	0	1			
82	*Myxosarcina*	1	0	0	0	1	0	0	0	0			
83	*Nodularia*	1	0	1	0	2	0	0	0	0			
84	*Raphidiopsis*	0	0	1	1	2	0	0	0	0			
85	*Stichosiphon*	0	0	1	1	2	0	1	0	1			
86	*Stigonema*	1	1	0	0	2	0	0	0	0			
87	*Symploca*	0	0	0	0	0	0	0	1	1			
88	*Trichodesmium*	0	0	1	0	1	0	0	0	0			
89	*Chlorameoba*	0	0	0	1	1	0	0	0	0			
90	*Chlorocloster*	0	0	0	1	1	0	0	0	0			
91	*Chlorogibba*	1	1	1	0	3	0	0	0	0			
92	*Chrysamoeba*	0	0	0	0	0	1	0	0	1			
93	*Chrysochromulina*	0	1	0	0	1	1	1	0	2			
94	*Chrysococcus*	1	0	0	1	2	0	0	0	0			
95	*Dichotomococcus*	0	0	0	1	1	0	0	0	0			
96	*Dinobryon*	0	1	0	0	1	0	0	0	0			

97	*Heterogloea*	0	0	1	0	1	0	0	0	0			
98	*Hydrurus*	0	0	0	0	0	1	0	0	1			
99	*Goniochloris*	0	1	0	0	1	0	0	0	0			
100	*Mischococcus*	0	0	0	0	0	0	0	1	1			
101	*Pseudostaurastrum*	1	0	0	0	1	1	1	0	2			
102	*Tetraedriella*	1	1	1	1	4	0	0	0	0			
103	*Trachychloron*	0	0	1	1	2	0	0	0	0			
104	*Achnanthes*	1	0	1	0	2	0	0	0	0			
105	*Actinocyclus*	0	0	0	0	0	1	0	0	1			
106	*Amphicampa*	1	1	1	0	3	0	0	0	0			
107	*Amphipora*	0	1	0	0	1	0	0	0	0			
108	*Amphora*	1	1	1	0	3	0	0	0	0			
109	*Aneumastis*	0	0	1	0	1	0	0	0	0			
110	*Bacillaria*	1	0	0	0	1	0	0	0	0			
111	*Biddulphia.*	0	1	0	0	1	0	0	0	0			
112	*Brebissona*	1	0	0	0	1	0	0	0	0			
113	*Campylodiscus*	0	0	1	0	1	0	0	0	0			
114	*Cyclotella*	0	0	1	0	1	0	0	0	0			
115	*Cymbella*	0	1	1	0	2	0	0	0	0			
116	*Denticula*	1	1	0	0	2	0	0	0	0			
117	*Diadesmus*	0	1	1	0	2	0	0	0	0			
118	*Diatomella*	1	0	0	0	1	0	0	0	0			
119	*Encyonema*	0	1	0	0	1	0	0	0	0			
120	*Eunotia*	0	0	1	0	1	0	0	0	0			
121	*Fragillaria*	1	1	0	0	2	0	0	0	0			
122	*Gomphoneis*	1	0	0	0	1	0	0	0	0			
123	*Gyrosigma*	1	1	0	0	2	0	0	0	0			
124	*Hydrosera*	1	1	1	1	4	1	1	1	3			
125	*Mastogloia*	0	1	0	0	1	0	0	0	0			
126	*Meridion*	0	0	1	0	1	0	0	0	0			
127	*Navicula*	1	1	0	0	2	0	0	0	0			
128	*Opephora*	1	1	0	0	2	0	0	0	0			
129	*Rhopalodia*	0	1	0	0	1	0	0	0	0			
130	*Scoliopleura*	0	0	1	0	1	0	0	0	0			
131	*Stauroneis*	1	0	0	0	1	0	0	0	0			
132	*Surirella*	1	1	1	0	3	0	0	0	0			
133	*Tabellaria*	1	1	0	0	2	0	0	0	0			
134	*Euglena*	1	1	1	1	4	0	0	0	0			
135	*Euglenomorpha*	1	1	0	0	2	0	0	0	0			
136	*Phacus*	1	1	1	1	4	0	1	1	2			
137	*Gonyostomum*	1	1	1	1	4	0	0	0	0			
138	*Merotrichia sp.*	1	0	0	0	1	0	0	0	0			
139	*Vacuolaria*	0	0	0	1	1	0	0	0	0			
140	*Cystodinium*	0	0	0	1	1	0	0	0	0			
141	*Glenodinium*	1	0	0	1	2	0	0	0	0			
142	*Gloeodinium*	1	1	1	0	3	1	1	0	2			
143	*Gymnodinium*	1	0	0	0	1	0	0	0	0			
144	*Hypnodinium*	1	0	0	0	1	0	0	0	0			
145	*Perinidium*	0	0	0	1	1	0	0	0	0			

146	*Urococcus*	1	0	0	0	1	0	0	0	0			
147	*Chroomonas*	0	1	0	0	1	0	0	0	0			
148	*Cryptomonas*	1	1	0	0	2	0	0	0	0			
149	*Rhodomonas*	1	1	0	0	2	0	0	0	0			
150	*Tetragonidium*	1	1	1	1	4	0	0	0	0			
	TOTAL	70	58	59	41	228	26	23	21	70			
	Mekong River has total species =134 species							Pak Mun Dam has total species =43 species					
	Unique species = 79							Unique species = 24					
Jackknife estimate of species richness													
S=s+((n-1)/n)^k													
S =Jackknife estimate of species richness													
s = Observed total number of species presene in n quadrats													
n = Total number of quadrats sampled													
k = Number of unique species													
	134									43			
Jackknife estimate of species richness = 134 species								**Jackknife estimate of species richness = 43 species**					
Variance*(S)=(n-1/n)*[sum(j^2*fj)-k^2/n]*							91.3125						5.33
	n-1/n=	0.75											
	[sum((j^2)*fj)-k^2/n]	121.75											
Variance of *(S) = 91.31*								**Variance of *(S) = 5.33***					
	No. of unique spec	No. of quadrat containing *j* unique species, *fj*					***j^2*fj***						***j^2*fj***
	16	2 (samplr no.=B,D)					512			6			36
	21	1 (sample no. = C)					441			8			64
	27	1 (sample no. =A)					729			10			100
	Sum =						**1682**						**200**
	k^2/n =						**1560.25**						**192**
Jackknife estimator of species richness obtains confidence limit as follows: *t(alpha) = Student's t value for n-1 degree of freedom for the appropriate value.*													
t(alpha) =3.182 (at df.=3, p=0.975)													
Upper limit S = S + *t*Variance^0.5 =134 + 3.182*(91.31^0.5)*							**164**						
Lower limit S = S - *t*Variance^0.5 = 134 -3.182*(91.31^0.5)*							**103.594**						
Jackknife estimator of species richness will possibly occur from 164 species to 104 species in the Mekong River during rainy season 1997.													
t(alpha) = 4.303 (at df.=2, p=0.975)													
Upper limit S = S + *t*Variance^0.5 =43 + 4.303*(5.33^0.5)*							**52.93**						
Lower limit S = S - *t*Variance^0.5 = 43 -4.303*(5.33^0.5)*							**33.07**						
Jackknife estimator of species richness will possibly occur from 53 species to 33 species in the Pak Mun Dam during rainy season 1997.													

APPENDIX II: CHAPTER FIVE

5.1 A comparison of biomass of the different equations and size-class of tree in Thai forest during the dry season 1998

5.2 Annual maximum and minimum temperature at Khong Chiam during 1988-1997

5.3 Annual precipitation (mm) at Khong Chiam during 1988-1997

5.4 Monthly data of water quality such as DO, conductivity, pH, temperature, flow and total suspended solid at Khong Chiam in the Mekong River during 1988-1997

5.5 Water level (MSL) at Khong Chiam and Ban Kum

5.6 A comparison of ground floor biomass of Thai study site during the rainy and dry season

5.7 Estimation of size-class of tree species in the difference forest types

5.8 Carbon storage and carbon storage value in terrestrial ecosystems during 50Year-period under three scenarios

Appendix 5.1: A comparison of biomass of the different equations and size-class of tree in Thai forest during dry season (April' 98).																
Tree no.	Local name	Sci. name	Circumference	DBH*(cm)	DBH2	HeightB	HeightB2*	D2HB	HeightOg	D2HOg	BiomOg2	BiomB	BiomB2	BiomBDE	BiomOg2	D2HB2
1	" "	*Haldina cordifolia* Ridsd.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
2	Chig/Teng	*Shorea obtusa* Wall.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
3	Mueat bai khon	*Aporusa ficifolia* Baill.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
4	Chig/Teng	*Shorea obtusa* Wall.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
5	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
6	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
7	Muaeat ae	*Memecylon scutellatum* Nuad.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
8	Muaeat ae	*Memecylon scutellatum* Nuad.	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
9	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
10	" " "	*Erythroleum teysmannii* Craib	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
11	Yo paa	*Morinda coreia* Ham	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
12	Yo paa	*Morinda coreia* Ham	14.5	4.615	21.303	6.954	9.100	148.13	4.304	91.693	3.145	5.718	7.867	4.740	3.145	193.86
13	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
14	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
15	Rang haeng	*Pectacme suavis*	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
16	Som kob	*Hymenodictyon excelsum Wall.*	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
17	Ka ka lao		15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
18	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
19	Tiu daeng	*Cartoxylum pruniflorum* Gogel.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
20	Chig/Teng	*Shorea obtusa* Wall.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
21	Daeng	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
22	Daeng	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
23	Muaeat bai kliang		15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
24	Daeng	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
25	Ee tok	*Passiflora foetida* Linn.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
26	" "	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
27	Muaeat bai kliang	*Helicia robusta* (Roxb.) R. Br. ex Wall.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
28	Muaeat bai khon	*Aporusa ficifolia* Baill.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
29	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
30	Muaeat bai khon	*Aporusa ficifolia* Baill.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
31	Muaeat ae	*Memecylon scutellatum* Nuad.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
32	Chig/Teng	*Shorea obtusa* Wall.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
33	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
34	" " "	*Erythroleum teysmannii* Craib	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
35	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
36	Phok	*Parinari anamense* Hance	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
37	Chig/Teng	*shorea obtusa* Wall.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
38	Mok	*Wrightia pubescens* R. Br.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
39	Taa nok krot	*Dillenia ovata* Wall. ex Hook.f. & Thom	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
40	Ma kam pom	*Phyllanthus emblica* Linn.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
41	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
42	" "		15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
43	Kok kan	*Canarium subulatum* Guill.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10

44	Daeng	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
45	Thom	*Mitragyna javanica Koord. & Val*	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
46	Muaeat bai khon	*Aporusa ficifolia* Baill.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
47	Chig/Teng	*Shorea obtusa* Wall.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
48	Daeng	*Xylia xylocarpa* Taub.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
49	Sa thon	*Milletoa leucantha* Kurz.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
50	Phaeng/San chaang	*Dillenia pentagyna Roxb.*	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
51	Chig/Teng	*Shorea obtusa* Wall.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
52	Chig/Teng	*Shorea obtusa* Wall.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
53	Daeng	*Xylia xylocarpa* Taub.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
54	" "	*Shorea obtusa* Wall.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
55	Mueat bai khon	*Aporusa ficifolia* Baill.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
56	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
57	Muaeat ae	*Memecylon scutellatum* Nuad.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
58	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
59	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
60	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
61	" " "		15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
62	" " "		15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
63	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
64	Ma kam pom	*Phyllanthus emblica* Linn.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
65	Ma kok paa	*Spondias biinnata* Airy Shaw & Forman	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
66	Sa thon	*Milletoa leucantha* Kurz.	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03
67	Po gaeng		16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
68	Unknown species	*Diospyros sp.*	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
69	Sa thon	*Milletoa leucantha Kurz.*	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
70	Tiu daeng	*Cartoxylum pruniflorum* Gogel.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
71	Pluei see daa	*Lagerstroemia duperreana Pierre*	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
72	Pluei see daa	*Lagerstroemia duperreana Pierre*	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
73	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
74	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
75	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
76	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
77	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
78	Daeng	*Xylia xylocarpa* Taub.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
79	Ee tok	*Passiflora foetida* Linn.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
80	Muaeat bai khon	*Aporusa ficifolia* Baill.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
81	Daeng	*Xylia xylocarpa* Taub.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
82	Muaeat ae	*Memecylon scutellatum* Nuad.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
83	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
84	Chig/Teng	*Shorea obtusa* Wall.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
85	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
86	Mai pae/Sa kang	*Vitex tripinnate* Merr.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
87	Daeng	*Xylia xylocarpa* Taub.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
88	Thom	*Mitragyna javanica Koord. & Val*	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66

89	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm, ex	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
90	Sa thon	*Milletoa leucantha* Kurz.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
91	Sa thon	*Milletoa leucantha* Kurz.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
92	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
93	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
94	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
95	Khaao	*Haldina cordifolia* Ridsd.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
96	Mok	*Wrightia pubescens* R. Br.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
97	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
98	Daeng	*Xylia xylocarpa* Taub.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
99	Saai den	*Polyathia cerasoides* Benth. ex Bedd.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
100	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
101	Thom		16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
102	Yo paa	*Morinda coreia* Ham	16.5	5.252	27.585	7.483	9.389	206.41	4.818	132.915	4.476	7.893	10.081	6.571	4.476	258.98
103	Unknown species		17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
104	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
105	Kor	*Livistona speciosa*	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
106	Tub tao/Huean kwaa	*Diospyros ehretioides Wall.*	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
107	Chig/Teng	*Shorea obtusa* Wall.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
108	Chig/Teng	*Shorea obtusa* Wall.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
109	Saat	*Erythrophleum succirubrum* Gagnep.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
110	Ee tok	*Passiflora foetida* Linn.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
111	Daeng	*Xylia xylocarpa* Taub.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
112	Muaeat bai khon	*Aporusa ficifolia* Baill.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
113	Muaeat ae	*Memecylon scutellatum* Nuad.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
114	Muaeat ae	*Memecylon scutellatum* Nuad.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
115	Muaeat bai khon	*Aporusa ficifolia* Baill.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
116	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
117	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
118	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
119	Mok	*Wrightia pubescens* R. Br.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
120	Daeng	*Xylia xylocarpa* Taub.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
121	Daeng	*Xylia xylocarpa* Taub.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
122	Liang	*Parkia timoriana* (DC.) Merr.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
123	Mok	*Wrightia pubescens* R. Br.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
124	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
125	Mao		17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
126	Thom		17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
127	Sa thon	*Milletoa leucantha* Kurz.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
128	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
129	Chig/Teng	*Shorea obtusa* Wall.	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
130	Khai nao	*Vitex glabrata R. Br.*	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
131	Muaeat bai khon	*Aporusa ficifolia* Baill.	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
132	Ma kham pom	*Phyllanthus emblica* Linn.	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
133	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79

134	" "	*Haldina cordifolia* Ridsd.	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
135	Hnaam rawiang	*Randia dasycarpa Bakh.f.*	17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
136	Thom		17.5	5.570	31.030	7.737	9.532	240.08	5.069	157.298	5.252	9.142	11.333	7.629	5.252	295.79
137	Unknown species	*Diospyros sp.*	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
138	Ee tok	*Passiflora foetida Linn.*	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
139	Ee hen		18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
140	Mueat bai khon	*Aporusa ficifolia* Baill.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
141	Chig/Teng	*Shorea obtusa* Wall.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
142	Phok		18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
143	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
144	Ee tok	*Passiflora foetida* Linn.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
145	Muaeat ae	*Memecylon scutellatum* Nuad.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
146	" " "	*Dipterocarpus tuberculatus* Roxb.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
147	Muaeat ae	*Memecylon scutellatum* Nuad.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
148	Muaeat ae	*Memecylon scutellatum* Nuad.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
149	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
150	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
151	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
152	Phut phaa	*Gardenia collinsea* Craib	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
153	Muaeat bai khon	*Aporusa ficifolia* Baill.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
154	Mueat bai kliang	*Helicia robusta* (Roxb.) R. Br. ex Wall.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
155	Yor paa	*Morinda coreia* Ham.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
156	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
157	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
158	Rawiang	*Randia dasycarpa* Barkh.f.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
159	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
160	Khaao	*Haldina cordifolia* Ridsd.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
161	Som kop	*Hymenodictyon excelsum* Wall.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
162	Kor	*Livistona speciosa*	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
163	Ma kham pom	*Phyllanthus emblica* Linn.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
164	Daeng	*Xylia xylocarpa* Taub.	18	5.730	32.828	7.862	9.604	258.08	5.193	170.483	5.670	9.807	11.996	8.195	5.670	315.29
165	Pluei luead/Ta baek	*Terminalia corticosa* Pierre ex Lanessa	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
166	Daeng	*Xylia xylocarpa* Taub.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
167	" "	*Polyathia cerasoides* Benth. ex Bedd.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
168	Pluei see daa	*Lagerstroemia duperreana Pierre*	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
169	Mueat bai khon	*Aporusa ficifolia* Baill.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
170	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
171	Muaeat ae	*Memecylon scutellatum* Nuad.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
172	Kuun	*Cassia fistula* Linn.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
173	Som kop	*Hymenodictyon excelsum* Wall.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
174	Ma kam pom	*Phyllanthus emblica* Linn.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
175	Daeng	*Xylia xylocarpa* Taub.	18.5	5.889	34.677	7.985	9.676	276.90	5.316	184.349	6.107	10.501	12.684	8.786	6.107	335.53
176	Mok	*Wrightia pubescens* R. Br.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
177	Daeng	*Xylia xylocarpa* Taub.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
178	Chig/Teng	*Shorea obtusa* Wall.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54

179	Som kob	*Hymenodictyon excelsum Wall*	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
180	" " "	*Aporusa ficifolia* Baill.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
181	" " "	*Aporusa ficifolia* Baill.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
182	Muaeat ae	*Memecylon scutellatum* Nuad.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
183	" " "	*Aporusa ficifolia* Baill.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
184	Muaeat ae	*Memecylon scutellatum* Nuad.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
185	Muaeat ae	*Memecylon scutellatum* Nuad.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
186	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
187	Ee tok	*Passiflora foetida* Linn.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
188	Muaeat bai khon	*Aporusa ficifolia* Baill.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
189	Kok kan	*Canarium subulatum* Guill.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
190	" " " "	*Homalium tomentosum* Benth.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
191	Ngiu paa	*Bombax anceps Pierre*	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
192	Kor	*Livistona speciosa*	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
193	Ehn mon	*Anogeissus acuminata Wall.*	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
194	Sa thon	*Milletoa leucantha* Kurz.	19	6.048	36.577	8.107	9.748	296.52	5.438	198.910	6.564	11.224	13.398	9.403	6.564	356.54
195	Chig/Teng	*Shorea obtusa* Wall.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
196	" " "	*Morinda coreia* Ham.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
197	" "	*Polyathia cerasoides* Benth. ex Bedd.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
198	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
199	" "	*Shorea obtusa* Wall.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
200	" " " "	*Homalium tomentosum* Benth.	19.5	6.207	38.527	8.227	9.819	316.97	5.559	214.178	7.042	11.976	14.138	10.045	7.042	378.31
201	" "	*Homalium tomentosum* Benth.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
202	Hmueid bai khon	*Helicia petiolaris* Benn.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
203	Khee kaa		20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
204	Mok	*Wrightia pubescens* R. Br.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
205	Daeng	*Xylia xylocarpa* Taub.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
206	" "	*Xylia xylocarpa* Taub.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
207	Mueat bai khon	*Aporusa ficifolia* Baill.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
208	Ma muang hua mala	*Buchanania reticulata* Hance	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
209	" " "		20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
210	Muaeat ae	*Memecylon scutellatum* Nuad.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
211	Muaeat ae	*Memecylon scutellatum* Nuad.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
212	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
213	Chig/Teng	*shorea obtusa* Wall.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
214	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
215	Som kop	*Hymenodictyon excelsum* Wall.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
216	Mok	*Wrightia pubescens* R. Br.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
217	Ngiu phaa	*Bombax anceps* Pierre	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
218	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
219	Daeng	*Xylia xylocarpa* Taub.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
220	Huean kwanng	*Diospyros ehretioides* Wall.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
221	Daeng	*Xylia xylocarpa* Taub.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
222	Daeng	*Xylia xylocarpa* Taub.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
223	Sai		20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85

224	Ma kham pom	*Phyllanthus emblica* Linn.	20	6.366	40.529	8.346	9.891	338.26	5.679	230.167	7.541	12.757	14.905	10.714	7.541	400.85
225	Khaao	*Haldina cordifolia* Ridsd.	20.5	6.525	42.580	8.464	9.962	360.40	5.798	246.890	8.060	13.568	15.698	11.410	8.060	424.18
226	Hnaam pla duk*		20.5	6.525	42.580	8.464	9.962	360.40	5.798	246.890	8.060	13.568	15.698	11.410	8.060	424.18
227	Ma mong hua malan	*Buchanania reticulata Hance*	20.5	6.525	42.580	8.464	9.962	360.40	5.798	246.890	8.060	13.568	15.698	11.410	8.060	424.18
228	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	20.5	6.525	42.580	8.464	9.962	360.40	5.798	246.890	8.060	13.568	15.698	11.410	8.060	424.18
229	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
230	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
231	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
232	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
233	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
234	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
235	Huean kwanng	*Diospyros ehretioides* Wall.	21	6.685	44.683	8.581	10.033	383.41	5.916	264.360	8.601	14.409	16.519	12.133	8.601	448.32
236	Hnaam taeng	*Randia dasycarpa* Bakh.f.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
237	Daeng	*Xylia xylocarpa* Taub.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
238	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
239	Muaeat bai khon	*Aporusa ficifolia* Baill.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
240	Daeng	*Xylia xylocarpa* Taub.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
241	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
242	Kok kan	*Canarium subulatum* Guill.	21.5	6.844	46.836	8.696	10.105	407.29	6.034	282.590	9.164	15.280	17.367	12.884	9.164	473.26
243	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
244	" " "	*Diospyros castanea* Fletch	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
245	Hnaam taeng	*Randia dasycarpa* Bakh.f.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
246	Chig/Teng	*Shorea obtusa* Wall.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
247	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
248	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
249	Muaeat bai khon	*Aporusa ficifolia* Baill.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
250	Muaeat bai khon	*Aporusa ficifolia* Baill.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
251	Ma kham pom	*Phyllanthus emblica* Linn.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
252	" " "		22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
253	Thom	*Mitragyna javanica Koord. & Val*	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
254	Daeng	*Xylia xylocarpa* Taub.	22	7.003	49.040	8.810	10.176	432.05	6.150	301.591	9.748	16.182	18.242	13.662	9.748	499.01
255	Ma khaam pom	*Phyllanthus emblica* Linn.	22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
256	Muaeat bai khon	*Aporusa ficifolia* Baill.	22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
257	" " " "	*Homalium tomentosum* Benth.	22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
258	" "	*Xylia xylocarpa* Taub.	22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
259	Hnaam riang		22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
260	" "		22.5	7.162	51.294	8.923	10.247	457.72	6.265	321.376	10.355	17.116	19.146	14.468	10.355	525.60
261	Pha yom	*Shorea floribunda* Kurz	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
262	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
263	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
264	Kra don	*Careya sphaerica* Roxb.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
265	Mueat bai khon	*Aporusa ficifolia* Baill.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
266	" "	*Xylia xylocarpa* Taub.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
267	Khai naao	*Vitex glabrata* R. Br.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
268	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03

269	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
270	Ma kam pom	*Phyllanthus emblica* Linn.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
271	Som kop	*Hymenodictyon excelsum* Wall.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
272	" "	*Lennea coromandelica* (Houtt.) Merr.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
273	Daeng	*Xylia xylocarpa* Taub.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
274	" "	*Randia dasycarpa* Barkh. f.	23.5	7.480	55.955	9.146	10.389	511.79	6.494	363.346	11.635	19.078	21.040	16.167	11.635	581.30
275	Daeng	*Xylia xylocarpa* Taub.	23.5	7.480	55.955	9.146	10.389	511.79	6.494	363.346	11.635	19.078	21.040	16.167	11.635	581.30
276	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	23.5	7.480	55.955	9.146	10.389	511.79	6.494	363.346	11.635	19.078	21.040	16.167	11.635	581.30
277	Khee kra thoe		23.5	7.480	55.955	9.146	10.389	511.79	6.494	363.346	11.635	19.078	21.040	16.167	11.635	581.30
278	Kor	*Livistona speciosa*	23.5	7.480	55.955	9.146	10.389	511.79	6.494	363.346	11.635	19.078	21.040	16.167	11.635	581.30
279	Mok	*Wrightia pubescens* R. Br.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
280	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
281	Yo paa	*Morinda coreia* Ham.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
282	Ee hen		24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
283	" " "	*Aporusa ficifolia* Baill.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
284	Muaeat bai khon	*Aporusa ficifolia* Baill.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
285	" "	*Xylia xylocarpa* Taub.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
286	Muaeat bai khon	*Aporusa ficifolia* Baill.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
287	Chig/Teng	*shorea obtusa* Wall.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
288	Sa thon	*Milletoa leucantha* Kurz.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
289	Chig/Teng	*Shorea obtusa* Wall.	24	7.639	58.361	9.256	10.460	540.22	6.606	385.555	12.310	20.107	22.031	17.061	12.310	610.44
290	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	24.5	7.799	60.818	9.365	10.531	569.59	6.718	408.594	13.008	21.169	23.051	17.984	13.008	640.45
291	" "	*Haldina cordifolia* Ridsd.	24.5	7.799	60.818	9.365	10.531	569.59	6.718	408.594	13.008	21.169	23.051	17.984	13.008	640.45
292	Daeng	*Xylia xylocarpa* Taub.	24.5	7.799	60.818	9.365	10.531	569.59	6.718	408.594	13.008	21.169	23.051	17.984	13.008	640.45
293	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
294	Mok	*Wrightia pubescens* R. Br.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
295	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
296	Daeng	*Xylia xylocarpa* Taub.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
297	" "	*Haldina cordifolia* Ridsd.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
298	Yo paa	*Morinda coreia* Ham.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
299	Rang	*Shorea simensis*	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
300	Mueat bai khon	*Aporusa ficifolia* Baill.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
301	" "	*Morinda coreia* Ham.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
302	Kor	*Livistona speciosa*	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
303	" "	*Xylia xylocarpa* Taub.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
304	Khaao	*Haldina cordifolia* Ridsd.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
305	Mueat bai kliang	*Helicia robusta* (Roxb.) R.Br. Ex Wall.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
306	Ngiu phaa	*Bombax anceps* Pierre	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
307	Po daeng	*Colona ebolata Craib.*	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
308	Liang	*Parkia timoriana* (DC.) Merr.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
309	Daeng	*Xylia xylocarpa* Taub.	25	7.958	63.326	9.473	10.601	599.91	6.829	432.475	13.729	22.263	24.101	18.937	13.729	671.33
310	Daeng	*Xylia xylocarpa* Taub.	25.5	8.117	65.884	9.581	10.672	631.21	6.940	457.210	14.474	23.391	25.182	19.920	14.474	703.11
311	Huean kwanng	*Diospyros ehretioides* Wall.	25.5	8.117	65.884	9.581	10.672	631.21	6.940	457.210	14.474	23.391	25.182	19.920	14.474	703.11
312	Som kop	*Hymenodictyon excelsum* Wall.	25.5	8.117	65.884	9.581	10.672	631.21	6.940	457.210	14.474	23.391	25.182	19.920	14.474	703.11
313	Kor	*Livistona speciosa*	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79

314	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
315	Saat	*Erythrophleum succirubrum* Gagnep.	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
316	Muaeat bai khon	*Aporusa ficifolia* Baill.	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
317	Som kop	*Hymenodictyon excelsum* Wall.	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
318	Daeng	*Xylia xylocarpa* Taub.	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
319	Rok faa	*Terminalia alata*	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
320	Sa thon	*Milletoa leucantha* Kurz.	26	8.276	68.493	9.687	10.742	663.48	7.049	482.810	15.242	24.553	26.293	20.934	15.242	735.79
321	" "	*Xylia xylocarpa* Taub.	26.5	8.435	71.153	9.792	10.813	696.73	7.158	509.284	16.035	25.748	27.435	21.979	16.035	769.37
322	Rawiang	*Randia dasycarpa* Barkh. f.	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
323	Teen nok	*Vitex pinnate* Linn.	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
324	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
325	Yo paa/Salak paa	*Morinda coreia* Ham.	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
326	Khee ka thoe		27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
327	Ma muang hua mala	*Buchanania reticulata* Hance	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
328	" " "	*Aporusa ficifolia* Baill.	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
329	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	27	8.594	73.863	9.897	10.883	730.99	7.265	536.644	16.853	26.977	28.608	23.056	16.853	803.88
330	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
331	Daeng	*Xylia xylocarpa* Taub.	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
332	Daeng	*Xylia xylocarpa* Taub.	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
333	Ma muang hua mala	*Buchanania reticulata* Hance	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
334	Muaeat bai khon	*Aporusa ficifolia* Baill.	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
335	Sa thon	*Milletoa leucantha* Kurz.	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
336	Ma kam pom	*Phyllanthus emblica* Linn.	27.5	8.754	76.624	10.000	10.954	766.25	7.372	564.900	17.695	28.241	29.813	24.164	17.695	839.32
337	Kor	*Livistona speciosa*	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
338	Phaeng/San chaang	*Dillenia pentagyna* Roxb.	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
339	Kra don	*Careya sphaerica* Roxb.	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
340	" "	*Polyathia cerasoides* Benth. ex Bedd.	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
341	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
342	Po daeng	*Colona ebolata* Craib	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
343	Haen	*Terminalia bellerica Roxb.*	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
344	" "	*Livistona speciosa*	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
345	Daeng	*Xylia xylocarpa* Taub.	28	8.913	79.436	10.103	11.024	802.54	7.479	594.063	18.561	29.540	31.050	25.304	18.561	875.70
346	Liang	*Parkia timoriana* (DC.) Merr.	28.5	9.072	82.298	10.205	11.094	839.85	7.584	624.142	19.453	30.874	32.319	26.476	19.453	913.03
347	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	28.5	9.072	82.298	10.205	11.094	839.85	7.584	624.142	19.453	30.874	32.319	26.476	19.453	913.03
348	Mok	*Wrightia pubescens* R. Br.	28.5	9.072	82.298	10.205	11.094	839.85	7.584	624.142	19.453	30.874	32.319	26.476	19.453	913.03
349	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	28.5	9.072	82.298	10.205	11.094	839.85	7.584	624.142	19.453	30.874	32.319	26.476	19.453	913.03
350	" "	*Xylia xylocarpa* Taub.	29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
351	" "	*Xylia xylocarpa* Taub.	29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
352	Ma muang hua mala	*Buchanania reticulata* Hance	29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
353	" " "		29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
354	Khee kra thoe		29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
355	Kor	*Livistona speciosa*	29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
356	Phan see		29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
357	Chig/Teng	*Shorea obtusa* Wall.	29.5	9.390	88.175	10.407	11.234	917.62	7.792	687.090	21.312	33.649	34.956	28.920	21.312	990.59
358	" " "		29.5	9.390	88.175	10.407	11.234	917.62	7.792	687.090	21.312	33.649	34.956	28.920	21.312	990.59

359	Saai den	*Polyathia cerasoides* Benth. ex Bedd.	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
360	" "	*Polyathia cerasoides* Benth. ex Bedd.	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
361	Mueat bai khon	*Aporusa ficifolia* Baill.	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
362	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
363	Yor paa	*Morinda coreia* Ham.	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
364	Kor	*Livistona speciosa*	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
365	Daeng	*Xylia xylocarpa* Taub.	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
366	Thom	*Mitragyna javanica Koord. & Val*	30	9.549	91.189	10.507	11.304	958.08	7.895	719.979	22.280	35.090	36.324	30.192	22.280	1030.83
367	" " "	*Dillenia pentagyna* Roxb.	30.5	9.708	94.254	10.606	11.374	999.62	7.998	753.824	23.274	36.568	37.726	31.497	23.274	1072.06
368	Daeng	*Xylia xylocarpa* Taub.	30.5	9.708	94.254	10.606	11.374	999.62	7.998	753.824	23.274	36.568	37.726	31.497	23.274	1072.06
369	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	30.5	9.708	94.254	10.606	11.374	999.62	7.998	753.824	23.274	36.568	37.726	31.497	23.274	1072.06
370	Mok	*Wrightia pubescens* R. Br.	31	9.868	97.370	10.704	11.444	1042.24	8.099	788.634	24.294	38.083	39.162	32.836	24.294	1114.30
371	Ma kham pom	*Phyllanthus emblica* Linn.	31	9.868	97.370	10.704	11.444	1042.24	8.099	788.634	24.294	38.083	39.162	32.836	24.294	1114.30
372	Muaeat bai khon	*Aporusa ficifolia* Baill.	31	9.868	97.370	10.704	11.444	1042.24	8.099	788.634	24.294	38.083	39.162	32.836	24.294	1114.30
373	Khaao	*Haldina cordifolia* Ridsd.	31	9.868	97.370	10.704	11.444	1042.24	8.099	788.634	24.294	38.083	39.162	32.836	24.294	1114.30
374	" "	*Hymenodictyon excelsum* Wall.	31	9.868	97.370	10.704	11.444	1042.24	8.099	788.634	24.294	38.083	39.162	32.836	24.294	1114.30
375	Mueat bai khon	*Aporusa ficifolia* Baill.	31.5	10.027	100.536	10.802	11.514	1085.95	8.200	824.418	25.340	39.634	40.633	34.210	25.340	1157.55
376	Daeng	*Xylia xylocarpa* Taub.	31.5	10.027	100.536	10.802	11.514	1085.95	8.200	824.418	25.340	39.634	40.633	34.210	25.340	1157.55
377	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	31.5	10.027	100.536	10.802	11.514	1085.95	8.200	824.418	25.340	39.634	40.633	34.210	25.340	1157.55
378	Yor paa	*Morinda coreia* Ham.	31.5	10.027	100.536	10.802	11.514	1085.95	8.200	824.418	25.340	39.634	40.633	34.210	25.340	1157.55
379	Mok	*Wrightia pubescens* R. Br.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
380	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
381	Khee kaa		32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
382	Daeng	*Xylia xylocarpa* Taub.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
383	" "	*Xylia xylocarpa* Taub.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
384	" "	*Xylia xylocarpa* Taub.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
385	Chig/Teng	*Shorea obtusa* Wall.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
386	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
387	Khaao	*Haldina cordifolia* Ridsd.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
388	Khaao	*Haldina cordifolia* Ridsd.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
389	Ehn mon	*Anogeissus acuminata Wall.*	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
390	Muaeat bai khon	*Aporusa ficifolia* Baill.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
391	Daeng	*Xylia xylocarpa* Taub.	32	10.186	103.753	10.899	11.583	1130.76	8.300	861.186	26.413	41.223	42.138	35.618	26.413	1201.81
392	Pluei see daa	*Lagerstroemia duperreana Pierre*	32.5	10.345	107.021	10.995	11.653	1176.69	8.400	898.947	27.512	42.849	43.678	37.061	27.512	1247.11
393	Daeng	*Xylia xylocarpa* Taub.	32.5	10.345	107.021	10.995	11.653	1176.69	8.400	898.947	27.512	42.849	43.678	37.061	27.512	1247.11
394	Khee ka thoe		33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
395	Ma muang hua mala	*Buchanania reticulata* Hance	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
396	Chig/Teng	*Shorea obtusa* Wall.	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
397	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
398	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
399	Muaeat bai khon	*Aporusa ficifolia* Baill.	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
400	Phaeng/San chaang	*Dillenia pentagyna* Roxb.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
401	" " "	*Dillenia pentagyna* Roxb.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
402	" " "	*Dillenia pentagyna* Roxb.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
403	" "	*Xylia xylocarpa* Taub.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83

404	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
405	Som kop	*Hymenodictyon excelsum* Wall.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
406	Daeng	*Xylia xylocarpa* Taub.	33.5	10.663	113.708	11.186	11.792	1271.91	8.596	977.483	29.790	46.215	46.864	40.053	29.790	1340.83
407	" " "	*Dillenia pentagyna* Roxb.	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
408	Chueak	*Terminalia alata* Hayne ex Roth	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
409	Daeng	*Xylia xylocarpa* Taub.	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
410	Daeng	*Xylia xylocarpa* Taub.	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
411	Daeng	*Xylia xylocarpa* Taub.	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
412	Phan see		34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
413	Sa thon	*Milletoa leucantha* Kurz.	34	10.823	117.127	11.280	11.861	1321.23	8.694	1018.276	30.970	47.956	48.512	41.603	30.970	1389.28
414	" " "	*Aporusa ficifolia* Baill.	34.5	10.982	120.598	11.374	11.931	1371.69	8.790	1060.096	32.177	49.735	50.195	43.189	32.177	1438.80
415	Sa thon	*Milletoa leucantha* Kurz.	34.5	10.982	120.598	11.374	11.931	1371.69	8.790	1060.096	32.177	49.735	50.195	43.189	32.177	1438.80
416	Pluei khaao	*Lagerstroemia calyculata Kurz*	34.5	10.982	120.598	11.374	11.931	1371.69	8.790	1060.096	32.177	49.735	50.195	43.189	32.177	1438.80
417	Sa thon	*Milletoa leucantha* Kurz.	34.5	10.982	120.598	11.374	11.931	1371.69	8.790	1060.096	32.177	49.735	50.195	43.189	32.177	1438.80
418	Daeng	*Xylia xylocarpa* Taub.	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
419	Som kop	*Hymenodictyon excelsum* Wall.	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
420	Mueat bai khon	*Aporusa ficifolia* Baill.	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
421	" "		35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
422	Rok faa	*Terminalia alata*	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
423	Kra don	*Careya spaerica* Roxb.	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
424	Daeng	*Xylia xylocarpa* Taub.	35	11.141	124.119	11.467	12.000	1423.32	8.886	1102.952	33.412	51.553	51.915	44.811	33.412	1489.39
425	Yo paa/Salak paa	*Morinda coreia* Ham.	35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
426	" " "	*Dillenia pentagyna* Roxb.	35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
427	" " "	*Dillenia pentagyna* Roxb.	35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
428	Daeng	*Xylia xylocarpa* Taub.	35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
429	" "		35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
430	Khee kra theo		35.5	11.300	127.690	11.560	12.069	1476.11	8.982	1146.852	34.674	53.411	53.673	46.470	34.674	1541.08
431	Phaeng/San chaang	*Dillenia pentagyna* Roxb.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
432	" " "	*Dillenia pentagyna* Roxb.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
433	Mok	*Wrightia pubescens* R. Br.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
434	Ma muang hua mala	*Buchanania reticulata* Hance	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
435	Ma muang hua mala	*Buchanania reticulata* Hance	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
436	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
437	Yor paa	*Morinda coreia* Ham.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
438	Ma kam pom	*Phyllanthus emblica* Linn.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
439	Khaao	*Haldina cordifolia* Ridsd.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
440	Chig/Teng	*Shorea obtusa* Wall.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
441	Khee kra thoe		36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
442	Chig/Teng	*Shorea obtusa* Wall.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
443	Muaeat bai khon	*Aporusa ficifolia* Baill.	36	11.459	131.312	11.652	12.138	1530.09	9.076	1191.805	35.964	55.308	55.467	48.166	35.964	1593.86
444	Yo paa	*Morinda coreia* Ham.	36.5	11.618	134.985	11.744	12.207	1585.25	9.170	1237.819	37.281	57.245	57.300	49.900	37.281	1647.75
445	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
446	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
447	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
448	Daeng	*Xylia xylocarpa* Taub.	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76

449	" " "		37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
450	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
451	Yor paa	*Morinda coreia* Ham.	37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
452	" " "		37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
453	Phan see		37	11.777	138.709	11.835	12.276	1641.61	9.263	1284.901	38.627	59.222	59.170	51.671	38.627	1702.76
454	Daeng	*Xylia xylocarpa* Taub.	37.5	11.937	142.483	11.925	12.345	1699.18	9.356	1333.060	40.001	61.240	61.079	53.480	40.001	1758.90
455	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	37.5	11.937	142.483	11.925	12.345	1699.18	9.356	1333.060	40.001	61.240	61.079	53.480	40.001	1758.90
456	" " " "	*Homalium tomentosum* Benth.	37.5	11.937	142.483	11.925	12.345	1699.18	9.356	1333.060	40.001	61.240	61.079	53.480	40.001	1758.90
457	" " " "	*Homalium tomentosum* Benth.	37.5	11.937	142.483	11.925	12.345	1699.18	9.356	1333.060	40.001	61.240	61.079	53.480	40.001	1758.90
458	Ma rom paa	*Albizia lebbeck* (L.) Benth.	37.5	11.937	142.483	11.925	12.345	1699.18	9.356	1333.060	40.001	61.240	61.079	53.480	40.001	1758.90
459	Hnaam taeng	*Randia dasycarpa* Bakh.f.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
460	Daeng	*Xylia xylocarpa* Taub.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
461	Daeng	*Xylia xylocarpa* Taub.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
462	" " "	*Lagerstroemia calyculata Kurz.*	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
463	" " "		38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
464	Daeng	*Xylia xylocarpa* Taub.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
465	Huean kwanng	*Diospyros ehretioides* Wall.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
466	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
467	Phan see		38	12.096	146.308	12.015	12.413	1757.96	9.448	1382.303	41.404	63.298	63.026	55.327	41.404	1816.18
468	Ma muang hua mala	*Buchanania reticulata* Hance	38.5	12.255	150.184	12.105	12.482	1817.97	9.539	1432.637	42.835	65.397	65.012	57.213	42.835	1874.60
469	" "	*Lennea coromandelica* (Houtt.) Merr.	38.5	12.255	150.184	12.105	12.482	1817.97	9.539	1432.637	42.835	65.397	65.012	57.213	42.835	1874.60
470	Yo paa	*Morinda coreia* Ham	38.5	12.255	150.184	12.105	12.482	1817.97	9.539	1432.637	42.835	65.397	65.012	57.213	42.835	1874.60
471	Ma muang hua mala	*Buchanania reticulata* Hance	39	12.414	154.110	12.194	12.551	1879.21	9.630	1484.071	44.295	67.537	67.038	59.137	44.295	1934.18
472	Saat	*Erythrophleum succirubrum* Gagnep.	39	12.414	154.110	12.194	12.551	1879.21	9.630	1484.071	44.295	67.537	67.038	59.137	44.295	1934.18
473	" " "		39	12.414	154.110	12.194	12.551	1879.21	9.630	1484.071	44.295	67.537	67.038	59.137	44.295	1934.18
474	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	39.5	12.573	158.087	12.282	12.619	1941.69	9.720	1536.612	45.783	69.718	69.103	61.101	45.783	1994.92
475	Yo paa	*Morinda coreia* Ham.	39.5	12.573	158.087	12.282	12.619	1941.69	9.720	1536.612	45.783	69.718	69.103	61.101	45.783	1994.92
476	Mueat bai khon	*Aporusa ficifolia* Baill.	39.5	12.573	158.087	12.282	12.619	1941.69	9.720	1536.612	45.783	69.718	69.103	61.101	45.783	1994.92
477	Daeng	*Xylia xylocarpa* Taub.	39.5	12.573	158.087	12.282	12.619	1941.69	9.720	1536.612	45.783	69.718	69.103	61.101	45.783	1994.92
478	" "	*Homalium tomentosum* Benth.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
479	Rok faa	*Terminalia alata*	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
480	Pha yung	*Dalbergia cochinchinensis* Pierre	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
481	Pha lin		40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
482	Kra don	*Careya sphaerica* Roxb.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
483	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
484	Yor paa	*Morinda coreia* Ham.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
485	" "	*Milletoa leucantha* Kurz.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
486	Chig/Teng	*Shorea obtusa* Wall.	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
487	" "	*Xylia xylocarpa* Taub.	40.5	12.892	166.192	12.458	12.756	2070.43	9.898	1645.042	48.847	74.207	73.354	65.146	48.847	2119.94
488	Mee	*Eugenia euneura* Craib	40.5	12.892	166.192	12.458	12.756	2070.43	9.898	1645.042	48.847	74.207	73.354	65.146	48.847	2119.94
489	Som kop	*Hymenodictyon excelsum* Wall.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
490	Daeng	*Xylia xylocarpa* Taub.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
491	" " "	*Dillenia pentagyna* Roxb.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
492	Daeng	*Xylia xylocarpa* Taub.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
493	Daeng	*Xylia xylocarpa* Taub.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24

494	Chig/Teng	*Shorea obtusa* Wall.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
495	" "	*Irvingia malayana* Oliv. ex A. Benn.	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
496	" " "	*Erythroleum teysmannii* Craib	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
497	Mee	*Eugenia euneura* Craib	41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
498	Unidentified species 1		41	13.051	170.321	12.545	12.824	2136.70	9.987	1700.946	50.423	76.514	75.540	67.228	50.423	2184.24
499	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	41.5	13.210	174.501	12.632	12.892	2204.25	10.074	1757.986	52.028	78.864	77.767	69.351	52.028	2249.74
500	" "	*Lennea coromandelica* (Houtt.) Merr.	41.5	13.210	174.501	12.632	12.892	2204.25	10.074	1757.986	52.028	78.864	77.767	69.351	52.028	2249.74
501	Sa thon	*Milletoa leucantha* Kurz.	41.5	13.210	174.501	12.632	12.892	2204.25	10.074	1757.986	52.028	78.864	77.767	69.351	52.028	2249.74
502	Ma kok nam	*Elaeocarpus hygrophilus Kurz*	42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
503	" " "		42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
504	Muaeat bai khon	*Aporusa ficifolia* Baill.	42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
505	Pan see		42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
506	Daeng	*Xylia xylocarpa* Taub.	42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
507	Khee kra thoe		42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
508	Chig/Teng	*Shorea obtusa* Wall.	42	13.369	178.731	12.718	12.961	2273.09	10.161	1816.168	53.662	81.257	80.036	71.514	53.662	2316.46
509	Rang	*Shorea simensis*	42.5	13.528	183.012	12.804	13.029	2343.22	10.248	1875.499	55.326	83.692	82.346	73.718	55.326	2384.40
510	" " "	*Terminalia corticorsa* Pierre ex Laness	43	13.687	187.343	12.889	13.097	2414.66	10.334	1935.986	57.020	86.171	84.697	75.963	57.020	2453.57
511	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	43	13.687	187.343	12.889	13.097	2414.66	10.334	1935.986	57.020	86.171	84.697	75.963	57.020	2453.57
512	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	43	13.687	187.343	12.889	13.097	2414.66	10.334	1935.986	57.020	86.171	84.697	75.963	57.020	2453.57
513	" " "		43	13.687	187.343	12.889	13.097	2414.66	10.334	1935.986	57.020	86.171	84.697	75.963	57.020	2453.57
514	Rang haeng	*Pectacme suavis*	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
515	" "	*Dalbergia cochinchinensis* Pierre	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
516	Sa thon	*Milletoa leucantha Kurz.*	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
517	Daeng	*Xylia xylocarpa* Taub.	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
518	Yor paa	*Morinda coreia* Ham.	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
519	Kuun	*Cassia fistula* Linn.	43.5	13.846	191.725	12.974	13.165	2487.41	10.419	1997.636	58.743	88.693	87.091	78.249	58.743	2523.98
520	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
521	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
522	Rok faa	*Terminalia alata*	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
523	Khaao	*Haldina cordifolia* Ridsd.	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
524	Kor	*Livistona speciosa*	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
525	Daeng	*Xylia xylocarpa* Taub.	44.5	14.165	200.642	13.142	13.300	2636.89	10.588	2124.449	62.281	93.869	92.007	82.947	62.281	2668.57
526	Muaeat bai khon	*Aporusa ficifolia* Baill.	44.5	14.165	200.642	13.142	13.300	2636.89	10.588	2124.449	62.281	93.869	92.007	82.947	62.281	2668.57
527	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
528	Saai den	*Polyathia cerasoides* Benth. ex Bedd.	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
529	Mueat bai khon	*Aporusa ficifolia* Baill.	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
530	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
531	Daeng	*Xylia xylocarpa* Taub.	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
532	" "		45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
533	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forma	45	14.324	205.176	13.226	13.368	2713.64	10.672	2189.626	64.094	96.524	94.530	85.358	64.094	2742.76
534	" " "	*Dillenia pentagyna* Roxb.	45.5	14.483	209.761	13.309	13.435	2791.74	10.755	2255.990	65.938	99.222	97.096	87.812	65.938	2818.23
535	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	45.5	14.483	209.761	13.309	13.435	2791.74	10.755	2255.990	65.938	99.222	97.096	87.812	65.938	2818.23
536	Mok	*Wrightia pubescens* R. Br.	45.5	14.483	209.761	13.309	13.435	2791.74	10.755	2255.990	65.938	99.222	97.096	87.812	65.938	2818.23
537	Som kop	*Hymenodictyon excelsum* Wall.	45.5	14.483	209.761	13.309	13.435	2791.74	10.755	2255.990	65.938	99.222	97.096	87.812	65.938	2818.23
538	Som kop	*Hymenodictyon excelsum* Wall.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99

539	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
540	Unknown species	*Diospyros sp.*	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
541	Daeng	*Xylia xylocarpa* Taub.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
542	Teen nok	*Vitex pinnate* Linn.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
543	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
544	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	46	14.642	214.396	13.392	13.503	2871.19	10.838	2323.550	67.813	101.966	99.706	90.309	67.813	2894.99
545	Yo paa	*Morinda coreia* Ham.	46.5	14.801	219.082	13.474	13.570	2952.01	10.920	2392.310	69.718	104.754	102.359	92.849	69.718	2973.04
546	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	46.5	14.801	219.082	13.474	13.570	2952.01	10.920	2392.310	69.718	104.754	102.359	92.849	69.718	2973.04
547	Muaeat bai khon	*Aporusa ficifolia* Baill.	46.5	14.801	219.082	13.474	13.570	2952.01	10.920	2392.310	69.718	104.754	102.359	92.849	69.718	2973.04
548	Mueat bai kon	*Aporusa ficifolia Baill.*	47	14.961	223.819	13.556	13.638	3034.20	11.001	2462.276	71.654	107.588	105.058	95.431	71.654	3052.40
549	" "	*Shorea obtusa* Wall.	47	14.961	223.819	13.556	13.638	3034.20	11.001	2462.276	71.654	107.588	105.058	95.431	71.654	3052.40
550	" "		47	14.961	223.819	13.556	13.638	3034.20	11.001	2462.276	71.654	107.588	105.058	95.431	71.654	3052.40
551	Daeng	*Xylia xylocarpa* Taub.	47.5	15.120	228.606	13.638	13.705	3117.78	11.082	2533.456	73.620	110.467	107.801	98.058	73.620	3133.08
552	Khaao	*Haldina cordifolia* Ridsd.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
553	Som kop	*Hymenodictyon excelsum* Wall.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
554	" " "	*Dillenia pentagyna* Roxb.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
555	Muaeat bai khon	*Aporusa ficifolia* Baill.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
556	" "	*Canarium subulatum* Guill.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
557	Daeng	*Xylia xylocarpa* Taub.	48	15.279	233.444	13.719	13.772	3202.74	11.163	2605.854	75.617	113.391	110.589	100.728	75.617	3215.08
558	Kra don	*Careya spaerica* Roxb.	48.5	15.438	238.333	13.800	13.840	3289.10	11.243	2679.477	77.645	116.362	113.422	103.442	77.645	3298.41
559	Khaao	*Haldina cordifolia* Ridsd.	49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
560	Hnaam pla duk		49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
561	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
562	Chig/Teng	*shorea obtusa* Wall.	49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
563	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
564	Khee kra thoe		49	15.597	243.273	13.881	13.907	3376.88	11.322	2754.330	79.705	119.379	116.301	106.200	79.705	3383.09
565	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	50	15.916	253.303	14.041	14.041	3556.67	11.479	2907.749	83.917	125.552	122.197	111.850	83.917	3556.51
566	Chueak		50	15.916	253.303	14.041	14.041	3556.67	11.479	2907.749	83.917	125.552	122.197	111.850	83.917	3556.51
567	Muaeat bai khon	*Aporusa ficifolia* Baill.	50	15.916	253.303	14.041	14.041	3556.67	11.479	2907.749	83.917	125.552	122.197	111.850	83.917	3556.51
568	" "	*Lennea coromandelica* (Houtt.) Merr.	50	15.916	253.303	14.041	14.041	3556.67	11.479	2907.749	83.917	125.552	122.197	111.850	83.917	3556.51
569	Daeng	*Xylia xylocarpa* Taub.	50.5	16.075	258.395	14.121	14.107	3648.71	11.557	2986.327	86.069	128.709	125.215	114.742	86.069	3645.27
570	Ma lueam	*Canarium subulatum* Grill.	51.5	16.393	268.730	14.279	14.241	3837.13	11.712	3147.245	90.470	135.163	131.392	120.663	90.470	3826.93
571	Chig/Teng	*Shorea obtusa* Wall.	51.5	16.393	268.730	14.279	14.241	3837.13	11.712	3147.245	90.470	135.163	131.392	120.663	90.470	3826.93
572	Daeng	*Xylia xylocarpa* Taub.	52	16.552	273.973	14.357	14.307	3933.51	11.788	3229.597	92.717	138.462	134.551	123.691	92.717	3919.85
573	Chig/Teng	*Shorea obtusa* Wall.	52	16.552	273.973	14.357	14.307	3933.51	11.788	3229.597	92.717	138.462	134.551	123.691	92.717	3919.85
574	Chig/Teng	*Shorea obtusa* Wall.	52	16.552	273.973	14.357	14.307	3933.51	11.788	3229.597	92.717	138.462	134.551	123.691	92.717	3919.85
575	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	52	16.552	273.973	14.357	14.307	3933.51	11.788	3229.597	92.717	138.462	134.551	123.691	92.717	3919.85
576	Daeng	*Xylia xylocarpa* Taub.	52	16.552	273.973	14.357	14.307	3933.51	11.788	3229.597	92.717	138.462	134.551	123.691	92.717	3919.85
577	" "	*Lennea coromandelica* (Houtt.) Merr.	52.5	16.711	279.267	14.436	14.374	4031.36	11.864	3313.217	94.996	141.808	137.758	126.766	94.996	4014.18
578	Khaao	*Haldina cordifolia* Ridsd.	52.5	16.711	279.267	14.436	14.374	4031.36	11.864	3313.217	94.996	141.808	137.758	126.766	94.996	4014.18
579	Chig/Teng	*Shorea obtusa* Wall.	52.5	16.711	279.267	14.436	14.374	4031.36	11.864	3313.217	94.996	141.808	137.758	126.766	94.996	4014.18
580	Khaao	*Haldina cordifolia* Ridsd.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
581	Tub tao/Huean kwaa	*Diospyros ehretioides Wall.*	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
582	Chig/Teng	*shorea obtusa* Wall.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
583	Daeng	*Xylia xylocarpa* Taub.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92

584	" " "	*Phyllanthus emblica* Linn.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
585	Muaeat bai khon	*Aporusa ficifolia* Baill.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
586	Sa thon	*Milletoa leucantha* Kurz.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
587	Daeng	*Xylia xylocarpa* Taub.	53	16.870	284.612	14.513	14.440	4130.68	11.939	3398.110	97.307	145.203	141.013	129.887	97.307	4109.92
588	" "	*Haldina cordifolia* Ridsd.	53.5	17.030	290.007	14.591	14.507	4231.48	12.014	3484.283	99.650	148.645	144.317	133.055	99.650	4207.09
589	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	53.5	17.030	290.007	14.591	14.507	4231.48	12.014	3484.283	99.650	148.645	144.317	133.055	99.650	4207.09
590	Muaeat bai khon	*Aporusa ficifolia* Baill.	53.5	17.030	290.007	14.591	14.507	4231.48	12.014	3484.283	99.650	148.645	144.317	133.055	99.650	4207.09
591	" "	*Livistona speciosa*	54	17.189	295.453	14.668	14.573	4333.77	12.089	3571.740	102.024	152.137	147.669	136.269	102.024	4305.68
592	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	54	17.189	295.453	14.668	14.573	4333.77	12.089	3571.740	102.024	152.137	147.669	136.269	102.024	4305.68
593	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm. ex	54	17.189	295.453	14.668	14.573	4333.77	12.089	3571.740	102.024	152.137	147.669	136.269	102.024	4305.68
594	Yo paa	*Morinda coreia* Ham	54	17.189	295.453	14.668	14.573	4333.77	12.089	3571.740	102.024	152.137	147.669	136.269	102.024	4305.68
595	Som kop	*Hymenodictyon excelsum* Wall.	55	17.507	306.497	14.822	14.706	4542.84	12.237	3750.525	106.870	159.265	154.521	142.839	106.870	4507.21
596	Tub tao/Huean kwaa	*Diospyros ehretioides Wall.*	55	17.507	306.497	14.822	14.706	4542.84	12.237	3750.525	106.870	159.265	154.521	142.839	106.870	4507.21
597	Muaeat bai khon	*Aporusa ficifolia* Baill.	55	17.507	306.497	14.822	14.706	4542.84	12.237	3750.525	106.870	159.265	154.521	142.839	106.870	4507.21
598	Chig/Teng	*shorea obtusa* Wall.	55	17.507	306.497	14.822	14.706	4542.84	12.237	3750.525	106.870	159.265	154.521	142.839	106.870	4507.21
599	Pluei khaao	*Lagerstroemia calyculata Kurz*	55	17.507	306.497	14.822	14.706	4542.84	12.237	3750.525	106.870	159.265	154.521	142.839	106.870	4507.21
600	" "	*Haldina cordifolia* Ridsd.	55.5	17.666	312.095	14.898	14.772	4649.64	12.310	3841.864	109.341	162.903	158.021	146.195	109.341	4610.16
601	Mee	*Eugenia euneura Craib.*	56	17.825	317.744	14.974	14.838	4757.96	12.383	3934.506	111.844	166.590	161.571	149.599	111.844	4714.57
602	Yo paa	*Morinda coreia* Ham.	56	17.825	317.744	14.974	14.838	4757.96	12.383	3934.506	111.844	166.590	161.571	149.599	111.844	4714.57
603	Huean kwanng	*Diospyros ehretioides* Wall.	56	17.825	317.744	14.974	14.838	4757.96	12.383	3934.506	111.844	166.590	161.571	149.599	111.844	4714.57
604	" "	*Polyathia cerasoides* Benth. ex Bedd.	56.5	17.985	323.443	15.050	14.904	4867.81	12.455	4028.457	114.380	170.327	165.172	153.051	114.380	4820.46
605	Ma muang hua mala	*Buchanania reticulata* Hance	56.5	17.985	323.443	15.050	14.904	4867.81	12.455	4028.457	114.380	170.327	165.172	153.051	114.380	4820.46
606	Khee kra thoe		56.5	17.985	323.443	15.050	14.904	4867.81	12.455	4028.457	114.380	170.327	165.172	153.051	114.380	4820.46
607	Unidentified species 1		56.5	17.985	323.443	15.050	14.904	4867.81	12.455	4028.457	114.380	170.327	165.172	153.051	114.380	4820.46
608	Sa long kong	*Grewia asiatica Linn.*	57	18.144	329.193	15.125	14.969	4979.19	12.527	4123.721	116.948	174.113	168.823	156.551	116.948	4927.84
609	Chig/Teng	*Shorea obtusa* Wall.	57	18.144	329.193	15.125	14.969	4979.19	12.527	4123.721	116.948	174.113	168.823	156.551	116.948	4927.84
610	Phaeng/San chaang	*Dillenia pentagyna* Roxb.	57.5	18.303	334.994	15.201	15.035	5092.11	12.598	4220.302	119.549	177.950	172.524	160.099	119.549	5036.71
611	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	57.5	18.303	334.994	15.201	15.035	5092.11	12.598	4220.302	119.549	177.950	172.524	160.099	119.549	5036.71
612	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	58	18.462	340.845	15.276	15.101	5206.58	12.669	4318.206	122.182	181.837	176.277	163.696	122.182	5147.08
613	Chig/Teng	*Shorea obtusa* Wall.	58	18.462	340.845	15.276	15.101	5206.58	12.669	4318.206	122.182	181.837	176.277	163.696	122.182	5147.08
614	" "	*Grewia asiatica Linn.*	58.5	18.621	346.747	15.350	15.167	5322.61	12.740	4417.437	124.848	185.774	180.081	167.342	124.848	5258.96
615	Haen	*Terminalia bellerica Roxb.*	58.5	18.621	346.747	15.350	15.167	5322.61	12.740	4417.437	124.848	185.774	180.081	167.342	124.848	5258.96
616	Mueat bai khon	*Aporusa ficifolia* Baill.	58.5	18.621	346.747	15.350	15.167	5322.61	12.740	4417.437	124.848	185.774	180.081	167.342	124.848	5258.96
617	Daeng	*Xylia xylocarpa* Taub.	59	18.780	352.700	15.424	15.232	5440.21	12.810	4518.000	127.546	189.761	183.936	171.038	127.546	5372.37
618	Chig/Teng	*Shorea obtusa* Wall.	59	18.780	352.700	15.424	15.232	5440.21	12.810	4518.000	127.546	189.761	183.936	171.038	127.546	5372.37
619	" "	*Shorea obtusa* Wall.	59	18.780	352.700	15.424	15.232	5440.21	12.810	4518.000	127.546	189.761	183.936	171.038	127.546	5372.37
620	Chig/Teng	*Shorea obtusa* Wall.	59	18.780	352.700	15.424	15.232	5440.21	12.810	4518.000	127.546	189.761	183.936	171.038	127.546	5372.37
621	" "		59.5	18.939	358.703	15.499	15.298	5559.37	12.879	4619.898	130.277	193.800	187.844	174.782	130.277	5487.30
622	Chig/Teng	*Shorea obtusa* Wall.	59.5	18.939	358.703	15.499	15.298	5559.37	12.879	4619.898	130.277	193.800	187.844	174.782	130.277	5487.30
623	Yo paa	*Morinda coriea* Ham.	60	19.099	364.757	15.572	15.363	5680.12	12.949	4723.136	133.042	197.890	191.804	178.577	133.042	5603.76
624	" "	*Shorea obtusa* Wall.	60	19.099	364.757	15.572	15.363	5680.12	12.949	4723.136	133.042	197.890	191.804	178.577	133.042	5603.76
625	Kor	*Livistona speciosa*	60	19.099	364.757	15.572	15.363	5680.12	12.949	4723.136	133.042	197.890	191.804	178.577	133.042	5603.76
626	Pha yung	*Dalbergia cochinchinensis* Pierre	60.5	19.258	370.861	15.646	15.428	5802.46	13.018	4827.719	135.839	202.031	195.816	182.421	135.839	5721.78
627	" "	*Hymenodictyon excelsum* Wall.	60.5	19.258	370.861	15.646	15.428	5802.46	13.018	4827.719	135.839	202.031	195.816	182.421	135.839	5721.78
628	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34

629	Khaao	*Haldina cordifolia* Ridsd.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
630	Daeng	*Xylia xylocarpa* Taub.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
631	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
632	" "	*Xylia xylocarpa* Taub.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
633	Huean kwanng	*Diospyros ehretioides* Wall.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
634	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
635	Daeng	*Xylia xylocarpa* Taub.	61	19.417	377.017	15.719	15.494	5926.39	13.086	4933.651	138.669	206.224	199.882	186.315	138.669	5841.34
636	Sa long kong	*Grewia asiatica Linn.*	62	19.735	389.479	15.865	15.624	6179.06	13.222	5149.578	144.428	214.764	208.172	194.256	144.428	6085.17
637	Khaao	*Haldina cordifolia* Ridsd.	62	19.735	389.479	15.865	15.624	6179.06	13.222	5149.578	144.428	214.764	208.172	194.256	144.428	6085.17
638	" "	*Lagerstroemia calyculata Kurz*	62	19.735	389.479	15.865	15.624	6179.06	13.222	5149.578	144.428	214.764	208.172	194.256	144.428	6085.17
639	Chig/Teng	*Shorea obtusa* Wall.	62.5	19.894	395.787	15.937	15.689	6307.83	13.289	5259.582	147.357	219.112	212.397	198.302	147.357	6209.45
640	Khaao	*Haldina cordifolia* Ridsd.	63	20.054	402.144	16.010	15.754	6438.21	13.356	5370.950	150.320	223.513	216.677	202.399	150.320	6335.32
641	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	63	20.054	402.144	16.010	15.754	6438.21	13.356	5370.950	150.320	223.513	216.677	202.399	150.320	6335.32
642	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	63	20.054	402.144	16.010	15.754	6438.21	13.356	5370.950	150.320	223.513	216.677	202.399	150.320	6335.32
643	Daeng	*Xylia xylocarpa* Taub.	63	20.054	402.144	16.010	15.754	6438.21	13.356	5370.950	150.320	223.513	216.677	202.399	150.320	6335.32
644	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	64	20.372	415.012	16.153	15.884	6703.89	13.488	5597.801	156.345	232.472	225.399	210.748	156.345	6591.85
645	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	64	20.372	415.012	16.153	15.884	6703.89	13.488	5597.801	156.345	232.472	225.399	210.748	156.345	6591.85
646	Daeng	*Xylia xylocarpa* Taub.	64	20.372	415.012	16.153	15.884	6703.89	13.488	5597.801	156.345	232.472	225.399	210.748	156.345	6591.85
647	Muaeat bai khon	*Aporusa ficifolia* Baill.	64	20.372	415.012	16.153	15.884	6703.89	13.488	5597.801	156.345	232.472	225.399	210.748	156.345	6591.85
648	Daeng	*Xylia xylocarpa* Taub.	64.5	20.531	421.522	16.225	15.948	6839.20	13.554	5713.290	159.408	237.031	229.842	214.999	159.408	6722.53
649	Daeng	*Xylia xylocarpa* Taub.	64.5	20.531	421.522	16.225	15.948	6839.20	13.554	5713.290	159.408	237.031	229.842	214.999	159.408	6722.53
650	Som kop	*Hymenodictyon excelsum* Wall.	65	20.690	428.083	16.296	16.013	6976.16	13.619	5830.160	162.504	241.643	234.340	219.303	162.504	6854.83
651	Chank chan	*Miliettia pubinervis* Kurz	65	20.690	428.083	16.296	16.013	6976.16	13.619	5830.160	162.504	241.643	234.340	219.303	162.504	6854.83
652	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	65	20.690	428.083	16.296	16.013	6976.16	13.619	5830.160	162.504	241.643	234.340	219.303	162.504	6854.83
653	Daeng	*Xylia xylocarpa* Taub.	65	20.690	428.083	16.296	16.013	6976.16	13.619	5830.160	162.504	241.643	234.340	219.303	162.504	6854.83
654	Khaao	*Haldina cordifolia* Ridsd.	65.5	20.849	434.694	16.367	16.077	7114.78	13.684	5948.415	165.634	246.308	238.894	223.659	165.634	6988.77
655	Kra don	*Careya sphaerica* Roxb.	65.5	20.849	434.694	16.367	16.077	7114.78	13.684	5948.415	165.634	246.308	238.894	223.659	165.634	6988.77
656	Pra duu	*Pterocarpus macrocarpus* Kurz	65.5	20.849	434.694	16.367	16.077	7114.78	13.684	5948.415	165.634	246.308	238.894	223.659	165.634	6988.77
657	Sa baeng/Chaad	*Erythroleum teysmannii* Craib	66	21.008	441.356	16.438	16.142	7255.07	13.749	6068.060	168.797	251.027	243.503	228.068	168.797	7124.33
658	Sa baeng/Chaad	*Erythroleum teysmannii* Craib	66	21.008	441.356	16.438	16.142	7255.07	13.749	6068.060	168.797	251.027	243.503	228.068	168.797	7124.33
659	Chig/Teng	*Shorea obtusa* Wall.	66	21.008	441.356	16.438	16.142	7255.07	13.749	6068.060	168.797	251.027	243.503	228.068	168.797	7124.33
660	Daeng	*Xylia xylocarpa* Taub.	66	21.008	441.356	16.438	16.142	7255.07	13.749	6068.060	168.797	251.027	243.503	228.068	168.797	7124.33
661	Mee	*Eugenia euneura* Craib	66	21.008	441.356	16.438	16.142	7255.07	13.749	6068.060	168.797	251.027	243.503	228.068	168.797	7124.33
662	Khaao	*Haldina cordifolia* Ridsd.	66.5	21.168	448.068	16.509	16.206	7397.04	13.813	6189.097	171.994	255.800	248.169	232.529	171.994	7261.55
663	Sa long kong	*Grewia asiatica Linn.*	66.5	21.168	448.068	16.509	16.206	7397.04	13.813	6189.097	171.994	255.800	248.169	232.529	171.994	7261.55
664	Yor paa	*Morinda coreia* Ham.	66.5	21.168	448.068	16.509	16.206	7397.04	13.813	6189.097	171.994	255.800	248.169	232.529	171.994	7261.55
665	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forma	66.5	21.168	448.068	16.509	16.206	7397.04	13.813	6189.097	171.994	255.800	248.169	232.529	171.994	7261.55
666	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	67	21.327	454.832	16.579	16.271	7540.69	13.877	6311.530	175.225	260.627	252.890	237.043	175.225	7400.42
667	Khaao	*Haldina cordifolia* Ridsd.	67	21.327	454.832	16.579	16.271	7540.69	13.877	6311.530	175.225	260.627	252.890	237.043	175.225	7400.42
668	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	67.5	21.486	461.645	16.649	16.335	7686.03	13.940	6435.364	178.490	265.508	257.668	241.610	178.490	7540.95
669	Chig/Teng	*Shorea obtusa* Wall.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16
670	Mueat bai kliang	*Helicia robusta* (Roxb.) R. Br. ex Wall.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16
671	" "	*Lennea coromandelica* (Houtt.) Merr.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16
672	Yor paa	*Morinda coreia* Ham.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16
673	" "	*Shorea obtusa* Wall.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16

674	Chig/Teng	*Shorea obtusa* Wall.	68	21.645	468.510	16.719	16.399	7833.07	14.003	6560.601	181.788	270.443	262.503	246.231	181.788	7683.16
675	Chig/Teng	*shorea obtusa* Wall.	68.5	21.804	475.425	16.789	16.463	7981.81	14.066	6687.245	185.120	275.433	267.395	250.905	185.120	7827.04
676	Khee kra thoe		68.5	21.804	475.425	16.789	16.463	7981.81	14.066	6687.245	185.120	275.433	267.395	250.905	185.120	7827.04
677	Daeng	*Xylia xylocarpa* Taub.	69	21.963	482.391	16.858	16.527	8132.26	14.128	6815.300	188.486	280.477	272.345	255.633	188.486	7972.61
678	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	69	21.963	482.391	16.858	16.527	8132.26	14.128	6815.300	188.486	280.477	272.345	255.633	188.486	7972.61
679	" "	*Shorea obtusa* Wall.	69	21.963	482.391	16.858	16.527	8132.26	14.128	6815.300	188.486	280.477	272.345	255.633	188.486	7972.61
680	" "	*Shorea obtusa* Wall.	69	21.963	482.391	16.858	16.527	8132.26	14.128	6815.300	188.486	280.477	272.345	255.633	188.486	7972.61
681	Yo paa	*Morinda coreia* Ham.	69.5	22.123	489.407	16.927	16.591	8284.44	14.190	6944.769	191.886	285.577	277.352	260.415	191.886	8119.88
682	Chig/Teng	*Shorea obtusa* Wall.	69.5	22.123	489.407	16.927	16.591	8284.44	14.190	6944.769	191.886	285.577	277.352	260.415	191.886	8119.88
683	Khaao	*Haldina cordifolia* Ridsd.	70	22.282	496.475	16.997	16.655	8438.34	14.252	7075.656	195.320	290.732	282.417	265.251	195.320	8268.85
684	Pra duu	*Pterocarpus macrocarpus* Kurz	70	22.282	496.475	16.997	16.655	8438.34	14.252	7075.656	195.320	290.732	282.417	265.251	195.320	8268.85
685	Sa thon	*Milletoa leucantha* Kurz.	70	22.282	496.475	16.997	16.655	8438.34	14.252	7075.656	195.320	290.732	282.417	265.251	195.320	8268.85
686	Chig/Teng	*Shorea obtusa* Wall.	70	22.282	496.475	16.997	16.655	8438.34	14.252	7075.656	195.320	290.732	282.417	265.251	195.320	8268.85
687	Khaao	*Haldina cordifolia* Ridsd.	70.5	22.441	503.592	17.065	16.719	8593.97	14.313	7207.965	198.788	295.942	287.540	270.141	198.788	8419.53
688	Pluei kra deng	*Lagerstroemia calyculata Kurz.*	70.5	22.441	503.592	17.065	16.719	8593.97	14.313	7207.965	198.788	295.942	287.540	270.141	198.788	8419.53
689	Chig/Teng	*Shorea obtusa* Wall.	70.5	22.441	503.592	17.065	16.719	8593.97	14.313	7207.965	198.788	295.942	287.540	270.141	198.788	8419.53
690	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	71	22.600	510.761	17.134	16.783	8751.34	14.374	7341.697	202.290	301.208	292.722	275.087	202.290	8571.93
691	Chig/Teng	*Shorea obtusa* Wall.	71	22.600	510.761	17.134	16.783	8751.34	14.374	7341.697	202.290	301.208	292.722	275.087	202.290	8571.93
692	Kok kan	*Canarium subulatum* Guill.	71	22.600	510.761	17.134	16.783	8751.34	14.374	7341.697	202.290	301.208	292.722	275.087	202.290	8571.93
693	Chig/Teng	*Shorea obtusa* Wall.	71	22.600	510.761	17.134	16.783	8751.34	14.374	7341.697	202.290	301.208	292.722	275.087	202.290	8571.93
694	Chig/Teng	*Shorea obtusa* Wall.	71.5	22.759	517.980	17.202	16.846	8910.46	14.435	7476.858	205.827	306.529	297.962	280.087	205.827	8726.06
695	" "	*Shorea obtusa* Wall.	71.5	22.759	517.980	17.202	16.846	8910.46	14.435	7476.858	205.827	306.529	297.962	280.087	205.827	8726.06
696	Chig/Teng	*Shorea obtusa* Wall.	71.5	22.759	517.980	17.202	16.846	8910.46	14.435	7476.858	205.827	306.529	297.962	280.087	205.827	8726.06
697	Pra duu	*Pterocarpus macrocarpus* Kurz	72	22.918	525.250	17.271	16.910	9071.34	14.495	7613.450	209.397	311.906	303.261	285.142	209.397	8881.93
698	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	72	22.918	525.250	17.271	16.910	9071.34	14.495	7613.450	209.397	311.906	303.261	285.142	209.397	8881.93
699	Muaeat bai khon	*Aporusa ficifolia* Baill.	72	22.918	525.250	17.271	16.910	9071.34	14.495	7613.450	209.397	311.906	303.261	285.142	209.397	8881.93
700	Chig/Teng	*Shorea obtusa* Wall.	72	22.918	525.250	17.271	16.910	9071.34	14.495	7613.450	209.397	311.906	303.261	285.142	209.397	8881.93
701	Chig/Teng	*Shorea obtusa* Wall.	72	22.918	525.250	17.271	16.910	9071.34	14.495	7613.450	209.397	311.906	303.261	285.142	209.397	8881.93
702	" " "	*Dillenia pentagyna* Roxb.	72.5	23.077	532.570	17.338	16.973	9233.97	14.555	7751.476	213.002	317.340	308.620	290.253	213.002	9039.53
703	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	72.5	23.077	532.570	17.338	16.973	9233.97	14.555	7751.476	213.002	317.340	308.620	290.253	213.002	9039.53
704	Ma muang hua mala	*Buchanania reticulata* Hance	73	23.237	539.941	17.406	17.037	9398.37	14.614	7890.941	216.641	322.830	314.038	295.419	216.641	9198.89
705	" " "		73	23.237	539.941	17.406	17.037	9398.37	14.614	7890.941	216.641	322.830	314.038	295.419	216.641	9198.89
706	Sa thon	*Milletoa leucantha* Kurz.	73	23.237	539.941	17.406	17.037	9398.37	14.614	7890.941	216.641	322.830	314.038	295.419	216.641	9198.89
707	Haen	*Terminalia bellerica* Roxb.	73	23.237	539.941	17.406	17.037	9398.37	14.614	7890.941	216.641	322.830	314.038	295.419	216.641	9198.89
708	Pha yung	*Dalbergia cochinchinensis* Pierre	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
709	" " "	*Lagerstroemia duperreana Pierre*	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
710	Chig/Teng	*Shorea obtusa* Wall.	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
711	Khaao	*Haldina cordifolia* Ridsd.	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
712	Daeng	*Xylia xylocarpa* Taub.	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
713	Chig/Teng	*Shorea obtusa* Wall.	73.5	23.396	547.363	17.474	17.100	9564.55	14.674	8031.846	220.314	328.376	319.517	300.641	220.314	9360.02
714	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	74	23.555	554.836	17.541	17.163	9732.51	14.733	8174.195	224.022	333.979	325.055	305.919	224.022	9522.90
715	Daeng	*Xylia xylocarpa* Taub.	74	23.555	554.836	17.541	17.163	9732.51	14.733	8174.195	224.022	333.979	325.055	305.919	224.022	9522.90
716	Daeng	*Xylia xylocarpa* Taub.	74	23.555	554.836	17.541	17.163	9732.51	14.733	8174.195	224.022	333.979	325.055	305.919	224.022	9522.90
717	Chig/Teng	*Shorea obtusa* Wall.	74	23.555	554.836	17.541	17.163	9732.51	14.733	8174.195	224.022	333.979	325.055	305.919	224.022	9522.90
718	Chig/Teng	*Shorea obtusa* Wall.	74.5	23.714	562.359	17.608	17.227	9902.26	14.791	8317.991	227.764	339.639	330.653	311.253	227.764	9687.57

719	Chig/Teng	*shorea obtusa* Wall.	74.5	23.714	562.359	17.608	17.227	9902.26	14.791	8317.991	227.764	339.639	330.653	311.253	227.764	9687.57
720	Oi chaang	*Lennea coromandelica* (Houtt.) Merr.	74.5	23.714	562.359	17.608	17.227	9902.26	14.791	8317.991	227.764	339.639	330.653	311.253	227.764	9687.57
721	Kor	*Livistona speciosa*	75	23.873	569.933	17.675	17.290	10073.80	14.850	8463.238	231.541	345.356	336.312	316.644	231.541	9854.01
722	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	75	23.873	569.933	17.675	17.290	10073.80	14.850	8463.238	231.541	345.356	336.312	316.644	231.541	9854.01
723	Daeng	*Xylia xylocarpa* Taub.	75	23.873	569.933	17.675	17.290	10073.80	14.850	8463.238	231.541	345.356	336.312	316.644	231.541	9854.01
724	Nam kliang	*Melanorrhoea laccifera* Pierre	75	23.873	569.933	17.675	17.290	10073.80	14.850	8463.238	231.541	345.356	336.312	316.644	231.541	9854.01
725	Daeng	*Xylia xylocarpa* Taub.	75	23.873	569.933	17.675	17.290	10073.80	14.850	8463.238	231.541	345.356	336.312	316.644	231.541	9854.01
726	Sa baeng/Chaat	*Erythroleum teysmannii* Craib	75.5	24.032	577.557	17.742	17.353	10247.15	14.908	8609.938	235.352	351.131	342.033	322.091	235.352	10022.25
727	" "	*Shorea obtusa* Wall.	75.5	24.032	577.557	17.742	17.353	10247.15	14.908	8609.938	235.352	351.131	342.033	322.091	235.352	10022.25
728	Haen	*Terminalia bellerica Roxb.*	76	24.192	585.232	17.809	17.416	10422.30	14.965	8758.095	239.198	356.962	347.814	327.595	239.198	10192.29
729	Kor	*Livistona speciosa*	76	24.192	585.232	17.809	17.416	10422.30	14.965	8758.095	239.198	356.962	347.814	327.595	239.198	10192.29
730	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	76	24.192	585.232	17.809	17.416	10422.30	14.965	8758.095	239.198	356.962	347.814	327.595	239.198	10192.29
731	Chig/Teng	*Shorea obtusa* Wall.	76	24.192	585.232	17.809	17.416	10422.30	14.965	8758.095	239.198	356.962	347.814	327.595	239.198	10192.29
732	Daeng	*Xylia xylocarpa* Taub.	76	24.192	585.232	17.809	17.416	10422.30	14.965	8758.095	239.198	356.962	347.814	327.595	239.198	10192.29
733	Daeng	*Xylia xylocarpa* Taub.	76.5	24.351	592.958	17.875	17.479	10599.27	15.023	8907.711	243.078	362.852	353.657	333.156	243.078	10364.14
734	Kor	*Livistona speciosa*	77	24.510	600.734	17.941	17.542	10778.07	15.080	9058.789	246.993	368.799	359.561	338.774	246.993	10537.79
735	Pha yom	*Shorea floribunda* Kurz	77	24.510	600.734	17.941	17.542	10778.07	15.080	9058.789	246.993	368.799	359.561	338.774	246.993	10537.79
736	" "	*Irvingia malayana* Oliv. ex A. Benn.	77.5	24.669	608.561	18.008	17.604	10958.69	15.136	9211.333	250.943	374.805	365.527	344.450	250.943	10713.28
737	Ma muang hua mala	*Buchanania reticulata* Hance	77.5	24.669	608.561	18.008	17.604	10958.69	15.136	9211.333	250.943	374.805	365.527	344.450	250.943	10713.28
738	Chig/Teng	*Shorea obtusa* Wall.	78	24.828	616.439	18.073	17.667	11141.15	15.193	9365.345	254.927	380.868	371.556	350.184	254.927	10890.59
739	Chig/Teng	*Shorea obtusa* Wall.	78	24.828	616.439	18.073	17.667	11141.15	15.193	9365.345	254.927	380.868	371.556	350.184	254.927	10890.59
740	Som kop	*Hymenodictyon excelsum* Wall.	79	25.147	632.347	18.205	17.792	11511.60	15.305	9677.785	263.000	393.171	383.801	361.825	263.000	11250.74
741	Pra duu	*Pterocarpus macrocarpus* Kurz	79	25.147	632.347	18.205	17.792	11511.60	15.305	9677.785	263.000	393.171	383.801	361.825	263.000	11250.74
742	Chig/Teng	*Shorea obtusa* Wall.	79	25.147	632.347	18.205	17.792	11511.60	15.305	9677.785	263.000	393.171	383.801	361.825	263.000	11250.74
743	Som sieow/Chong ko	*Bauhinia acuminata* Linn.	79.5	25.306	640.376	18.270	17.854	11699.61	15.360	9836.218	267.089	399.410	390.018	367.733	267.089	11433.59
744	Rok faa	*Terminalia alata*	79.5	25.306	640.376	18.270	17.854	11699.61	15.360	9836.218	267.089	399.410	390.018	367.733	267.089	11433.59
745	Khan nang/Khaa nan	*Homalium tomentosum* Benth.	79.5	25.306	640.376	18.270	17.854	11699.61	15.360	9836.218	267.089	399.410	390.018	367.733	267.089	11433.59
746	" "	*Shorea obtusa* Wall.	79.5	25.306	640.376	18.270	17.854	11699.61	15.360	9836.218	267.089	399.410	390.018	367.733	267.089	11433.59
747	Daeng	*Xylia xylocarpa* Taub.	79.5	25.306	640.376	18.270	17.854	11699.61	15.360	9836.218	267.089	399.410	390.018	367.733	267.089	11433.59
748	Chig/Teng	*Shorea obtusa* Wall.	80	25.465	648.457	18.335	17.917	11889.48	15.415	9996.132	271.212	405.709	396.298	373.699	271.212	11618.30
749	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	80	25.465	648.457	18.335	17.917	11889.48	15.415	9996.132	271.212	405.709	396.298	373.699	271.212	11618.30
750	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	80	25.465	648.457	18.335	17.917	11889.48	15.415	9996.132	271.212	405.709	396.298	373.699	271.212	11618.30
751	Teen nok	*Vitex pinnate* Linn.	80	25.465	648.457	18.335	17.917	11889.48	15.415	9996.132	271.212	405.709	396.298	373.699	271.212	11618.30
752	Khaao	*Haldina cordifolia* Ridsd.	80	25.465	648.457	18.335	17.917	11889.48	15.415	9996.132	271.212	405.709	396.298	373.699	271.212	11618.30
753	Huean kwanng	*Diospyros ehretioides* Wall.	81	25.783	664.769	18.465	18.041	12274.83	15.525	10320.407	279.563	418.483	409.049	385.809	279.563	11993.34
754	" "	*Shorea obtusa* Wall.	81	25.783	664.769	18.465	18.041	12274.83	15.525	10320.407	279.563	418.483	409.049	385.809	279.563	11993.34
755	Rok faa	*Terminalia alata*	82	26.101	681.285	18.594	18.166	12667.72	15.633	10650.634	288.055	431.495	422.057	398.155	288.055	12375.91
756	Chig/Teng	*Shorea obtusa* Wall.	82	26.101	681.285	18.594	18.166	12667.72	15.633	10650.634	288.055	431.495	422.057	398.155	288.055	12375.91
757	Huean kwanng	*Diospyros ehretioides* Wall.	82.5	26.261	689.618	18.658	18.228	12867.00	15.687	10817.985	292.353	438.091	428.657	404.417	292.353	12570.04
758	Muaeat bai khon	*Aporusa ficifolia* Baill.	83	26.420	698.003	18.722	18.289	13068.19	15.740	10986.832	296.686	444.747	435.323	410.739	296.686	12766.08
759	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	83	26.420	698.003	18.722	18.289	13068.19	15.740	10986.832	296.686	444.747	435.323	410.739	296.686	12766.08
760	Chig/Teng	*Shorea obtusa* Wall.	84	26.738	714.923	18.850	18.413	13476.30	15.846	11329.022	305.458	458.240	448.849	423.563	305.458	13163.90
761	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	84	26.738	714.923	18.850	18.413	13476.30	15.846	11329.022	305.458	458.240	448.849	423.563	305.458	13163.90
762	Chig/Teng	*Shorea obtusa* Wall.	84	26.738	714.923	18.850	18.413	13476.30	15.846	11329.022	305.458	458.240	448.849	423.563	305.458	13163.90
763	Chig/Teng	*Shorea obtusa* Wall.	84.5	26.897	723.460	18.914	18.475	13683.23	15.899	11502.371	309.896	465.077	455.710	430.066	309.896	13365.71

764	Chig/Teng	*Shorea obtusa* Wall.	84.5	26.897	723.460	18.914	18.475	13683.23	15.899	11502.371	309.896	465.077	455.710	430.066	309.896	13365.71
765	Sa baeng/Chaad	*Erytholeum teysmannii* Craib	85	27.056	732.047	18.977	18.536	13892.09	15.951	11677.226	314.370	471.975	462.637	436.629	314.370	13569.44
766	Chig/Teng	*Shorea obtusa* Wall.	85	27.056	732.047	18.977	18.536	13892.09	15.951	11677.226	314.370	471.975	462.637	436.629	314.370	13569.44
767	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm.ex M	85.5	27.216	740.684	19.040	18.598	14102.89	16.004	11853.588	318.879	478.934	469.630	443.253	318.879	13775.13
768	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	85.5	27.216	740.684	19.040	18.598	14102.89	16.004	11853.588	318.879	478.934	469.630	443.253	318.879	13775.13
769	Khee kaa		86	27.375	749.373	19.103	18.659	14315.62	16.055	12031.462	323.423	485.954	476.690	449.938	323.423	13982.76
770	Chig/Teng	*Shorea obtusa* Wall.	86	27.375	749.373	19.103	18.659	14315.62	16.055	12031.462	323.423	485.954	476.690	449.938	323.423	13982.76
771	Daeng	*Xylia xylocarpa* Taub.	86.5	27.534	758.112	19.166	18.721	14530.31	16.107	12210.848	328.002	493.036	483.816	456.685	328.002	14192.35
772	Chig/Teng	*Shorea obtusa* Wall.	86.5	27.534	758.112	19.166	18.721	14530.31	16.107	12210.848	328.002	493.036	483.816	456.685	328.002	14192.35
773	Chig/Teng	*Shorea obtusa* Wall.	87.5	27.852	775.742	19.292	18.843	14965.55	16.209	12574.170	337.267	507.383	498.269	470.362	337.267	14617.45
774	Chig/Teng	*Shorea obtusa* Wall.	87.5	27.852	775.742	19.292	18.843	14965.55	16.209	12574.170	337.267	507.383	498.269	470.362	337.267	14617.45
775	Khee kaa		88	28.011	784.633	19.354	18.904	15186.12	16.260	12758.109	341.952	514.650	505.597	477.293	341.952	14832.96
776	Chig/Teng	*Shorea obtusa* Wall.	88	28.011	784.633	19.354	18.904	15186.12	16.260	12758.109	341.952	514.650	505.597	477.293	341.952	14832.96
777	" " "	*Dillenia pentagyna* Roxb.	88.5	28.170	793.574	19.417	18.965	15408.66	16.310	12943.572	346.673	521.978	512.992	484.286	346.673	15050.46
778	Chig/Teng	*Shorea obtusa* Wall.	89	28.330	802.566	19.479	19.026	15633.18	16.361	13130.559	351.429	529.369	520.454	491.341	351.429	15269.95
779	Chig/Teng	*Shorea obtusa* Wall.	89	28.330	802.566	19.479	19.026	15633.18	16.361	13130.559	351.429	529.369	520.454	491.341	351.429	15269.95
780	Chig/Teng	*Shorea obtusa* Wall.	89	28.330	802.566	19.479	19.026	15633.18	16.361	13130.559	351.429	529.369	520.454	491.341	351.429	15269.95
781	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forma	89.5	28.489	811.609	19.541	19.087	15859.69	16.411	13319.073	356.220	536.821	527.985	498.459	356.220	15491.45
782	Chig/Teng	*Shorea obtusa* Wall.	89.5	28.489	811.609	19.541	19.087	15859.69	16.411	13319.073	356.220	536.821	527.985	498.459	356.220	15491.45
783	Kung/Phlong	*Dipterocarpus tuberculatus* Roxb.	90	28.648	820.703	19.603	19.148	16088.19	16.460	13509.116	361.047	544.337	535.585	505.639	361.047	15714.96
784	Chig/Teng	*Shorea obtusa* Wall.	90	28.648	820.703	19.603	19.148	16088.19	16.460	13509.116	361.047	544.337	535.585	505.639	361.047	15714.96
785	" "	*Shorea obtusa* Wall.	90	28.648	820.703	19.603	19.148	16088.19	16.460	13509.116	361.047	544.337	535.585	505.639	361.047	15714.96
786	" "	*Shorea obtusa* Wall.	90.5	28.807	829.847	19.665	19.209	16318.69	16.510	13700.691	365.910	551.915	543.252	512.882	365.910	15940.48
787	Unidentified species 2		90.5	28.807	829.847	19.665	19.209	16318.69	16.510	13700.691	365.910	551.915	543.252	512.882	365.910	15940.48
788	Khan nang/Khaa nan	*Homalium Tomentosum* Benth.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
789	" "	*Shorea obtusa* Wall.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
790	Chig/Teng	*Shorea obtusa* Wall.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
791	" "	*Shorea obtusa* Wall.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
792	" "	*Xylia xylocarpa* Taub.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
793	Chig/Teng	*Shorea obtusa* Wall.	91	28.966	839.042	19.726	19.270	16551.19	16.559	13893.800	370.807	559.556	550.989	520.189	370.807	16168.03
794	Yo paa/Salak paa	*Morinda coreia* Ham.	91.5	29.125	848.288	19.788	19.330	16785.70	16.608	14088.444	375.741	567.260	558.795	527.558	375.741	16397.61
795	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	91.5	29.125	848.288	19.788	19.330	16785.70	16.608	14088.444	375.741	567.260	558.795	527.558	375.741	16397.61
796	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	92	29.285	857.584	19.849	19.391	17022.24	16.657	14284.627	380.710	575.027	566.670	534.991	380.710	16629.23
797	Ma muang paa	*Mangifera longipetiolata* King	92	29.285	857.584	19.849	19.391	17022.24	16.657	14284.627	380.710	575.027	566.670	534.991	380.710	16629.23
798	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	92.5	29.444	866.931	19.910	19.451	17260.79	16.705	14482.350	385.714	582.858	574.614	542.487	385.714	16862.89
799	Tae		93	29.603	876.328	19.971	19.512	17501.38	16.754	14681.615	390.754	590.752	582.629	550.047	390.754	17098.60
800	Pra duu	*Pterocarpus macrocarpus* Kurz	93	29.603	876.328	19.971	19.512	17501.38	16.754	14681.615	390.754	590.752	582.629	550.047	390.754	17098.60
801	Pha yom	*Shorea floribunda* Kurz	94	29.921	895.275	20.093	19.632	17988.67	16.849	15084.781	400.941	606.732	598.867	565.360	400.941	17576.22
802	Mok	*Wrightia pubescens* R. Br.	95	30.239	914.425	20.214	19.752	18484.15	16.944	15494.141	411.271	622.968	615.388	580.930	411.271	18062.12
803	Haen	*Terminalia bellerica Roxb.*	95	30.239	914.425	20.214	19.752	18484.15	16.944	15494.141	411.271	622.968	615.388	580.930	411.271	18062.12
804	" "	*Shorea obtusa* Wall.	95	30.239	914.425	20.214	19.752	18484.15	16.944	15494.141	411.271	622.968	615.388	580.930	411.271	18062.12
805	Chig/Teng	*Shorea obtusa* Wall.	95	30.239	914.425	20.214	19.752	18484.15	16.944	15494.141	411.271	622.968	615.388	580.930	411.271	18062.12
806	Haen	*Terminalia bellerica Roxb.*	96	30.558	933.778	20.334	19.872	18987.88	17.038	15909.712	421.743	639.462	632.193	596.759	421.743	18556.38
807	Pluei kra deng	*Lagerstroemia calyculata Kurz.*	96	30.558	933.778	20.334	19.872	18987.88	17.038	15909.712	421.743	639.462	632.193	596.759	421.743	18556.38
808	Chig/Teng	*Shorea obtusa* Wall.	96	30.558	933.778	20.334	19.872	18987.88	17.038	15909.712	421.743	639.462	632.193	596.759	421.743	18556.38

809	Saat/Hiang	*Dipterocarpus obtusifolius* Teysm, ex	96	30.558	933.778	20.334	19.872	18987.88	17.038	15909.712	421.743	639.462	632.193	596.759	421.743	18556.38
810	Chig/Teng	*Shorea obtusa* Wall.	96	30.558	933.778	20.334	19.872	18987.88	17.038	15909.712	421.743	639.462	632.193	596.759	421.743	18556.38
811	" "	*Shorea obtusa* Wall.	96.5	30.717	943.530	20.395	19.932	19242.85	17.085	16119.831	427.032	647.806	640.702	604.771	427.032	18806.65
812	Chig/Teng	*Shorea obtusa* Wall.	96.5	30.717	943.530	20.395	19.932	19242.85	17.085	16119.831	427.032	647.806	640.702	604.771	427.032	18806.65
813	" "	*Shorea obtusa* Wall.	96.5	30.717	943.530	20.395	19.932	19242.85	17.085	16119.831	427.032	647.806	640.702	604.771	427.032	18806.65
814	Chig/Teng	*Shorea obtusa* Wall.	97	30.876	953.333	20.454	19.992	19499.90	17.131	16331.509	432.358	656.215	649.283	612.849	432.358	19059.03
815	Chig/Teng	*Shorea obtusa* Wall.	98	31.194	973.090	20.574	20.111	20020.26	17.223	16759.548	443.116	673.228	666.661	629.201	443.116	19570.15
816	" "	*Shorea obtusa* Wall.	98	31.194	973.090	20.574	20.111	20020.26	17.223	16759.548	443.116	673.228	666.661	629.201	443.116	19570.15
817	Chig/Teng	*Shorea obtusa* Wall.	98	31.194	973.090	20.574	20.111	20020.26	17.223	16759.548	443.116	673.228	666.661	629.201	443.116	19570.15
818	Chig/Teng	*Shorea obtusa* Wall.	98	31.194	973.090	20.574	20.111	20020.26	17.223	16759.548	443.116	673.228	666.661	629.201	443.116	19570.15
819	Chig/Teng	*Shorea obtusa* Wall.	98	31.194	973.090	20.574	20.111	20020.26	17.223	16759.548	443.116	673.228	666.661	629.201	443.116	19570.15
820	Chig/Teng	*Shorea obtusa* Wall.	98.5	31.354	983.045	20.633	20.171	20283.59	17.269	16975.913	448.549	681.832	675.459	637.475	448.549	19828.90
821	Chig/Teng	*Shorea obtusa* Wall.	98.5	31.354	983.045	20.633	20.171	20283.59	17.269	16975.913	448.549	681.832	675.459	637.475	448.549	19828.90
822	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	99	31.513	993.051	20.693	20.230	20549.02	17.314	17193.844	454.018	690.502	684.329	645.816	454.018	20089.78
823	" "	*Shorea obtusa* Wall.	99	31.513	993.051	20.693	20.230	20549.02	17.314	17193.844	454.018	690.502	684.329	645.816	454.018	20089.78
824	Chig/Teng	*Shorea obtusa* Wall.	99	31.513	993.051	20.693	20.230	20549.02	17.314	17193.844	454.018	690.502	684.329	645.816	454.018	20089.78
825	Som kop	*Hymenodictyon excelsum* Wall.	100	31.831	1013.214	20.811	20.349	21086.21	17.404	17634.412	465.063	708.040	702.287	662.697	465.063	20617.98
826	" " "	*Dillenia pentagyna* Roxb.	101	32.149	1033.579	20.929	20.468	21631.90	17.494	18081.268	476.251	725.842	720.539	679.844	476.251	21154.80
827	Som kop	*Hymenodictyon excelsum* Wall.	102	32.468	1054.147	21.047	20.586	22186.12	17.582	18534.424	487.583	743.909	739.086	697.260	487.583	21700.29
828	Ma lueam	*Canarium subulatum* Grill.	102.5	32.627	1064.507	21.105	20.645	22466.44	17.626	18763.370	493.303	753.043	748.470	706.069	493.303	21976.31
829	Ma muang hua mala	*Buchanania reticulata* Hance	102.5	32.627	1064.507	21.105	20.645	22466.44	17.626	18763.370	493.303	753.043	748.470	706.069	493.303	21976.31
830	Chig/Teng	*Shorea obtusa* Wall.	103	32.786	1074.918	21.163	20.703	22748.92	17.670	18993.896	499.059	762.243	757.929	714.946	499.059	22254.51
831	Chig/Teng	*Shorea obtusa* Wall.	103	32.786	1074.918	21.163	20.703	22748.92	17.670	18993.896	499.059	762.243	757.929	714.946	499.059	22254.51
832	Chig/Teng	*Shorea obtusa* Wall.	104	33.104	1095.892	21.280	20.821	23320.35	17.757	19459.698	510.679	780.846	777.071	732.902	510.679	22817.51
833	Chig/Teng	*Shorea obtusa* Wall.	104	33.104	1095.892	21.280	20.821	23320.35	17.757	19459.698	510.679	780.846	777.071	732.902	510.679	22817.51
834	Pra duu	*Pterocarpus macrocarpus* Kurz	105	33.423	1117.068	21.396	20.938	23900.47	17.843	19931.842	522.443	799.718	796.514	751.132	522.443	23389.35
835	Haen	*Terminalia bellerica Roxb.*	105	33.423	1117.068	21.396	20.938	23900.47	17.843	19931.842	522.443	799.718	796.514	751.132	522.443	23389.35
836	Sa thon	*Milletoa leucantha* Kruz	105	33.423	1117.068	21.396	20.938	23900.47	17.843	19931.842	522.443	799.718	796.514	751.132	522.443	23389.35
837	Pra duu	*Pterocarpus macrocarpus* Kurz	105.5	33.582	1127.732	21.453	20.997	24193.79	17.886	20170.297	528.378	809.255	806.348	760.349	528.378	23678.59
838	Chig/Teng	*Shorea obtusa* Wall.	105.5	33.582	1127.732	21.453	20.997	24193.79	17.886	20170.297	528.378	809.255	806.348	760.349	528.378	23678.59
839	Phaeng/San chaang	*Dillenia pentagyna* Roxb.	106.5	33.900	1149.212	21.569	21.113	24787.01	17.971	20651.981	540.359	828.533	826.244	778.991	540.359	24263.77
840	Daeng	*Xylia xylocarpa* Taub.	107	34.059	1160.028	21.626	21.172	25086.92	18.013	20895.213	546.403	838.275	836.306	788.415	546.403	24559.72
841	Chig/Teng	*Shorea obtusa* Wall.	108	34.377	1181.812	21.741	21.288	25693.35	18.096	21386.465	558.599	857.963	856.660	807.471	558.599	25158.36
842	Chig/Teng	*Shorea obtusa* Wall.	108	34.377	1181.812	21.741	21.288	25693.35	18.096	21386.465	558.599	857.963	856.660	807.471	558.599	25158.36
843	Chig/Teng	*Shorea obtusa* Wall.	108	34.377	1181.812	21.741	21.288	25693.35	18.096	21386.465	558.599	857.963	856.660	807.471	558.599	25158.36
844	Chig/Teng	*shorea obtusa* Wall.	109	34.696	1203.799	21.855	21.404	26308.65	18.179	21884.112	570.941	877.925	877.321	826.807	570.941	25766.04
845	" "	*Shorea obtusa* Wall.	109.5	34.855	1214.868	21.912	21.462	26619.64	18.220	22135.337	577.165	888.009	887.768	836.579	577.165	26073.29
846	Pluei lueat/Ta baek	*Terminalia corticorsa* Pierre ex Laness	110	35.014	1225.988	21.968	21.520	26932.87	18.261	22388.166	583.426	898.163	898.292	846.422	583.426	26382.81
847	Kor	*Livistona speciosa*	110	35.014	1225.988	21.968	21.520	26932.87	18.261	22388.166	583.426	898.163	898.292	846.422	583.426	26382.81
848	Pra duu	*Pterocarpus macrocarpus* Kurz	111	35.332	1248.380	22.081	21.635	27566.04	18.343	22898.640	596.057	918.678	919.572	866.319	596.057	27008.72
849	Nam kliang	*Melanorrhoea laccifera* Pierre	112	35.651	1270.975	22.194	21.750	28208.22	18.423	23415.545	608.832	939.472	941.166	886.499	608.832	27643.81
850	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	113.5	36.128	1305.247	22.362	21.922	29188.48	18.543	24202.987	628.267	971.186	974.145	917.302	628.267	28613.79
851	Chig/Teng	*Shorea obtusa* Wall.	113.5	36.128	1305.247	22.362	21.922	29188.48	18.543	24202.987	628.267	971.186	974.145	917.302	628.267	28613.79
852	Nang dum/Lang dum	*Diospyros castanea* Fletch	114	36.287	1316.772	22.418	21.979	29519.79	18.582	24468.696	634.817	981.898	985.296	927.713	634.817	28941.77
853	Mai pae/Sa kang	*Vitex tripinnate* Merr.	114	36.287	1316.772	22.418	21.979	29519.79	18.582	24468.696	634.817	981.898	985.296	927.713	634.817	28941.77

854	Saen kum	*Terminalia nigrorenulosa* Pierre ex Lan	114.5	36.447	1328.348	22.474	22.036	29853.38	18.622	24736.021	641.404	992.681	996.527	938.196	641.404	29272.07
855	Pra duu	*Pterocarpus macrocarpus* Kurz	115	36.606	1339.975	22.530	22.093	30189.26	18.661	25004.964	648.027	1003.534	1007.837	948.750	648.027	29604.72
856	Chig/Teng	*Shorea obtusa* Wall.	116	36.924	1363.380	22.641	22.207	30867.92	18.739	25547.709	661.383	1025.453	1030.696	970.077	661.383	30277.06
857	Chig/Taeng	*Shorea obtusa* Wall.	116	36.924	1363.380	22.641	22.207	30867.92	18.739	25547.709	661.383	1025.453	1030.696	970.077	661.383	30277.06
858	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	116	36.924	1363.380	22.641	22.207	30867.92	18.739	25547.709	661.383	1025.453	1030.696	970.077	661.383	30277.06
859	Unidentified species 1		117	37.242	1386.988	22.751	22.321	31555.82	18.816	26096.943	674.883	1047.656	1053.876	991.693	674.883	30958.83
860	Chig/Teng	*Shorea obtusa* Wall.	117	37.242	1386.988	22.751	22.321	31555.82	18.816	26096.943	674.883	1047.656	1053.876	991.693	674.883	30958.83
861	Pra duu	*Pterocarpus macrocarpus* Kurz	118	37.561	1410.799	22.862	22.434	32252.99	18.892	26652.674	688.529	1070.145	1077.379	1013.601	688.529	31650.08
862	Saai den	*Polyathia cerasoides* Benth. ex Bedd.	118	37.561	1410.799	22.862	22.434	32252.99	18.892	26652.674	688.529	1070.145	1077.379	1013.601	688.529	31650.08
863	Chig/Teng	*Shorea obtusa* Wall.	118	37.561	1410.799	22.862	22.434	32252.99	18.892	26652.674	688.529	1070.145	1077.379	1013.601	688.529	31650.08
864	" "	*Homalium tomentosum* Benth.	119	37.879	1434.812	22.971	22.547	32959.49	18.968	27214.915	702.320	1092.921	1101.205	1035.802	702.320	32350.86
865	Chig/Teng	*Shorea obtusa* Wall.	120.5	38.356	1471.211	23.135	22.716	34036.83	19.080	28070.503	723.279	1127.625	1137.556	1069.656	723.279	33419.99
866	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forma	121	38.516	1483.446	23.190	22.772	34400.65	19.117	28358.965	730.339	1139.338	1149.836	1081.089	730.339	33781.18
867	Daeng	*Xylia xylocarpa* Taub.	122.5	38.993	1520.454	23.352	22.940	35506.32	19.227	29234.164	751.735	1174.913	1187.171	1115.833	751.735	34879.27
868	Chig/Teng	*Shorea obtusa* Wall.	122.5	38.993	1520.454	23.352	22.940	35506.32	19.227	29234.164	751.735	1174.913	1187.171	1115.833	751.735	34879.27
869	Ma rum paa	*Albizia lebbeck* (L.) Benth.	123.5	39.311	1545.379	23.460	23.052	36255.33	19.300	29825.821	766.181	1198.994	1212.474	1139.370	766.181	35623.48
870	Chig/Teng	*Shorea obtusa* Wall.	124	39.470	1557.917	23.514	23.107	36633.42	19.336	30124.110	773.458	1211.145	1225.251	1151.251	773.458	35999.26
871	Chig/Teng	*Shorea obtusa* Wall.	124.5	39.630	1570.506	23.568	23.163	37013.91	19.372	30424.041	780.772	1223.369	1238.110	1163.208	780.772	36377.48
872	Chig/Taeng	*Shorea obtusa* Wall.	124.5	39.630	1570.506	23.568	23.163	37013.91	19.372	30424.041	780.772	1223.369	1238.110	1163.208	780.772	36377.48
873	Chig/Teng	*Shorea obtusa* Wall.	125	39.789	1583.146	23.622	23.218	37396.80	19.408	30725.615	788.123	1235.667	1251.053	1175.240	788.123	36758.16
874	Chig/Teng	*Shorea obtusa* Wall.	127	40.425	1634.212	23.836	23.440	38952.51	19.550	31948.369	817.890	1285.597	1303.665	1224.126	817.890	38305.55
875	Daeng	*Xylia xylocarpa* Taub.	128	40.744	1660.049	23.942	23.550	39744.92	19.620	32569.635	832.992	1311.008	1330.476	1249.027	832.992	39094.12
876	" "	*Shorea obtusa* Wall.	128.5	40.903	1673.044	23.995	23.605	40144.79	19.654	32882.744	840.598	1323.825	1344.009	1261.592	840.598	39492.14
877	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	129.5	41.221	1699.184	24.101	23.715	40951.87	19.724	33513.920	855.919	1349.685	1371.330	1286.954	855.919	40295.70
878	" "	*Shorea obtusa* Wall.	129.5	41.221	1699.184	24.101	23.715	40951.87	19.724	33513.920	855.919	1349.685	1371.330	1286.954	855.919	40295.70
879	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	130	41.380	1712.331	24.154	23.769	41359.09	19.758	33831.989	863.634	1362.727	1385.118	1299.751	863.634	40701.24
880	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	132	42.017	1765.423	24.364	23.988	43012.66	19.894	35120.830	894.860	1415.650	1441.129	1351.712	894.860	42348.61
881	Rok faa	*Terminalia alata*	138	43.927	1929.564	24.987	24.635	48213.22	20.288	39146.932	992.045	1581.731	1617.485	1515.134	992.045	47535.57
882	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	139	44.245	1957.630	25.089	24.742	49115.40	20.352	39841.302	1008.754	1610.490	1648.107	1543.485	1008.754	48436.20
883	Kra bok	*Irvingia malayana* Oliv. ex A. Benn.	139.5	44.404	1971.739	25.140	24.796	49570.33	20.384	40190.997	1017.164	1624.986	1663.550	1557.780	1017.164	48890.43
884	Chig/Teng	*Shorea obtusa* Wall.	140	44.563	1985.899	25.192	24.849	50027.82	20.415	40542.366	1025.610	1639.560	1679.083	1572.156	1025.610	49347.26
885	Chig/Teng	*Shorea obtusa* Wall.	142	45.200	2043.044	25.395	25.061	51883.51	20.540	41964.598	1059.760	1698.637	1742.104	1630.470	1059.760	51200.83
886	" "	*Livistona speciosa*	143	45.518	2071.920	25.497	25.167	52826.88	20.602	42685.782	1077.054	1728.647	1774.152	1660.114	1077.054	52143.42
887	Ma kok paa	*Spondias bipinnata* Airy Shaw & Forma	147	46.792	2189.453	25.899	25.586	56704.73	20.844	45637.791	1147.696	1851.852	1905.955	1781.971	1147.696	56019.97
888	Chig/Teng	*Shorea obtusa* Wall.	158	50.293	2529.386	26.982	26.715	68248.07	21.473	54313.635	1354.041	2217.257	2298.747	2144.709	1354.041	67572.67
889	Kok kan	*Canarium subulatum* Guill.	158	50.293	2529.386	26.982	26.715	68248.07	21.473	54313.635	1354.041	2217.257	2298.747	2144.709	1354.041	67572.67
890	Saen kum	*Terminalia nigrorenulosa* Pirre ex Lane	159	50.611	2561.505	27.079	26.816	69362.70	21.528	55143.107	1373.679	2252.444	2336.699	2179.735	1373.679	68688.91
891	Kor	*Livistona speciosa*	169	53.794	2893.839	28.033	27.807	81122.87	22.052	63813.635	1578.106	2622.768	2737.224	2549.285	1578.106	80469.07
892	Yo paa/Salak paa	*Morinda coreia* Ham.	169.5	53.954	2910.988	28.080	27.856	81740.57	22.077	64265.148	1588.712	2642.176	2758.263	2568.696	1588.712	81087.87
893	Chig/Teng	*Shorea obtusa* Wall.	170	54.113	2928.187	28.127	27.904	82361.13	22.102	64718.377	1599.354	2661.669	2779.400	2588.196	1599.354	81709.53
894	Chig/Teng	*Shorea obtusa* Wall.	188	59.842	3581.102	29.781	29.607	106648.25	22.949	82182.881	2006.831	3421.620	3606.094	3351.393	2006.831	106024.07
895	Kor	*Livistona speciosa*	226	71.938	5175.090	33.062	32.876	171097.18	24.436	126461.066	3022.230	5416.918	5785.978	5376.633	3022.230	170138.28
896	Chig/Teng	*Shorea obtusa* Wall.	233	74.166	5500.635	33.639	33.431	185036.92	24.674	135723.784	3232.151	5845.370	6253.569	5814.675	3232.151	183890.96
897	Sa thon	*Milletoa leucantha* Kurz.	15	4.775	22.797	7.089	9.172	161.60	4.434	101.092	3.451	6.222	8.386	5.163	3.451	209.10
898	Thom	*Mitragyna javanica Koord. & Val*	15.5	4.934	24.342	7.222	9.245	175.80	4.563	111.085	3.774	6.753	8.927	5.609	3.774	225.03

899	Daeng	*Xylia xylocarpa* Taub.	16	5.093	25.938	7.353	9.317	190.73	4.691	121.688	4.116	7.310	9.492	6.078	4.116	241.66
900	Daeng	*Xylia xylocarpa* Taub.	17	5.411	29.282	7.611	9.461	222.85	4.944	144.780	4.854	8.504	10.695	7.088	4.854	277.02
901	" "	*Morinda coreia* Ham.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
902	Teen nok	*Vitex pinnate* Linn.	23	7.321	53.599	9.035	10.318	484.29	6.380	341.957	10.984	18.081	20.079	15.303	10.984	553.03
903	Daeng	*Xylia xylocarpa* Taub.	29	9.231	85.211	10.306	11.164	878.21	7.689	655.148	20.370	32.244	33.621	27.682	20.370	951.32
904	Kan Krao		31.5	10.027	100.536	10.802	11.514	1085.95	8.200	824.418	25.340	39.634	40.633	34.210	25.340	1157.55
905	Chig/Teng	*Shorea obtusa* Wall.	32.5	10.345	107.021	10.995	11.653	1176.69	8.400	898.947	27.512	42.849	43.678	37.061	27.512	1247.11
906	Chig/Teng	*Shorea obtusa* Wall.	33	10.504	110.339	11.091	11.722	1223.73	8.498	937.710	28.637	44.513	45.253	38.539	28.637	1293.45
907	Pha yom	*Shorea floribunda* Kurz	36.5	11.618	134.985	11.744	12.207	1585.25	9.170	1237.819	37.281	57.245	57.300	49.900	37.281	1647.75
908	Thom	*Mitragyna javanica Koord. & Val*	40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
909	Saen phan		40	12.732	162.114	12.370	12.688	2005.43	9.810	1590.266	47.300	71.942	71.209	63.104	47.300	2056.84
910	Huean kwanng	*Diospyros ehretioides* Wall.	44	14.006	196.158	13.058	13.232	2561.49	10.504	2060.455	60.497	91.259	89.528	80.577	60.497	2595.64
911	Yor paa	*Morinda coreia* Ham.	50	15.916	253.303	14.041	14.041	3556.67	11.479	2907.749	83.917	125.552	122.197	111.850	83.917	3556.51
912	Huean kwanng	*Diospyros ehretioides* Wall.	58	18.462	340.845	15.276	15.101	5206.58	12.669	4318.206	122.182	181.837	176.277	163.696	122.182	5147.08
913	Chig/Teng	*Shorea obtusa* Wall.	89	28.330	802.566	19.479	19.026	15633.18	16.361	13130.559	351.429	529.369	520.454	491.341	351.429	15269.95
914	Yor paa	*Morinda coreia* Ham.	91.5	29.125	848.288	19.788	19.330	16785.70	16.608	14088.444	375.741	567.260	558.795	527.558	375.741	16397.61
915	Chig/Teng	*Shorea obtusa* Wall.	105	33.423	1117.068	21.396	20.938	23900.47	17.843	19931.842	522.443	799.718	796.514	751.132	522.443	23389.35
916	Chig/Teng	*Shorea obtusa* Wall.	113	35.969	1293.772	22.306	21.865	28859.45	18.503	23938.893	621.752	960.545	963.073	906.963	621.752	28288.15
917	Chig/Teng	*Shorea obtusa* Wall.	135	42.972	1846.582	24.677	24.313	45567.65	20.093	37103.901	942.795	1497.311	1527.736	1432.000	942.795	44895.87
918	Chig/Teng	*Shorea obtusa* Wall.	245	77.986	6081.814	34.612	34.347	210504.00	25.060	152408.324	3608.500	6625.830	7103.549	6614.951	3608.500	208890.38

Appendix 5.2: Annual maximum & minimum temperature at Khong Chiam during 1988-1997.

Year	Max. Temp (C)	Mini. Temp (C)	Average temp.	NPP
1988	41.0	15.0	28.00	2647.711
1989	39.5	15.0	27.25	2619.000
1990	41.0	15.0	28.00	2647.711
1991	40.5	16.5	28.5	2665.794
1992	41.0	13.5	27.25	2619.000
1993	39.0	13.5	26.25	2577.632
1994	39.5	13.5	26.50	2588.313
1995	39.5	13.5	26.50	2588.313
1996	40.0	13.0	26.50	2588.313
1997	39.0	15.0	27.00	2608.995
Mean	39.938	14.2	27.06	2615.078
S.D.	0.861	1.255	0.9174	30.406

Miami model:

$NPP = 3000/(1+e^{(1.315-0.119T)})$

2906.574 **g/m2/yr***

*Miami model(Leith, 1973) for annual maximum temperature.

1776.777 **g/m2/yr****

** Miami model(Leith, 1973) for annual minimum temperature.

2611.517 **g/m2/yr*****

***Miami model(Leith, 1973) for annual average temperature.

Khao Chong (Kira et al., 1967), ANPP= 2923g/m2/yr, annual temperature = 27.2

2617.017 **g/m2/yr***** 89.53 %

1308.508 **gC/m2/yr**

Field data:Miami model = 1.132203804

Appendix 5.3: Annual precipitation (mm) at Khong Chiam and Ban Kum during 1988-1997

Year	Khong Chiam	NPP	Ban Kum	NPP
1988	1763.6	2069.86		0.00
1989	2196.4	2302.18		0.00
1990	2216.9	2311.62	2127.0	2269.27
1991	2425.5	2400.66	2328.6	2360.83
1992	2000.4	2205.19	1963.4	2185.42
1993	1559.3	1934.72	1570.1	1942.33
1994	2223.4	2314.58	2485.9	2424.22
1995	1483.4	1879.66	1361.5	1785.20
1996	2331.1	2361.89	1854.1	2124.11
1997	2316.0	2355.46	2260.1	2331.08
Mean	2069.500	2213.580	1993.838	2201.72
STD	360.543	187.017	361.019	639.45

NPP = 3000(1-e^-*0.000664N)*

2240.83398 g/m2/yr

1120.41699 gC/m2/yr

*Miami model (Leith, 1973) for annual precipitation vs. productivity

Khao Chong NPP (Kira et al., 1967), annual precipitation = 2696 mm.

2499.19101 g/m2/yr

1249.5955 gC/m2/yr

Ratio= 1.169574264

Appendix 5.4: Monthly data of water quality such as DO, conductivity, pH, temperature flow and total suspended solid (TSS) at Khong Chiam, Mekong River during 1988-1997.

Month	DO(mg/l)	Conductivity(mS/m)	pH	Temp(C)	Flow(cms)	TSS (mg/l)
Jan-88	7.92	22.6	8.17	23.6	2580	10
Feb-88	7.74	23.3	8.26	26.4	2110	6
Mar-88	8.04	24.7	8.02	25.2	1850	6
Apr-88	7.26	25	7.95	26	1350	7
May-88	6.55	23.3	8.04	29.4	3430	92
Jun-88	6.51	17	7.63	29.2	7320	262
Jul-88	6.49	20.1	7.77	30.0	8290	385
Aug-88	6.67	15.8	8.23	26.8	27900	704
Sep-88	6.55	15.8	7.94	28.2	14900	348
Oct-88	6.58	17.3	7.76	26.6	15500	490
Nov-88	7.67	18.3	8	23.6	5300	178
Dec-88	7.62	20.9	7.86	22.0	3590	63
Jan-89	7.52	23.4	8.63	25.6	2400	13
Feb-89	8.33	24.6	8.72	22.8	1800	6
Mar-89	9.52	25.5	9.04	23.8	1460	5
Apr-89	7.01	24.5	8.74	28.0	1620	8
May-89	6.84	24.4	8.58	30.8	2230	13
Jun-89	6.59	17.5	8.29	27.8	12800	384
Jul-89	7.46	21.6	8.72	28.8	8520	655
Aug-89	7.33	15	7.95	27.0	20900	568
Sep-89	7.2	13.7	7.74	27.4	19800	252
Oct-89	6.48	15.1	7.88	26.0	18000	676
Nov-89	8.15	18.7	7.99	26.6	6950	368
Dec-89	8.38	22.1	7.86	23.4	4080	116
Jan-90	8.32	22.3	7.86	25.4	3040	30
Feb-90	7.64	22.8	8.1	25.4	2260	23
Mar-90	7.88	24.3	7.58	25.4	2230	13
Apr-90	8.64	23.3	8.07	29.8	1990	9
May-90	6.69	24.4	7.82	30.4	2200	36
Jun-90	6.92	16.4	7.43	27.6	15200	484
Jul-90	7.14	15.8	7.4	27.2	17600	575
Aug-90	6.82	16.7	7.77	29.2	25400	598
Sep-90	6.98	15.6	8.17	28.4	21400	419
Oct-90	7.69	21.4	7.94	26.4	15500	543
Nov-90	8.4	19.4	9.01	24.4	8370	302
Dec-90	10.47	21.2	8.06	23.2	4400	120
Jan-91	9.06	22.8	7.98	25.4	2940	24
Feb-91	9.69	24.8	7.15	25.4	2120	31
Mar-91	9.29	25.1	8.4	28.4	2020	5
Apr-91	11.3	25.2	7.42	30.0	2320	8
May-91	8.46	25.2	8.2	31.0	1780	25
Jun-91	7.76	22.4	8.26	29.2	4490	162
Jul-91	7.67	15.7	7.72	28.6	9610	566
Aug-91	8.43	17.2	8.28	28.0	17800	830
Sep-91	7.62	17.4	7.61	28.4	21300	643
Oct-91	8.56	17.5	8.0	27.8	14400	597
Nov-91	8.19	18.2	8.01	25.4	8520	622
Dec-91	8.91	21.8	8.03	23.8	3980	172
Jan-92	9.23	23.4	8.28	21.6	3620	72.0
Feb-92	7.55	23.0	8.28	25.6	2910	39.0
Mar-92	7.12	25.0	7.38	26	2740	17.0
Apr-92	7.39	24.2	7.91	19.6	2160	5.0
May-92	7.82	26.2	8.17	31.4	1990	29.0
Jun-92	7.73	23.6	8.16	29.2	5030	169.0
Jul-92	8.15	17.6	7.9	28	10200	293.0
Aug-92	7.34	15.0	7.51	28.4	16000	553.0
Sep-92	9.39	13.6	7.64	28.4	16500	273.0
Oct-92	7.88	16.9	8.02	27.2	10600	404.0
Nov-92	9.36	18.2	7.88	22.8	52500	311.0

Dec-92	9.43	22.1	8.1	24.8	3420	104.0
Jan-93	8.7	22.2	8.05	24.3	2820	29.0
Feb-93	8.75	26.1	7.97	23.6	2140	11.0
Mar-93	8.32	25.6	8.5	27.2	2040	6.0
Apr-93	8.54	25.0	8	28	1640	18.0
May-93	8.22	24.9	8.2	30.8	2230	6.0
Jun-93	7.26	17.9	8.43	29.4	7230	225.0
Jul-93	8.1	15.0	7.85	27.8	15500	211.0
Aug-93	6.95	15.4	7.8	27.7	17600	347.0
Sep-93	7.15	16.5	8.13	25.8	24000	1675.0
Oct-93	8.49	18.8	8	27.4	92900	129.0
Nov-93	8.4	19.0	7.64	26.2	5630	196.0
Dec-93	8.65	21.4	7.97	24.2	3330	56.0
Jan-94	8.88	23.0	8.28	23.8	2860	31.0
Feb-94	8.86	24.0	8.55	26.6	2140	23.0
Mar-94	6.58	25.5	8.57	26.8	2040	13.0
Apr-94	8.05	26.3	8.48	30.4	1640	13.0
May-94	7.08	24.8	7.79	31	2570	9.0
Jun-94	7.17	12.2	8.1	27.2	7510	171.0
Jul-94	6.67	10.9	7.48	26.6	12200	496.0
Aug-94	6.89	12.6	7.97	29.4	17100	184.0
Sep-94	7.39	12.3	7.93	28	24000	393.0
Oct-94	7.41	15.9	8.17	28.2	9290	400.0
Nov-94	7.7	18.0	8.28	24.9	5900	135.0
Dec-94	9.19	20.1	7.51	26	3300	64.0
Jan-95	8.36	22.7	8.19	23		56.0
Feb-95	8.3	21.9	8.32	24.2		19.0
Mar-95	7.41	21.9	8.08	27.4		58.0
Apr-95	7.52	24.1	8.29	30.4		66.0
May-95	7.47	19.5	7.93	29		78.0
Jun-95	7.43	15.8	7.71	28.4		274.0
Jul-95	7.74	16.2	7.86	28.1		322.0
Aug-95	7.87	13.7	7.73	27.2		374.0
Sep-95	6.42	12.1	7.75	27.8		310.0
Oct-95	7.25	14.7	7.69	26.4		245.0
Nov-95	7.9	19.2	7.88	26		137.0
Dec-95	8.4	18.4	7.98	22.4		115.0
Jan-96	8.13	21.6	8.09	23	2327	23.0
Feb-96	8.05	22.2	7.78	23	2316	10.0
Mar-96	7.97	23.2	8.26	26.8	1862	6.0
Apr-96	10.01	25.0	7.95	29.4	2088	14.0
May-96	7.22	22.0	7.97	30	3039	70.0
Jun-96	8.18	19.9	8.03	30.8	5061	16.0
Jul-96	7.62	18.9	7.76	30	10086	69.0
Aug-96	6.77	14.1	7.84	27	25819	106.0
Sep-96	7.46	10.9	7.65	26.4	28176	107.0
Oct-96	7.99	15.7	7.41	27.4	14860	239.0
Nov-96	9.58	17.3	7.61	26.8	7803	109.0
Dec-96	8.46	20.1	7.52	23.4	4052	27.0
Jan-97	9.35	22.2	8.2	21.4	2659	16.0
Feb-97	7.97	22.6	8.08	25.4		7.0
Mar-97	6.46	22.8	8.03	26.9		21.0
Apr-97	7.06	22.0	7.73	29		33.0
May-97	8.73	22.2	7.82	30.4		20.0
Jun-97	9.13	20.6	7.83	29.5		39.0
Mean	**7.9**	**20.1**	**8.0**	**26.8**	**9391.5**	**197.8**
SD.	**0.9**	**4.0**	**0.3**	**2.5**	**12145**	**250.4**

Appendix 5.5 : Water level (MSL) at Khong Chiam and Ban Kum (Jan'96-Dec'97)

Month	Khong Chiam	Ban Kum
Jan-96	90.98	91.07
Feb-96	90.89	91.06
Mar-96	90.64	90.69
Apr-96	90.66	90.64
May-96	90.85	90.96
Jun-96	91.76	91.90
Jul-96	93.54	93.62
Aug-96	99.47	101.04
Sep-96	98.06	100.08
Oct-96	95.57	96.23
Nov-96	94.27	94.69
Dec-96	92.77	91.63
Jan-97	91.18	91.22
Feb-97	90.70	90.93
Mar-97	90.55	90.46
Apr-97	90.61	90.78
May-97	90.80	91.05
Jun-97	94.83	95.38
Jul-97	102.47	104.78
Aug-97	103.64	106.02
Sep-97	102.59	105.73
Oct-97	98.22	99.26
Nov-97	93.83	94.91
Dec-97	92.27	92.9

Appendix 5.6: A comparison of ground floor biomass of Thai study site during the rainy and dry season. (July 97 &April 98)

Plot no.	Mean(June 97)	Mean(April 98)
1	245.12	117.46
2	155.28	87.29
3	225.78	137.02
4	192.26	54.26
5	223.78	76.53
6	203.25	83.59
7	128.9	90.05
8	173.01	70.78
9	140.06	108.86
10	127.97	150.48
11	113.92	104.29
12	138.31	90.94
13	345.6	98.86
14	97.31	154.94
15	160.76	150.54
16	946.89	1568.5
17	58.4	227.06
18	120.29	112.99
19	90.37	0
20	164.23	113.04
21	133.45	119.58
22	134.88	114.67
23	157.29	104.87
24	163.14	109.18
25	908.38	935.35
26	220.3	119.92
27	156.82	128.58
28	126.83	149.3
29	181.19	227.46
30	190.14	164.83
Mean	214.13	192.37
SD.	201.52	303.06

Appendix 5.7: Estimation of size-class of tree species in the different forest types				
	Primary forest	Secondary forest	Riparian forest	
Class of dbh	No. of tree/ha	No. of tree/ha	No. of tree/ha	
>4.5-5	13	54	28	
>5-10	107	236	192	
>10-15	81	132	136	
>15-20	69	60	92	
>20-25	49	76	56	
>25-30	47	51	28	
>30-35	27	33	32	
>35-40	17	22	16	
>40-45	6	8	12	
>45	43	4	36	
Total	459	676	628	

Appendix 5.8: Carbon storage and carbon storage value in terrestrial ecosystems during 50 year-period under three scenarios (I=$11, II=$56 and III=$200 per tonne C).

Year	TCprim	TCsecon	TCripar	TCiripzon	TCgras	TCrice	TChgarden	TC-gain	TC-gain (I)	TC-gain (II)	TC-gain (III)	TC-loss	TC-loss value (I)	TC-loss value(II)	TC-loss value(III)	Land use	Encroachment	Year	TC-gain	TC-loss
0	478951.0	124775.0	54099.0	495.0	81	374	446	659221	7.25	36.92	131.84	-659221	-7.25	-36.92	-131.84	9400.0	0	0	659221	-659221
1	481115.0	130543.4	56179.8	1535.4	81	374	630.96	670461	7.38	37.55	134.09	-695090	-7.65	-38.93	-139.02	9644.4	-244.4	1	670461	-695090
2	483279.1	136311.9	58260.6	2575.8	81	374	815.92	681700	7.50	38.18	136.34	-731891	-8.05	-40.99	-146.38	9895.2	-250.8	2	681700	-731891
3	485443.1	142080.3	60341.4	3616.2	81	374	1000.88	692940	7.62	38.80	138.59	-769649	-8.47	-43.10	-153.93	10152.4	-257.3	3	692940	-769649
4	487607.1	147848.8	62422.2	4656.6	81	374	1185.84	704180	7.75	39.43	140.84	-808388	-8.89	-45.27	-161.68	10416.4	-264.0	4	704180	-808388
5	489771.2	153617.2	64503.0	5697.0	81	374	1370.8	715419	7.87	40.06	143.08	-848135	-9.33	-47.50	-169.63	10687.2	-270.8	5	715419	-848135
6	491935.2	159385.6	66583.8	6737.4	81	374	1555.76	726659	7.99	40.69	145.33	-888915	-9.78	-49.78	-177.78	10965.1	-277.9	6	726659	-888915
7	494099.2	165154.1	68664.6	7777.8	81	374	1740.72	737898	8.12	41.32	147.58	-930756	-10.24	-52.12	-186.15	11250.2	-285.1	7	737898	-930756
8	496263.3	170922.5	70745.4	8818.2	81	374	1925.68	749138	8.24	41.95	149.83	-973684	-10.71	-54.53	-194.74	11542.7	-292.5	8	749138	-973684
9	498427.3	176691.0	72826.2	9858.6	81	374	2110.64	760378	8.36	42.58	152.08	-1017729	-11.20	-56.99	-203.55	11842.8	-300.1	9	760378	-1017729
10	500591.3	182459.4	74907.0	10899.0	81	374	2295.6	771617	8.49	43.21	154.32	-1062919	-11.69	-59.52	-212.58	12150.7	-307.9	10	771617	-1062919
11	502755.4	188227.8	76987.8	11939.4	81	374	2480.56	782857	8.61	43.84	156.57	-1109283	-12.20	-62.12	-221.86	12466.6	-315.9	11	782857	-1109283
12	504919.4	193996.3	79068.6	12979.8	81	374	2665.52	794097	8.74	44.47	158.82	-1156853	-12.73	-64.78	-231.37	12790.8	-324.1	12	794097	-1156853
13	507083.4	199764.7	81149.4	14020.2	81	374	2850.48	805336	8.86	45.10	161.07	-1205660	-13.26	-67.52	-241.13	13123.3	-332.6	13	805336	-1205660
14	509247.4	205533.2	83230.2	15060.6	81	374	3035.44	816576	8.98	45.73	163.32	-1255736	-13.81	-70.32	-251.15	13464.5	-341.2	14	816576	-1255736
15	511411.5	211301.6	85311.0	16101.0	81	374	3220.4	827815	9.11	46.36	165.56	-1307114	-14.38	-73.20	-261.42	13814.6	-350.1	15	827815	-1307114
16	513575.5	217070.0	87391.8	17141.4	81	374	3405.36	839055	9.23	46.99	167.81	-1359828	-14.96	-76.15	-271.97	14173.8	-359.2	16	839055	-1359828
17	515739.5	222838.5	89472.6	18181.8	81	374	3590.32	850295	9.35	47.62	170.06	-1413912	-15.55	-79.18	-282.78	14542.3	-368.5	17	850295	-1413912
18	517903.6	228606.9	91553.4	19222.2	81	374	3775.28	861534	9.48	48.25	172.31	-1469403	-16.16	-82.29	-293.88	14920.4	-378.1	18	861534	-1469403
19	520067.6	234375.4	93634.2	20262.6	81	374	3960.24	872774	9.60	48.88	174.55	-1526336	-16.79	-85.47	-305.27	15308.3	-387.9	19	872774	-1526336
20	522231.6	240143.8	95715.0	21303.0	81	374	4145.2	884014	9.72	49.50	176.80	-1584750	-17.43	-88.75	-316.95	15706.3	-398.0	20	884014	-1584750
21	524395.7	245912.2	97795.8	22343.4	81	374	4330.16	895253	9.85	50.13	179.05	-1644682	-18.09	-92.10	-328.94	16114.7	-408.4	21	895253	-1644682
22	526559.7	251680.7	99876.6	23383.8	81	374	4515.12	906493	9.97	50.76	181.30	-1706172	-18.77	-95.55	-341.23	16533.7	-419.0	22	906493	-1706172
23	528723.7	257449.1	101957.4	24424.2	81	374	4700.08	917733	10.10	51.39	183.55	-1769262	-19.46	-99.08	-353.85	16963.6	-429.9	23	917733	-1769262
24	530887.8	263217.6	104038.2	25464.6	81	374	4885.04	928972	10.22	52.02	185.79	-1833991	-20.17	-102.70	-366.80	17404.6	-441.1	24	928972	-1833991
25	533051.8	268986.0	106119.0	26505.0	81	374	5070	940212	10.34	52.65	188.04	-1900404	-20.90	-106.42	-380.08	17857.1	-452.5	25	940212	-1900404
26	535215.8	274754.4	108199.8	27545.4	81	374	5254.96	951451	10.47	53.28	190.29	-1968543	-21.65	-110.24	-393.71	18321.4	-464.3	26	951451	-1968543
27	537379.9	280522.9	110280.6	28585.8	81	374	5439.92	962691	10.59	53.91	192.54	-2038454	-22.42	-114.15	-407.69	18797.8	-476.4	27	962691	-2038454
28	539543.9	286291.3	112361.4	29626.2	81	374	5624.88	973931	10.71	54.54	194.79	-2110182	-23.21	-118.17	-422.04	19286.5	-488.7	28	973931	-2110182
29	541707.9	292059.8	114442.2	30666.6	81	374	5809.84	985170	10.84	55.17	197.03	-2183776	-24.02	-122.29	-436.76	19788.0	-501.4	29	985170	-2183776
30	543872.0	297828.2	116523.0	31707.0	81	374	5994.8	996410	10.96	55.80	199.28	-2259283	-24.85	-126.52	-451.86	20302.5	-514.5	30	996410	-2259283
31	546036.0	303596.6	118603.8	32747.4	81	374	6179.76	1007650	11.08	56.43	201.53	-2336753	-25.70	-130.86	-467.35	20830.3	-527.9	31	1007650	-2336753
32	548200.0	309365.1	120684.6	33787.8	81	374	6364.72	1018889	11.21	57.06	203.78	-2416237	-26.58	-135.31	-483.25	21371.9	-541.6	32	1018889	-2416237
33	550364.1	315133.5	122765.4	34828.2	81	374	6549.68	1030129	11.33	57.69	206.03	-2497788	-27.48	-139.88	-499.56	21927.6	-555.7	33	1030129	-2497788
34	552528.1	320902.0	124846.2	35868.6	81	374	6734.64	1041368	11.46	58.32	208.27	-2581460	-28.40	-144.56	-516.29	22497.7	-570.1	34	1041368	-2581460
35	554692.1	326670.4	126927.0	36909.0	81	374	6919.6	1052608	11.58	58.95	210.52	-2667306	-29.34	-149.37	-533.46	23082.6	-584.9	35	1052608	-2667306
36	556856.2	332438.8	129007.8	37949.4	81	374	7104.56	1063848	11.70	59.58	212.77	-2755385	-30.31	-154.30	-551.08	23682.8	-600.1	36	1063848	-2755385
37	559020.2	338207.3	131088.6	38989.8	81	374	7289.52	1075087	11.83	60.20	215.02	-2845754	-31.30	-159.36	-569.15	24298.5	-615.8	37	1075087	-2845754
38	561184.2	343975.7	133169.4	40030.2	81	374	7474.48	1086327	11.95	60.83	217.27	-2938472	-32.32	-164.55	-587.69	24930.3	-631.8	38	1086327	-2938472
39	563348.2	349744.2	135250.2	41070.6	81	374	7659.44	1097567	12.07	61.46	219.51	-3033601	-33.37	-169.88	-606.72	25578.5	-648.2	39	1097567	-3033601
40	565512.3	355512.6	137331.0	42111.0	81	374	7844.4	1108806	12.20	62.09	221.76	-3131204	-34.44	-175.35	-626.24	26243.5	-665.0	40	1108806	-3131204
41	567676.3	361281.0	139411.8	43151.4	81	374	8029.36	1120046	12.32	62.72	224.01	-3231344	-35.54	-180.96	-646.27	26925.9	-682.3	41	1120046	-3231344
42	569840.3	367049.5	141492.6	44191.8	81	374	8214.32	1131286	12.44	63.35	226.26	-3334087	-36.67	-186.71	-666.82	27625.9	-700.1	42	1131286	-3334087
43	572004.4	372817.9	143573.4	45232.2	81	374	8399.28	1142525	12.57	63.98	228.51	-3439503	-37.83	-192.61	-687.90	28344.2	-718.3	43	1142525	-3439503
44	574168.4	378586.4	145654.2	46272.6	81	374	8584.24	1153765	12.69	64.61	230.75	-3547658	-39.02	-198.67	-709.53	29081.2	-736.9	44	1153765	-3547658
45	576332.4	384354.8	147735.0	47313.0	81	374	8769.2	1165004	12.82	65.24	233.00	-3658626	-40.24	-204.88	-731.73	29837.3	-756.1	45	1165004	-3658626
46	578496.5	390123.2	149815.8	48353.4	81	374	8954.16	1176244	12.94	65.87	235.25	-3772479	-41.50	-211.26	-754.50	30613.0	-775.8	46	1176244	-3772479
47	580660.5	395891.7	151896.6	49393.8	81	374	9139.12	1187484	13.06	66.50	237.50	-3889293	-42.78	-217.80	-777.86	31409.0	-795.9	47	1187484	-3889293
48	582824.5	401660.1	153977.4	50434.2	81	374	9324.08	1198723	13.19	67.13	239.74	-4009143	-44.10	-224.51	-801.83	32225.6	-816.6	48	1198723	-4009143
49	584988.6	407428.6	156058.2	51474.6	81	374	9509.04	1209963	13.31	67.76	241.99	-4132109	-45.45	-231.40	-826.42	33063.5	-837.9	49	1209963	-4132109
50	587152.6	413197.0	158139.0	52515.0	81	374	9694	1221203	13.43	68.39	244.24	-4258273	-46.84	-238.46	-851.65	33923.1	-859.7	**50**	1221203	-4258273
TOTAL=								Initial:Fi	**1.85**	**1.85**	**1.85**	Initial:Fin	**6.46**	**6.46**	**6.46**		**-24523.1281**			
NOTE:												Lost:Gain	**-3.49**							

Total carbon gain = The condition of equation is no land use change (land area = 74200ha), NPP at 11.56 tonneC/ha/yr and NEP = 0.1as the growing ecosystem.

Total carbon gain1 = The condition of equation is depended on the land use types and the different rate NEP but the land area is the same as 74200ha. NPP is constant at 11.56 tonneC/ha/yr but NEP = 0.2in the secondary and riparian forest and NEP = 0.04 in the primary forest. The paddy rice field and grassland assumed constant production because their systems are annual production. The riparian zone and home gardening system have NEP at 0.1.

Total carbon lost = The condition of encroachment rate is considered at the national rate of deforestation in Thailand at 2.6% per year from the total flooded area of Ban Koum project.

APPENDIX III: CHAPTER SIX

6.1 Questionnaires (set A) for people along the Mekong River

6.2 Questionnaires (set B) for people near the Pak Mun Dam

6.3 Statistical analysis of multiple-regression

6.4 Statistical analysis of independent variables as the units of measurement in multiple-regression equation

Appendix 6.1: Questionnaires (set A) for people along the Mekong River

Questionaires (แบบสอบถาม)

Date of interview (วันสัมภาษณ์).....

Time interview (ใช้เวลาสัมภาษณ์).....

Name of interviewer (ชื่อผู้สัมภาษณ์).....

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1. Name (ชื่อ).....Surname (นามสกุล).....
2. Sex (เพศ).....
3. Age (อายุ).....
4. Education (การศึกษา):
   - ❑ Primary (ประถมศึกษา)
   - ❑ Secondary (มัธยมศึกษา)
   - ❑ Diploma (ประกาศนียบัตร)
   - ❑ Bachelor degree (ปริญญาตรี)
   - ❑ Etc. (อื่นๆ).....
5. Address (ที่อยู่).....

   Province (จังหวัด).....Country (ประเทศ).....
   - ❑ How far is house from the forest?(อยู่ห่างจากป่า?).....Km.(กิโลเมตร)
   - ❑ How far is house from the river? (อยู่ห่างจากแม่น้ำ?).....Km. (กิโลเมตร)
   - ❑ How far is house from the reservoir? (อยู่ห่างจากอ่างเก็บน้ำหรือเขื่อน?) ?).....Km. (กิโลเมตร)
6. How long have you lived in this area? (ท่านอาศัยในภูมิลำเนานี้นานเท่าไร?).....year (ปี)
7. Occupation (อาชีพ).....
8. Personal monthly income (รายได้ส่วนบุคคล/เดือน).....Baht (บาท)
9. Source of personal income (แหล่งที่มาของรายได้ส่วนบุคคล)
   - ❑ Employed (รับจ้าง)
     - go to question 16 (ตอบคำถามข้อ 16)
   - ❑ Business (ธุรกิจ-ค้าขาย)
     - go to question 17 (ตอบคำถามข้อ 17)
   - ❑ Agriculture (การเกษตร)
     - go to question 18 (ตอบคำถามข้อ 18)
   - ❑ Fisheries (การประมง)
     - go to question 19 (ตอบคำถามข้อ 19)
   - ❑ Etc. (อื่นๆ).....
     - to give some detail of income(โปรดระบุรายละเอียดของรายได้).....

10. Number of family member per household (จำนวนสมาชิกในครอบครัว).....capita (คน)

11. Number of family member in school or higher education

(จำนวนสมาชิกในครอบครัวที่กำลังศึกษาอยู่).....capita (คน)

12. Who else in household works (ใครบ้างในครอบครัวที่ทำงาน?).....

13. Monthly income of whole household (รายได้รวมทั้งหมดในครอบครัว).....baht (บาท)

14. Number of vehicle in your household (จำนวนยานพาหนะที่มีใช้ในครอบครัว)

- ❑ Yes (มี): Type of vehicle (ชนิดของยานพาหนะ)
  - ❑ Bicycle (จักรยาน).....คัน
  - ❑ Motorcycle (จักรยานยนต์).....คัน
  - ❑ Van (รถกระบะ).....คัน
  - ❑ Car (รถยนต์).....คัน
  - ❑ Small tractor (รถอีแต๋น).....คัน
  - ❑ Boat (เรือ).....ลำ
  - ❑ Etc. (อื่นๆ).....คัน
- ❑ No (ไม่มี)

15. Land area per household (ที่ดินที่ใช้ทำกินต่อครอบครัว).....rai (ไร่)

- Consist of (ประกอบด้วย):
  - ❑ Housing (บ้านที่พักอาศัย).....rai (ไร่)
  - ❑ Home gardening (สวนครัว).....raiไร่)
  - ❑ Farming (เลี้ยงสัตว์).....rai (ไร่)
  - ❑ Fishing pond (บ่อเลี้ยงปลา).....rai (ไร่)
  - ❑ Rice field (นาข้าว).....rai (ไร่)
  - ❑ Orchard (สวนผลไม้).....rai (ไร่)
  - ❑ Shifting cultivation.....rai (ไร่)
  - ❑ Etc. (อื่นๆ).....rai (ไร่)

16. Status in land right (สถานะภาพในสิทธิ์การครอบครองที่ดิน):

- ❑ Ownership (เป็นเจ้าของกรรมสิทธิ์).....rai (ไร่)
  - how long (เป็นเวลานาน).....year (ปี)
  - marketable value (มูลค่า).....baht (บาท)
- ❑ Rent (เช่า).....rai (ไร่)
  - how long (เป็นเวลานาน).....year (ปี)
  - rental rate (อัตราค่าเช่า).....baht/rai/year (บาท/ไร่/ปี)
- ❑ Etc. (อื่นๆ).....

17. Detail of employment (รายละเอียดของการรับจ้าง)

- ❑ Full-time employment (รับจ้างทำงานตลอดทั้งวัน)
  - monthly wage (ค่าจ้าง/เดือน).....baht (บาท)
- ❑ Part-time employment (รับจ้างทำงานเป็นบางช่วงเวลา)
  - ❑ Daily (บางวัน) : wage/day (ค่าจ้าง/วัน).....baht (บาท)
  - ❑ weekly (บางสัปดาห์) : wage/week (ค่าจ้าง/สัปดาห์).....baht (บาท)

18. Detail of business (รายละเอียดของธุรกิจ-ค้าขาย)

- ❑ Commercial retail consumer products (ค้าขายเครื่องอุปโภค-บริโภค)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Commercial agricultural products (ค้าขายสินค้าเกษตร)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Catering business (ธุรกิจเกี่ยวกับอาหารและเครื่องดื่ม)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Tourism (การท่องเที่ยว)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Etc. (อื่นๆ).....
  - income/month (รายได้/เดือน).....baht (บาท)

19. Details of agriculture (รายละเอียดของการทำการเกษตร)

- ❑ Rice field (ทำนา) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ (ทำไร่) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Orchard (ทำสวนผลไม้) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Farming (เลี้ยงสัตว์) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Etc. (อื่นๆ).....: income/month (รายได้/เดือน).....baht (บาท)

20. Detail of fisheries (รายละเอียดของการทำประมง)

- ❑ Fishing in natural habitat (การจับปลาในแหล่งน้ำธรรมชาติ)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Fishing in dam or reservoir (การจับปลาในเขื่อนหรืออ่างเก็บน้ำ)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Aquaculture (การเพาะเลี้ยงสัตว์น้ำ)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Etc. (อื่นๆ).....
  - income/month (รายได้/เดือน).....baht (บาท)

21. Do you think forest ecosystem is important to your life? (ท่านคิดว่าระบบนิเวศป่ามีความสำคัญต่อชีวิตของท่าน?)

❑ Yes (ใช่) - go to question 22 (ตอบคำถามข้อ 22)

❑ No (ไม่)

22. Do you get any benefit from forest ecosystem? (ท่านได้รับผลประโยชน์จากระบบนิเวศป่าหรือไม่?)

❑ Yes (ได้) - go to question 23-24 (ตอบคำถามข้อ 23-24)

❑ No (ไม่ได้)

23. What kind of benefit do you get from forest ecosystem? (ท่านได้รับผลประโยชน์อะไรบ้างจากระบบนิเวศป่า?)

❑ Subsistence foods(อาหารเพื่อดำรงชีวิตประจำวัน)

❑ Fruit & vegetable(ผัก):

Type and quantity of fruit & vegetable collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								

Time: in hours (ชั่วโมงที่ใช้ในการเก็บ)

Distance: in kilometers (ระยะทางที่เดินทางไปเก็บเป็น กิโลเมตร)

Quantity: in kilograms (ปริมาณที่เก็บเป็นกิโลกรัม)

-How much does it cost in term of marketable value?

(ผลไม้และผักที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Fire wood (ไม้ฟืน):

- Quantity of fire wood collection/day (ปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								

6.								
7.								
8.								

-How much does it cost in term of marketable value?

(ไม้ฟืนที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Medicinal plant (พืชสมุนไพร):

- Type and quantity of plant collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								

-How much does it cost in term of marketable value?

(พืชสมุนไพรที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Oil and resin (น้ำมัน และ ยางไม้):

- Type and quantity of oil & resin collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								

-How much does it cost in term of marketable value?

น้ำมันและยาง ไม้ที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Hunting (ล่าสัตว์):

- Type and quantity of animal hunted/day (ชนิดและปริมาณที่จับได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Big animals								
2.Small animals								
3.Fishes								
4.Insects								

-How much does it cost in term of marketable value?

(สัตว์ที่ล่าได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Building material collection (วัสดุที่ใช้ในการก่อสร้างที่เก็บได้):

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Roofing mat.								
2.Poles								

Quanuty: in #bundles,# poles (จำนวนเป็นมัด หรือ ต้น)

24. Do you get any benefit from aquatic ecosystem? (ท่านได้รับผลประโยชน์จากระบบนิเวศแหล่งน้ำหรือไม่?)

❑ Yes (ได้) - go to question 25 (ตอบคำถามข้อ 25) ❑ No (ไม่ได้)

25. What kind of benefit do you get from aquatic ecosystem?(ผลประโยชน์อะไรที่เก็บเกี่ยวได้จากระบบนิเวศน้ำ?)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Fishes								
2.Shrimps								
3.Crabs								
4.Others								

-How much does it cost in term of marketable value?

(สัตว์ที่ล่าได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

Appendix 6.2: Questionnaires (set B) for people near the Pak Mun Dam

Questionaires (แบบสอบถาม)

Date of interview (วันสัมภาษณ์).....

Time interview (ใช้เวลาสัมภาษณ์).....

Name of interviewer (ชื่อผู้สัมภาษณ์).....

---

1. Name (ชื่อ).....Surname (นามสกุล).....
2. Sex (เพศ).....
3. Age (อายุ).....
4. Education (การศึกษา):
   - ❑ Primary (ประถมศึกษา) ❑ Secondary (มัธยมศึกษา)
   - ❑ Diploma (ประกาศนียบัตร) ❑ Bachelor degree (ปริญญาตรี)
   - ❑ Etc. (อื่นๆ).....
5. Address (ที่อยู่).....

   Province (จังหวัด).....Country (ประเทศ).....
   - ❑ How far is house from the forest?(อยู่ห่างจากป่า?).....Km.(กิโลเมตร)
   - ❑ How far is house from the river? (อยู่ห่างจากแม่น้ำ?).....Km. (กิโลเมตร)
   - ❑ How far is house from the reservoir? (อยู่ห่างจากอ่างเก็บน้ำหรือเขื่อน?).....Km. (กิโลเมตร)
6. How long have you lived in this area? (ท่านอาศัยในภูมิลำเนานี้นานเท่าไร?).....year (ปี)
   - ❑ Previous address (ภูมิลำเนาเดิมก่อนย้ายมาอยู่ที่ที่อยู่ปัจจุบัน).....

     .....
   - ❑ How do you feel about the new settlement area nearby reservoir?

     (ท่านรู้สึกอย่างไรบ้างเกี่ยวกับการโยกย้ายมาตั้งบ้านเรือนบริเวณเขื่อน?)
     - ❑ Socio-economic situation (สถานะภาพทางด้านเศรษฐกิจและสังคม)
       - ❑ Better quality of life (คุณภาพชีวิตดีขึ้น)
       - ❑ Poorer quality of life (คุณภาพชีวิตแย่ลง)
       - ❑ The same quality of life (คุณภาพชีวิตเหมือนเดิม)
7. Occupation (อาชีพ).....
8. Personal monthly income (รายได้ส่วนบุคคล/เดือน).....Baht (บาท)
9. Source of personal income (แหล่งที่มาของรายได้ส่วนบุคคล)
   - ❑ Employed (รับจ้าง)

     - go to question 16 (ตอบคำถามข้อ 16)

❑ Business (ธุรกิจ-ค้าขาย)

- go to question 17 (ตอบคำถามข้อ 17)

❑ Agriculture (การเกษตร)

- go to question 18 (ตอบคำถามข้อ 18)

❑ Fisheries (การประมง)

- go to question 19 (ตอบคำถามข้อ 19)

❑ Etc. (อื่นๆ).....

- to give some detail of income(โปรดระบุรายละเอียดของรายได้).....

10. Number of family member per household (จำนวนสมาชิกในครอบครัว).....capita (คน)

11. Number of family member in school or higher education

(จำนวนสมาชิกในครอบครัวที่กำลังศึกษาอยู่).....capita (คน)

12. Who else in household works (ใครบ้างในครอบครัวที่ทำงาน?).....

13. Monthly income of whole household (รายได้รวมทั้งหมดในครอบครัว).....baht (บาท)

14. Number of vehicle in your household (จำนวนยานพาหนะที่มีใช้ในครอบครัว)

❑ Yes (มี): Type of vehicle (ชนิดของยานพาหนะ)

- ❑ Bicycle (จักรยาน).....คัน
- ❑ Motorcycle (จักรยานยนต์).....คัน
- ❑ Van (รถกระบะ).....คัน
- ❑ Car (รถยนต์).....คัน
- ❑ Small tractor (รถอีแต๋น).....คัน
- ❑ Boat (เรือ).....ลำ
- ❑ Etc. (อื่นๆ).....คัน

❑ No (ไม่มี)

15. Land area per household (ที่ดินที่ใช้ทำกินต่อครอบครัว).....rai (ไร่)

- Consist of (ประกอบด้วย):

- ❑ Housing (บ้านที่พักอาศัย).....rai (ไร่)
- ❑ Home gardening (สวนครัว).....raiไร่)
- ❑ Farming (เลี้ยงสัตว์).....rai (ไร่)
- ❑ Fishing pond (บ่อเลี้ยงปลา).....rai (ไร่)
- ❑ Rice field (นาข้าว).....rai (ไร่)
- ❑ Orchard (สวนผลไม้).....rai (ไร่)
- ❑ Shifting cultivation.....rai (ไร่)
- ❑ Etc. (อื่นๆ).....rai (ไร่)

16. Status in land right (สถานะภาพในสิทธิ์การครอบครองที่ดิน):

- ❑ Ownership (เป็นเจ้าของกรรมสิทธิ์).....rai (ไร่)
  - how long (เป็นเวลานาน).....year (ปี)
  - marketable value (มูลค่า).....baht (บาท)
- ❑ Rent (เช่า).....rai (ไร่)
  - how long (เป็นเวลานาน).....year (ปี)
  - rental rate (อัตราค่าเช่า).....baht/rai/year (บาท/ไร่/ปี)
- ❑ Etc. (อื่นๆ).....

17. Detail of employment (รายละเอียดของการรับจ้าง)

- ❑ Full-time employment (รับจ้างทำงานตลอดทั้งวัน)
  - monthly wage (ค่าจ้าง/เดือน).....baht (บาท)
- ❑ Part-time employment (รับจ้างทำงานเป็นบางช่วงเวลา)
  - ❑ Daily (บางวัน) : wage/day (ค่าจ้าง/วัน).....baht (บาท)
  - ❑ weekly (บางสัปดาห์) : wage/week (ค่าจ้าง/สัปดาห์).....baht (บาท)

18. Detail of business (รายละเอียดของธุรกิจ-ค้าขาย)

- ❑ Commercial retail consumer products (ค้าขายเครื่องอุปโภค-บริโภค)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Commercial agricultural products (ค้าขายสินค้าเกษตร)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Catering business (ธุรกิจเกี่ยวกับอาหารและเครื่องดื่ม)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Tourism (การท่องเที่ยว)
  - income/month (รายได้/เดือน).....baht (บาท)
- ❑ Etc. (อื่นๆ).....
  - income/month (รายได้/เดือน).....baht (บาท)

19. Details of agriculture (รายละเอียดของการทำการเกษตร)

- ❑ Rice field (ทำนา) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ (ทำไร่) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Orchard (ทำสวนผลไม้) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Farming (เลี้ยงสัตว์) : income/month (รายได้/เดือน).....baht (บาท)
- ❑ Etc. (อื่นๆ).....: income/month (รายได้/เดือน).....baht (บาท)

20. Detail of fisheries (รายละเอียดของการทำประมง)

- ❑ Fishing in natural habitat (การจับปลาในแหล่งน้ำธรรมชาติ)

- income/month (รายได้/เดือน).....baht (บาท)

❑ Fishing in dam or reservoir (การจับปลาในเขื่อนหรืออ่างเก็บน้ำ)

- income/month (รายได้/เดือน).....baht (บาท)

❑ Aquaculture (การเพาะเลี้ยงสัตว์น้ำ)

- income/month (รายได้/เดือน).....baht (บาท)

❑ Etc. (อื่นๆ).....

- income/month (รายได้/เดือน).....baht (บาท)

21. Do you think forest ecosystem is important to your life? (ท่านคิดว่าระบบนิเวศป่ามีความสำคัญต่อชีวิตของท่าน?)

❑ Yes (ใช่) - go to question 22 (ตอบคำถามข้อ 22)

❑ No (ไม่)

22. Do you get any benefit from forest ecosystem? (ท่านได้รับผลประโยชน์จากระบบนิเวศป่าหรือไม่?)

❑ Yes (ได้) - go to question 23-24 (ตอบคำถามข้อ 23-24)

❑ No (ไม่ได้)

23. What kind of benefit do you get from forest ecosystem? (ท่านได้รับผลประโยชน์อะไรบ้างจากระบบนิเวศป่า?)

❑ Subsistence foods(อาหารเพื่อดำรงชีวิตประจำวัน)

❑ Fruit & vegetable(ผัก):

Type and quantity of fruit & vegetable collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								

Time: in hours (ชั่วโมงที่ใช้ในการเก็บ)

Distance: in kilometers (ระยะทางที่เดินทางไปเก็บเป็น กิโลเมตร)

Quantity: in kilograms (ปริมาณที่เก็บเป็นกิโลกรัม)

-How much does it cost in term of marketable value?

(ผลไม้และผักที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Fire wood (ไม้ฟืน):

- Quantity of fire wood collection/day (ปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

-How much does it cost in term of marketable value?

(ไม้ฟืนที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Medicinal plant (พืชสมุนไพร):

- Type and quantity of plant collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								

-How much does it cost in term of marketable value?

(พืชสมุนไพรที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Oil and resin (น้ำมัน และ ยางไม้):

- Type and quantity of oil & resin collection/day (ชนิดและปริมาณที่เก็บได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.								
2.								

3.								
4.								
5.								
6.								
7.								
8.								
9.								

-How much does it cost in term of marketable value?

(น้ำมันและยางไม้ที่เก็บได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Hunting (ล่าสัตว์):

- Type and quantity of animal hunted/day (ชนิดและปริมาณที่จับได้ต่อวัน)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Big animals								
2.Small animals								
3.Fishes								
4.Insects								

-How much does it cost in term of marketable value?

(สัตว์ที่ล่าได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

❑ Building material collection (วัสดุที่ใช้ในการก่อสร้างที่เก็บได้):

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Roofing mat.								
2.Poles								

Quantity: in #bundles,# poles (จำนวนเป็นมัด หรือ ต้น)

24. Do you get any benefit from aquatic ecosystem? (ท่านได้รับผลประโยชน์จากระบบนิเวศแหล่งน้ำหรือไม่?)

❑ Yes (ได้) - go to question 25 (ตอบคำถามข้อ 25) ❑ No (ไม่ได้)

25. What kind of benefit do you get from aquatic ecosystem?(ผลประโยชน์อะไรที่เก็บเกี่ยวได้จากระบบนิเวศน้ำ?)

Species	Male	Female	Child	Time/trip	istance/trip	#trip/month	Qty/trip	%Sold(Baht)
1.Fishes								
2.Shrimps								
3.Crabs								
4.Others								

-How much does it cost in term of marketable value?

(สัตว์ที่ล่าได้ทั้งหมดมีราคาตามตลาดเท่าไร?).....baht/day(บาท/วัน)

26. What do you think about the important of forest and river/reservoir to your life? (ท่านมีความคิดเห็นอะไรต่อความสำคัญของป่าและแม่น้ำ/เขื่อนต่อการดำรงชีวิตของท่าน?)

- ❑ Forest is more important than river/reservoir.(ป่าไม้มีความสำคัญกว่าแม่น้ำ/เขื่อน)
- ❑ River/reservoir is more important than forest.(แม่น้ำ/เขื่อนมีความสำคัญกว่าป่าไม้)
- ❑ Forest and river/reservoir are equally important.(ป่าไม้และแม่น้ำ/เขื่อนมีความสำคัญเท่ากัน)

27. How many busket of rice do your family consume each month? (ครอบครัวของท่านบริโภคข้าวเดือนละกี่ถัง?).....ถั

Appendix 6.3: Statistical analysis of multiple-regression

* * * * M U L T I P L E R E G R E S S I O N * * * *

Mean Substituted for Missing Data

	Mean	Std Devi	Cases	Label
LOCATION	1.247	.434	89	Location
MFORVALU	756.309	1860.048	66	Monthly forest marketable value
FEMPLOY	.172	.376	87	FULL EMPLOYMED
IRICE	.314	.631	70	RICE MONTHLY INCOME
MFISHVAL	4310.302	3506.021	49	MONTHLY FISHERY MARKETABLE VALUE
MCYCLE	.386	.553	88	NUMBER OF MOTORCYCLE
QTYTRIP	2.386	2.905	66	QUANTIITY OF MUSHROOM PER TRIP (KG)
EDUCATI	1.047	.562	86	EDUCATION
DAYPYR10	187.272	168.766	81	DAYPYR FOR FISHERY
RICONSU	228.649	73.823	57	RICECONSUMPTION(KG/CAP/YR)
HOUSING	.647	.518	55	HOUSING AREA
LIVED	4.092	2.141	87	TIME OF SETTLEMENT

N of Cases encountered = 89

Minimum Pairwise N of Cases = 32

* * * * M U L T I P L E R E G R E S S I O N * * * *

Correlation, 1-tailed Sig, N of Cases:

	LOCATION	MFORVALU	FEMPLOY	IRICE	MFISHVAL	MCYCLE	QTYTRIP	EDUCATI
LOCATION	1.000	-.043	.224	.014	.306	.184	-.264	.046
	.	.343	.018	.447	.002	.042	.006	.336
	89	66	87	70	49	88	66	86
MFORVALU	-.043	1.000	-.006	-.006	.097	-.066	-.041	.023
	.343	.	.476	.476	.182	.268	.352	.414
	66	66	65	52	41	65	51	63
FEMPLOY	.224	-.006	1.000	-.082	-.006	.080	.113	.294
	.018	.476	.	.223	.477	.229	.147	.003
	87	65	87	68	47	86	65	85
IRICE	.014	-.006	-.082	1.000	-.022	.068	.005	.002
	.447	.476	.223	.	.419	.264	.482	.492
	70	52	68	70	41	69	53	67
MFISHVAL	.306	.097	-.006	-.022	1.000	.090	-.121	-.023
	.002	.182	.477	.419	.	.200	.130	.417
	49	41	47	41	49	48	35	47
MCYCLE	.184	-.066	.080	.068	.090	1.000	.170	.016
	.042	.268	.229	.264	.200	.	.056	.440
	88	65	86	69	48	88	66	85
QTYTRIP	-.264	-.041	.113	.005	-.121	.170	1.000	.025
	.006	.352	.147	.482	.130	.056	.	.407
	66	51	65	53	35	66	66	64
EDUCATI	.046	.023	.294	.002	-.023	.016	.025	1.000
	.336	.414	.003	.492	.417	.440	.407	.
	86	63	85	67	47	85	64	86
DAYPYRIC	-.052	.132	-.170	-.038	.026	.129	.121	-.014
	.313	.108	.056	.361	.405	.115	.130	.447
	81	58	79	65	44	80	63	78
RICONSU	.064	.016	.149	.106	.149	.203	.134	-.099
	.276	.442	.082	.162	.082	.028	.106	.179
	57	43	57	45	32	56	42	55
HOUSING	.157	.160	.050	.214	.201	.135	-.018	-.093
	.071	.068	.320	.022	.030	.103	.433	.193
	55	41	55	44	32	54	42	53

* * * * M U L T I P L E R E G R E S S I O N * * * *

	LOCATION	MFORVALU	FEMPLOY	IRICE	MFISHVAL	MCYCLE	QTYTRIP	EDUCATI
LIVED	-.832	.072	-.199	.006	-.248	-.126	.205	-.191
	.000	.252	.031	.477	.010	.119	.027	.037
	87	64	85	68	48	86	64	84

* * * * M U L T I P L E R E G R E S S I O N * * * *

	DAYPYR10	RICONSU	HOUSING	LIVED
LOCATION	-.052	.064	.157	-.832
	.313	.276	.071	.000
	81	57	55	87
MFORVALU	.132	.016	.160	.072
	.108	.442	.068	.252
	58	43	41	64
FEMPLOY	-.170	.149	.050	-.199
	.056	.082	.320	.031
	79	57	55	85
IRICE	-.038	.106	.214	.006
	.361	.162	.022	.477
	65	45	44	68
MFISHVAL	.026	.149	.201	-.248
	.405	.082	.030	.010
	44	32	32	48
MCYCLE	.129	.203	.135	-.126
	.115	.028	.103	.119
	80	56	54	86
QTYTRIP	.121	.134	-.018	.205
	.130	.106	.433	.027
	63	42	42	64
EDUCATI	-.014	-.099	-.093	-.191
	.447	.179	.193	.037
	78	55	53	84
DAYPYR10	1.000	-.052	-.050	.171
	.	.316	.320	.055
	81	52	50	79
RICONSU	-.052	1.000	-.062	.015
	.316	.	.282	.445
	52	57	53	57
HOUSING	-.050	-.062	1.000	-.073
	.320	.282	.	.249
	50	53	55	55
LIVED	.171	.015	-.073	1.000
	.055	.445	.249	.
	79	57	55	87

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. LOCATION Location

Descriptive Statistics are printed on Page 50

Block Number 1. Method: Enter
MFORVALU FEMPLOY IRICE MFISHVAL MCYCLE QTYTRIP EDUCATI DAYPYR10
RICONSU HOUSING LIVED

Variable(s) Entered on Step Number

1..	LIVED	TIME OF SETTLEMENT
2..	IRICE	RICE MONTHLY INCOME
3..	MFORVALU	Monthly forest marketable value
4..	RICONSU	RICECONSUMPTION(KG/CAP/YR)
5..	EDUCATI	EDUCATION
6..	DAYPYR10	DAYPYR FOR FISHERY
7..	QTYTRIP	QUANTIITY OF MUSHROOM PER TRIP (KG)
8..	HOUSING	HOUSING AREA
9..	MCYCLE	NUMBER OF MOTORCYCLE
10..	MFISHVAL	MONTHLY FISHERY MARKETABLE VALUE
11..	FEMPLOY	FULL EMPLOYMED

Multiple R	.87091
R Square	.75849
Adjusted R Square	.72399
Standard Error	.22792

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	11	12.56197	1.14200
Residual	77	3.99983	.05195

F = 21.98441 Signif F = .0000

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. LOCATION Location

---------- Variables in the Equation ----------

Variable	B	SE B	Beta	T	Sig T
MFORVALU	-4.14711E-06	1.3589E-05	-.017781	-.305	.7611
FEMPLOY	.142236	.072290	.123142	1.968	.0527
IRICE	.008342	.040354	.012142	.207	.8368
MFISHVAL	7.74109E-06	7.5427E-06	.062561	1.026	.3080
MCYCLE	.043934	.047460	.055954	.926	.3575
QTYTRIP	-.020026	.008954	-.134078	-2.236	.0282
EDUCATI	-.096602	.046942	-.125188	-2.058	.0430
DAYPYR10	3.06134E-04	1.5338E-04	.119092	1.996	.0495
RICONSU	3.04645E-04	3.5942E-04	.051841	.848	.3993
HOUSING	.057161	.051623	.068263	1.107	.2716
LIVED	-.161430	.012747	-.796573	-12.664	.0000
(Constant)	1.818303	.125640		14.472	.0000

End Block Number 1 All requested variables entered.

* * * * M U L T I P L E R E G R E S S I O N * * * *

Equation Number 1 Dependent Variable.. LOCATION Location

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*PRED	.7520	2.0392	1.2472	.3778	89
*ZPRED	-1.3107	2.0962	.0000	1.0000	89
*SEPRED	.0432	.2072	.0779	.0307	89
*ADJPRED	.7356	2.1307	1.2473	.3793	89
*RESID	-.7158	.3664	.0000	.2132	89
*ZRESID	-3.1408	1.6075	.0000	.9354	89
*SRESID	-3.2967	1.6835	-.0009	.9902	89
*DRESID	-.7887	.4018	-.0001	.2406	89
*SDRESID	-3.5341	1.7042	-.0086	1.0151	89
*MAHAL	2.1760	71.7575	10.8764	11.3412	89
*COOK D	.0000	.0921	.0110	.0199	89
*LEVER	.0247	.8154	.1236	.1289	89

Total Cases = 89

Hi-Res Chart # 13:Histogram of *zresid

Hi-Res Chart # 15:Normal p-p plot of *zresid

Hi-Res Chart # 14:Scatterplot of location with *sdresid

Appendix 6.4: Statistical analysis of independent variables as the unit of measurement in multiple-regression

LOCATION Location by DAYPYR10 DAYPYR FOR FISHERY

LOCATION	Count / Tot Pct	DAYPYR10 .00	12.00	52.00	60.00	90.00	Row Total
1 Mekong villages		25	1	1	1	1	62
		30.9	1.2	1.2	1.2	1.2	76.5
2 Dam village		9					19
		11.1					23.5
Column Total		34	1	1	1	1	81
		42.0	1.2	1.2	1.2	1.2	100.0

(Continued)

LOCATION Location by DAYPYR10 DAYPYR FOR FISHERY

LOCATION	DAYPYR10 120.00	180.00	240.00	365.00	Row Total
1 Mekong villages		1 1.2	1 1.2	31 38.3	62 76.5
2 Dam village	1 1.2	1 1.2		8 9.9	19 23.5
Column Total	1 1.2	2 2.5	1 1.2	39 48.1	81 100.0

Count
Tot Pct

Chi-Square	Value	DF	Significance
Pearson	5.94048	8	.65390
Likelihood Ratio	6.59661	8	.58071
Linear-by-Linear Association	.25097	1	.61639

Minimum Expected Frequency - .235
Cells with Expected Frequency < 5 - 14 of 18 (77.8%)

Statistic	Value	ASE1	Val/ASE0	Approximate Significance
Pearson's R	-.05601	.10973	-.49861	.61944
Spearman Correlation	-.06351	.11083	-.56567	.57322

Number of Missing Observations: 8

LOCATION Location by FEMPLOY FULL EMPLOYMED

FEMPLOY Page 1 of 1

LOCATION	Count / Tot Pct	NO 0	YES 1	Row Total
1 Mekong villages		57 / 65.5	8 / 9.2	65 / 74.7
2 Dam village		15 / 17.2	7 / 8.0	22 / 25.3
Column Total		72 / 82.8	15 / 17.2	87 / 100.0

Chi-Square	Value	DF	Significance
Pearson	4.38498	1	.03626
Continuity Correction	3.12422	1	.07714
Likelihood Ratio	3.97353	1	.04622
Linear-by-Linear Association	4.33458	1	.03735
Fisher's Exact Test:			
One-Tail			.04294
Two-Tail			.05082

Minimum Expected Frequency - 3.793
Cells with Expected Frequency < 5 - 1 of 4 (25.0%)

Statistic	Value	ASE1	Val/ASE0	Approximate Significance
Pearson's R	.22450	.11943	2.12405	.03657
Spearman Correlation	.22450	.11943	2.12405	.03657

Number of Missing Observations: 2

LOCATION Location by QTYTRIP QUANTITY OF MUSHROOM PER TRIP (KG)

LOCATION	Count / Tot Pct	QTYTRIP .00	.50	1.00	2.00	3.00	Row Total
1 Mekong villages		17	2		14	4	51
		25.8	3.0		21.2	6.1	77.3
2 Dam village		8	3	3	1		15
		12.1	4.5	4.5	1.5		22.7
Column Total		25	5	3	15	4	66
		37.9	7.6	4.5	22.7	6.1	100.0

(Continued)

LOCATION Location by QTYTRIP QUANTIITY OF MUSHROOM PER TRIP (KG)

LOCATION	Count / Tot Pct	QTYTRIP 4.00	5.00	8.00	10.00	14.00	Row Total
1 Mekong villages	1	1	5	4	2	1	51
		1.5	7.6	6.1	3.0	1.5	77.3
2 Dam village	2						15
							22.7
(Continued)	Column Total	1	5	4	2	1	66
		1.5	7.6	6.1	3.0	1.5	100.0

LOCATION Location by QTYTRIP QUANTITY OF MUSHROOM PER TRIP (KG)

QTYTRIP

LOCATION	Count / Tot Pct 15.00	Row Total
1 Mekong villages	1 / 1.5	51 / 77.3
2 Dam village		15 / 22.7
Column Total	1 / 1.5	66 / 100.0

Chi-Square	Value	DF	Significance
Pearson	22.87655	10	.01121
Likelihood Ratio	25.32522	10	.00476
Linear-by-Linear Association	6.48276	1	.01089

Minimum Expected Frequency - .227
Cells with Expected Frequency < 5 - 19 of 22 (86.4%)

Statistic	Value	ASE1	Val/ASE0	Approximate Significance
Pearson's R	-.31581	.05054	-2.66273	.00979
Spearman Correlation	-.34882	.08656	-2.97756	.00410

Number of Missing Observations: 23

LOCATION Location by LIVED TIME OF SETTLEMENT

	LIVED					
Count Tot Pct	0-5 YRS	6-10 YRS	11-20 YRS	21-30 YRS	31-40 YR S	Row Total
	1	2	3	4	5	
LOCATION						
1	2	2	6	7	6	65
Mekong villages	2.3	2.3	6.9	8.0	6.9	74.7
2	22					22
Dam village	25.3					25.3
Column	24	2	6	7	6	87
(Continued) Total	27.6	2.3	6.9	8.0	6.9	100.0

LOCATION Location by LIVED TIME OF SETTLEMENT

LOCATION	Count / Tot Pct	>40 YRS	Row Total
Mekong villages	1	42	65
		48.3	74.7
Dam village	2		22
			25.3
Column Total		42	87
		48.3	100.0

Chi-Square	Value	DF	Significance
Pearson	77.29615	5	.00000
Likelihood Ratio	84.62367	5	.00000
Linear-by-Linear Association	60.03482	1	.00000

Minimum Expected Frequency - .506
Cells with Expected Frequency < 5 - 7 of 12 (58.3%)

Statistic	Value	ASE1	Val/ASE0	Approximate Significance
Pearson's R	-.83551	.04347	-14.0189	.00000
Spearman Correlation	-.78442	.04877	-11.6604	.00000

Number of Missing Observations: 2

LOCATION Location by EDUCATI EDUCATION

LOCATION	EDUCATI 0	PRIMARY SCHOOL 1	SECONDARY SCHOOL 2	DIPLOMA 3	BACHELOR 4	Row Total
1 Mekong villages	7	51	4	1	1	64
	8.1	59.3	4.7	1.2	1.2	74.4
2 Dam village	1	18	3			22
	1.2	20.9	3.5			25.6
Column Total	8	69	7	1	1	86
	9.3	80.2	8.1	1.2	1.2	100.0

Chi-Square	Value	DF	Significance
Pearson	2.51327	4	.64226
Likelihood Ratio	3.00870	4	.55637
Linear-by-Linear Association	.17808	1	.67303

Minimum Expected Frequency - .256
Cells with Expected Frequency < 5 - 6 of 10 (60.0%)

Statistic	Value	ASE1	Val/ASE0	Approximate Significance
Pearson's R	.04577	.09306	.41995	.67560
Spearman Correlation	.09971	.10086	.91845	.36101

Number of Missing Observations: 3

APPENDIX IV: CHAPTER SEVEN

7.1 Economic analysis of Ban Koum Hydropower Project by MRC

7.2 A comparison of economic analysis between the traditional an the alternative IA under the different carbon storage loss value

7.3 Carbon storage value in terrestrial ecosystem during 50 year-period under three scenarios

7.4 A summary of sensitivity test based on weighting and scoring of biodiversity indicators under the different scenarios

Appendix 7.1: Economic analysis of Ban Koum Hydropower Project by MRC.

SITE OF BAN KOUM 120 MSL - CASE BKC20

RUN OF THE RIVER HYDROPOWER POSSIBILITIES ON THE MEKONG MAINSTREAM (BASINWIDE)

PHASE II - COST ESTIMATION

item	Description of the item	Variables	Main unit	Unit price	Quantity	Total (10^6 US $)	Observations
1	**Feasibility study**	formula	L.S.		1	10.375	formula: see WP 20/31
2	**Preliminary works**					57.495	
	Site development		L.S.		1		formula
	Construction camp and operation		L.S.		1		see WP 20/31
	Construction townsite		L.S.		1		
	Access roads	location	km, L.S.				
3	**General civil works**						
	River diversion	Q 30				48.979	
	Excavation, grouting and final ground preparation	width structures	m			91.210	see WP 20/29
	Dewatering (quantity = number of phases)		L.S.	8.6*10^6	3	25.800	
	Protections and backfill		m3			9.514	
	Switchyards	Power output	MW	4000	2 331	9.324	
4	**Power house civil works**	concrete	m3	176	821 340	144.556	preadsheets WP20/17 & 20/2
5	**Navigation lock civil works**	16.44	m and u	39.26	2	78.529	see WP 20/32, WP 20/33,
6	**Spillway civil works**	concrete	m3	106	390 220	41.363	spreadsheets WP20/2 & 20/4
7	**Closure dams**	earthfill	m3	10	505 320	5.053	preadsheets WP20/24 & 20/2
8	**Electro-mecanical equipment**						
	Powerhouse	n(u), H	u	42.54	20	850.720	same screening phase
	Spillway	n(b)	u	1.38	14	19.264	"
	Locks	16.44	u	6.48	2	12.956	spreadsheet : CSTLOxx.XLS
	Contingencies on civil works (20 % of items 2 to 7)					102.365	
	Contingencies on Electromechanical Equipment (15 % of item 8)					132.441	
TOTAL DIRECT COSTS (10^6US$)							**1640**
9	**Environmental and socioeconomic aspects**						
	Environmental mitigation (3% of direct costs)	formula	L.S.		1	49.198	
	Resettlement costs	nb of people	u	5 500	2 573	8.487	
10	**Management, administration and engineering**	formula	L.S.		1	128.442	formula: see WP 20/31
TOTAL PROJECT COST (Without TRANSMISSION LINES) (10^6US$)							**1826**
11	Transmission lines and system	spreadsheet	km			366.444	same screening phase
TOTAL PROJECT COST INCLUDING TRANSMISSION LINES AND SYSTEM (10^6US$)							**2193**

Appendix 7.2: A comparison of economic analysis between the traditional and the alternative IA under the different carbon storage loss value.

Year	Direct cost	Services	M&ad. Cost	Oper. Cost	Envimiti cost	Social cost	Carbon1	Carbon2	Carbon3	Carbon4	Carbon5	Carbon6	Total cost1	Total cost2	Total cost3	Total cost4	Total cost5	Total cost6	Total benefit	Trad. total co	Benefit
0	1640	366.44	128.44	0	49.2	8.49	-7.23	-36.83	-131.53	-131.53	-36.83	-131.53	2867.26	2897.97	2991.56	2991.56	2896.86	2991.56	415	2,860	415
1				28			-7.63	-38.84	-138.70	-133.77	-38.51	-136.5849	$2,895.66	$2,927.98	$3,026.73	$3,021.80	$2,926.54	$3,024.61	$792.27	$2,888.00	$377.27
2				$25.45			-8.03	-40.90	-146.06	-136.02	-40.23	-141.719	$2,921.52	$2,955.49	$3,059.55	$3,049.50	$2,953.72	$3,055.20	$1,135.25	$2,913.45	$342.98
3				$23.14			-8.45	-43.01	-153.61	-138.27	-41.99	-146.93	$2,945.07	$2,980.75	$3,090.24	$3,074.89	$2,978.61	$3,083.56	$1,447.04	$2,936.60	$311.80
4				$21.04			-8.87	-45.18	-161.36	-140.51	-43.77	-152.2192	$2,966.54	$3,003.95	$3,119.02	$3,098.17	$3,001.44	$3,109.88	$1,730.49	$2,957.63	$283.45
5				$19.12			-9.31	-47.41	-169.31	-142.76	-45.60	-157.5877	$2,986.10	$3,025.30	$3,146.10	$3,119.54	$3,022.39	$3,134.37	$1,988.18	$2,976.76	$257.68
6				$17.39			-9.76	-49.69	-177.47	-145.00	-47.46	-163.0367	$3,003.93	$3,044.97	$3,171.64	$3,139.18	$3,041.63	$3,157.21	$2,222.43	$2,994.14	$234.26
7				$15.81			-10.22	-52.03	-185.83	-147.25	-49.36	-168.5675	$3,020.20	$3,063.12	$3,195.81	$3,157.23	$3,059.34	$3,178.54	$2,435.39	$3,009.95	$212.96
8				$14.37			-10.69	-54.44	-194.42	-149.50	-51.29	-174.1813	$3,035.04	$3,079.89	$3,218.77	$3,173.84	$3,075.64	$3,198.53	$2,628.99	$3,024.32	$193.60
9				$13.06			-11.18	-56.90	-203.23	-151.74	-53.27	-179.8792	$3,048.59	$3,095.42	$3,240.64	$3,189.15	$3,090.68	$3,217.29	$2,804.99	$3,037.38	$176.00
10				$11.87			-11.67	-59.43	-212.27	-153.99	-55.28	-185.6627	$3,060.96	$3,109.83	$3,261.55	$3,203.27	$3,104.57	$3,234.95	$2,965.00	$3,049.25	$160.00
11				$10.80			-12.18	-62.03	-221.54	-156.24	-57.34	-191.5328	$3,072.26	$3,123.22	$3,281.62	$3,216.31	$3,117.42	$3,251.61	$3,110.45	$3,060.05	$145.45
12				$9.81			-12.71	-64.69	-231.05	-158.48	-59.43	-197.4911	$3,082.60	$3,135.70	$3,300.94	$3,228.37	$3,129.33	$3,267.38	$3,242.68	$3,069.86	$132.23
13				$8.92			-13.24	-67.43	-240.81	-160.73	-61.57	-203.5387	$3,092.06	$3,147.35	$3,319.63	$3,239.54	$3,140.39	$3,282.35	$3,362.89	$3,078.78	$120.21
14				$8.11			-13.80	-70.23	-250.83	-162.98	-63.75	-209.677	$3,100.72	$3,158.27	$3,337.75	$3,249.90	$3,150.68	$3,296.60	$3,472.18	$3,086.89	$109.28
15				$7.37			-14.36	-73.11	-261.11	-165.22	-65.98	-215.9074	$3,108.66	$3,168.52	$3,355.40	$3,259.52	$3,160.27	$3,310.20	$3,571.52	$3,094.27	$99.35
16				$6.70			-14.94	-76.06	-271.65	-167.47	-68.24	-222.2312	$3,115.94	$3,178.17	$3,372.65	$3,268.47	$3,169.24	$3,323.23	$3,661.84	$3,100.97	$90.32
17				$6.09			-15.54	-79.09	-282.47	-169.71	-70.56	-228.6499	$3,122.63	$3,187.29	$3,389.56	$3,276.81	$3,177.65	$3,335.74	$3,743.94	$3,107.06	$82.11
18				$5.54			-16.15	-82.20	-293.56	-171.96	-72.92	-235.1649	$3,128.78	$3,195.94	$3,406.20	$3,284.59	$3,185.55	$3,347.80	$3,818.59	$3,112.60	$74.64
19				$5.04			-16.77	-85.39	-304.95	-174.21	-75.33	-241.7776	$3,134.44	$3,204.17	$3,422.62	$3,291.88	$3,193.00	$3,359.45	$3,886.44	$3,117.64	$67.86
20				$4.58			-17.41	-88.66	-316.63	-176.45	-77.78	-248.4895	$3,139.66	$3,212.01	$3,438.88	$3,298.70	$3,200.03	$3,370.74	$3,948.13	$3,122.22	$61.69
21				$4.16			-18.07	-92.01	-328.62	-178.70	-80.29	-255.3021	$3,144.48	$3,219.53	$3,455.03	$3,305.11	$3,206.70	$3,381.71	$4,004.21	$3,126.38	$56.08
22				$3.78			-18.75	-95.46	-340.92	-180.95	-82.84	-262.2169	$3,148.94	$3,226.76	$3,471.11	$3,311.14	$3,213.03	$3,392.41	$4,055.19	$3,130.16	$50.98
23				$3.44			-19.44	-98.99	-353.53	-183.19	-85.45	-269.2354	$3,153.08	$3,233.73	$3,487.17	$3,316.83	$3,219.08	$3,402.87	$4,101.54	$3,133.60	$46.35
24				$3.13			-20.16	-102.61	-366.48	-185.44	-88.10	-276.3592	$3,156.92	$3,240.48	$3,503.24	$3,322.20	$3,224.86	$3,413.12	$4,143.67	$3,136.73	$42.13
25				$2.84			-20.89	-106.33	-379.76	-187.69	-90.82	-283.5898	$3,160.49	$3,247.05	$3,519.37	$3,327.29	$3,230.42	$3,423.19	$4,181.97	$3,139.57	$38.30
26				$2.58			-21.64	-110.15	-393.39	-189.93	-93.58	-290.9289	$3,163.82	$3,253.45	$3,535.58	$3,332.12	$3,235.77	$3,433.12	$4,216.79	$3,142.16	$34.82
27				$2.35			-22.41	-114.06	-407.37	-192.18	-96.40	-298.378	$3,166.94	$3,259.71	$3,551.91	$3,336.71	$3,240.94	$3,442.91	$4,248.45	$3,144.51	$31.66
28				$2.14			-23.19	-118.08	-421.72	-194.42	-99.28	-305.9389	$3,169.87	$3,265.86	$3,568.39	$3,341.10	$3,245.95	$3,452.61	$4,277.23	$3,146.64	$28.78
29				$1.94			-24.00	-122.20	-436.44	-196.67	-102.21	-313.6133	$3,172.62	$3,271.93	$3,585.05	$3,345.28	$3,250.83	$3,462.23	$4,303.39	$3,148.58	$26.16
30				$1.77			-24.83	-126.43	-451.54	-198.92	-105.21	-321.4027	$3,175.21	$3,277.92	$3,601.92	$3,349.30	$3,255.59	$3,471.78	$4,327.17	$3,150.35	$23.78
31				$1.60			-25.69	-130.77	-467.03	-201.16	-108.26	-329.309	$3,177.67	$3,283.86	$3,619.02	$3,353.15	$3,260.24	$3,481.29	$4,348.79	$3,151.95	$21.62
32				$1.46			-26.56	-135.22	-482.93	-203.41	-111.37	-337.3339	$3,180.00	$3,289.77	$3,636.37	$3,356.85	$3,264.82	$3,490.78	$4,368.45	$3,153.41	$19.66
33				$1.33			-27.46	-139.79	-499.24	-205.66	-114.55	-345.4791	$3,182.23	$3,295.67	$3,654.01	$3,360.43	$3,269.32	$3,500.25	$4,386.31	$3,154.74	$17.87
34				$1.21			-28.38	-144.47	-515.97	-207.90	-117.79	-353.7465	$3,184.35	$3,301.56	$3,671.95	$3,363.88	$3,273.76	$3,509.72	$4,402.56	$3,155.94	$16.24
35				$1.10			-29.32	-149.28	-533.14	-210.15	-121.09	-362.138	$3,186.39	$3,307.46	$3,690.21	$3,367.22	$3,278.16	$3,519.21	$4,417.33	$3,157.04	$14.77
36				$1.00			-30.29	-154.21	-550.76	-212.40	-124.47	-370.6553	$3,188.36	$3,313.39	$3,708.83	$3,370.46	$3,282.53	$3,528.72	$4,430.75	$3,158.04	$13.42
37				$0.91			-31.29	-159.27	-568.83	-214.64	-127.90	-379.3003	$3,190.26	$3,319.36	$3,727.81	$3,373.61	$3,286.88	$3,538.27	$4,442.96	$3,158.94	$12.20
38				$0.82			-32.31	-164.47	-587.38	-216.89	-131.41	-388.0751	$3,192.10	$3,325.37	$3,747.17	$3,376.68	$3,291.21	$3,547.87	$4,454.05	$3,159.77	$11.09
39				$0.75			-33.35	-169.79	-606.40	-219.13	-134.99	-396.9814	$3,193.90	$3,331.45	$3,766.95	$3,379.68	$3,295.53	$3,557.53	$4,464.14	$3,160.51	$10.09
40				$0.68			-34.43	-175.26	-625.92	-221.38	-138.64	-406.0214	$3,195.65	$3,337.59	$3,787.15	$3,382.61	$3,299.86	$3,567.25	$4,473.31	$3,161.19	$9.17
41				$0.62			-35.53	-180.87	-645.95	-223.63	-142.36	-415.197	$3,197.37	$3,343.82	$3,807.79	$3,385.47	$3,304.20	$3,577.04	$4,481.64	$3,161.81	$8.34
42				$0.56			-36.66	-186.62	-666.50	-225.87	-146.15	-424.5102	$3,199.06	$3,350.14	$3,828.91	$3,388.28	$3,308.56	$3,586.92	$4,489.22	$3,162.38	$7.58
43				$0.51			-37.82	-192.52	-687.58	-228.12	-150.03	-433.963	$3,200.73	$3,356.55	$3,850.50	$3,391.04	$3,312.94	$3,596.88	$4,496.11	$3,162.89	$6.89
44				$0.46			-39.01	-198.58	-709.21	-230.37	-153.98	-443.5577	$3,202.39	$3,363.07	$3,872.60	$3,393.75	$3,317.36	$3,606.94	$4,502.37	$3,163.35	$6.26
45				$0.42			-40.23	-204.79	-731.41	-232.61	-158.01	-453.2963	$3,204.03	$3,369.71	$3,895.21	$3,396.42	$3,321.81	$3,617.10	$4,508.07	$3,163.77	$5.69
46				$0.38			-41.48	-211.17	-754.18	-234.86	-162.11	-463.181	$3,205.67	$3,376.47	$3,918.37	$3,399.05	$3,326.30	$3,627.37	$4,513.24	$3,164.16	$5.18
47				$0.35			-42.76	-217.71	-777.54	-237.11	-166.31	-473.214	$3,207.30	$3,383.36	$3,942.08	$3,401.64	$3,330.84	$3,637.75	$4,517.95	$3,164.51	$4.71
48				$0.32			-44.08	-224.42	-801.51	-239.35	-170.58	-483.3974	$3,208.94	$3,390.39	$3,966.37	$3,404.21	$3,335.44	$3,648.25	$4,522.22	$3,164.83	$4.28
49				$0.29			-45.44	-231.31	-826.10	-241.60	-174.94	-493.7336	$3,210.58	$3,397.56	$3,991.25	$3,406.74	$3,340.08	$3,658.88	$4,526.11	$3,165.11	$3.89
50							-46.82	-238.37	-851.34	-243.84	-179.39	-504.2249	$3,211.97	$3,404.63	$4,016.48	$3,408.99	$3,344.53	$3,669.37	$4,529.65	$3,165.11	$3.54
				$305.11																	$4,529.65
						B:C=							1.41	1.33	1.13	1.33	1.35	1.23	B:C=	1.43	

Note: Carbon1 = Total carbon value of encroachment rate at 2.6% with price of US$11/tonneC
Carbon2 = Total carbon value of encroachment rate at 2.6% with price of US$56/tonneC
Carbon3 = Total carbon value of encroachment rate at 2.6% with price of US$200/tonneC
Carbon4 = Total carbon value of encroachment rate at 0% with price of US$200/tonneC
Carbon5 = Total carbon value of encroachment rate at 1.5% with price of US$200/tonneC
Carbon6 = Total carbon value of encroachment rate at 2.0% with price of US$56/tonneC

Appendix 7.3: Carbon storage value in terrestrial ecosystems during 50 year-period under three scenarios (I=$11, II=$56 and III=$200 per tonne C).
depending on the human encroachment rate of A=2.6, B=2 and C=1.5%, respectively.

Year	TCprim	TCsecond	TCripar	TCiripzon	TCgras	TCrice	TChgarden	TC-gain1	TC-loss(A)	TC-loss val(AI	TC-loss val(AII	TC-loss val(AIII	Land useA	Hu-encro(A)	TC-loss(B)	TC-loss val(BI)	TC-loss val(BII)	TC-loss val(BIII)	Land useB	Hu-encro(B)	TC-loss(C)	TC-lossval(CI)	TC-loss val(CII	TC-loss val(CIII)	Land useC	Hu-encro(C)
0	478951.0	124775.0	54099.0	495.0	81	374	446.0	659221	-659221	-7.25	-36.92	-131.84	9400.0	0.0	-659221	-7.25	-36.92	-131.84	9400.0	0.0	-659221	-7.25	-36.92	-131.84	9400.0	0.0
1	481115.0	182979.6	56179.8	1535.4	81	374	631.0	722897	-695090	-7.65	-38.93	-139.02	9644.4	-244.4	-689320	-7.58	-38.60	-137.86	9588.0	-188.0	-684512	-7.53	-38.33	-136.90	9541.0	-141.0
2	483279.1	241184.2	58260.6	2575.8	81	374	815.9	786573	-731891	-8.05	-40.99	-146.38	9895.2	-250.8	-720021	-7.92	-40.32	-144.00	9779.8	-191.8	-710182	-7.81	-39.77	-142.04	9684.1	-143.1
3	485443.1	299388.8	60341.4	3616.2	81	374	1000.9	850248	-769649	-8.47	-43.10	-153.93	10152.4	-257.3	-751335	-8.26	-42.07	-150.27	9975.4	-195.6	-736237	-8.10	-41.23	-147.25	9829.4	-145.3
4	487607.1	357593.4	62422.2	4656.6	81	374	1185.8	913924	-808388	-8.89	-45.27	-161.68	10416.4	-264.0	-783276	-8.62	-43.86	-156.66	10174.9	-199.5	-762683	-8.39	-42.71	-152.54	9976.8	-147.4
5	489771.2	415798.0	64503.0	5697.0	81	374	1370.8	977600	-848135	-9.33	-47.50	-169.63	10687.2	-270.8	-815856	-8.97	-45.69	-163.17	10378.4	-203.5	-789525	-8.68	-44.21	-157.91	10126.5	-149.7
6	491935.2	474002.6	66583.8	6737.4	81	374	1555.8	1041276	-888915	-9.78	-49.78	-177.78	10965.1	-277.9	-849088	-9.34	-47.55	-169.82	10585.9	-207.6	-816771	-8.98	-45.74	-163.35	10278.4	-151.9
7	494099.2	532207.2	68664.6	7777.8	81	374	1740.7	1104952	-930756	-10.24	-52.12	-186.15	11250.2	-285.1	-882984	-9.71	-49.45	-176.60	10797.6	-211.7	-844425	-9.29	-47.29	-168.88	10432.5	-154.2
8	496263.3	590411.8	70745.4	8818.2	81	374	1925.7	1168627	-973684	-10.71	-54.53	-194.74	11542.7	-292.5	-917558	-10.09	-51.38	-183.51	11013.6	-216.0	-872493	-9.60	-48.86	-174.50	10589.0	-156.5
9	498427.3	648616.4	72826.2	9858.6	81	374	2110.6	1232303	-1017729	-11.20	-56.99	-203.55	11842.8	-300.1	-952824	-10.48	-53.36	-190.56	11233.9	-220.3	-900983	-9.91	-50.46	-180.20	10747.9	-158.8
10	500591.3	706821.0	74907.0	10899.0	81	374	2295.6	1295979	-1062919	-11.69	-59.52	-212.58	12150.7	-307.9	-988794	-10.88	-55.37	-197.76	11458.5	-224.7	-929900	-10.23	-52.07	-185.98	10909.1	-161.2
11	502755.4	765025.6	76987.8	11939.4	81	374	2480.6	1359655	-1109283	-12.20	-62.12	-221.86	12466.6	-315.9	-1025485	-11.28	-57.43	-205.10	11687.7	-229.2	-959251	-10.55	-53.72	-191.85	11072.7	-163.6
12	504919.4	823230.2	79068.6	12979.8	81	374	2665.5	1423331	-1156853	-12.73	-64.78	-231.37	12790.8	-324.1	-1062909	-11.69	-59.52	-212.58	11921.5	-233.8	-989042	-10.88	-55.39	-197.81	11238.8	-166.1
13	507083.4	881434.8	81149.4	14020.2	81	374	2850.5	1487006	-1205660	-13.26	-67.52	-241.13	13123.3	-332.6	-1101081	-12.11	-61.66	-220.22	12159.9	-238.4	-1019280	-11.21	-57.08	-203.86	11407.4	-168.6
14	509247.4	939639.4	83230.2	15060.6	81	374	3035.4	1550682	-1255736	-13.81	-70.32	-251.15	13464.5	-341.2	-1140017	-12.54	-63.84	-228.00	12403.1	-243.2	-1049972	-11.55	-58.80	-209.99	11578.5	-171.1
15	511411.5	997844.0	85311.0	16101.0	81	374	3220.4	1614358	-1307114	-14.38	-73.20	-261.42	13814.6	-350.1	-1179732	-12.98	-66.06	-235.95	12651.2	-248.1	-1081124	-11.89	-60.54	-216.22	11752.2	-173.7
16	513575.5	1056048.6	87391.8	17141.4	81	374	3405.4	1678034	-1359828	-14.96	-76.15	-271.97	14173.8	-359.2	-1220241	-13.42	-68.33	-244.05	12904.2	-253.0	-1112743	-12.24	-62.31	-222.55	11928.5	-176.3
17	515739.5	1114253.2	89472.6	18181.8	81	374	3590.3	1741709	-1413912	-15.55	-79.18	-282.78	14542.3	-368.5	-1261560	-13.88	-70.65	-252.31	13162.3	-258.1	-1144837	-12.59	-64.11	-228.97	12107.4	-178.9
18	517903.6	1172457.8	91553.4	19222.2	81	374	3775.3	1805385	-1469403	-16.16	-82.29	-293.88	14920.4	-378.1	-1303706	-14.34	-73.01	-260.74	13425.5	-263.2	-1177412	-12.95	-65.94	-235.48	12289.0	-181.6
19	520067.6	1230662.4	93634.2	20262.6	81	374	3960.2	1869061	-1526336	-16.79	-85.47	-305.27	15308.3	-387.9	-1346694	-14.81	-75.41	-269.34	13694.0	-268.5	-1210475	-13.32	-67.79	-242.10	12473.3	-184.3
20	522231.6	1288867.0	95715.0	21303.0	81	374	4145.2	1932737	-1584750	-17.43	-88.75	-316.95	15706.3	-398.0	-1390543	-15.30	-77.87	-278.11	13967.9	-273.9	-1244035	-13.68	-69.67	-248.81	12660.4	-187.1
21	524395.7	1347071.6	97795.8	22343.4	81	374	4330.2	1996413	-1644682	-18.09	-92.10	-328.94	16114.7	-408.4	-1435268	-15.79	-80.38	-287.05	14247.3	-279.4	-1278098	-14.06	-71.57	-255.62	12850.3	-189.9
22	526559.7	1405276.2	99876.6	23383.8	81	374	4515.1	2060088	-1706172	-18.77	-95.55	-341.23	16533.7	-419.0	-1480888	-16.29	-82.93	-296.18	14532.2	-284.9	-1312671	-14.44	-73.51	-262.53	13043.1	-192.8
23	528723.7	1463480.8	101957.4	24424.2	81	374	4700.1	2123764	-1769262	-19.46	-99.08	-353.85	16963.6	-429.9	-1527420	-16.80	-85.54	-305.48	14822.9	-290.6	-1347764	-14.83	-75.47	-269.55	13238.7	-195.6
24	530887.8	1521685.4	104038.2	25464.6	81	374	4885.0	2187440	-1833991	-20.17	-102.70	-366.80	17404.6	-441.1	-1574883	-17.32	-88.19	-314.98	15119.3	-296.5	-1383383	-15.22	-77.47	-276.68	13437.3	-198.6
25	533051.8	1579890.0	106119.0	26505.0	81	374	5070.0	2251116	-1900404	-20.90	-106.42	-380.08	17857.1	-452.5	-1623295	-17.86	-90.90	-324.66	15421.7	-302.4	-1419536	-15.61	-79.49	-283.91	13638.9	-201.6
26	535215.8	1638094.6	108199.8	27545.4	81	374	5255.0	2314792	-1968543	-21.65	-110.24	-393.71	18321.4	-464.3	-1672675	-18.40	-93.67	-334.53	15730.1	-308.4	-1456231	-16.02	-81.55	-291.25	13843.5	-204.6
27	537379.9	1696299.2	110280.6	28585.8	81	374	5439.9	2378467	-2038454	-22.42	-114.15	-407.69	18797.8	-476.4	-1723043	-18.95	-96.49	-344.61	16044.7	-314.6	-1493477	-16.43	-83.63	-298.70	14051.1	-207.7
28	539543.9	1754503.8	112361.4	29626.2	81	374	5624.9	2442143	-2110182	-23.21	-118.17	-422.04	19286.5	-488.7	-1774418	-19.52	-99.37	-354.88	16365.6	-320.9	-1531282	-16.84	-85.75	-306.26	14261.9	-210.8
29	541707.9	1812708.4	114442.2	30666.6	81	374	5809.8	2505819	-2183776	-24.02	-122.29	-436.76	19788.0	-501.4	-1826821	-20.10	-102.30	-365.36	16692.9	-327.3	-1569653	-17.27	-87.90	-313.93	14475.8	-213.9
30	543872.0	1870913.0	116523.0	31707.0	81	374	5994.8	2569495	-2259283	-24.85	-126.52	-451.86	20302.5	-514.5	-1880272	-20.68	-105.30	-376.05	17026.8	-333.9	-1608601	-17.69	-90.08	-321.72	14693.0	-217.1
31	546036.0	1929117.6	118603.8	32747.4	81	374	6179.8	2633171	-2336753	-25.70	-130.86	-467.35	20830.3	-527.9	-1934791	-21.28	-108.35	-386.96	17367.3	-340.5	-1648132	-18.13	-92.30	-329.63	14913.3	-220.4
32	548200.0	1987322.2	120684.6	33787.8	81	374	6364.7	2696846	-2416237	-26.58	-135.31	-483.25	21371.9	-541.6	-1990402	-21.89	-111.46	-398.08	17714.7	-347.3	-1688256	-18.57	-94.54	-337.65	15137.0	-223.7
33	550364.1	2045526.8	122765.4	34828.2	81	374	6549.7	2760522	-2497788	-27.48	-139.88	-499.56	21927.6	-555.7	-2047124	-22.52	-114.64	-409.42	18069.0	-354.3	-1728983	-19.02	-96.82	-345.80	15364.1	-227.1
34	552528.1	2103731.4	124846.2	35868.6	81	374	6734.6	2824198	-2581460	-28.40	-144.56	-516.29	22497.7	-570.1	-2104981	-23.15	-117.88	-421.00	18430.4	-361.4	-1770320	-19.47	-99.14	-354.06	15594.6	-230.5
35	554692.1	2161936.0	126927.0	36909.0	81	374	6919.6	2887874	-2667306	-29.34	-149.37	-533.46	23082.6	-584.9	-2163995	-23.80	-121.18	-432.80	18799.0	-368.6	-1812277	-19.94	-101.49	-362.46	15828.5	-233.9
36	556856.2	2220140.6	129007.8	37949.4	81	374	7104.6	2951550	-2755385	-30.31	-154.30	-551.08	23682.8	-600.1	-2224189	-24.47	-124.55	-444.84	19174.9	-376.0	-1854863	-20.40	-103.87	-370.97	16065.9	-237.4
37	559020.2	2278345.2	131088.6	38989.8	81	374	7289.5	3015225	-2845754	-31.30	-159.36	-569.15	24298.5	-615.8	-2285587	-25.14	-127.99	-457.12	19558.4	-383.5	-1898089	-20.88	-106.29	-379.62	16306.9	-241.0
38	561184.2	2336549.8	133169.4	40030.2	81	374	7474.5	3078901	-2938472	-32.32	-164.55	-587.69	24930.3	-631.8	-2348213	-25.83	-131.50	-469.64	19949.6	-391.2	-1941962	-21.36	-108.75	-388.39	16551.5	-244.6
39	563348.2	2394754.4	135250.2	41070.6	81	374	7659.4	3142577	-3033601	-33.37	-169.88	-606.72	25578.5	-648.2	-2412092	-26.53	-135.08	-482.42	20348.6	-399.0	-1986494	-21.85	-111.24	-397.30	16799.8	-248.3
40	565512.3	2452959.0	137331.0	42111.0	81	374	7844.4	3206253	-3131204	-34.44	-175.35	-626.24	26243.5	-665.0	-2477248	-27.25	-138.73	-495.45	20755.6	-407.0	-2031694	-22.35	-113.77	-406.34	17051.8	-252.0
41	567676.3	2511163.6	139411.8	43151.4	81	374	8029.4	3269928	-3231344	-35.54	-180.96	-646.27	26925.9	-682.3	-2543708	-27.98	-142.45	-508.74	21170.7	-415.1	-2077572	-22.85	-116.34	-415.51	17307.5	-255.8
42	569840.3	2569368.2	141492.6	44191.8	81	374	8214.3	3333604	-3334087	-36.67	-186.71	-666.82	27625.9	-700.1	-2611496	-28.73	-146.24	-522.30	21594.1	-423.4	-2124138	-23.37	-118.95	-424.83	17567.2	-259.6
43	572004.4	2627572.8	143573.4	45232.2	81	374	8399.3	3397280	-3439503	-37.83	-192.61	-687.90	28344.2	-718.3	-2680640	-29.49	-150.12	-536.13	22026.0	-431.9	-2171402	-23.89	-121.60	-434.28	17830.7	-263.5
44	574168.4	2685777.4	145654.2	46272.6	81	374	8584.2	3460956	-3547658	-39.02	-198.67	-709.53	29081.2	-736.9	-2751168	-30.26	-154.07	-550.23	22466.5	-440.5	-2219376	-24.41	-124.29	-443.88	18098.1	-267.5
45	576332.4	2743982.0	147735.0	47313.0	81	374	8769.2	3524632	-3658626	-40.24	-204.88	-731.73	29837.3	-756.1	-2823105	-31.05	-158.09	-564.62	22915.8	-449.3	-2268069	-24.95	-127.01	-453.61	18369.6	-271.5
46	578496.5	2802186.6	149815.8	48353.4	81	374	8954.2	3588307	-3772479	-41.50	-211.26	-754.50	30613.0	-775.8	-2896482	-31.86	-162.20	-579.30	23374.1	-458.3	-2317492	-25.49	-129.78	-463.50	18645.1	-275.5
47	580660.5	2860391.2	151896.6	49393.8	81	374	9139.1	3651983	-3889293	-42.78	-217.80	-777.86	31409.0	-795.9	-2971326	-32.68	-166.39	-594.27	23841.6	-467.5	-2367657	-26.04	-132.59	-473.53	18924.8	-279.7
48	582824.5	2918595.8	153977.4	50434.2	81	374	9324.1	3715659	-4009143	-44.10	-224.51	-801.83	32225.6	-816.6	-3047667	-33.52	-170.67	-609.53	24318.5	-476.8	-2418574	-26.60	-135.44	-483.71	19208.7	-283.9
49	584988.6	2976800.4	156058.2	51474.6	81	374	9509.0	3779335	-4132109	-45.45	-231.40	-826.42	33063.5	-837.9	-3125534	-34.38	-175.03	-625.11	24804.8	-486.4	-2470255	-27.17	-138.33	-494.05	19496.8	-288.1
50	587152.6	3035005.0	158139.0	52515.0	81	374	9694.0	3843011	-4258273	-46.84	-238.46	-851.65	33923.1	-859.7	-3204959	-35.25	-179.48	-640.99	25300.9	-496.1	-2522711	-27.75	-141.27	-504.54	19789.3	-292.5
TOTAL=								Initial:Fin	Initial:Fina	6.46	6.46	6.46		-24523.1						-15900.9						-10389.3

NOTE:

Total carbon gain = The condition of equation is no land use change (land area = 9400ha), NPP at 11.56 tonneC/ha/yr and NEP = 0.1as the growing ecosystem.

Total carbon gain1 = The condition of equation is depended on the land use types and the different rate NEP but the land area is the same as 74200ha. NPP is constant at 11.56 tonneC/ha/yr but NEP = 0.2in the secondary and riparian forest and NEP = 0.04 in the primary forest. The paddy rice field and grassland assumed constant production because their systems are annual production. The riparian zone and home gardening system have NEP at 0.1.

Total carbon loss = The condition of encroachment rate is considered at the national rate of deforestation in Thailand at 2.6% per year from the total flooded area of Ban Koum project.

Appendix 7.4: A summary of sensitivity test based on weighting and scoring of biodiversity indicators under the different scenarios.

		PRESENT SCENARIO			IDEAL SCENARIO			PREDICTED SCENARIO1			PREDICTED SCENARIO2			PREDICTED SCENARIO3		
	Indicators	Existing value	Weight	ScoreEx	Value	Weight	ScoreID	Value	Weight	ScorePred1	Value	Weight	ScorePred2	Value	Weight	ScorePred3
Species level	Species composition	55.67	60.93		67.00	100.00		44.54	22.55		50.01	41.41		52.89	95.01	
	Species richness	54.33	61.30		76.00	100.00		43.46	41.89		48.88	51.57		51.61	56.45	
	Species diversity	3.03	52.17	**0.58**	3.14	100.00	**1.00**	2.51	-173.91	**-0.36**	2.73	-78.26	**0.05**	2.88	-13.04	**0.46**
Ecosystem level	Carbon storage (10^6 C)	-0.66	22.95	**0.23**	1.22	100.00	**1.00**	-3.2	-81.15	**-0.81**	-2.52	-53.28	**-0.53**	-0.66	22.95	**0.23**
Human level	Socio-economic impact	1.18	0.00	**0.00**	1.18	0.00	**0.00**	1.67	100.00	**1.00**	1.55	75.51	**0.76**	1.43	51.02	**0.51**
Economic analysis (B:C ratio)	B:C ratio	1.43	100.00	**1.00**	1.38	88.37	**0.88**	1.35	81.40	**0.81**	1.23	53.49	**0.53**	1.37	86.05	**0.86**
Composite score				**0.45**			**0.72**			**0.16**			**0.20**			**0.52**

	Maximum	Medium	Minimum	Mean
Species composition	67	62	38	55.67
Species richness	76	67	20	54.33
Species diversity	3.14	3.04	2.91	3.03
Carbon storage (10^6 C)	1.22		-1.22	
Socio-economic impact	1.67		1.18	
B:C ratio	1.43		1.00	

Assumption of 'with-project condition':

Present scenario (Scenario A) = All variables are quantified from the field that presents the existing condition of biodiversity in the Lower Mekong River.
The species variables is used the average/mean values based on the field data. The carbon storage is calculated from the equation of potential carbon loss at 0.66 million tonne C.
The economic value is used the benefit to cost ratio at 1.43 from the chapter five according to MRC report without carbon storage value.

Ideal scenario (Scenario B) = All variables are estimated at the high values from the field data especially from the primary forest relative to the species level.
The carbon storage is assumed from the equation to predict the potential of carbon stored (1.22 million tonne C) during 50 year-period without human encroachment.
The socio-economic impact indicator is assumed that the socio-economic impact indicator will not change from the existing condition.
The economic value is based on the benefit to cost ratio at 1.38 including carbon storage gain value ($200/tonne C) into IA.

Predicted scenario1 (Scenario C) = All species indicators are reduced at rate of 20% from the existing condition.
The carbon storage is estimated as the carbon storage released at the encroachment rate of 2.0%, which forest is deforested and carbon released at 3.20 million tonne C during 50-year period.
The socio-economic impact indicator is assumed the it is increased impact from 1.18 to 1.67 as the result from Pak Mun Dam, which assumed to be maximum change of 100%.
The economic value is based on the benefit to cost ratio at 1.35 according to the carbon value ($56/tonneC at 2.0% encroachment rate) integration in economic analysis.

Predicted scenario2 (Scenario D) = All species indicators are reduced at rate of 10% from the existing condition.
The carbon storage is estimated as the carbon storage released at the encroachment rate of 1.5%, which forest is deforested and carbon released at 2.52 million tonne C during 50-year period.
The socio-economic impact indicator is assumed the it is increased impact at the rate of 75% change.
The economic value is based on the benefit to cost ratio of 1.23 according to the carbon value ($200/tonneC at 1.5% encroachment rate) integration in economic analysis

Predicted scenario3 (Scenario E) = All species indicators are reduced at rate of 5% from the existing condition.
The carbon storage is estimated as the carbon storage released from terrestrial ecosystem at the encroachment rate of 0%, which forest is deforested
and carbon released at 0.66 million tonne C during 50-year period.
The socio-economic impact indicator is assumed the it is increased impact at the rate of 50% change.
The economic value is based on the benefit to cost ratio of 1.37 according to the carbon value ($200/tonneC at 0% encroachment rate) integration in economic analysis

Weighting: Each variable needs to standardise to same scale by 0-100 (Rossiter, 1995).

Weight = *(ri-rmin)/(rmax-rmin)*100*

ri = existing variable or average variable
rmin = minimum value of variable
rmax = maximum value of variable

Normalising score: The maximum score is equal 1.0 (Hruby, 1999).

Score (index) for variable = (V1+V2+V3+V4)/4

V = Weighting variable related to the model or assessment.

Summary table:

	ScenarioA	ScenarioB	ScenarioC	ScenarioD	ScenarioE
Species indicator	0.58	**1.00**	-0.36	0.05	0.46
Ecosystem indicator	0.23	**1.00**	-0.81	-0.53	0.23
Socio-economic impact	0.00	**0.00**	1.00	0.76	0.51
B:C ratio	1.00	**0.88**	0.81	0.53	0.86
Composite score	0.45	**0.72**	0.16	0.20	0.52

APPENDIX V: ABSTRACT



14th SESSION OF THE GLOBAL BIODIVERSITY FORUM

Palais des Congrès
Montreal, Canada
18-20 June 1999

BACKGROUND DOCUMENTATION

(Abstracts and Papers)

Organized by:

Green Earth Organization
International Plant Genetic Resources Institute (IPGRI)
Tropenbos
North American Sustainable Use Specialist Group
IUCN Sustainable Use Initiative
WWF Côte d'Ivoire
IUCN - The World Conservation Union
World Resources Institute (WRI)
African Centre for Technological Studies (ACTS)
Biodiversity Action Network (BIONET)
Indigenous Peoples Biodiversity Network (IPBN)
United Nations Environment Programme (UNEP)

in collaboration with

the Secretariat to the Convention on Biological Diversity (SCBD)

Title: **Alternative Methodology of Biodiversity Evaluation: Case Study in the Lower Mekong River Basin**

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Workshop: Building biodiversity into sectoral plans, policies, and programmes

ABSTRACT:

Incorporating biodiversity and other environmental factors into decision-making remains a difficult problem. Economists suggest that valuation of the direct and indirect benefits of biodiversity is one approach, while conservationists argue for environmental protection for a host of non-monetary reasons as well. These issues are particularly relevant to many developing countries where the conflict between biodiversity and human needs is most acute, and effective lobbying by non-governmental organisations and others is generally absent.

Traditionally, development policies, plans and projects have sought to include environmental factors in decisions through the use of Environmental Impact Assessment (EIA). While the use of EIA is increasingly advocated, experience suggests that environmental factors tend to carry most (any) weight in EIAs when their direct monetary value is explicit. Not only it is attaining monetary value for biodiversity a difficult task - but also has the potential to lead to decisions which severely disrupt the normal functioning of ecosystems.

This paper explores alternative methods of incorporating biodiversity into EIA. Specifically the research aims to identify non-monetary indicators of biodiversity, which are both easy to measure in the field and meaningful and simple to incorporate into decision-making processes. Indicators explored to date include carbon storage in ecosystems, tree species diversity and livelihood strategies of local people. The functionality of applying these indicators is being explored at the site of a planned hydropower project in the Lower Mekong Basin. If these indicators prove to be useful then it is hoped that the research may lead to practicable techniques for application in Southeast Asia, offering a realistic but holistic decision-making framework.