ISSN: 1683-1489

Mekong River Commission

Multi-functionality of Paddy Fields over the Lower Mekong Basin

MRC Technical Paper
No. 26

February 2010

Meeting the Needs, Keeping the Balance

ISSN: 1683-1489

Mekong River Commission

Multi-functionality of Paddy Fields over the Lower Mekong Basin

MRC Technical Paper
No. 26

February 2010

Published in Vientiane, Lao PDR in February 2010 by the Mekong River Commission

Acknowledgements

The Mekong River Commission would like to express its gratitude to the Government of Japan for its support of the programme to Demonstrate the Multi-functionality of Paddy Fields over the Mekong River Basin

Cite this document as:

MRC (2010) Multi-functionality of Paddy Fields over the Lower Mekong Basin, MRC Technical Paper No. 26, Mekong River Commission, Vientiane. 72 pp.

Authors: G. P. Shivakoti, R. C. Bastakoti
Editor: J. Simery
Graphic design: J. Simery

184 Fa Ngoum Road, Unit 18, Ban Sithane Neua, Sikhottabong District,
Vientiane 01000, Lao PDR
Telephone: (856–21) 263 263 Facsimile: (856–21) 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org

Table of contents

Table of figures

List of tables

Abbreviations and acronyms

AW	Autumn - Winter
BDP	Basin Development Plan
BDP2	Basin Development Plan Phase 2
CAWS	Cumulative data of available soil water storage
DMPF	Project to Demonstrate the Multi-functionality of Paddy Fields over the Mekong River Basin
FAO	Food and Agriculture Organisation of the United Nations
FGD	Focus group discussion
GIS	Geographical Information System
HH	Household
IQQM	Integrated water quantity and quality model
ISD	Irrigation Scheme Database
IWRM	Integrated Water Resources Management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
NPS	Nonpoint source pollution
NTCs	Non-trade Concerns
OECD	Organisation for Economic Co-operation and Development
PPP	Polluter pays principle
PRA	Participatory rural appraisal
RRA	Rapid results approach
SA	Summer - Autumn
SQ	Stability quotient
SR	Soil ripening
US$	US dollar (currency)
VND	Vietnamese Dong (currency)
WS	Winter - Spring
WTP	Willingness to pay

Summary

The term ‘multi-functionality’ refers to an agricultural activity that could have multiple outputs besides providing food and fibres and, therefore, may contribute to several objectives at once.

Considering the importance of irrigation water use and of the multifunctional roles of paddy fields in the region, the Mekong River Commission (MRC) implemented a project to Demonstrate the Multi-functionality of Paddy Fields over the Mekong River Basin (DMPF), which was implemented during 2002-2007 to facilitate the sustainable development of the Lower Mekong Basin (LMB) region though improved agricultural production. The aim was to provide some methods or means by which MRC’s Member Countries could measure and improve the multi-functionality of paddy fields in the LMB region.

Though the economic contribution to the household income from rice grain production is the primary function of paddy rice farming, it also generates employment and other associated opportunities. Under the project, some selected roles of paddy fields were analysed. The main focus was on the multifunctional roles that generate non-commodity outputs, such as flood mitigation, nurturing and restoring aquatic ecosystem, soil productivity and soil conservation.

The multifunctional roles of paddy fields in the LMB region were analysed in selected areas in Viet Nam and Thailand. In Viet Nam, the study focused on the Mekong Delta region whereas in Thailand it focused on the Northeastern region of the country.

Multifunctional roles of paddy fields in the Vietnamese part of the Mekong Delta

In the Mekong Delta, the findings showed that paddy fields have the capacity to store flood water, which reduces the threat of severe floods. Thus it can be concluded that paddy fields contribute to flood mitigation. In addition, during the flooding season, paddy fields get flooded and sediments deposited.

Paddy fields in the Mekong Delta have played an important role in nurturing aquatic ecosystems by nursing and creating refuges for fish and fish food. Fisheries resources have contributed significantly to the income of farmers, especially in areas where paddy fields are surrounded by ditches. In addition, paddy fields can help reduce and prevent pollution resulting from heavy aquaculture activities in the surrounding areas, such as intensive catfish or shrimp aquaculture. However, the increasing use of pesticides in paddy cultivation may have negative effects on the biodiversity of aquatic ecosystems.

At the same time, the results showed that cultivating paddy intensively on healthy soils will gradually reduce the soil productivity. While on the positive side, paddy fields on unhealthy soils (Acid Sulphate Soils) effectively improve soil productivity.

Besides being the main source of household income in the Mekong Delta, paddy fields have significantly contributed to generating employment. Paddy farming requires a large number of hired labourers, contributing to poverty reduction by creating employment opportunities for resource-poor households. In addition, paddy cultivation has contributed to food security as well as exports.

Multifunctional role of paddy fields in Northeastern Thailand

Similarly, the results showed that in Northeastern Thailand paddy fields have also served as water reservoirs around the city areas, effectively storing flood water and significantly reducing the threat of flooding. The rapid transformation of paddy fields to other land uses could however have negative effects in the future.

As in Viet Nam, paddy fields in Northeastern Thailand provide many valuable wild products that are of great economic value to farm households. These wild species make important contributions to the food supply of rural households, especially as sources of nutritionally valuable vegetables and proteins.

Rain-fed and irrigated paddy fields play an important roles in the economic life of households in Northeastern Thailand. Paddy cultivation was the most important source of income for both types of households. In the dry season also, households with irrigated fields are able to spend more of their time working in the fields, whereas those with rain-fed paddy fields needed to find non-farm and off-farm work. Irrigated paddy fields could help stabilise rural livelihoods and retain people in the agricultural sector, thereby reducing livelihood insecurity.

These multifunctional roles of paddy fields are at risk, especially in the context of the rapid transformation of agricultural land to other uses. The reduction of paddy cultivation areas around urban centres could severely influence the function of paddy fields on flood mitigation. The reduction of paddy cultivation areas can have negative consequences on the diversity of wild species in rural areas. In addition, the intensive cultivation of rice with an increased use of chemical fertilisers and pesticides is having negative effects on the availability of aquatic resources.

Socioeconomic contribution is not often considered as a multifunctional role. But future research could also focus on the importance of the socioeconomic multi-functionality, especially the off-farm and non-farm opportunities created by paddy cultivation. The backward and forward linkages of paddy cultivation in the overall economy could be considered as an important multifunctional role and deserves more investigation.

1. Introduction

1.1 Paddy production in Asia and the Lower Mekong Basin

Rice is the most important irrigated crop in Asia and covers almost 50% of the net irrigated area. For centuries, rice has been the main staple food in most parts of Asia and has been the most important source of employment and income for rural people. The current estimate shows that rice is grown in about 250 million farms in Asia and most of them are family-owned with an average size varying from less than 0.5 ha to 4 ha (FAO, 2007).

In Asian countries rice is highly valued owing to its strong linkages with food security, socio-economic development of the rural community, and conservation of natural resources and the environment. Paddy cultivation has been the basis for economic life, as well as social and cultural life, for several thousand years. Paddy farming continues to be the dominant agricultural activity in Southeast Asia, and also the major consumer of water (Groenfeldt, 2006).

In Southeast Asia, between 40 to 90% of the population are engaged in agriculture or related industries. Rice cultivation dominates cropping patterns in much agricultural land (FAO, 2007). The land-use map of the Lower Mekong Basin (LMB) region clearly depicts the dominant coverage of paddy fields (Figure 1.1). The paddy planted areas and the productivity of paddy cultivation in the region are presented in Figure 1.2 and Figure 1.3 respectively.

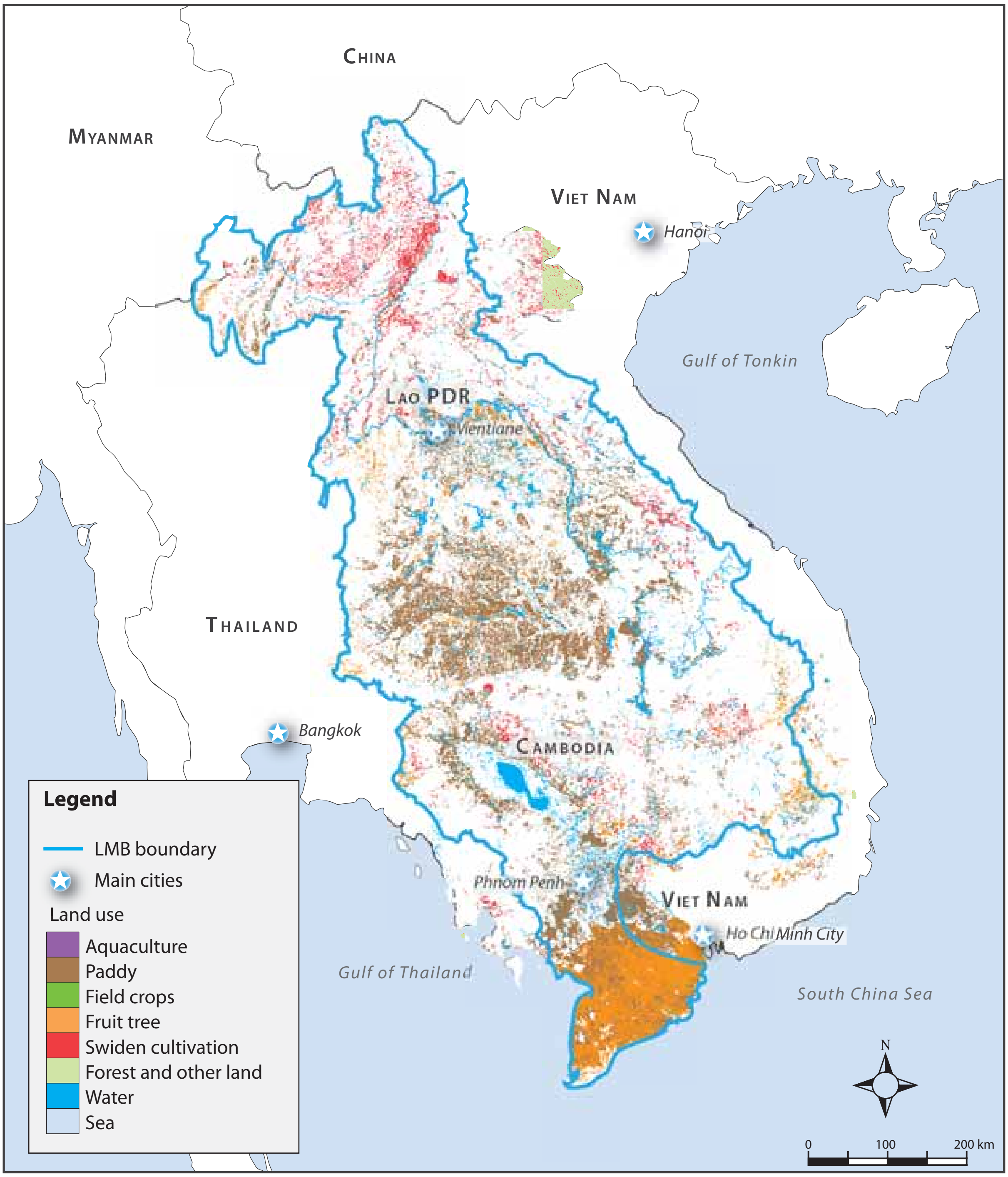


Figure 1.1 Land use map in the Lower Mekong Basin

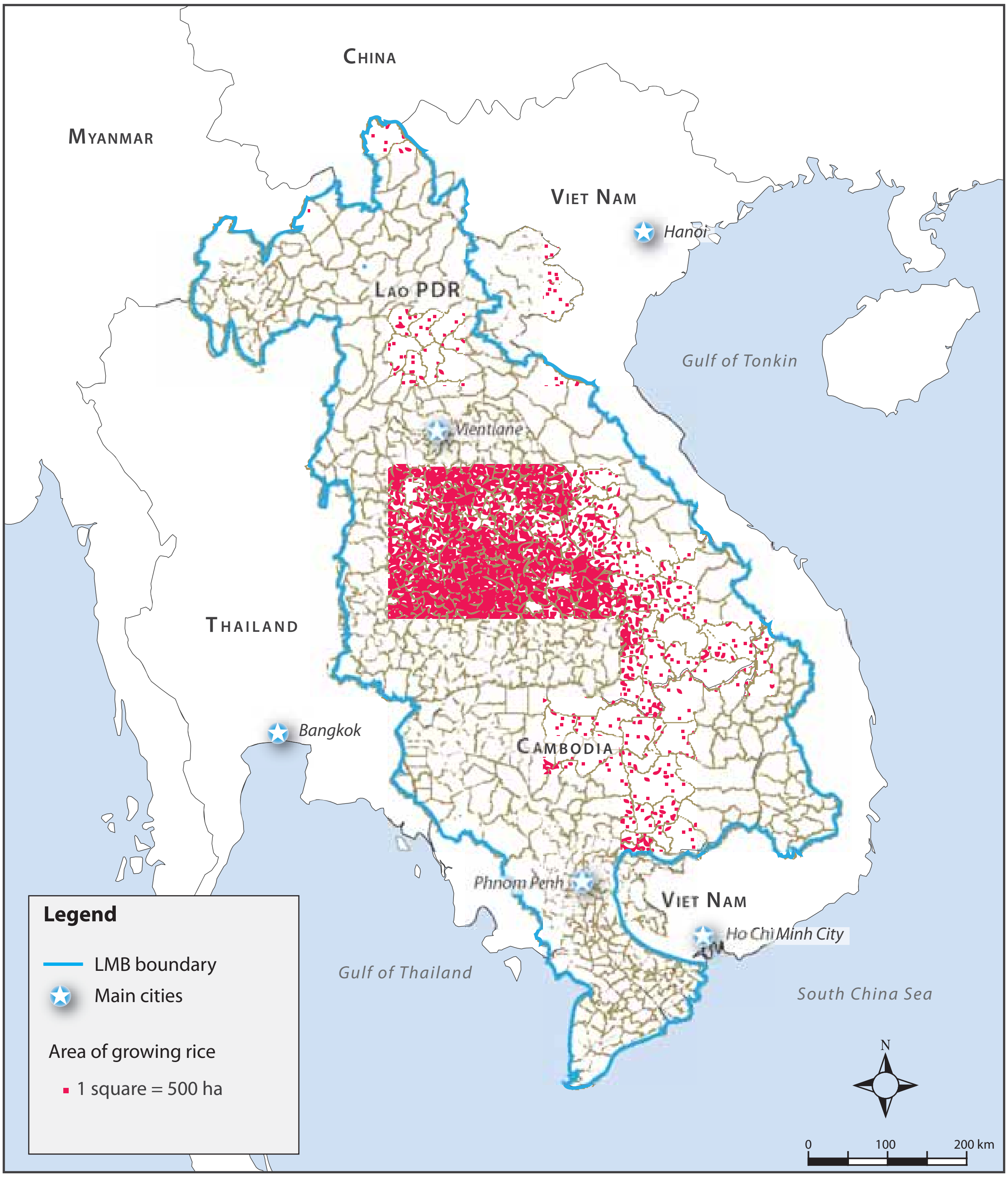


Figure 1.2 Paddy planted areas in the Lower Mekong Basin in the month of August

The detail on monthly changes in rice area is presented in Appendix 2. It shows that rice is produced all year round in the Vietnamese part of the Mekong Delta.

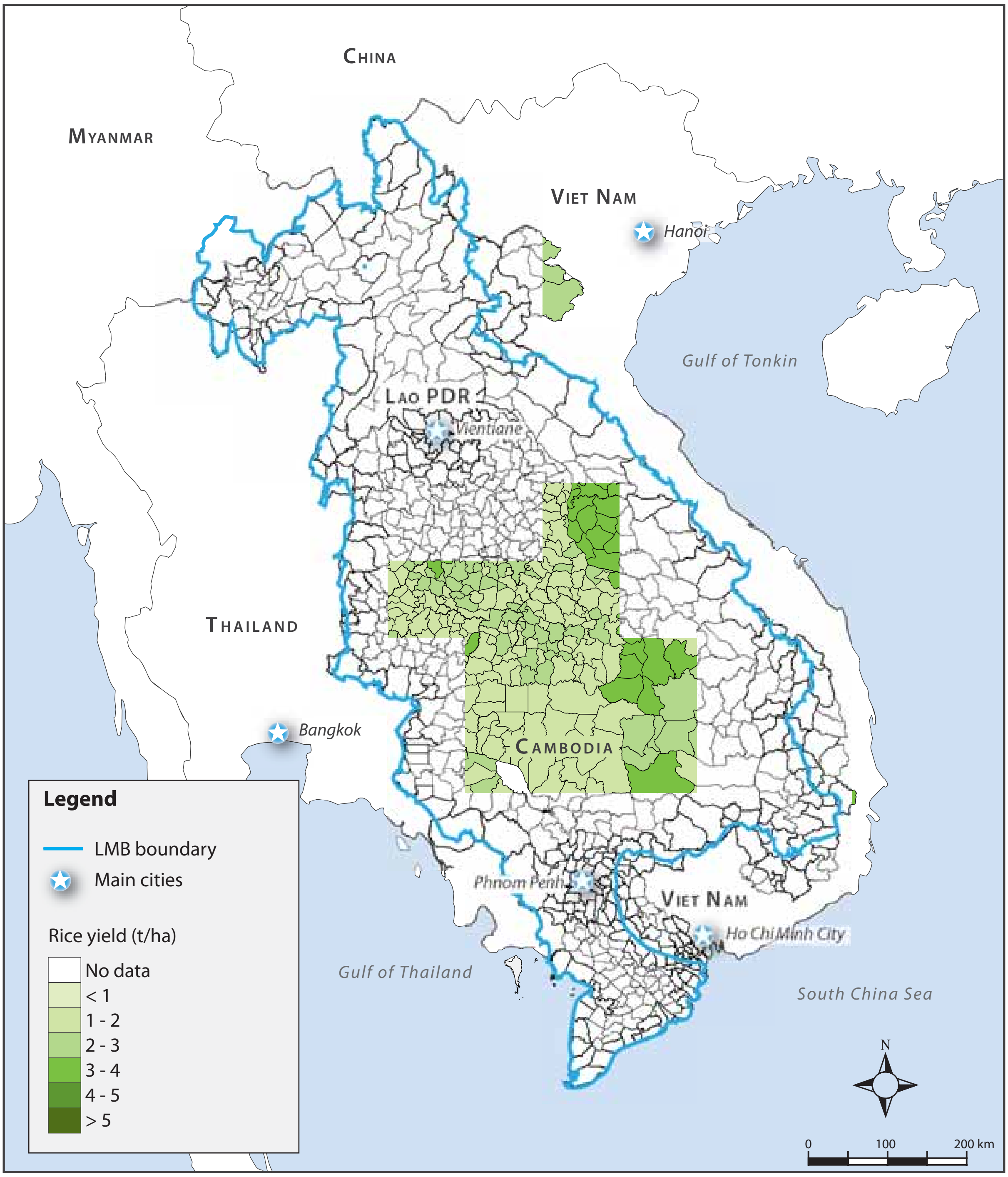


Figure 1.3 Paddy productivity in the Lower Mekong Basin

These three maps indicate that paddy production is widely spread over the LMB region, and the major concentration areas are in the Vietnamese part of the Mekong Delta and Northeastern Thailand. The monthly changes of rice planted areas indicate that rice is grown all year round in most parts of the Mekong Delta region. Considering the types of land-use, and particularly the widespread paddy cultivation in the region, the water abstraction for agriculture is high in this region. It is estimated that water abstraction for agriculture accounts for around 90% of all water diversions (Cambodia: 94%, Lao PDR: 82%, Viet Nam: 86%, and Thailand: 91%) in the region

(MRC, 2003; and Hoanh *et al.*, 2009). Among these countries, Thailand and Viet Nam have extensively developed their irrigation infrastructure. But the ratio of irrigated land to total arable land is still very low in the region (26.8%) compared to the Asian average of 45% (Hoanh *et al*., 2009).

Given the importance of rice production in the economy of the LMB region and the export potential, further irrigation infrastructure development seems inevitable. This situation demands for further investigation on net water use in different sectors of agriculture and taking stock of existing irrigation infrastructures. Such information is helpful in better planning the development of water resourcesover to meet the ever increasing demand for water in different sectors, particularly agriculture and paddy production. This report is drafted in light of this background.

1.2 Overview of the multifunctional roles of paddy fields

The countries in the monsoon region of Asia have a long history of collective, small-scale paddy cultivation. A typical rural landscape is that of paddy fields in the plain areas stretching as far as the eye can see, or terraced paddy fields on mountain slopes. Recently, however, traditional landscapes have been increasingly threatened by urban encroachment, and many developed and developing countries in monsoon Asia are taking stock of the role that paddy cultivation plays in their social, cultural, spiritual, economic, and ecological well-being. Irrigated paddy cultivation, and the crucial role that water plays in making cultivation possible, is an integral dimension of this.

Paddy fields are mainly used for rice production. However, water use and management of paddy fields as well as rice cultivation activities on paddy fields also generate non-production benefits which are called multifunctional roles of paddy fields. The multifunctional impacts of rice production vary in regions, depending on the climate, social, cultural, and economic conditions, in addition to the settings of infrastructure and management systems.

The multi-functionality of paddy fields and irrigation water has become a major issue recently in Asian monsoon regions. The irrigation facilities targeted to deliver water to rice fields serve several other purposes such as: flood control; support of other natural vegetation; ground water recharge, as well as spawning and breeding grounds for several aquatic species. In some industrialised countries like Japan and Taiwan, the paddy fields provide environmental services and opportunities for recreational activities (Groenfeldt, 2006).

Paddy cultivation in monsoon Asia illustrates the many complex functions of agricultural water (Groenfeldt, 2006). The lowland rice landscape provides many ecosystem services which have been receiving increased recognition under the term ‘multi-functionality’. In East Asian countries like Japan, the Republic of Korea, and Taiwan, multi-functionality has become a focal issue in agricultural policy in the context of international trade negotiations (FAO, 2007). In South Korea, for example, the multifunctional roles of paddy fields include: flood mitigation, ground water recharge, water purification; soil erosion control; air purification and climate change mitigation; and biodiversity conservation, recreation and amenities (Kim *et al.*, 2006). Similarly, various multifunctional roles of paddy fields have been highlighted in Japan (Matsuno *et al.*, 2006) and Taiwan (Huang *et al.* 2006).

In the LMB region, the multifunctional roles of paddy fields have also been recognised, although it has not received sufficient attention from the authorities. In the context of the LMB, traditionally the agricultural production of the region is dominated by rice production that consumes large amounts of water from the small basin. The multi-functionality of these paddy fields has been established both from a socioeconomic and environmental viewpoint. But the study on these important multifunctional roles of paddy is virtually non-existent.

1.3 Study objectives

In the context of the importance of irrigation water use and realised multifunctional roles of paddy fields in the region, the Mekong River Commission (MRC) implemented a programme to Demonstrate Multi-functionality of Paddy Fields over the basin (DMPF). The project was implemented during 2002-2007 with the major purpose of facilitating the sustainable development of the LMB region though improved agricultural production. The aim was to provide some methods or means by which MRC Member Countries could measure and improve the multi-functionality of rice farming.

Initially the project aimed to cover all four Member Countries in all aspects of this research project. There were two stages; data collection on irrigation and agriculture; and the analysis of multifunctional roles of paddy fields. The data collection stage faced long delays and later led to a change in the direction of the project.

The project objective was adapted to ‘achieving a better understanding of multi-functionality of paddy fields in the Lower Mekong Basin’. The immediate objective was ‘to show visible examples of paddy fields’ functions with quantified evaluation’. Thus, this report has reviewed the multi-functionality as a concept and its application in paddy fields in the LMB region based on the research results and preliminary reports documented during the period 2002-2007.

2. Multi-functionality: Review and analytical framework

2.1 Multi-functionality of Agriculture

The term 'multi-functionality' refers to an agricultural activity that could have multiple outputs besides providing food and fibres and, therefore, may contribute to several objectives at once. The multiple roles of agriculture include food security, maintaining and ensuring viability of rural communities, and environmental protection, such as land conservation, sustainable management of renewable natural resources, preservation of biodiversity, landscape, and moreover acting as a critical link between aquatic and inland agricultural resources in irrigated agricultural fields (OECD, 1998).

The key issues of multifunctional agriculture recognised by the Organisation for Economic Co-operation and Development (OECD) are: (i) the existence of jointness between commodity (food and fibre) and non-commodity outputs (multifunctional attributes); (ii) some of the non-commodity outputs exhibit the characteristics of externalities, for instance, existence of market failure; and (iii) whether government intervention is the best option to minimise market failures. The pattern and degree of jointness with rice production is different for each multifunctional attribute. The OECD (2001) says that jointness of rural amenity and cultural heritages with food production is quite strong, while that of food security and rural viability is relatively weak.

The most important issue on the production side of multi-functionality concerns the nature and degree of jointness between the production of crop and livestock products on the one hand, and production of multifunctional attributes on the other hand. If there were no jointness, multifunctional attributes could be provided independently of agricultural commodities and there would be no case for agricultural price and income support programs as a mechanism for promoting multi-functionality. In general, jointness can arise due to either technical interdependencies in production or economic interdependencies.

A great deal has been written in the past few years about the multi-functionality of agriculture, particularly in the context of the European Union where a common agricultural policy has been negotiated by member states. The concept of multifunctional agriculture recognises important potential benefits of agriculture in addition to the production of food. The concept of multi-functionality was firstly introduced by the OECD in 1992 at an Agriculture Ministerial level meeting (Huang *et al.* 2006). It was then discussed in detail at the 1992 Earth Summit in Rio in the context of food security and sustainable development. The term 'multi-functionality' was used in Agenda 21 to describe the potential for positive environmental benefits from eco-friendly agriculture. This environmental heritage of the multi-functionality concept can be seen in the conference held by the FAO-Netherlands in Maastricht in 1999. The title of that conference was 'Taking Stock of the Multifunctional Character of Agriculture and Land' with the objective to 'identify new practices and the necessary enabling environments that will lead to increased agricultural sustainability' (Groenfeldt, 2006). Furthermore, the multi-functionality was also identified to be an element of 'non-trade concerns (NTCs)' in Article 20 of the Agreement on Agriculture in the WTO Uruguay Round (Anderson, 2000).

There has been a gradual expansion of the meaning of multi-functionality (Groenfeldt, 2006). Multi-functionality has been defined according to the local context as well. The contents of multi-functionality may vary based on the different environments, and farming traditions for each country. In Europe, multi-functionality is contributing to a broad discourse about the nature of development and the future character of rural life in a 'post-productive' society. In Asia, multi-functionality has been incorporated into the agricultural policies of Japan but remains outside official policy in other countries of the region (Matsuno *et al.*, 2006). So far, proponents of multi-functionality in this region remain in the research mode, studying the concept and proposing indicators that may eventually support policy measures.

2.2 Externality and multifunctional roles

The study on multifunctional roles of paddy fields point towards the associated externalities, the non-commodity outputs, that can be both positive and negative (FAO, 2007). The externality aspect of agriculture, particularly the paddy fields, is gaining more recognition as the non-market outputs may have significant impacts on the sustainability of agriculture and paddy farming. Positive impacts could include public goods provision, while negative impacts could include the environmental burden (Abler, 2004). Negative externalities may include problems like soil erosion, nutrient runoff and leaching, and methane from livestock manure—all governed by biophysical processes, although they can be mitigated using alternative production or abatement technologies.

Matsuno *et al.* (2002) noted that the comprehensive assessments of agricultural externalities are very recent. Most of the attention was focused on negative externalities such as salinisation, and more recently on the non-point pollution. The recognition of positive externalities of agriculture, particularly irrigated paddy cultivation, is relatively new. Recently, there has been a broad consensus regarding positive externality associated with agriculture;.including erosion protection, soil and air purification, flood mitigation, groundwater recharge, biodiversity conservation, landscape improvement, subsistence reduction, and reduction of global climate impacts.

The associated positive and negative externalities raise concerns regarding policy options to facilitate positive externalities and discouraging negative externalities. Pretty *et al.* (2001) propose some options for internalising the externalities of agriculture while encouraging positive ones at the same time. These options focus on regulatory and institutional measures such as: environmental taxes, subsidy and incentive reforms, institutional and participatory mechanisms. Pretty (2003) further suggested putting monetary values on externalities.

European Union countries have many agri-environmental programs at various levels of government. Those programs are usually voluntary and generally compensate farmers for following certain management practices. The majority of such programs have more than one objective including the reduction of negative externalities from agriculture (Abler, 2004).

2.3 Analytical framework

In any analysis of agricultural/environmental policy and multi-functionality, it is essential to consider not only public goods and beneficial externalities associated with agriculture, but also negative externalities (Abler, 2004).

It is not easy to assign a monetary value to many of the non-market functions of paddy fields. However, there have been some efforts in this regards. Various non-market valuation methods have been used to estimate the multi-functionality of paddy fields.

A common method is toestimate the willingness to pay (WTP) for multifunctional attributes of paddy fields. Kim *et al.* (2006) reviewed various stated preference approaches used in the estimation of WTP of Korean paddy farming. Matsuno *et al.* (2002) used the Contingent Valuation Method to study the multifunctional roles of paddy fields including flood control. Putting monetary values on externalities, non-market functions, gives a better understanding of their negative or positive effects (Pretty *et al.*, 2001; Pretty, 2003).

Under the DMPF project some selected multifunctional roles of paddy fields were analysed. Paddy cultivation generates both commodity (marketed) and non-commodity (non-marketed) outputs. The main focus was on multifunctional roles that generate non-commodity outputs such as mitigating floods, nurturing and restoring aquatic ecosystem, and improving soil productivity and soil conservation. These multifunctional roles are analysed based on physical and technical indicators. In addition, though the economic contribution to the household income from rice grain production is the primary function of paddy farming, it also generates employment and other associated opportunities. This role has also been included as one of the multifunctional roles of paddy fields.

3. Research approach and methodology

3.1 Study sites for analysing the multi-functionality of paddy fields

The multifunctional roles of paddy fields in the LMB region were analysed in selected areas of two countries: Viet Nam and Thailand. In Viet Nam the study focused on the Mekong Delta region whereas in Thailand it focused on the Northeastern region.

Study sites in Viet Nam

Six sub-project study sites were selected from the four provinces in the Mekong Delta for collection and monitoring of the different indicators of selected multifunctional roles of paddy fields. Figure 3.1 shows the location of sub-project study sites in the Mekong Delta. The details on locations, land use and the functions analysed in each sites are presented in Table 3.1.

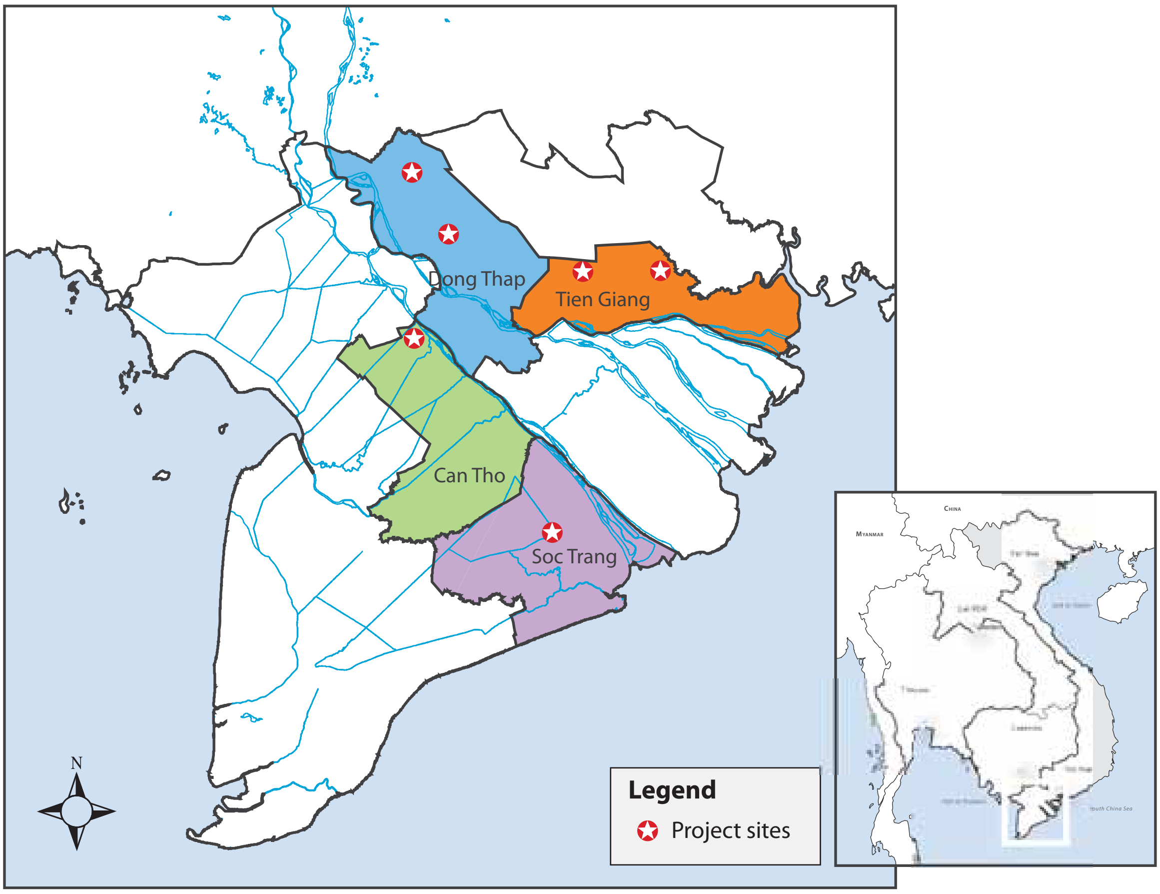


Figure 3.1 Map showing the location of the study sites in the Vietnamese part of the Mekong Delta

Table 3.1 *Study sites selected in the Mekong Delta for analysing the multi-functionality of paddy fields*

Study site	Location	Land use	Functions analysed
Study site 1 (deep flooded area)	Phu Tho village Tam Nong district Dong Thap province	2 paddy crops, 1 paddy crop and freshwater fish	Flood mitigation Soil conservation Aquatic ecosystem Socioeconomic aspects
Study site 2 (early shallow flooded area)	Hoa An village Cao Lanh district Dong Thap province	2 paddy crops, 1 upland crop	Flood mitigation Soil conservation Socioeconomic aspects
Study site 3 (full flood control area)	My Thanh Nam village Cai Lay district Tien Giang province	3 paddy crops	Soil conservation Socioeconomic aspects
Study site 4 (non-flooded area)	Than Cuu Nghia Chau Thanh district Tien Giang province	3 non-paddy crops (upland crops, cash crops)	Socioeconomic aspects
Study site 5 (late shallow flooded area)	Thot Not and Co Do district Can Tho City Can Tho province	Paddy crop, Fresh water aquaculture (fish, prawn)	Aquatic ecosystem
Study site 6 (coastal area)	My Xuyen district Soc Trang province	Paddy crop, Brackish water aquaculture (shrimp)	Aquatic ecosystem

In order to analyse the selected multifunctional roles of paddy fields in Northeastern Thailand, three sub-project study sites were selected. Figure 3.2 shows the location of sub-project study sites in Northeastern Thailand. The details on locations, land use and the functions analysed in each sites are presented in Table 3.2.

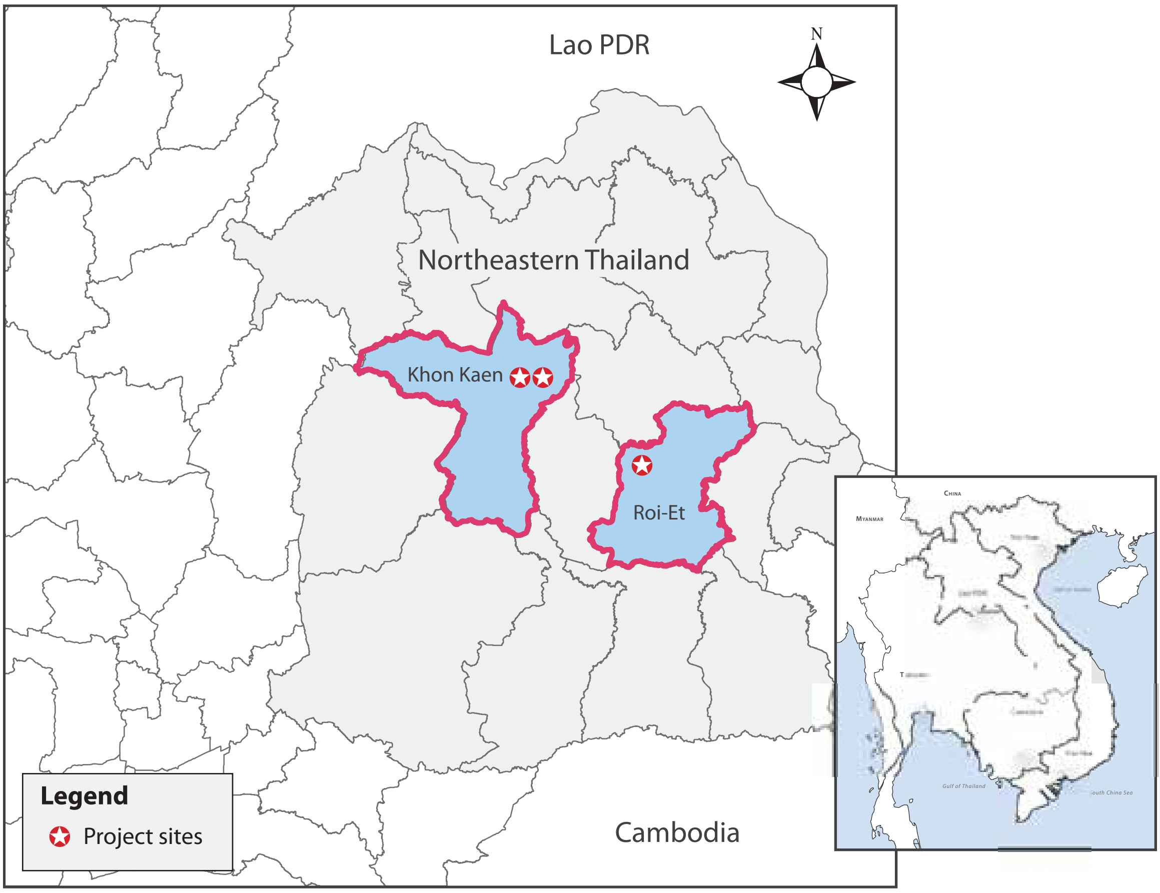


Figure 3.2 Map showing the study sites in Northeastern Thailand

Table 3.2 *Sub-project study sites selected in Northeastern Thailand for analysing the multi-functionality of paddy fields*

Study site	Location	Land use	Functions analysed
Study site 1	Nai Muang Sub-district, Muang district, Roi Et province	Paddy crops and urban areas	Flood mitigation
Study site 2	Nong Ben Village, Nong Thon Subdistrict, Muang District, Khon Kaen province	Irrigated and rainfed paddy cultivation	Nurturing and restoring aquatic ecosystem
Study site 3	Dong Yen Village, Numpong District, Khon Kaen Province	Irrigated and rainfed paddy cultivation	Socioeconomic aspects

3.2 Selected multifunctional roles of paddy fields for analysis

The key functions of paddy fields selected for analysis in the framework of DMPF project were as follows:

- function of paddy fields on flood mitigation: analysing the indicators measured in flooding areas,

- function of paddy fields on the improvement of soil productivity and soil conservation: analysing the indicators on physical and chemical characteristics of paddy soils,

- function of paddy fields on nurturing and restoring aquatic ecosystems: analysing the data on the nutrient load trapped in paddy fields and its purification capacity as well as the nurturing function for wild aquatic species such as fish, and:

- besides the direct contribution to the household income of the farmers, paddy fields provide other multifunctional roles such as employment generation and food security.

All four functions were included in the Mekong Delta while the Northeast Thailand study included only three of them (it excluded the soil productivity and soil conservation functions).

3.3 Multiple Data acquisition and collection techniques

Irrigation water use estimation

Water is an essential component of security, social, economics and other development issues that influence water related resources and the natural environment especially for agricultural development. Evaluation of the irrigation water use is necessary to gather basic information on rice farming and agriculture water use as well as to evaluate the efficiency of water use in the LMB.

Assessment of the irrigation water use under the project could be taken through a number of possible methods, such as: (i) remote sensing; (ii) Integrated quantity-quality model (IQQM) software; and (iii) Geographic Information Systems (GIS) using ArcView. The first method of remote sensing technology could be applied to the whole basin if the methodology was adequate enough for a wider area, although it might be costly. The second method on IQQM would not be easy to process because of the difficulty to transfer data as well as the limited output. The third one was mainly based on GIS. This could be an appropriate methodology to assess irrigation water use in the LMB by building up and analysing data in a series of various GIS layers to calculate the water use. After some discussion it was agreed to base the analysis on GIS system using ArcView.

GIS and Spatial Analysis for flooding and land cover changes

The analysis of multi-functionality of paddy fields used various spatial and GIS tools. Aerial photographs taken at different periods were used for land use mapping and to fill out the GIS database. The detail of this technique is discussed in relevant sub-sections in chapters 4 and 5.

Field experiments and sampling of soil and water

The study of some of the selected multifunctional roles of paddy fields included field works such as monitoring households' collection of wild products regularly, keeping daily records on all the farm activities etc. Some functions needed soil and water sampling as well. The details are discussed in relevant subsections in chapters 4 and 5.

Community and household survey

Similarly, various participatory data collection techniques were used in the analysis of multifunctional roles of paddy fields. It varied across the functional roles under study, ranging from rapid rural appraisal to participatory rural appraisal tools. In addition, household surveys were also used in many cases. The details of the methods used are discussed in relevant subsections in chapters 4 and 5.

4. Multifunctional roles of paddy fields in the Vietnamese part of the Mekong Delta

This section discusses the major findings from the analysis of selected multifunctional roles of paddy fields in the Vietnamese part of the Mekong Delta. The main objective of the analysis was to provide a clear and better understanding of the multi-functionality of paddy fields by showing visible examples of key functions selected for the Mekong Delta.

Three key multifunctional roles of paddy fields were selected for analysis in the Mekong Delta:

- Flood control (by analysing the indicators measured in flooding areas);
- Improvement of soil productivity and soil conservation (by analysing the indicators on physical and chemical characteristics of paddy soils);
- Nurturing and restoring aquatic ecosystems (by analysing the data on nutrient load trapped in the paddy fields and its purification capacity as well as nurturing function for wild aquatic species such as fish).

In addition, the associated socioeconomic contribution in rural areas (besides direct household incomes from paddy production) was included in the analysis of multifunctional roles.

4.1 Multifunctional roles of paddy fields on flood control

Flooding has both positive and negative effects on the Mekong Delta. During large floods, serious damage occurs to lives, property and production; however, flood water also transports an enormous mass of sediment to the Mekong Delta. The sediment is not only deposited in the fields where it enables the cultivation of high yield crops, but it also supplies an important food source for the aquatic fauna and flora during the 5-6 months of the flood season. In the flood season, paddy fields in the Mekong Delta become a natural storage reservoir for flood water, which helpd with flood mitigation. Flood water storage and sedimentation were studied as part of the flood mitigation function of paddy fields in the Mekong Delta.

Study sites

This sub-study was conducted in two sites from the province of Dong Thap: Cao Lanh town and Tam Nong suburban district (as presented in Figure 3.1 and Table 3.1).

Tam Nong pilot site covered two communes: Phu Tho, Tan My and Tam Nong town, in the district of Tam Nong. It has a total area of 3,260 ha, and is surrounded by large canals in the north, east and west. In addition, there is an August embankment system along the secondary canals. The August flood control systems serve as intake and dams to hold water during the dry season. The irrigation network, embankment system and road structures in the Tam Nong pilot area are presented in Table 4.1. The land use at present is dominated by two seasons of rice crops during the Winter-Spring seasons (WS) and the Summer-Autumn seasons (SA). A strip of land along Dong Tien canal has been utilised for aquaculture. Annually, after the harvest of SA rice crops, flood water is taken into the fields starting mid-August and the whole area is inundated until the end of November.

The Cao Lanh town pilot site covers the commune of Hoa An and has a total area of 120 ha. It is surrounded by trenches, canals and roads. A dike system for full flood control is situated in the west and south. The embankment system for August flood control spread in the north and east. The Cao Lanh pilot site is a closed rice-field with a nearly perfect water-works system. On the August flood control system, a series of sluices are built to serve as intake of water for agricultural production. The irrigation network, embankment system and road structures in the Tam Nong pilot area are presented in Table 4.1. In Cao Lanh pilot site, most of the area includes triple paddy cropping with WS, SA, and Autumn-Winter (AW) crops. Some areas at a higher level near the roads are used as orchards. Annually, at the end of August or beginning of September, after harvesting SA crop, the paddy fields area is flooded through water gates in the August dikes.

Table 4.1 *Irrigation network, embankment system and road structures in the pilot study sites*

Water control structures	Length (km)	Width (m)	Density (m/ha)
Tam Nong Pilot area			
Main canal system	35.88	8 - 25	10.91
Secondary canal system	75.85	2 - 8	23.05
Embankment system	35.87	1.5 – 3.0	10.90
Transport roads system	16.49	10 - 14	5.01
Cao Lanh Pilot area			
Main Canal system	4.87	10 - 20	40.57
Secondary Canal system	6.623	2 - 6	55.19
Embankment system	4.868	1.5 - 3	40.57
Transport roads system	1.84	4 - 6	15.33

Methods

Field surveys were conducted in the selected two pilot areas of the flooded part of Dong Thap province in the Mekong Delta. Three main indicators were included: water level; flooding depth, and sedimentation, and were monitored in the selected pilot areas during the 2006 floods:

- Water level was observed by gauge markers set up at the entrance and exit points of the pilot areas, with 2 sites upstream and downstream of each pilot area.
- Depth of flood inundation at each pilot area was measured directly by boat. A digital flood depth map was built to estimate the flood water storage on the 15th of each month.
- Sediment concentration of flood waters was analysed by sampling at 20 different sites for each pilot area.

A desk study was done to collect secondary data (both digital and non-digital data) on flooding in the Mekong Delta and selected pilot areas. The present capacities of paddy fields to store flood water and sediments were calculated using primary data from the pilot sites. GIS tools were used to extend the estimates to the whole flooding areas of the Mekong Delta and analyse the expected functions of paddy fields on flood mitigation (water storage, sedimentation) as well as to map the results of the analysis.

Demonstrated role in flood control

- *Flood water levels and water storage capacity in the pilot areas*

The results showed that from August, in the Tam Nong pilot area, a part of the flood water overflows the August flood control system, canals and trenches and then water goes into fields causing inundations. The results showed that in the middle of August, water levels increase gradually. The water level in the field was higher than the water level in the canal. The water level continues to increase at the beginning of September until October before slowly going down in November. The state of water level in fields and canals showed that water levels were always higher in fields than in canals. This clearly showed that paddy fields stock the water and control the flooding. The average flooded area, flood depth and capacity to store the flood water in the main flooding season is presented in Table 4.2. The capacity to contain flood water in the rice fields reaches a peak in October and declines in November.

The Cao Lanh pilot area is a shallow flooded area in the Mekong Delta. In this area, the flood water starts to overflow the August embankment in September, flooding the rice fields. The water level starts to decrease in November. The average flooded area, flood depth and capacity to store flood water in the main flooding season is presented in Table 4.2. The capacity to contain flood water in the rice fields reaches a peak in October and declines in November.

Table 4.2 *Capacity and total volume of flood water stored in paddy fields in selected study areas*

Months	The average flooded area (m^2)	The average flooded depth (m)	Total water volume (m^3)
Tam Nong Pilot area			
August	12,003,204	0.31	3,720,993
September	24,582,562	0.52	12,782,932
October	32,648,715	0.68	22,201,126
November	18,576,488	0.35	6,501,771
Cao Lanh Pilot area			
September	437,500	0.20	87,500
October	896,000	0.37	331,520
November	677,087	0.27	182,813

- *Sedimentation and depositing capacity in pilot study areas*

The preliminary capacity and total volume of sediment was calculated based on the monitored flood events during the year 2006. In the Tam Nong pilot sites, the total volume of sediment deposition at the beginning of the flooding season in August was 129.57 tons (accumulation in field-square). The total volume of sediment deposition during the full flood (September-October) and the end of flood season (November) are presented in Table 4.3. In the Cao Lanh pilot sites, there was no flooding in the paddy fields at the beginning of the flooding season (in August) because of the August flood control system, and thus no sediment deposition. But once the full flooding season started, paddy fields got flooded and sediments deposited.

Table 4.3 *Total volume of sediment deposition in the pilot study areas*

Month	Average sediment volume in canals (mg/l)	Average sediment volume in fields (mg/l)	Flooded area of the paddy fields (ha)	Average flooded depth in paddy fields (m)	Total volume of deposited sediments (ton)
Tam Nong Pilot area					
August	137	102	1,200	0.31	129.57
September	93	73	2,458	0.52	293.33
October	81	68	3,265	0.68	137.06
November	37	21	1,858	0.35	305.77
Cao Lanh Pilot area					
September	92	68	44	0.20	209.90
October	84	67	90	0.37	428.90
November	71	64	90	0.27	65.90

- *Current capacity of paddy fields in the Mekong Delta for storage of flood water and deposition of sediments*

The estimation of the current capacity to store flood water and deposit sediment within paddy fields was then expanded to the Mekong Delta as a whole. It was based on the existing area of paddy fields cultivated in the flooding season (from August to November), flooding depths in paddy fields at various stages of the flooding season, and contour map of the monthly sedimentation in the Mekong Delta. The estimation was made for two situations: high flood considering the flooding of the year 2000; and weak flood considering the flooding of the year 2005.

For the high flood scenario, the results showed that in the early flooding stage in August, the total volume of flood water stored and sediment deposited in paddy fields over the Mekong Delta was 9633 million m^3 and 1,359,587 tons respectively. The flood water volume and sediment volume increase in the full flood stage (September-October) and then slowly decreases in the receding stage in November (Table 4.4). In comparison to the high flood year, the total sediment deposition was lower in the weak flood scenario.

Table 4.4 *Flood water storage and sediment deposition in the Mekong Delta for different flooding months considering the high flood case (2000) and weak flood case (2005)*

Months	Depth (m)	Flooded Area (ha)	Sediment content (g/m^3)	Flood water volume (m^3)	Sediment volume (ton)
High flood case (year 2000)					
August	0.5–3.0	1,113,126	50 – 200	9,632,958,273	1,369,587
September	0.5-3.0	1,108,048	25 – 200	15,990,137,583	1,966,798
October	0.5-3.0	1,131,692	25 – 200	16,448,190,946	2,179,792
November	0.5-3.0	1.135.195	25 – 200	12,682,034,367	932,789
Weak flood case (year 2005)					
August	0.5-3.0	1,131,089	25 - 200	8,303,305,845	876,911
September	0.5-3.0	1,149,767	25 - 200	11,965,716,668	903,049
October	0.5-3.0	1,217,521	25 - 200	14,679,840,950	868,977
November	0.5-3.0	932,012	25 - 200	11,776,720,057	569,048

- *Conclusion*

The findings showed that paddy fields have the capacity to store the flood water, reducing the threat of severe flooding in the surrounding areas. It can be concluded that paddy fields contribute to flood mitigation. In addition, during the flood season paddy fields get flooded and sediment is deposited.

4.2 Nurturing and restoring aquatic ecosystems

Paddy fields are closely associated with the farmers' livelihood and play an important role in the subsistence of farmers in the Mekong Delta. Traditional experiences show that paddy fields can absorb nutrients and trap organic matters to improve the quality of the water that passes through them. Moreover, paddy fields are also known to be reservoirs for fishes and other aquatic animals. This section demonstrates the multi-functionality of paddy fields in nurturing the aquatic ecosystems with a special attention on rice-aquaculture systems.

Study sites

Four study areas were selected in the Mekong Delta based on natural characteristics. Irrigated paddy fields (Tam Nong district in Dong Thap province), rain-fed paddy fields (My Xuyen district in Soc Trang province), and flooded paddy fields (Thot Not and Co Do districts in Can Tho province) were chosen in order to investigate any differences or changes in the multi-functionality of paddy fields in different habitats (see Figure 3.1). In addition, one site was selected in My Xuyen as a reference site for other freshwater areas and to compare the functioning roles of paddy fields in freshwater and brackish water areas.

The design of paddy fields varied from place to place, resulting in differences in the fish resources harvest and management. In some areas (such as Can Tho and My Xuyen), paddy fields were surrounded by trenches while they were inexistent in other areas (such as Tien Giang and Dong Thap)(see Figure 4.1).

Figure 4.1 Pictures showing paddy cultivation with (in Soc Trang and Can Tho) and without surrounding trenches (in Dong Thap and Tien Giang)

Methods

Fisheries resources in paddy fields were investigated by farmers' interviewed as well as daily data recorded from selected paddy fields. A total of 80 farmers from five selected areas were interviewed. Farmers were requested to recall all fish species caught, fishing gear, monthly or seasonal production; income from fish; roles of rice on fish resources and vice-versa; pesticides and herbicides used for rice and their effects on fish resources; and others. In addition, the daily record of fish from rice fields was monitored in 13 households of Co Do district, Can Tho province for three consecutive months.

Assessment of the restoring function of paddy fields was carried out by sampling the water quality in and out of the paddy fields. The water samples were taken from three areas; two of them were affected by aquaculture activities (prawn pond in Tam Nong and catfish ponds in Thot Not) and one unaffected by aquaculture activities (direct input from a river in Cai Lay). Water parameters were sampled both outside and inside the paddy to assess the filtration/ purification of nutrients from the paddy fields. In Thot Not, water was monitored in three paddy fields where the water source was affected by discharge from catfish ponds.

Plankton and benthos were also sampled to investigate the biodiversity of aquatic organisms associated with paddy fields. Samples were taken qualitatively and quantitatively in the surrounding ditches in the paddy field located in Thot Not.

Demonstrated roles in nurturing and restoring aquatic ecosystem

- *Nurturing function of paddy fields*

In My Xuyen area, a brackish water area, paddy fields are surrounded by trenches that serve as refuges for cultured shrimp during the dry season. A total of 15 fish and shrimp species were recorded in the area. It provided a significant income for the farmers. The yield of wild catches varied, but was between 5-10 kg/ha/month on average. The income from fisheries resources fluctuated substantially from farmers to farmers due to different consumption demands, fish species, and fish catch. In general, farmers reported a monthly income in the range of US$6-20 (Figure 4.2). Fisheries production was reported to be highest near the end of the rainy season, starting in August, until November. Farmers reported that the production of wild fisheries has declined due to the excessive use of chemicals in shrimp farming and the discharge of polluted effluents during the preparation of ponds for the shrimp culture. Almost half of the farmers agreed that there are more fish in the presence of rice in paddy fields. But about one-fourth of the farmers opined that paddy fields hamper the growth of fishes.

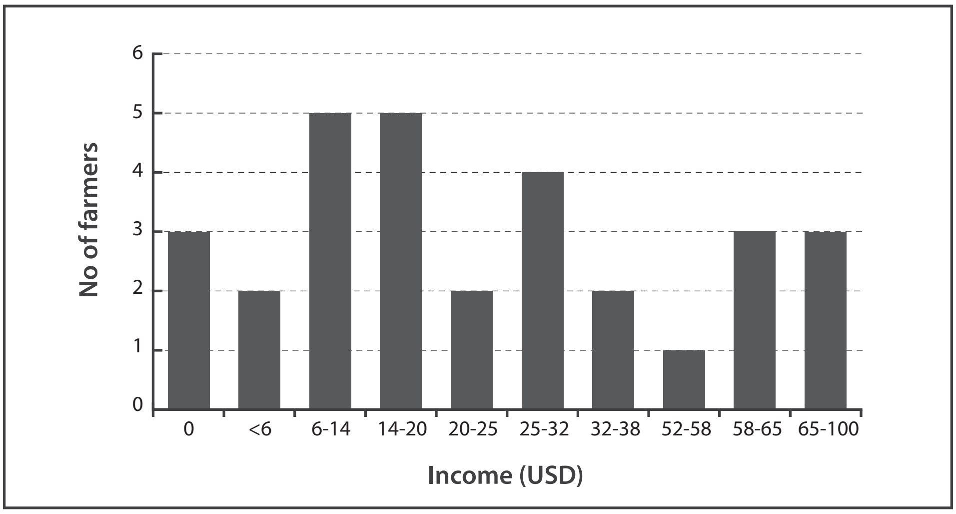


Figure 4.2 Income level of farmers from wild fish collection in the paddy fields

In Thot Not and Co Do (Can Tho City) areas, a freshwater area, the paddy fields are also surrounded by trenches. Farmers collect wild fish in a similar way as those in My Xuyen. Farmers collected 13 different fish species, slightly less compared with the number collected in the brackish water area. Farmers reported that fishing activities occur mostly in November. Almost all farm households harvested wild fish at the end of the crop while a few of them fished them almost daily for food. For a majority of farmers, harvesting fish was one of main source of household income. In some cases, the amount earned from fisheries resources may equal that from rice and contribute significantly to improving their living conditions in a rural area. In this area also, farmers reported that fisheries resources have declined in the recent years due to the indiscriminate use of pesticides, the use of electric fishing devices, and other reasons. However, most of the farmers agreed on the role of rice in the abundance of fish in the paddy fields, they admitted that in the presence of rice, there was more fish.

In addition, the composition of phytoplankton species in the paddy fields was very diverse. A total of 61 species belonging to 4 phyla were recorded in Thot Not (Can Tho city). The composition and density of the phytoplankton and zooplankton in the paddy fields indicated that the richness of natural feed is favourable to the growth of fish as well as other aquatic organisms. This, in turn, proved the importance and function of paddy fields in nurturing aquatic ecosystems.

- *Restoring function of paddy fields*

In the Tam Nong study site, two paddy fields were sampled: one was fertilised and the other was not. After one month, nutrients and suspension solid matters in the paddy field not fertilised reduced substantially. Similarly, in the fertilised paddy field, nutrients and suspended organic matter reduced significantly after being filtered in the paddy field (Figure 4.3). In addition, the comparison of nutrients reduction between the prawn pond and the adjacent rice field also showed that the nutrients were significantly reduced in the paddy fields. The results showed that paddy fields can effectively absorb and filter out the significant amount of nutrients and substantially contribute to purifying the environment and prevent the eutrophication that may pollute the ecosystems.

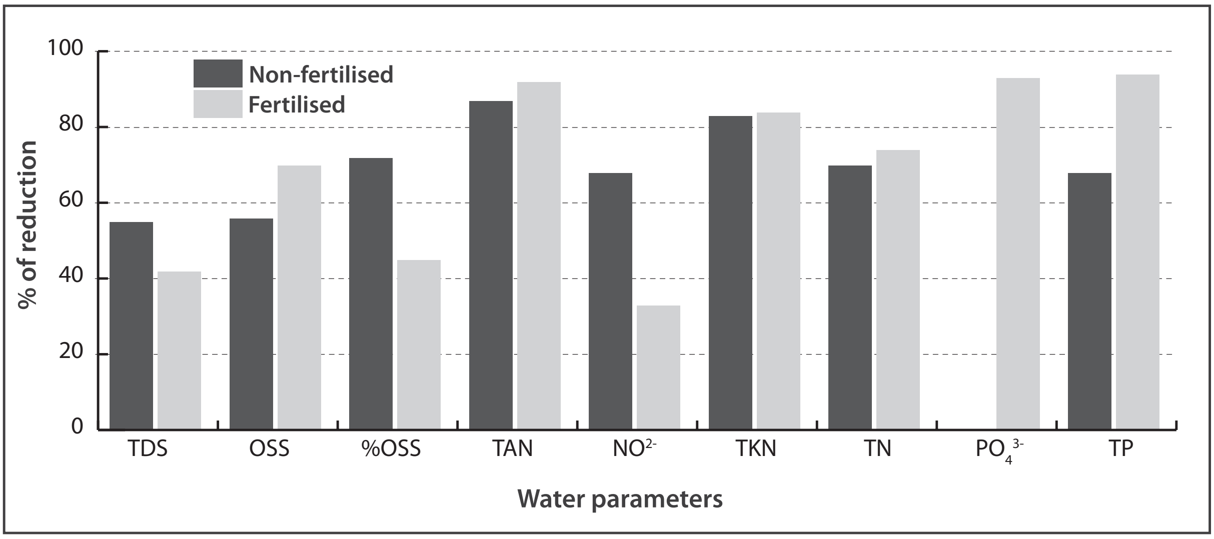


Figure 4.3 Reduction of nutrients in paddy fields after 1 month in the non-fertilised and fertilised paddy fields in Tam Nong (Dong Thap)

In the Tien Giang study site, water was taken directly from the river to the paddy field. The results showed that all parameters were reduced after being stored one month in the paddy field. The same trend was recorded in the paddy field from the first to the second month. The comparative reduction in two cases is presented in Figure 4.4.

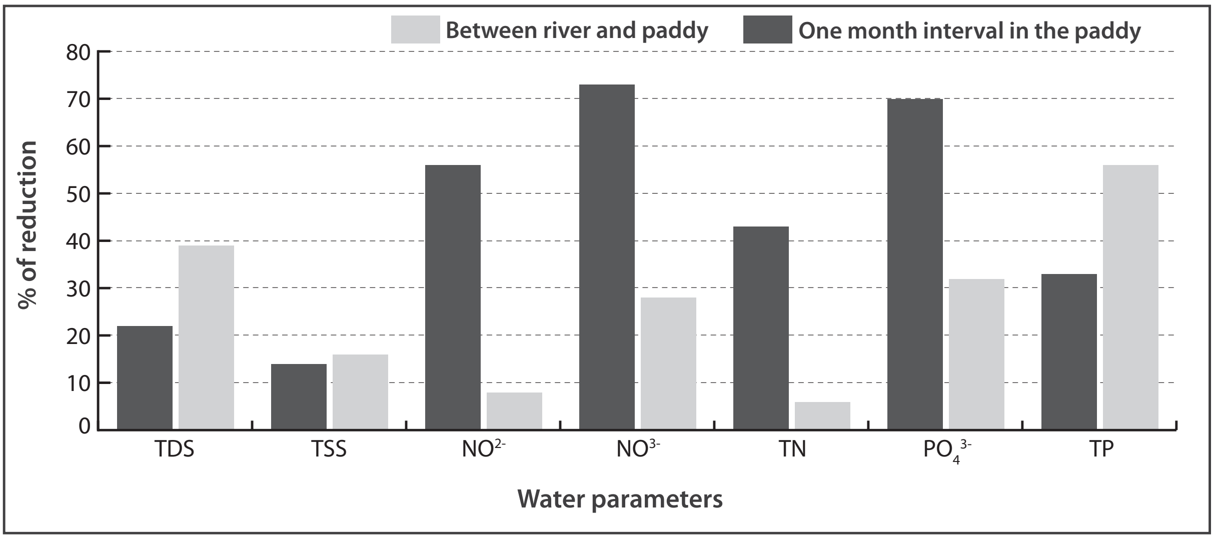


Figure 4.4 Reduction of nutrients and suspension solids in the paddy field in Cai Lay (Tien Giang)

- *Conclusion*

Paddy fields play an important role in nurturing aquatic ecosystems by nursing and acting as refuges for fish, and providing natural food for fish growth. Fisheries resources have contributed significantly to the income of farmers, especially in areas where paddy fields are surrounded by trenches. However, consideration should be paid to protect the resources from the indiscriminate use of pesticides and over-fishing in paddy fields. The practice of three consecutive rice crops in these areas may result in an excessive use of pesticides. An alternative culture of fish or shrimp with paddy can be a sustainable way to maintain rice and fish production to support livelihood in rural areas. In addition, paddy fields can help reduce and prevent pollution from heavy aquaculture activities in the surrounding areas such as intensive catfish or shrimp cultures.

4.3 Soil productivity and soil conservation

Rice is widely grown over the Mekong Delta because of the favourable physical conditions (such as available freshwater and developed soils) for its cultivation. However, in practice, the paddy production in the Mekong Delta has to overcome soil constraints (acidification, nutrient depletion, physical problem, salinisation). Therefore, in order to obtain a stable increase of paddy production, many methods of land and water management have been widely applied to improve soil conditions. The observation and analysis of the functional role of paddy fields in relation with soil productivity and soil conservation are very important.

Study sites

Four study sites were selected; they represent the typical paddy cultivated in the Mekong Delta with problem soils (Acid Sulphate Soils) and without problem soils (alluvial soils).

- Study site 1 (VN1): Phu Tho village, Tam Nong district, Dong Thap province for a case of paddy field on actual Acid Sulphate Soils with perdysic materials (without Jarosites mottles),
- Study site 2: Hoa An village, Cao Lanh town, Dong Thap province for a case of paddy field with alternative crop (two rice crops - soybean), situated on an alluvial soil,
- Study site 3: My Thanh Nam village, Cai Lay district, Tien Giang province for a case of continuous paddy cultivation (some areas alternated with water-melon), situated on a recent alluvial soil,
- Study site 4: Hoa An village, Phung Hiep district, Hau Giang province for a case of paddy field on actual Acid Sulphate Soils with Jarosite mottles (for data reference).

Methods

In each study location, a representative field area was selected and soil profiles were dug (dimensions: 1.2m x 3m x 2m) in accordance with the USDA/Soil Taxonomy Classification system (1996). All the master soil horizons were described using the guidelines of FAO/ UNESCO (1990) and the 'Munsell soil color chart'.

Soil physical measurements were performed directly in the paddy field. Soil ripening stages were measured by squeezing soil in hand. Undisturbed soil sample were taken at the depth of the master soil horizons. In addition, about 3 kg of the disturbed soil samples were taken from each soil master horizon above with the sampling plan for physical and chemical determinants.

Local government officers and local owner-farmers of the study fields and from surrounding areas were interviewed. The main informations collected were: history of land exploitation and land use development, cropping patterns and changes of land use types; cultivation techniques and land management; soil preparation and management activities within a year; annual fertiliser used (chemical, organic, manure or others) including type, amount, number, and application methods; irrigation and drainage (irrigation ways and water quality); and yield and limiting factors to crop yield and soil productivity.

Demonstrated role in soil productivity and soil conservation

- *Roles of paddy fields and soil productivity*

In recent decades, rice production has become increasingly dependent on inorganic fertilisers, and less attention has been paid to soil management. The local farmers have relied on fertiliser applications to improve their crop yield rather than soil capacity. Those activities have reduced soil productivity and are leading to soil degradation. Rice yield has kept improving over the past 5 years, but now seems to have stagnated and soil problems have occurred.

The stability of soil aggregates was analysed as part of the soil quality related to the soil productivity in the study locations. It can be influenced by cropping system and/or soil formation processes on each study location. The Stability Quotient (SQ) of the soil master horizons A and B is presented in Figure 4.5. The stability was not at a high level (136.2 is the maximum SQ value) and the difference between horizons A and B was not important except for the study site VN2. The results showed that in the case of paddy field with alternate farming including cash crops, the SQ improved a lot on both horizons A and B compared to the continuous rice cultivation, as in siteVN3. With mono-rice cultivation and high soil rotation, SQ tends to be reduced.

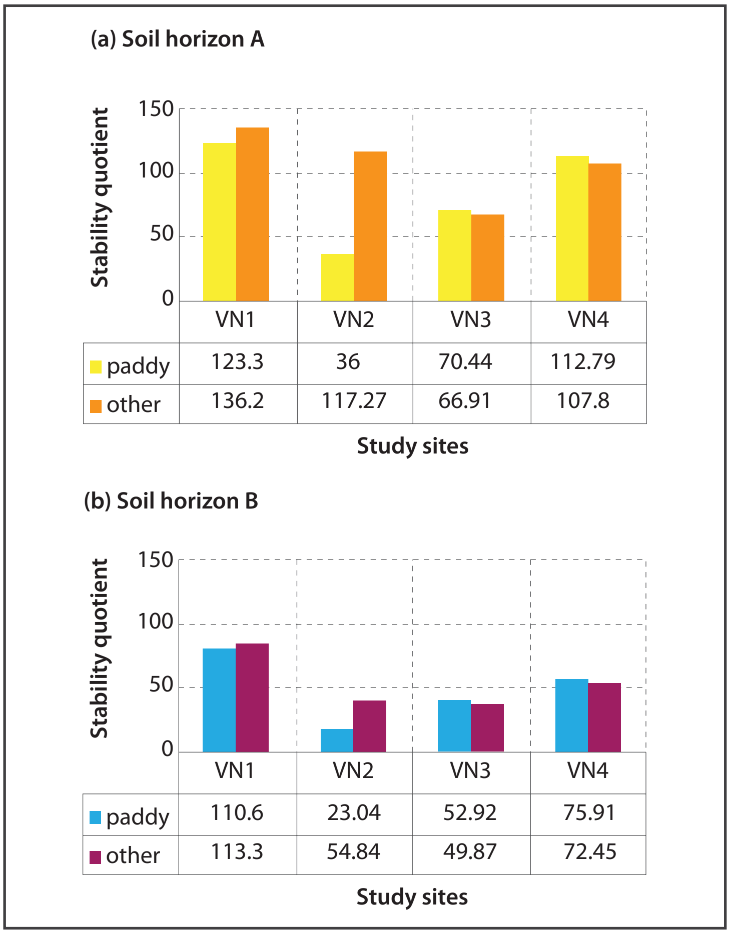


Figure 4.5 Stability Quotient (SQ) of soil horizons in the different study sites

Soil compaction is one of the physical degradation types significantly related to crop production. Physical soil characteristics related to soil compaction both for soil master horizon A and B are summarised in Table 4.5. In the intensive paddy cultivation areas, soil compaction has formed below the top soil horizon. The results showed soil compactions under the depth of the plow layer in study sites 2 and 3. Other studies on intensive rice cultivation spread in the Mekong Delta (Le Van Khoa, 2002; 2005) also showed that paddy fields with mono-rice cultivation strongly deteriorated the physical fertility of soils.

Table 4.5 *Physical soil characteristics related to soil compaction of the soil master horizon A and B in the study locations*

Study sites	Soil depth (cm)	Physical soil characteristics			
		ρb (Mg/m^3)	ρp (Mg/m^3)	φ (%)	SR (stage)
Soil horizon A					
VN1	0-25	0.71	1.01	29	r
	(0-25)	0.65	0.98	34	r
VN2	0-15	1.23	2.52	51	R
	(0-15)	1.20	2.36	49	R
VN3	0-20	1.13	2.44	53	r
	(0-20)	1.21	2.46	50	r
VN4	0-25	0.86	2.21	61	r
	(0-25)	0.95	2.22	57	r
Soil horizon B					
VN1	25-80	0.77	1.71	55	r
	(25-80)	0.71	1.70	58	r
VN2	15-65	1.47	2.55	42	R
	(15-65)	1.30	2.55	49	R
VN3	20-65	1.34	2.46	45	Rr
	(20-65)	1.38	2.40	42	Rr
VN4	45-90	1.03	2.43	57	r
	(45-90)	1.15	2.51	54	r

Note (): indicated for soil depth of other cultivation (alternate with cash crop, fallow, mono-rice)
ρb: Bulk density; ρp: Particle density; φ: Porosity;
SPR: Soil penetration resistance; SR: Soil ripening

The results showed that the soil penetration resistance in the paddy fields cultivated intensively and other cases was still too low to prevent root penetration. In the study site 2, the value was higher than in others, but it did not reach the critical value. In comparison to the previous estimate (Le Van Khoa, 2002), it has improved significantly, while it tends to increase in the subsoil in the mono-rice field. Overall, paddy fields influenced the soil consistency negatively.

Soil ripening (SR) represents a development stage of soil formation processes and is mainly influenced by soil types, but paddy fields also play an important role. With the alternating crops, SR improved, compared to others, specially the continuous rice cultivation under restricted conditions such as at study site 3. Although soil compaction, at the time, was not severe on the paddy fields, it partly decreased soil productivity and rice yield.

The total available soil water content was estimated only for soil master horizons A and B, which are commonly considered as the effective rooting depth in the Mekong Delta. The cumulative data of available soil water storage (CAWS) gives the difference of the cumulative soil water storage at field capacity and wilting point respectively. The results showed that in the paddy field with Acid Sulphate Soils, CAWS was higher than that of the area with alluvial soils.

In paddy fields with non-problem soils, the CAWS improved in the field with alternated crops compared to the mono-rice field.

The results showed that in most of the study sites, soil nutrients are rather poor in the subsoil horizons, even in the areas of intensive rice cultivation (the so-called non-problem soils). Most of the soils in the selected study sites, where rice is continuously grown, showed physical problems and were rather poor in chemical soil fertility compared to paddy fields where cash crops were alternated with rice. Human-induced soil degradation tends to increase, especially in the area of mono-rice cultivation. Soil compaction was the main problem in intensive paddy cultivation areas. This study raises the alarm on the functions of paddy fields to the soil productivity in the current intensive rice cultivation areas.

- *Conclusion*

Based on the findings, paddy fields with three rice crops cultivated intensively on non-problem soils will gradually reduce the soil productivity, essentially to the physical soil fertility, indicating a negative effect. On the positive side, paddy fields on problem soils (Acid Sulphate Soils) effectively improved soil productivity. Considering these findings, alternative land use (especially soybean as cash crop) was the best solution for soil conservation and sustainable agricultural production in the Mekong Delta. It helps improve soil compaction. It suggests that alternative uses of land (for example eco-tourism) in the problem soil should be considered.

4.4 Farm household income and multifunctional roles in other socioeconomic aspects

Rice production in the Vietnamese part of the Mekong Delta as a whole plays a crucial role in the economic development of the region. Though rice production is the basic function of paddy fields, it also plays many other vital socioeconomic roles in the life of rural people such as employment generation and national food supply. However, these functions and their impacts on the rural livelihoods are not sufficiently understood.

Study sites

Four study sites were selected within the Vietnamese part of the Mekong Delta. The villages selected for this study cover at least the major rice-based production systems in the Mekong Delta. In addition, a village with non-paddy production was also selected in order to compare with villages relying on the paddy production. The characteristics of the selected study sites are summarised in Table 4.6.

Table 4.6 *Characteristics of the selected study sites in the Mekong Delta*

Study site	Location	Agro-ecological zone	Soil characters	Crop production systems
Site 1	Phu Tho Tam Nong Dong Thap province	Deep flooded	Acid sulphate soils	2 paddy crops
Site 2	Hoa An Cao Lanh Dong Thap province	Shallow flooded	Undeveloped alluvial soils	2 paddy crops and 1 upland crop
Site 3	My Thanh Nam Cai Lay Tien Giang province	Flood control area	Developed alluvial soils	3 paddy crops
Site 4	Than Cuu Nghia Chau Thanh Tien Giang province	Flood control area	Developed alluvial soils	Non-paddy crops

Methods

The information was collected from two main sources. Primary data was collected through field survey using participatory approaches (Participatory rural appraisal or PRA). The secondary data was mainly collected from available reports related to paddy and non-paddy crops production, statistical yearbook and others.

The field survey was planned for collecting information with a focus on indicators that enabled measurement of the incomes and employment generation, which are considered to be crucial functions of paddy fields. Two main steps were involved in the field survey: a focus group discussion (FGD) and a household survey.

The FGD was conducted to gather informations that provide a general picture on the role of paddy fields with regard to socioeconomic issues. The household survey was conducted to collect socioeconomic data on farm households in selected villages. A total of 40 households from the four selected villages were interviewed: 10 households in Phu Tho village; 10 in Hoa An village; 9 in My Thanh Nam village; and 11 in Than Cuu Nghia village.

Contribution to household income and demonstrated socioeconomic roles

Many farmers in the Mekong Delta are still living in poverty with a low household income. However, the average income per capita in the Mekong Delta has increased gradually in the recent years (Can N.D. 2004; Duong *et al.*, 2005). In irrigated areas, rice production is the main source of income, contributing about 60% to the total income (Can N.D. 2005).

Recently, rice farmers have paid attention to paddy field investment such as improving land quality, irrigation development, as well as applying advanced farming practices. These investments facilitate the obtention of high yields and higher incomes, helping alleviate farmers' poverty. Besides the direct production of grains, paddy cultivation requires a lot of manual labour and thus require the use of hired labour in addition to family labour. In the Mekong Delta, a labour force of approximately 8.9 million is engaged in agriculture and paddy production (CSO, 2005) and a large part of this hired labour migrate to paddy production areas in the peak harvest time (Can N.D. 2004).

- *Role of paddy fields in increasing farm household income*

The contribution to the farm household income is the primary role of paddy cultivation and thus it is in fact not a multifunctional role. However, this subsection discusses the relative contribution of paddy cultivation in comparison to other sources of income. Paddy was the main source of income contributing on average nearly 60% to the farm household income. Other significant sources of income were wage labour, non-agricultural activities, and services (Table 4.7); but the income contribution from other sources was low.

Table 4.7 *Structure of household income by sources in the study villages (in%age)*

Sources of income	Hoa An	Phu Tho	Than Cuu Nghia	My Thanh Nam
Paddy farming	60.6	72.1	56.6	41.9
Livestock	4.1	1.8	1.8	8.4
Homestead	5.7	-	-	13.9
Agriculture wage labor	6.3	18.2	3.1	5.9
Non-agriculture	-	-	17.7	16.9
Services	23.3	7.9	20.8	13.0

Source: Household Survey, 2007.

Large variations were found on the average annual income across the four study villages. The average annual household income was the lowest in Hoa An and the highest in My Thanh Nam village (Table 4.8). Similarly, the average annual income from paddy was the lowest in Hoa An and the highest in Phu Tho. Consequently, the average per capita income was the lowest in Hoa An.

Table 4.8 *Average household income (in 000'VND) by sources in the study villages*

Sources of income	Hoa An	Phu Tho	Than Cuu Nghia	My Thanh Nam
Paddy farming	19,106	36,670	24,772	22,571
Livestock	1,300	933	800	4,533
Homestead	1,800	-	-	7,480
Agric. wage labor	2,000	9,250	1,350	3,150
Non-agriculture	-	-	7,733	9,100
Services	7,333	4,000	9,125	7,000
Total income	31,539	50,854	43,780	53,834
Per capita income	5,006	10,820	9,443	11,012

Source: Household Survey, 2007. Exchange rate: US$1 = VND 17857 (19 October 2009)

The interesting fact was that the crop diversification resulted in a higher per unit return than paddy cultivation alone. The crop production systems varied across selected villages. Most of the villagers in Hoa cultivated 2 paddy crops and one other crop such as soybean, mung bean or maize. The villagers in Phu Tho cultivated 2 paddy crops per year. Villagers of Than Cuu Nghia grew non-paddy crops (mainly vegetables). Farmers of My Thanh Nam cultivated 3 paddy crops. The results showed significant differences in per hectare (ha) profitability among the four production systems (Table 4.9). The net return per ha was highest for non-paddy crops (107 million VND, equivalent US$6710 with a Benefit-Cost ratio of 2.04), as farmers use their land very effectively with about ten harvests per year. However, in terms of per household it was still low compared to other systems, especially due to the land size.

Table 4.9 *Productivity and profitability of paddy farming in different farming systems (costs and income in 000'VND)*

	2 Paddy + 1 non-paddy	2 Paddy crops	Non-paddy crops	3 Paddy crops
Rice yield (t/ha)	5.51	6.08	-	6.73
Productivity, rice equivalent (t/ha/year)	17.14	11.55	58.20	17.26
Total costs (/ha/year)	18169	13507	52695	20820
Gross value of production (/ha/year)	47144	31761	160058	48238
Net return (/ha/year)	28975	18255	107363	27419
Benefit/ cost ratio	1.59	1.35	2.04	1.32

Source: Household Survey, 2007. Exchange rate: US$1 = VND 17857 (19 October 2009)

- *Role of paddy fields in generating employment for farmers*

The multiplication of rice crops and diversification of crops on paddy fields generate additional employment as it requires a lot of manual labour. The labour use in different paddy production systems is presented in Table 4.10. It shows that paddy production generates employment for farm households. The other factor to consider for employment generation is hired labour. The paddy production has generated opportunities for hired labourers, for the landless and marginal farmers. Labourers from the different regions migrated to work in paddy farming, especially for harvesting rice. The total hired labour requirement was higher in the 3 paddy crops system.

Table 4.10 *Family labour and hired labour required for paddy production by cropping season (per ha per year)*

Production systems	Winter-Spring crop		Summer-Autumn crop		Autumn-Winter crop	
	Family labour	Hired labour	Family labour	Hired labour	Family labour	Hired labour
2 paddy crops	10	63	11	71	-	-
2 paddy+1 non-paddy	27	55	25	63	32	50
3 paddy crops	20	56	24	61	23	58

Source: Household Survey, 2007.

- *Role in contributing to the economic development and food security*

The Mekong Delta is an important region for paddy production in Viet Nam as it produces more than half of the total paddy production of the country (accounted for 54% of the total national production). Agricultural production, especially paddy production, continues to play a dominant role in the economy.

Paddy significantly contributed to food security in the country. Rice is a staple food in Viet Nam and the demand increases with the population growth. Table 4.11 shows the trends of population growth and projected rice demands from 2005 onwards. In 2000, the rice consumption of the country was about 20 million tons (rough rice) and it is expected to increase to about 22 million tons in 2010. In the Mekong Delta, rice consumption was 4.21 tons in 2000 and should increase to 4.64 tons in 2010. At the same time, rice production is projected to be 20.8 million tons in 2010 in the Mekong Delta alone. It shows that paddy production in the Mekong Delta could contribute to food security for the delta as well as other regions in Viet Nam.

Table 4.11 *Trends of population growth, rice consumption demands, and paddy productions in Viet Nam and the Mekong Delta*

	Years		
	2000	2005	2010
Population (mil. people)			
Viet Nam Total	77.69	83.74	89.81
Mekong Delta	16.38	17.67	18.90
Paddy production (mil. tons)			
Viet Nam Total	32.53	35.79	38.00
Mekong Delta	17.11	19.23	20.86
Consumption (mil. tons; rough rice)			
Viet Nam Total	20.00	21.00	22.00
Mekong Delta	4.21	4.41	4.64

Source: GSO (2004), Duong et al (2005) and calculation under study.

The Mekong Delta produces rice not only for meeting domestic demand—but also for exports. A large volume of the exported rice of the country came from the Mekong Delta. The amount of milled rice for export has increased year by year. It was about 3.4 million tons in 2000 and increased to 4.5 million tons in 2005 (Table 4.12). Dong Thap and Tien Giang, provinces (the two provinces covered by the study) were also the rice exporters in the region. In 2005, Dong Thap exported about 0.31 million tons (milled rice) and Tien Giang about 0.28 million tons to the world market. Producing rice for export continues to be the major focus of Mekong Delta farmers.

Table 4.12 *Contribution of the Mekong delta (and details for the two provinces included in the study) to the export of rice (milled rice) between 2000 and 2005*

Provinces	Years					
	2000	2001	2002	2003	2004	2005
Mekong Delta (mil. tons)	3.37	4.00	3.90	4.55	4.00	4.45
Dong Thap (mil. tons)	0.27	0.24	0.28	0.35	0.25	0.31
Tien Giang (mil. tons)	0.27	0.22	0.12	0.21	0.17	0.28

Source: SOT (2005), SOD (2005)

- *Conclusions*

Paddy fields significantly contribute to socioeconomic improvement. Besides being the main source of household income in the Mekong Delta, it has contributed significantly to the generation of employment in farm households. Paddy farming involves not only family labour, but also a large number of hired labourers and thus it can contribute to poverty reduction by creating employment opportunities for resource-poor households. In addition, paddy cultivation has contributed to food security as well as exports.

5. Multifunctional roles of paddy fields in Northeastern Thailand

This section discusses the details of specific methods and major findings from the analysis of selected multifunctional roles of paddy fields in Northeastern Thailand. Two key multifunctional roles of paddy fields were selected for analysis:

- Flood control (by analysing the indicators measured in flooding areas).
- Nurturing and restoring aquatic ecosystem (by analysing the nurturing function for wild aquatic species).

In addition, the associated socioeconomic contribution to rural areas besides direct household income from paddy production was included in the analysis of multifunctional roles.

5.1 Multifunctional roles of paddy fields on flood control

Many towns and cities in Thailand are surrounded by paddy fields. With the increasing expansion of urban areas, many of these paddy fields have been transformed into housing areas, industrial areas, and other non-agricultural areas. Because of these changes, some cities are at risk from facing annual flash floods. In this context, the present capacity of paddy fields to store flood water has been analysed and includes predictions concerning the future conversion of paddy fields to other land use and the associated change in flood risk areas that the abolition of paddy fields implies.

Study Sites

Roi-Et city was selected from the Roi-Et province in Northeastern Thailand (see Figure 3.2). The study area covered the whole district of Muang Roi-Et, which has a land area of 49500 ha and a population of 118,789. The study of the flood mitigation function of paddy fields focused on the Roi-Et municipality, which is the main commercial and urban area of the district. It covers an area of 1163 ha and has a population of 35,894. The study area is generally flat, and slightly tilted from the Southwest to the Northeast.

Methods

Aerial photos of Roi-Et city were obtained for three different time periods, 1987, 1997 and 2005, as well as satellite data for the flooding period of Roe-Et area. In addition, the historical land use or land cover maps of Roi-Et area were collected. Other relevant data on infrastructures around the city were gathered from secondary sources. The historical rainfall data of the area was obtained for the past 50 years.

The aerial photographs of the area were used to create land use maps for different periods. The draft of land use maps were put into a GIS system. Urban and paddy field areas were then classified in the map and included various categories such as: urban area, rice fields, field crops, water resources, and forest.

The historical and present capacity of paddy fields to store water was calculated by using GIS tools. The historical rainfall data was used to determine the areas under flash flood risk. The future conversion of paddy fields into other land uses was predicted by scenario analysis. The change in flood risk areas by abolition of paddy fields was identified. Finally, the impacts of paddy fields on flood mitigation were analysed.

Demonstrated role of paddy fields in flood control

- *Paddy fields as water reservoirs around the city*

The land cover maps were produced for 3 periods: 1987, 1997 and 2005. Samples of aerial photos of rice fields, forest areas, urban areas and water resources in year 2002 were used. The historical rainfall data for the last 49 years (from 1958-2006) showed that the average rainfall in this city is approximately 1385 mm per annum. The land use change in the area from 1987 to 2005 is presented in Figure 5.1.

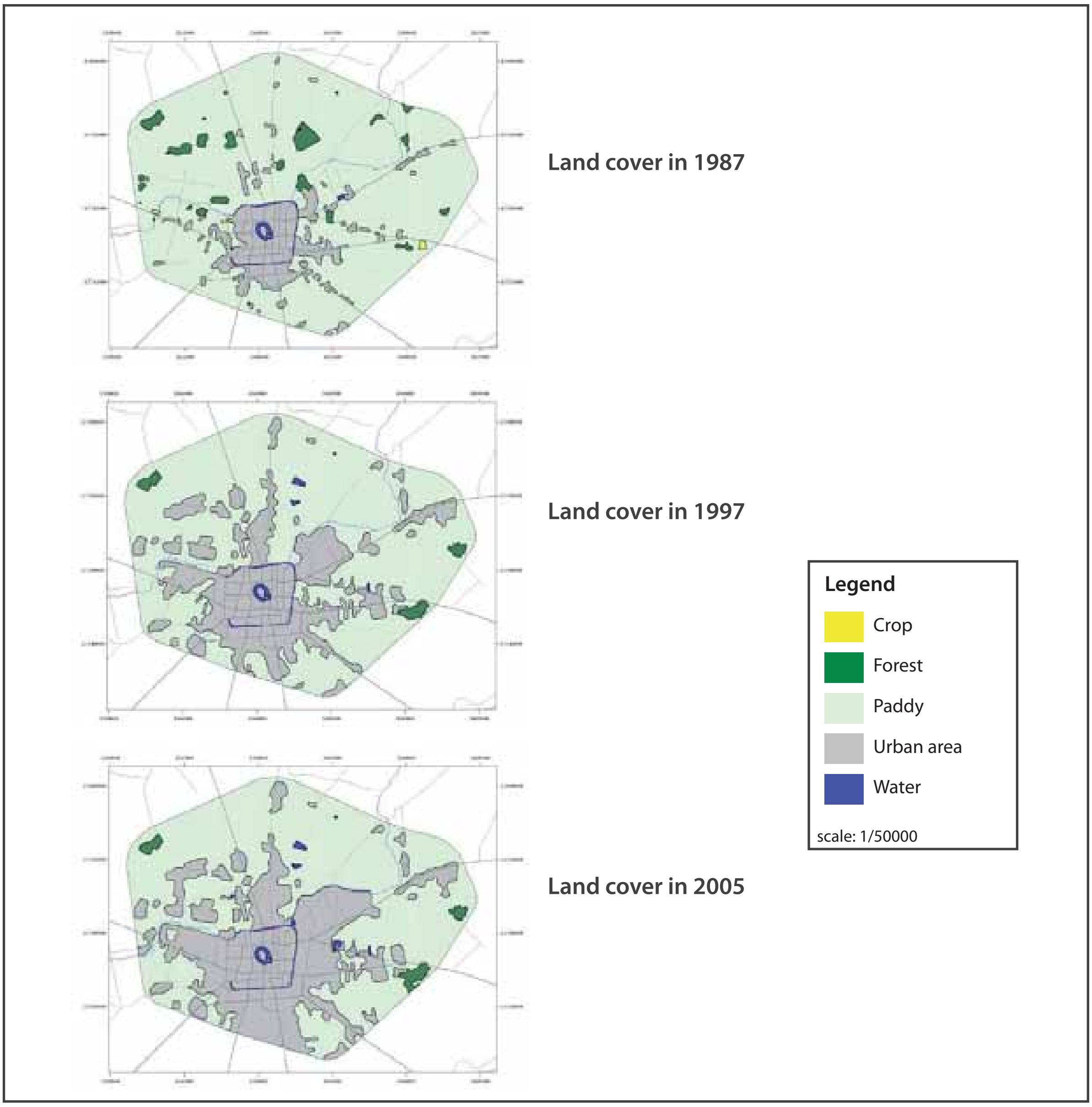


Figure 5.1 Land cover map of the study area in the year 1987, 1997, and 2005

Figure 5.1 clearly shows that the paddy cultivation area around the city has decreased over time. Between 1987 and 2005, paddy field areas fell from 4,306 ha to 3140 ha, a reduction of nearly 30%. In the same time period, urban areas increased from 608 ha in 1987 to 1858 ha in 2005 (more than 300% increase)(see Table 5.1). The water holding capacity of paddy fields around the city was calculated from rainfall data and land use changes. In 1987, paddy field areas around the city covered 4306 ha. Assuming an average water depth of 0.40 m, paddy fields could hold approximately 17,2 million m^3 of water at that time, but it has consequently decreased to 12.5 million m^3 in 2005 (Table 5.2). In the last two decades, the decrease of paddy field areas has reduced the flood water holding capacity around the city by nearly 30%.

Table 5.1 *Land use change and water holding capacity around Roi-Et city between 1987-2005*

Year	Paddy fields (ha)	Urban area (ha)	Water depth (in m)	Water holding capacity (m^3)
1987	4306,24	608,32	0.4	17,224,960
1997	3537,44	1474,88	0.4	14,149,760
2005	3140,16	1858,88	0.4	12,560,640

- *Water holding capacity of paddy fields in different scenarios and flood risk areas*

Assuming the additional rainfall and different water holding capacities (in terms of water depth), the additional volume of water needed to be drained from the city was calculated. The results showed that with additional rainfall, the total volume of water to be drained from the city increases substantially. The total area of Roi Et city covers 499 ha and has a total paddy area of 3140 ha in 2005. Assuming a 100 mm rainfall and a water depth of 10 cm (0.10 m) in paddy fields, the water holding capacity for the whole city area would be 4.9 million m^3 while the paddy fields can only hold a maximum of 3.1 million m^3 of water. In this scenario, more than 1 million m^3 needs to be drained from the city (Table 5.2).

Table 5.2 *Water holding capacity of paddy fields in different scenarios for the year 2005*

Rainfall (mm)	Rain water in whole area (m^3)	Water depth in paddy fields (m), water holding capacity (m^3) and surplus water needed to be drained out (in italic)			
Water depth in paddy fields		.10 m	.20 m	.30 m	.40 m
Water holding capacity in the fields		3,140,160	6,280,320	9,420,480	12,560,640
100	4,999,040	*(1,858,880)*	Surplus water needed to be drained out from		
200	9,998,080	*(6,857,920)*	*(3,717,760)*	*(577,600)*	city area
300	14,997,120	*(11,856,960)*	*(8,716,800)*	*(5,576,640)*	*(2,436,480)*
400	19,996,160	*(16,856,000)*	*(13,715,840)*	*(10,575,680)*	*(7,435,520)*

In addition, the future flood risk areas (due to land use change and urban development) have been identified around the city. This type of areas requires careful planning in order to allow paddy fields to store water, especially during flash floods in the event of heavy rains.

- *Conclusion*

The results showed that paddy fields have served as water reservoirs around the city, effectively storing flood water. With the rapid change of paddy fields to urban area, cities like Roi-Et need to plan carefully their drainage systems to avoid recurrent damage during flash floods (caused by rainfalls of more than 100 mm). Many cities at low altitude should pay attention to the role of paddy fields in flood mitigation. Based on the findings, planning to keep paddy fields seems more cost effective in flood mitigation than other measures like building dikes or ring roads as dam for flood prevention.

5.2 Role of paddy fields in nurturing and restoring aquatic ecosystems

It has been observed that the people of Northeastern Thailand cope with variability in their habitat factors by employing a 'combined subsistence system' in which their reliance on glutinous rice as the staple food is complemented by a large input from wild food sources (Moreno-Black, 1991). Wild products are collected from the forest as well as paddy fields, upland fields, garden and house areas, canals, ponds, swamps, rivers and dam areas (Moreno-Black, 1991). Many of these wild species play an important role in the income of farmers' household. Although it is already known that farmers tend to collect different wild species in different seasons (rainy, cool dry and hot dry), the extent of seasonal differences in the diversity of useful species collected from the paddy fields has not yet been fully documented.

Study Sites

Nong Ben village in Muang district of Khon Kaen province was selected for the study (see Figure 3.2). The village is located approximately 20 km from Khon Kaen municipality. Nong Ben village has the total population of 1,237 people in 337 households. The total agricultural land area in Nong Ben village is around 806 ha.

The total area of rain-fed and irrigated paddy fields in Nong Ben village covers 411 ha. The site was selected because previous study of wild products sold in Bang-Lam-Phu market in Khon Kaen Municipality revealed that Nong Ben villagers collected many wild products that were sold in the market. In addition, the location of the paddy fields is clearly divided into rain-fed paddy fields on the west side of the village and irrigated paddy fields on the east side.

Methods

This study is mainly based on primary data collected from the selected village. At the beginning of the study, a group interview was conducted with twenty villagers in order to gain a preliminary understanding of the village, including its history, the annual cycle of agricultural activities, and the diversity of wild products collected by villagers. In the next stage, all the household heads were interviewed using standardised questionnaires in order to classify their land holdings according to the type and area of paddy fields as well as the extent of their involvement in the collection of wild products.

After the survey with all the village households (337 households), the information was used to classify the households in different typologies and then select two sets of households to be included as samples in the study. The households were first categorised into households with rain-fed paddy fields and households with irrigated paddy fields. These two types were then divided into households collecting wild products and households not collecting wild products. The wild-products were further categorised into domesticated wild products and non-domesticated wild products, each of which category was further divided into large, medium and small farmers. Following this detailed typology, one set of 10 households with only rain-fed paddy fields; and the other set of 14 households with only irrigated paddy fields were selected for a detailed survey. The detail classification of the samples is presented in Table 5.3.

Table 5.3 *Selected sample households covering the different typology of households*

Land holding category (ha)	Domesticated wild products		Non-domesticated wild products	
	Total HH	Sample HH	Total HH	Sample HH
Rain-fed paddy households				
Large (>1.6)	4	2	2	1
Medium (0.8-1.6)	5	2	5	2
Small (<0.8)	5	2	3	1
Sub-total	14	6	10	4
Irrigated paddy households				
Large (>1.6)	15	2	13	2
Medium (0.8-1.6)	26	2	35	3
Small (<0.8)	19	2	39	3
Sub-total	60	6	87	8

Each household from the sample was interviewed in each of the three seasons (cool dry, hot dry and rainy season) to identify all of the useful species of plants and animals that they collected from their paddy fields. If the collected products were consumed at home, they were assigned a shadow value based on the estimate of their cash value. The data collected for selected periods (14 days in each) in all the seasons were combined to represent the total economic value for a year.

Demonstrated role of paddy fields in nurturing and restoring aquatic ecosystems

- *Wild species from different habitats in the village agro-ecosystem*

The results showed that a total of 96 species were collected from the paddy fields and surrounding areas over the period of one year, of which 38 were plants, 4 were fungi, and 54 were animals. Among the animal species were: 2 species of amphibian (frog, toad), 8 species of bird, 2 species of crustacean (crab, prawn), 19 species of fish (various fish, eel), 16 species of insect, 2 species of mammal, 2 mollusc species, and 3 reptile species (Table 5.4).

The availability of wild product species varied according to the seasons of the year. The climate in Northeastern Thailand is usually divided into three seasons: the hot dry season (March-May), the rainy season (June-October) and the cool dry season (November-February). The cool dry season is often marked by a sharp drop in temperature. In this season, water becomes very scarce, essentially disappearing from upland fields and rain-fed paddy fields, while the water level in aquatic ecosystems such as ponds, canals and river, drops sharply. The wild species are the scarcest during the hot dry season and only few can be found in dry paddy fields. The rainy season is the longest period of the year in this region.

Table 5.4 *Seasonal availability of wild species collected in Nong Ben village in Northeastern Thailand in 2006*

Collected species	Hot Dry	Rainy	Cool Dry	Total	Only Hot Dry	Only Rainy	Only Cool Dry	All Seasons
Plant	20	30	17	38	5	10	3	9
Fungi	4	1	0	4	3	0	0	0
Animal	38	39	27	54	8	8	5	17
Amphibian	2	2	1	2	0	0	0	1
Bird	4	4	6	8	1	0	3	2
Crustacean	2	2	2	2	0	0	0	2
Fish	11	15	11	19	2	5	1	7
Insect	12	13	5	16	2	3	1	4
Mammal	2	0	1	2	1	0	0	0
Mollusc	2	1	1	2	1	0	0	1
Reptile	3	2	0	3	1	0	0	0
Total	**62**	**70**	**44**	**96**	**16**	**18**	**8**	**26**

The results showed that the diversity of species was the highest in the rainy season, during which 70 species were recorded, compared to 62 species in the hot dry season and only 44 during the cool dry season. Plant species were much more diverse in the rainy season than in the hot dry and cool dry seasons. Animal species were the least available in the cool dry season and some species were available only in a specific season. 26% of all species recorded in the survey were available only in the rainy season, 24% were found only in the hot dry season, and 12% only in the cool dry season. About 38% of the species were available in all three seasons.

- *Wild products and their economic value*

The average number of species of wild products collected by households with rain-fed and irrigated paddy fields is presented in Table 5.5. On average, households with rain-fed paddy fields collected a slightly larger number of species (6.8) than those with irrigated paddy fields (6.0). Households with rain-fed paddy fields collected one species that was not collected by those who have irrigated paddy fields, while the latter collected two species that were not collected in rain-fed paddy fields.

Table 5.5 *Comparison of the average number of species of wild products collected by households with rain-fed and irrigated paddy fields*

Collected species	Households with rain-fed paddy fields (10HH)	Households with irrigated paddy fields (14HH)	Collected by households with only rain-fed paddy fields (10HH)	Collected by households with only irrigated paddy fields (14HH)
Plant	2.5	2.4	0.5	0.9
Fungi	0.1	0.3	0	0.2
Animal	4.2	3.5	0.5	0.9
Amphibian	0.2	0.1	0	0
Bird	0.6	0.4	0.2	0.1
Crustacean	0.2	0.1	0	0
Fish	1.4	1.2	0.2	0.4
Insect	1.2	1.1	0.1	0.3
Mammal	0.1	0.1	0	0.1
Mollusc	0.2	0.1	0	0
Reptile	0.3	0.2	0	0
Total	6.8	6.1	1	2

Table 5.6 presents information on the economic value of all wild products that are collected by Nong Ben villagers, including both cash and shadow values. The estimated average annual economic value per household of wild products was 14,841 Baht (US$424.01). The value of wild products was the highest in the rainy season followed by the cool dry season and the hot dry season.

Table 5.6 *Estimated value (in baht) of wild products collected by sampled households with rain-fed and irrigated paddy fields in different seasons in the Nong Ben village in 2006*

Seasons	Households with rain-fed paddy fields (10HH)	Households with irrigated paddy fields (10HH)	Average of all households
Hot Dry Season	1,809 ($51.69)	1,608 ($45.94)	1,709 ($48.81)
Rainy Season	6,837 ($195.34)	7,473 ($213.51)	7,155 ($204.43)
Cool Dry Season	8,757 ($250.20)	3,197 ($91.34)	5,977 ($170.77)
Whole year	17,403 ($497.23)	12,278 ($350.80)	14,841 ($424.01)

Note: Official exchange rate was US$1.00 = 35.06 baht on 13 April 2007

Wild products collected in rain-fed paddy fields have a significantly higher economic value (17,403 baht or US$497) than those collected in irrigated paddy fields (12,278 baht or US$351). The difference was particularly notable in the cool dry season. This difference is a reflection of the different seasonal agricultural activity patterns of the two types of households. In the cool dry season, rain-fed paddy fields involves limited agricultural activities so households can spend more time collecting wild products whereas households with irrigated paddy fields are busy growing two rice crops per year.

- *Contribution to the conservation of biodiversity*

The wild species are collected from several different habitats in the rural agro-ecosystems of Northeastern Thailand. These habitats include paddy fields, upland fields, forests, backyard gardens, ponds, and rivers and streams. The results showed that irrigated paddy fields were an habitat for the largest number of species (69 species), followed by rain-fed paddy fields (58 species), while the smallest number of species were found in ponds (16 species) and backyard gardens (11 species) (see Figure 5.2).

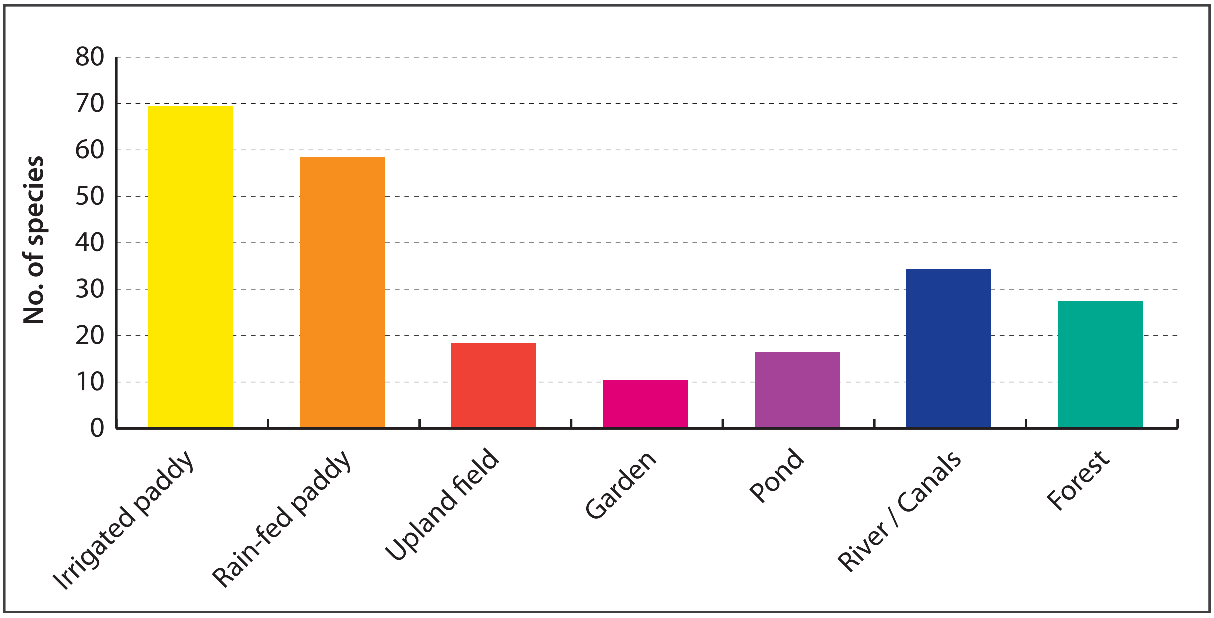


Figure 5.2 Number of wild species collected from different habitats

When rain-fed and irrigated paddy fields are compared, irrigated paddy fields support a higher biodiversity of useful wild species than rain-fed paddy fields. This probably reflects the greater sufficiency of water in irrigated paddy fields. The irrigated paddy fields present a much more stable environment and are more disposed to act as habitats for the wild species.

- *Conclusion*

The findings clearly demonstrated that paddy fields, both rain-fed and irrigated, provide many valuable wild products that are of great economic value to the farm households. These wild species make important contributions to the food supply of rural households, especially as a source of nutritionally valuable vegetables and proteins. They are also an important source of cash income for rural households. From the standpoint of biodiversity conservation, paddy fields play another valuable function. Any reduction of the paddy field surface area due to changes in cropping patterns, conversion to other land uses, or abandonment, can be expected to have important consequences on the rural biodiversity of Northeastern Thailand.

5.3 Farm household income and multifunctional roles in other socioeconomic aspects

Rice cultivation plays a key role in the household income of villagers in Northeastern Thailand. However, growing rice is considered a risky activity, because of many uncertainties that affect its production or sale, such as climate, disease and pests, and market fluctuations, and on which farmers only have limited control. On top of that, farmers generally consider only the direct income generated by rice grain production and tend not to understand well other secondary roles, like employment generation.

Study Sites

Field research for this sub-project was carried out in Dong Yen village in Khon Kaen province. This site was selected because this village has both rain-fed and irrigated paddy fields and the villagers engage in many different kinds of livelihood activities. Dong Yen village is one of the 17 villages of Bua Yai sub-district in Khon Kaen Province (see Figure 3.2). Dong Yen village has a total population of 393 people, of which 199 are males and 194 females. There are 65 households. The total area of agricultural land in Dong Yen village covers 320 ha. The total area of paddy land in Dong Yen is 112 ha. The village is on undulating terrains, typical in Northeastern Thailand. Wet rice is grown in fields surrounded by bounds at lower elevations; cassava and sugarcane are grown on drylands in the uplands, and forest areas occupy hilltops and other marginal areas. The main occupation of households in Dong Yen village is farming. Rice is the main food crop grown in the village. Other crops include fibre plants, corn, and beans. Cassava and sugarcane are grown as cash crops. Some households with rain-fed paddy fields grow peanuts after the rice harvest and sell them to food-processing factories. The village is well endowed with water resources, having both surface and groundwater irrigation facilities.

Methods

Data on the number of members, number, type and areas of fields, type of crops, number and type of livestock and diversity of livelihood activities were collected from every household in the village using a structured questionnaire. Based on the survey, households were classified based on their type of paddy fields and size of land holding. Two sets of 10 farm households, one cultivating only rain-fed paddy fields and the other cultivating only irrigated paddy fields, were selected as samples for a thorough study. After that, the detailed record keeping of the related information on household income was done with the sample of rice-growing households. In addition basic information on the village agro-ecosystem was collected using participatory methods employing the Rapid Results Approach (RRA).

Contribution to household income and demonstrated socioeconomic role

- *Number of livelihood activities engaged in by households*

The results showed that households with irrigated paddy fields were engaged in a higher number of livelihood activities (on average 6.9 activities in the rainy season and 5.8 in the dry season) than households with rain-fed paddy fields (on average 6.5 activities in the rainy season and 5.1 in the dry season). The detail is presented in Table 5.7. The difference between the two sample groups was relatively small, but a much larger sample would be needed to fully confirm this trend.

Table 5.7 *Number of livelihood activities engaged in by households with irrigated or rain-fed paddy fields in different seasons of the year in Dong Yen village*

Number of livelihood activities engaged in by households	Households with irrigated paddy fields (n=10)		Households with rain-fed paddy fields (n=10)	
	Rainy season	Dry season	Rainy season	Dry season
3	0	0	1	1
4	1	1	2	3
5	2	4	0	3
6	1	2	2	1
7	3	2	2	1
8	1	1	1	0
9	0	0	1	1
10	2	0	0	0
11	0	0	1	0
Mean no. of activities	6.9	5.8	6.5	5.1
Median no. of activities	6.5	5.5	6.0	5.0

Source: Household Survey, 2006

As presented in Figure 5.3, many of the households with irrigated paddy fields were engaged in 7 or more activities in the rainy season whereas a majority of the households with rain-fed paddy fields were engaged in 7 or less activities in the same season. In the dry season, the majority of farmers were engaged in 6 or less activities in both types of household.

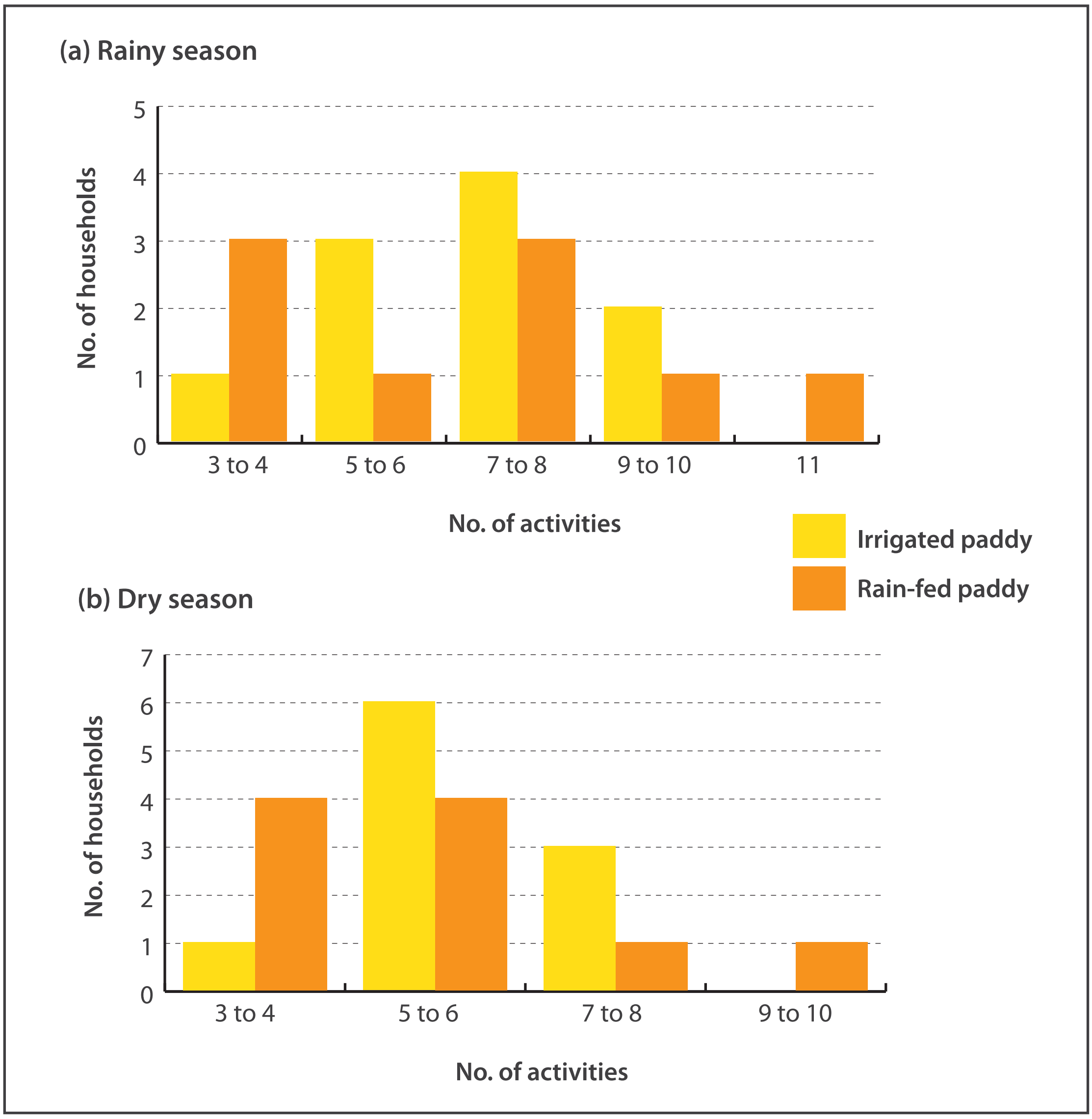


Figure 5.3 Comparison of the no. of livelihood activities engaged in by irrigated and rain-fed households in Dong Yen village in 2006 in (a) the rainy season, and (b) the dry season

The results showed that the number of livelihood activities engaged in by households was strongly associated with the size of land holding, regardless of the type of paddy field. Households having larger areas of paddy fields engage in more livelihood activities in both seasons than households holding less land. This is more evident with the scatter plot diagrams between the size of land holding and the number of activities engaged in by households in rainy and dry seasons (Figure 5.4). Statistical analysis determined a correlation coefficient of 0.47 in the rainy season and 0.43 in the dry season (both correlation coefficients were highly significant ($P < 0.01$)).

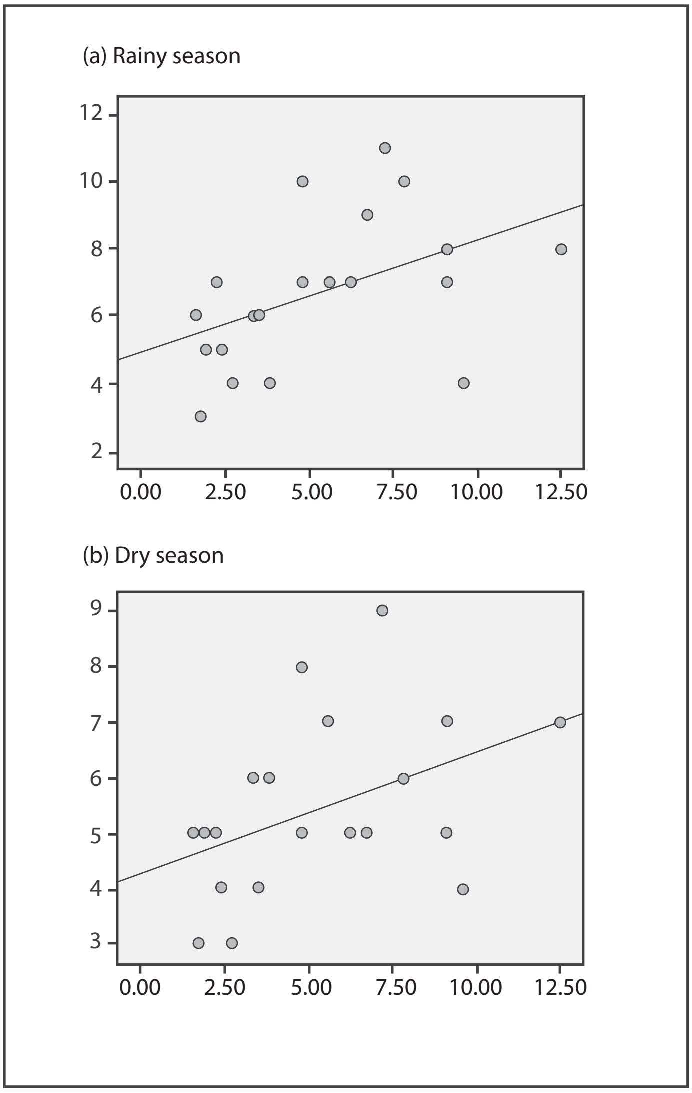


Figure 5.4 Scatter plots showing the relationship between the size of land holding and the number of livelihood activities in (a) the rainy season and in (b) the dry season

Based on the findings, there was not much difference between the number of income generating activities engaged in by households with comparable land holding size, regardless of the type of paddy fields. However, on average, households with irrigated paddy fields engage in slightly more activities than households with rain-fed paddy fields.

- *Share of different sources in the household income*

Paddy was the most important source of income for both types of households in the dry season. The%age of total household income that both types of household generated from different sources in the rainy and dry seasons is presented in Table 5.8. Most of the income obtained from households with rain-fed paddy fields was actually derived from the rice harvest at the end of the rainy season. In order to obtain more cash, some farmers with rain-fed paddy fields sold part of their rice stocks in the dry season. Rain-fed households made more than 25% of their total income in both seasons from non-farm sources, including work at home (making handicrafts), off-farm wage labour and commercial activities. Households with irrigated paddy fields made a considerably larger share of their total income from on-farm sources due to the stability of production of irrigated systems.

Table 5.8 *Percentages of total household income obtained from different sources by households with rain-fed and irrigated paddy fields in Dong Yen Village*

Sources of income	Households with irrigated paddy fields (n =10)		Households with rain-fed paddy fields (n =10)	
	Rainy season	Dry season	Rainy season	Dry season
Paddy fields	9.0	49.0	11.0	39.0
Upland fields	24.0	9.0	26.0	14.0
Gardens	18.0	11.0	15.0	12.0
Forest	22.0	8.0	16.0	3.0
Ponds	10.0	4.0	5.0	5.0
Home	7.0	8.0	12.0	9.0
Off-farm	10.0	11.0	15.0	18.0

- *Comparison of the relative importance of different sources of household income*

The contribution of the different income-generating activities to the total household incomes is presented in Table 5.9. In both seasons, households with irrigated paddy fields obtained a greater share of their total income from agricultural activities than households with rain-fed paddy fields. Agricultural activities included growing rice, peanuts, corn, vegetables, and rattan. Households with rain-fed paddy fields, on the other hand, were much more dependent on non-farm and off-farm activities.

Table 5.9 *Percentages of total household income obtained from different activities*

Type of activity	Households with irrigated paddy fields (n =10)		Households with rain-fed paddy fields (n =10)	
	Rainy season	Dry season	Rainy season	Dry season
Agriculture	56.0	66.0	49.0	56.0
Collection of wild products	18.0	12.0	20.0	4.0
Handicrafts	4.0	2.0	6.0	16.0
Non-farm labour	7.0	7.0	8.0	15.0
Commercial	15.0	13.0	17.0	9.0

- *Share of time spent for different income sources*

The%ages of time dedicated by the households to each income source are presented in Table 5.10. In the rainy season, there were only a few differences in the allocation of labour time to different sources of income by both types of household. Both types of household spent roughly half of their labour time in paddy fields, and a quarter in upland fields. In the dry season however, households with irrigated paddy fields could still spend nearly half of their time in paddy fields while households with rain-fed paddy fields needed to find other activities, including off-farm work.

Table 5.10 *Percentages of time spent by households for each income source*

Sources of income	Households with irrigated paddy fields (n =10)		Households with rainfed paddy fields (n =10)	
	Rainy season	Dry season	Rainy season	Dry season
Paddy fields	53.0	42.0	48.0	3.0
Upland fields	23.0	15.0	26.0	38.0
Gardens	8.0	10.0	9.0	17.0
Forest	5.0	8.0	3.0	5.0
Ponds	3.0	7.0	2.0	9.0
Home	2.0	11.0	5.0	13.0
Off-farm	6.0	7.0	7.0	15.0

- *Conclusion*

The findings showed that paddy fields play an important role in the economic life of both types of households in a village in Northeastern Thailand. On average, households with irrigated paddy fields engage in more income-generating activities than those with rain-fed paddy fields. The paddy cultivation was the most important source of income for both types of household in the dry season. Though there was not much difference in allocated labour for different income sources during the rainy season, it was significantly different in the dry season. Households with irrigated fields could spend much more of their time working in the paddy fields, whereas those with rain-fed paddy fields needed to do non-farm and off-farm work. In a sense, it shows that paddy cultivation gives rural people the opportunity to be self-employed. Irrigated paddy fields could help stabilise rural livelihoods and retain people in the agricultural sector, thereby reducing livelihood insecurity.

6. Irrigation water use estimation in the LMB

6.1 Irrigation water use database

Three types of database were developed to estimate the irrigation water use in the LMB, namely: Irrigation Scheme Database (ISD), Irrigation Water Use Key Database (referred to as 'key database') and Irrigation Water Use Supporting Database (also referred to as 'supporting database').

The ISD was designed to record locations of irrigation systems, headworks and command areas. It can be linked to irrigation projects by project code. The ISD was developed in 2000/01 and has been updated with some information from 2004.

The Irrigation Water Use Database, or key database, is a spatial model in GIS format that can be easily applied to a wide number of applications depending on the requirements of the user. The key database is designed to complement the ISD and has a compatible referencing system that allows the two databases to be easily linked. The Irrigation Water Use Supporting Database, or supporting database, was developed to estimate the irrigation water use and includes a number of supporting databases from which the key water use data is derived. The supporting database can be linked to the main database and can be used as required to meet specific needs. It includes crop schedules, monthly irrigation schedule data and so on. The latter two databases were designed to complement the ISD and are linked to the main database to meet specific needs to estimate the irrigation water use.

6.2 Estimated net water use in the LMB

The analysis of the updated database has produced various outputs. The monthly and annual figures of the total estimated net water use were calculated. Table 6.1 presents the estimated annual net water use in the MRC's Member Countries . The monthly details are presented in Appendix 1.

Table 6.1 *Estimated annual net water use in the MRC's Member Countries*

Country	Annual net water use (million m^3)
Cambodia	2,749
Lao PDR	2,957
Thailand	9,352
Viet Nam	26,776
Total	**41,834**

Of the total net water use, it is estimated that 78% (32,000 million m^3) is used for rice production, 20% (8000 million m^3) for fish ponds, and 2% (800 million m^3) for crops other than rice. The data for fish and non-rice crops is very limited and must be considered as indicative. It does however show the very high volume of water used by fish ponds.

6.3 Irrigation projects, area coverage and irrigation requirements in the LMB

A series of summary maps namely: irrigation projects, irrigation areas, irrigation headworks, irrigation reservoirs, total and net diversion water use requirement of each irrigation scheme, irrigation requirement, and others were produced.

The number of irrigation projects and their distribution are shown in Figure 6.1. The density of irrigation projects in Thailand is much higher than in other countries, Cambodia for instance, while the number of irrigation projects in the Vietnamese part of the Mekong Delta was spread out all over the Delta. Similarly, Figure 6.2 shows the distribution of irrigation projects by size, and shows that the projects in the Vietnamese part of the Mekong Delta are relatively larger compared to other areas in the LMB. This obviously resulted into higher areas coverage under irrigation in the Mekong Delta region (Figure 6.3).

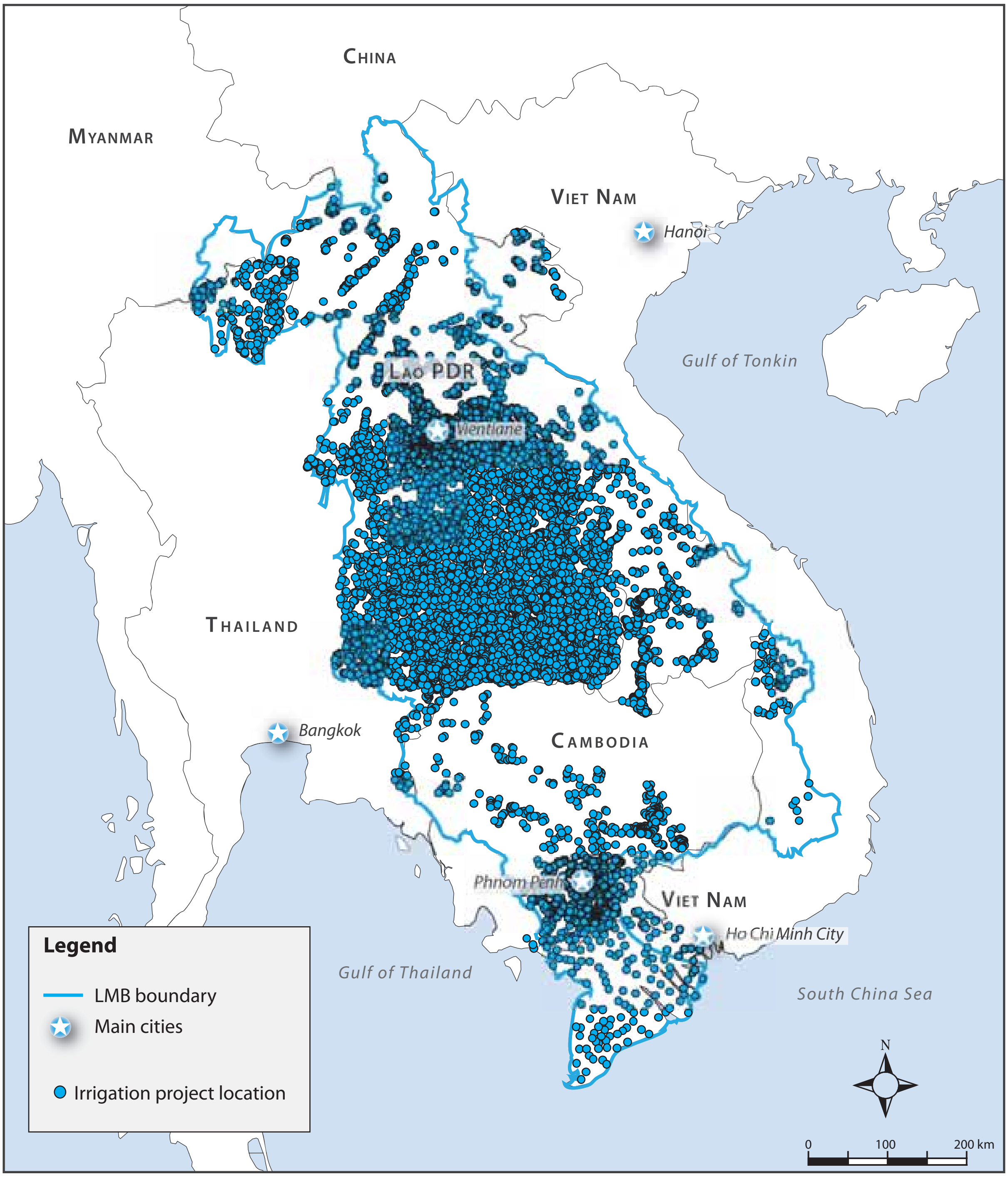


Figure 6.1 Irrigation Projects in the Lower Mekong Basin (distribution by number)

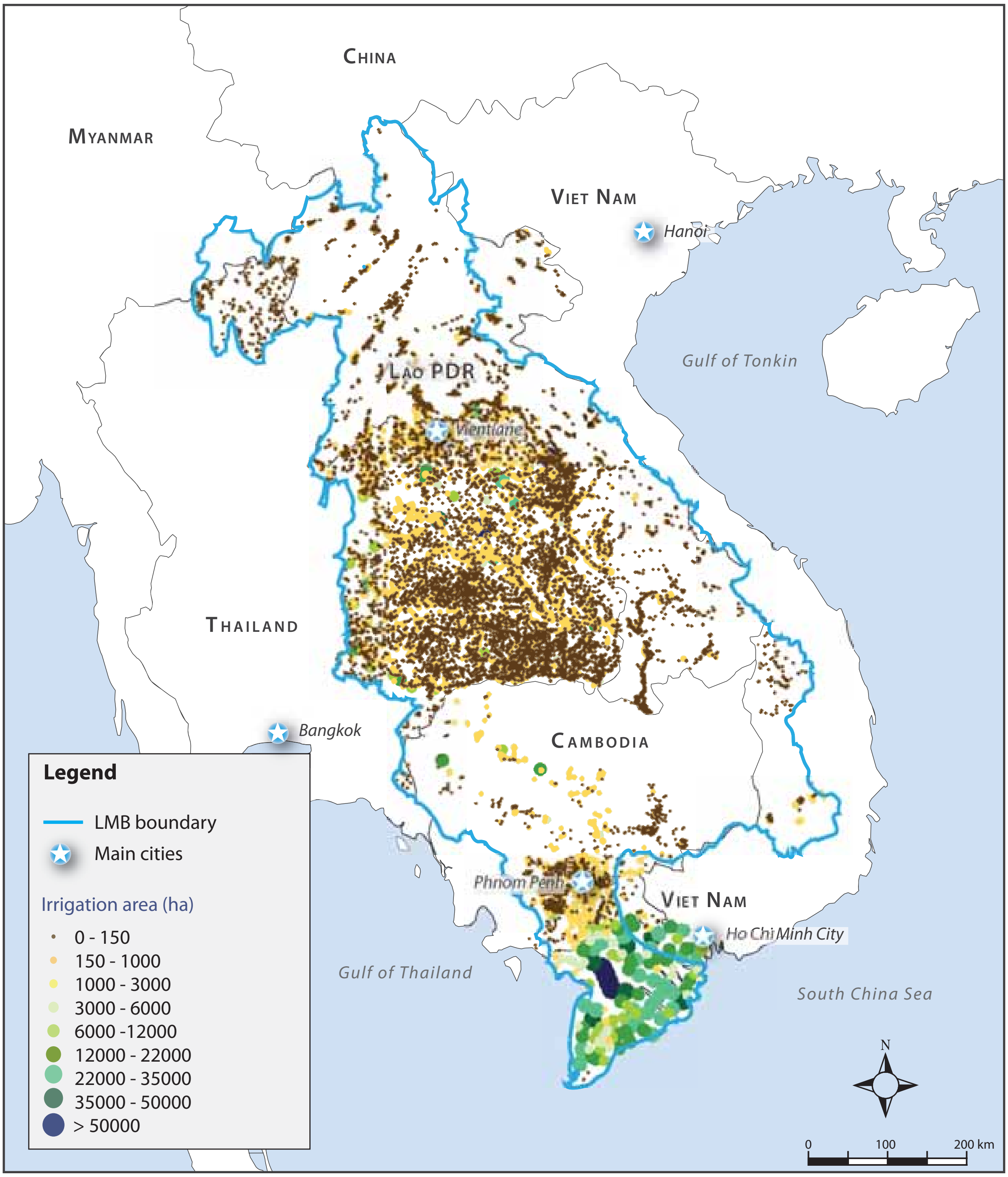


Figure 6.2 Irrigation Projects in the Lower Mekong Basin (distribution by size)

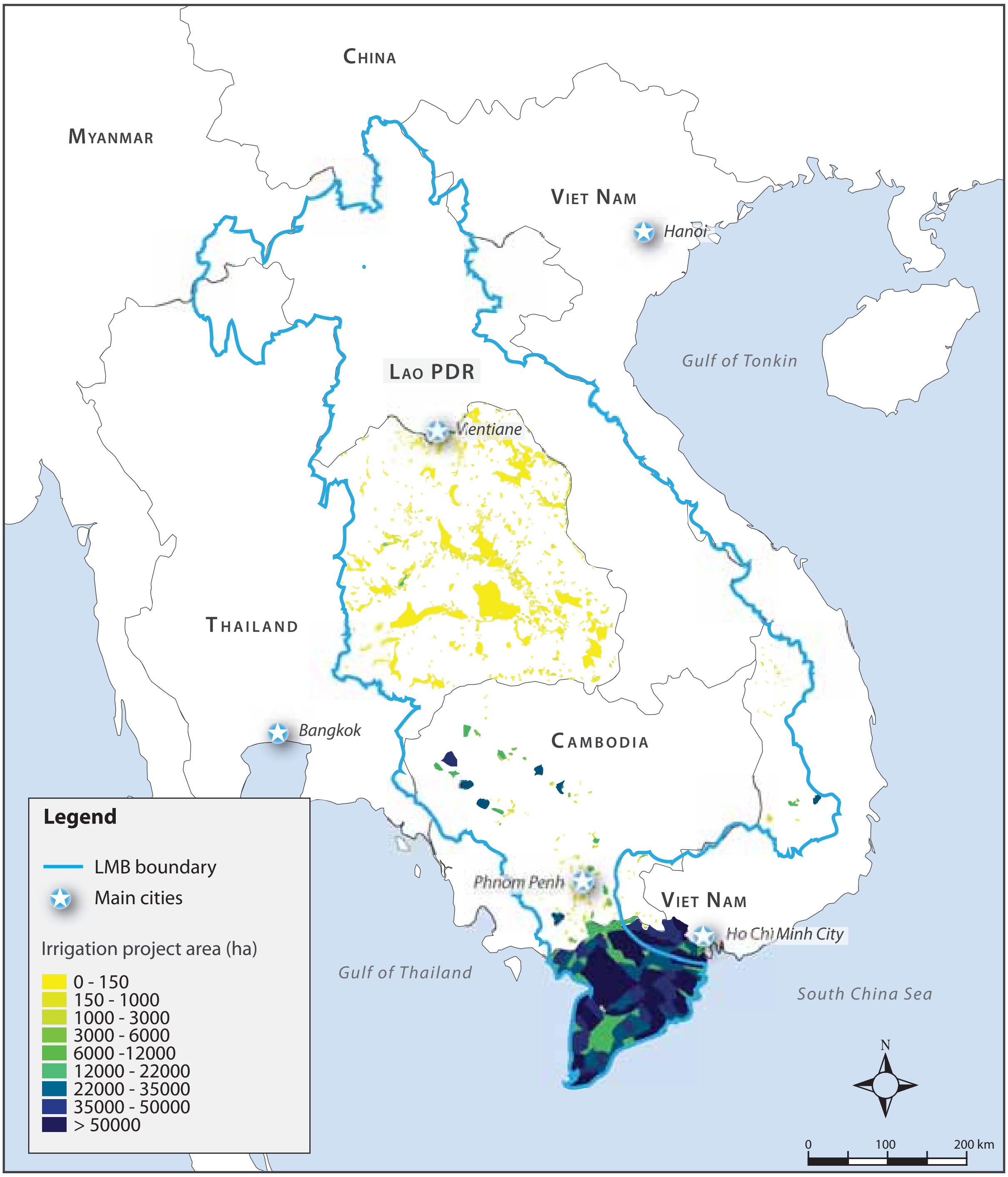


Figure 6.3 Irrigation area coverage in different parts of the Lower Mekong Basin

By showing a picture of the Total and Net Diversion Water Use (Appendix A2 to Appendix A5), it is recognised that consumption of water in the Vietnamese part of the Mekong Delta is always higher than in the other areas of the LMB. The maps of 'irrigation requirement' present the requirement of irrigation tendency which takes into account the effective rainfall in every month of the year (Appendices A6 and A7). It showed the irrigation needs in specific areas and demonstrate that irrigation requirement in the LMB is the lowest in September and increases from October, December to its highest value in March.

The output of selected maps such as: irrigation projects, diversion water-use, trends of irrigation requirements might be useful for planning the management of irrigation or take decisions related to water requirement in preliminary stages, not only for agriculture but also for water supply for other industries in MRC's Member Countries .

6.4 Other efforts within MRC on ISD update

The Irrigation Scheme Database is being updated under other programmes within MRC. The MRC's Basin Development Plan Phase 2 (BDP2) has implementing the irrigation sector review in 2008 and 2009, which included the update of the irrigation database. The BDP is designed to provide an integrated basin perspective through the participatory development of a rolling Integrated Water Resources Management (IWRM) based Basin Development Plan.

Under the BDP2, it has been proposed to update the inventory of existing, planned and potential irrigation projects; and ranking of the projects. These data and information are used in BDP scenario analysis to assess the hydrological, social and economic impacts of water resource development.

It also included developing an outline institutional framework for irrigation development including support measures to ensure the viability and sustainability of investments, and a portfolio of viable irrigation development projects as well as non-structural support initiatives.

7. Towards a better methodology for effective and efficient irrigation water use in the LMB

7.1 Multi-functionality, water use and its importance in the context of climate change

Paddy cultivation generates opportunities for people who are not directly involved in farming. Paddy cultivation aimed at export may flourish the processing and marketing sector. It has huge backward and forward linkages in the overall economy and thus provides strong incentives for paddy cultivation in irrigated systems.

Similarly, the various opportunities created by the changing economic context may encourage many to continue agriculture as part-time farmers especially in peri-urban areas. It will create various off-farm and non-farm opportunities. In such a context, farmers may still continue to cultivate paddy, but as a minor livelihood option.

However, the export oriented intensive rice cultivation has caused some problems such as reduction of soil productivity, and substantial reduction of fisheries resources due to the overuse of pesticides. Similarly, in the climate change scenario, long dry spells may affect most of the functions in different ways:

- reduction in species abundance,
- flash floods exceeding the carrying capacity of paddy fields,
- further soil problems, such as compaction and salinisation,
- low productivity/production of paddy and thus decrease in household income.

However, farmers have also developed adaptation strategies in order to minimise the effect of climate change, including on multi-functionality, such as:

- adjusting the transplantation time by either delaying or pre-poning by one week or ten days,
- developing effective mechanisms for water storage and rain water harvest,
- choosing varieties robust to delay or unaffected by heavy rainfall patterns.

In addition, climate mitigation by paddy fields has been recognised as a function in peri-urban areas where paddy fields and urban land are intermingled (FAO, 2007).

7.2 Policy options

Some proponents of multi-functionality have emphasised only public goods and beneficial externalities while downplaying negative externalities (Abler, 2001). Failure to consider both positive and negative external effects can lead to erroneous policy conclusions. Policies adopted to promote public goods could worsen, or at least fail to improve, negative externalities.

Policies for enhancing positive externalities: such as subsidies, eco-labeling of organic products and certification processes, government subsidised support services and involvement of NGOs in enhancing the multifunctional roles of paddy fields are some possible interventions.

Reducing negative externalities, the Polluter Pays Principal (PPP) and taxing and discouraging water and land polluting practices are initial steps that can be integrated in Nonpoint Source Pollution (NPS) issues. Similarly, incentive mechanisms for farmers to create rule based institutions (for instance, a water users' association with a legal status) may be crucial in case of both positive and negative externalities.

The socioeconomic contribution is often not considered as a multifunctional role. But future research could also focus on the importance of the socioeconomic multi-functionality, especially for the off-farm and non-farm opportunities created by paddy cultivation. The backward and forward linkages of paddy cultivation in the overall economy could be considered as an important multifunctional role and deserves more investigation.

Finally, the irrigation database developed under the Water Use Assessment can be applied to assess a wide number of issues relating to irrigation water use. However, the results should be interpreted with caution due to the many limitations in the original data.

References

Abler, D. 2001. A synthesis of country reports on jointness between commodity and non-commodity outputs in OECD Agriculture. Paris: Organization for Economic Cooperation and Development (OECD).

Abler, D. 2004. Multifunctionality, agricultural policy, and environmental policy. Agricultural and Resource Economics Review, 33 (1):8-17.

Anderson, K. 2000. Agriculture's multifunctionality and the WTO. Australian Journal of Agricultural and Resource Economics, 44 (3): 475-494.

Brunstad, R. J., I. Gaasland, and E. Vardal. 2005. Multifunctionality of agriculture: an inquiry into the complementarity between landscape preservation and food security. European Review of Agricultural Economics, 32 (4): 469–488.

Can, N. D. 2004. Baseline study cum needs assessment on post harvest handling in the Mekong River delta (A synthesis report of 12 Provinces). MARD - DANIDA. ASPS - Post Harvest Handling Component. Sub-Component Management Unit, Mekong Delta, Viet Nam.

CSO. 2005. Socio-economic data of 13 provinces of Mekong Delta. Cantho Statistical Office, Cantho, Viet Nam.

Duong, L.T., ND. Can, and T. T. Phan.2005. Current status of integrated crop-animal systems (ICAS) in Viet Nam: a case study in the Mekong Delta. In: Sombilla, M. A., B. Hardy, (eds). Integrated crop-animal systems in Southeast Asia: Current status and prospects. IRRI Limited Proceedings No.11. Los Banos, Philippines. Pp 46-62.

FAO. 2007. The future of large rice-based irrigation systems in Southeast Asia. In: Proceedings of the regional workshop on the future of large rice-based irrigation systems in Southeast Asia, Ho Chi Minh City, Viet Nam 26–28 October 2005. FAO, Bangkok, Thailand

Groenfeldt, d. 2006. Multifunctionality of agricultural water: Looking beyond food production and ecosystem services. Irrigation and drainage, 55: 73–83.

GSO. 2004. Statistical Yearbook 2004. Statistical Publishing House. General Statistic Office.

Hoanh, C.T., Facon, T., Thuon, T., Bastakoti, R.C., and Phengphaengsy, F. 2009. Irrigation in the Lower Mekong Basin countries: The beginning of a new era? In Molle *et al.* (eds) Contested Waterscapes in the Mekong Region: Hydropower, Livelihoods and Governance. Earthscan.

Hoi, Nguyen Thanh, *et al.* 2006. Study on some cultural methods on summer - autumn rice crop for increasing yields and reducing production costs in the Mekong Delta. Research study theme of the Ministry of Education and Training, Viet Nam. Code: B2003-31-73TD (in Vietnamese).

Huang, C. C., M. H. Tsai, W. T. Lin, Y. F. Ho, and C. H. Tan. 2006. Multifunctionality of paddy fields in Taiwan. Paddy Water Environ, 4:199–204.

Khoa, Le Van. 2002. Physical fertility of typical Mekong Delta Soils (Viet Nam) and Land Suitability Assessment for alternative crops with rice cultivation. PhD Thesis. Gent University, Belgium.

Khoa, Le Van. 2005. Rice production, actual soil productivity and agricultural potential in the mekong delta, Viet Nam. Scientific Paper. The Royal Academy of OverseasSciences, Belgium.

Kim, T-C, U-S Gim, J. S. Kim, and D-S Kim. 2006. The multi-functionality of paddy farming in Korea. Paddy Water Environ, 4:169–179.

Mastuno, Y., H. S. Ko, C. H. Tan, R. Barker, and G. Levine. 2002. Accounting of agricultural and nonagricultural impacts of irrigation and drainage systems: A study of multifunctionality in rice. Working Paper 43. Colombo, Sri Lanka: International Water Management Institute.

Masumoto, T., P. T. Hai, and K. Shimizu. 2008. Impact of paddy irrigation levels on floods and water use in the Mekong River basin. Hydrological Processes, 22:1321–1328.

Matsuno, Y., K. Nakamura, T. Masumoto, H. Matsui, T. Kato, and Y. Sato. Prospects for multifunctionality of paddy rice cultivation in Japan and other countries in monsoon Asia. Paddy Water Environ, 4:189–197.

Moreno-Black, G. 1991. Traditional Foods in Northeast Thailand: Environmental, Cultural and Economic Factors. Paper presented at the American Anthropological Association Meetings, Chicago 1991.

MRC. 2003. State of the Basin Report: 2003. Mekong River Commission, Phnom Penh, Cambodia.

OECD. 1998. Multifunctionality: a Framework for Policy Analysis. Directorate of Food, Agriculture and Fisheries, Committee for Agriculture: Paris.

OECD. 2001. Multifunctionality: Towards an Analytical Framework. Paris: Organization for Economic Cooperation and Development (OECD).

Pretty, J. 2003. The externalities and multifunctionality of agriculture. EuroChoices, 2 (3): 40-45.

Pretty, J., Brett, C., Gee, D., Hine, R., Mason, C., Morison, J., Rayment, R., Bijl, G. V. D., and Dobbs, T. 2001. Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture. Journal of Environmental Planning and Management, 44(2): 263–283.

Sajise, P. E., and A. U. Sajise. 2006. The ecological and economic aspects of the multifunctional role of agroecosystems. Asian Journal of Agriculture and Development, 3 (1): 59-68.

SOD. 2005. Statistical yearbook Dong Thap 2005. Statistical Office of Dong Thap Province.

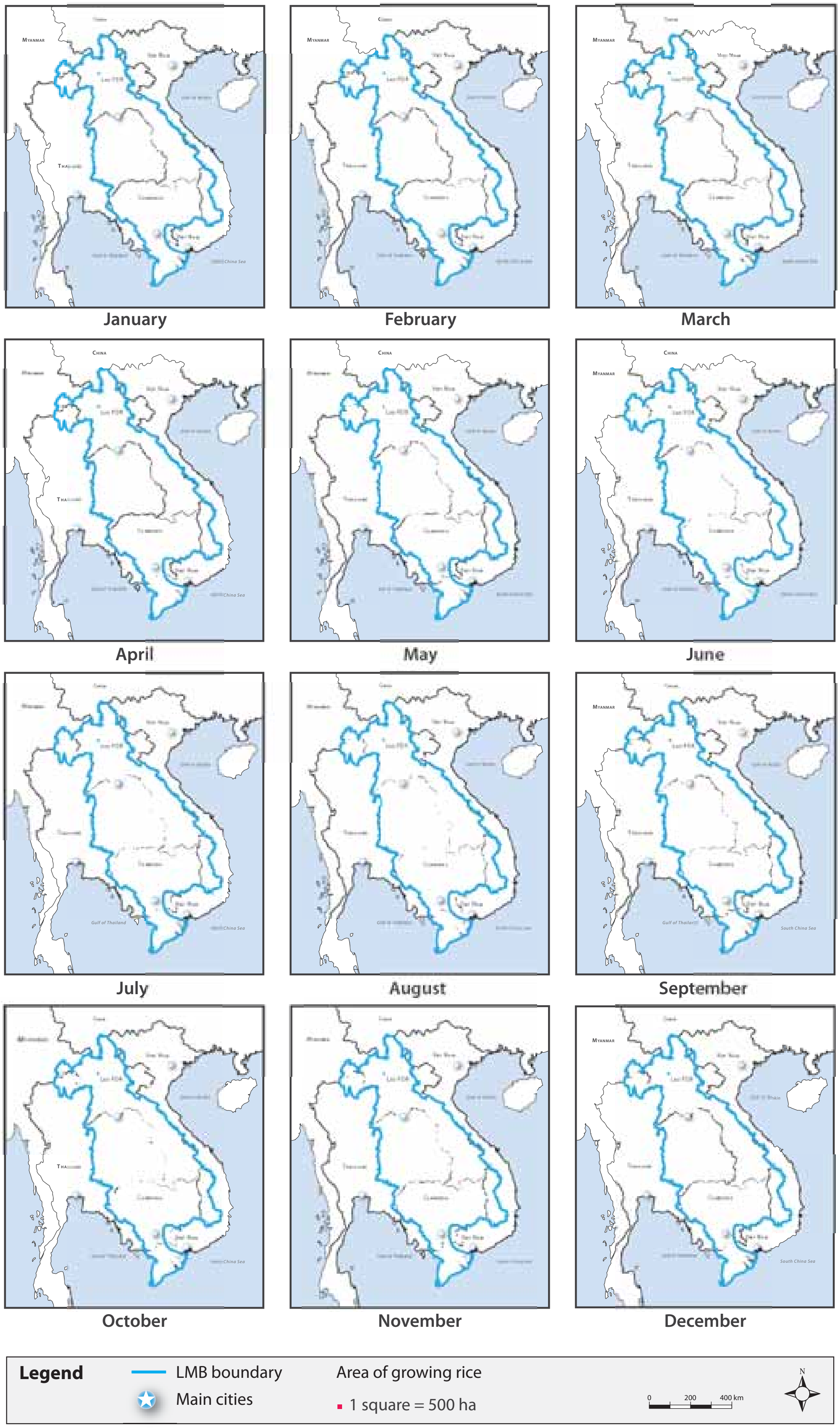
SOT. 2005. Statistical yearbook Tien Giang province 2005. Statistical Office of Tien Giang Province.

Appendix 1

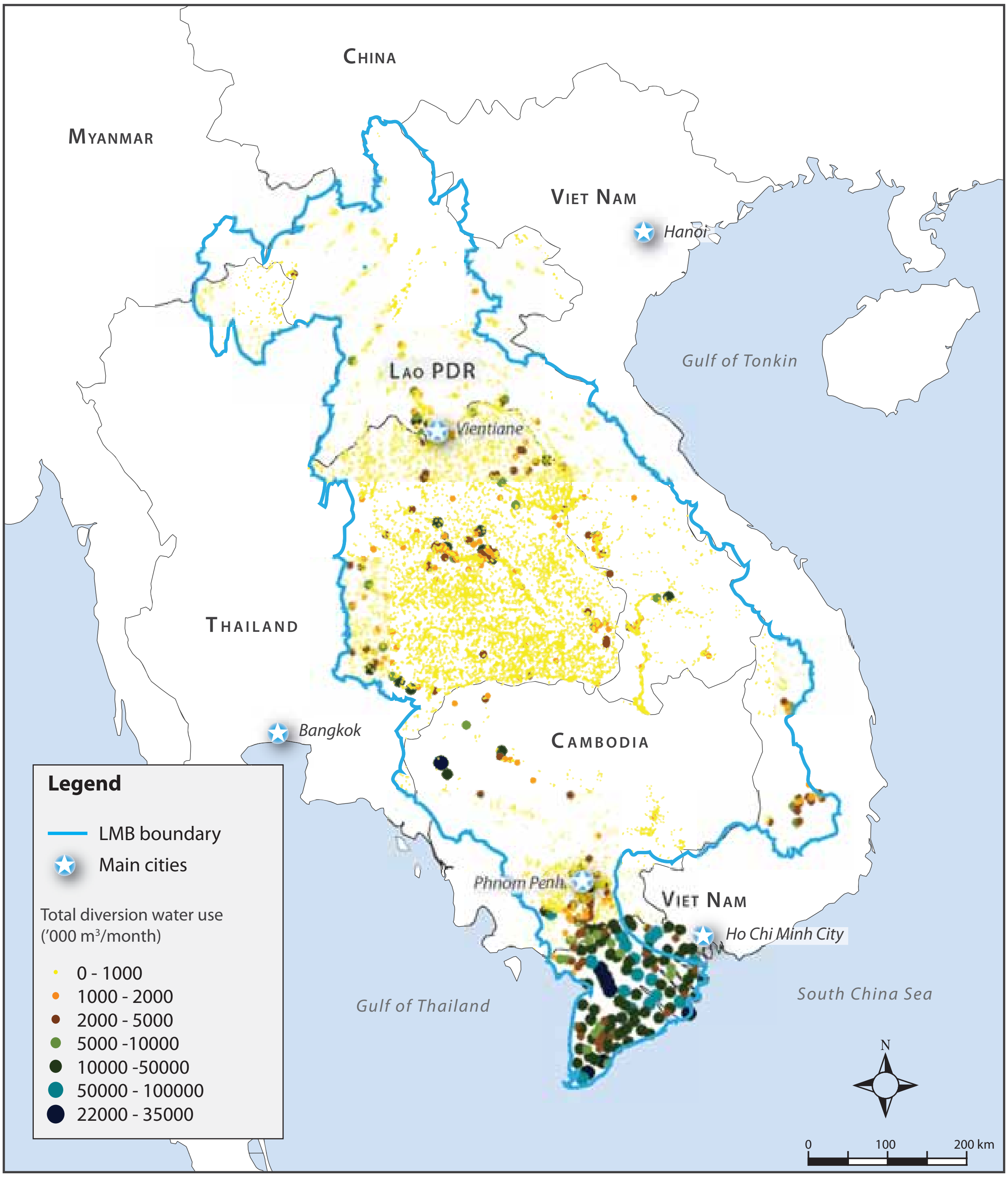
Table A1 *Total Estimated Net Water Use in the LMB region*

Month	Total Net Annual Irrigation Water Use (million m³)					
	Cambodia	Laos	Thailand	Viet Nam Delta	Viet Nam Highland	Total LMB
January	365	488	654	4,273	100	5,881
February	408	393	685	3,884	84	5,454
March	413	360	536	3,319	38	4,665
April	274	164	202	3,911	3	4,554
May	57	55	681	2,286	-	3,079
June	198	17	584	1,248	38	2,086
July	186	263	1,003	1,405	24	2,882
Aug	129	9	957	753	12	1,861
Sept	81	94	959	665	20	1,819
October	95	303	1,511	477	34	2,420
November	199	284	1,085	887	50	2,504
December	343	528	494	3,183	82	4,630
Total for Year	2749	2,957	9,352	26,291	485	41,835

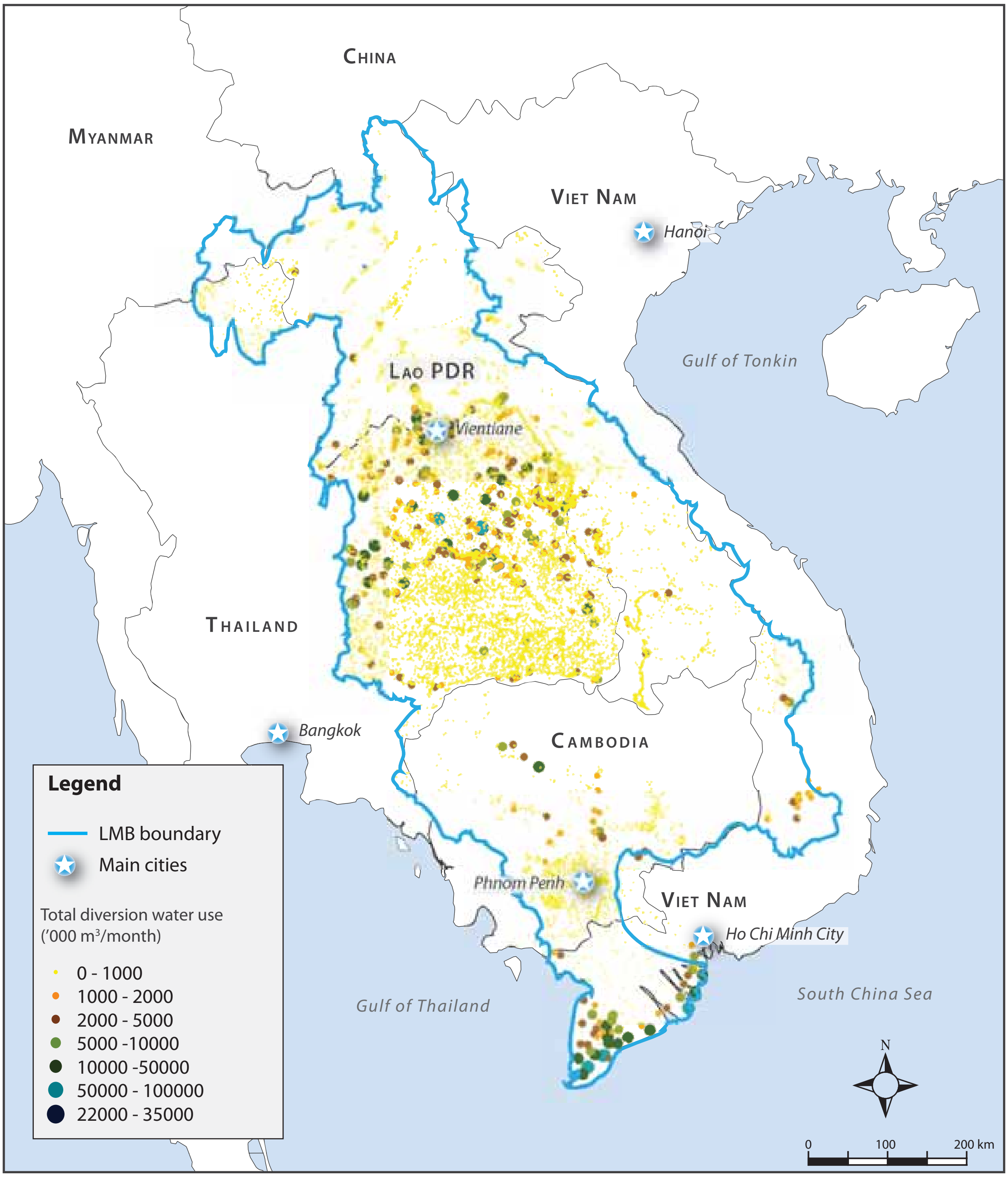
Appendix 2. Monthly changes of the rice planted area in the LMB region



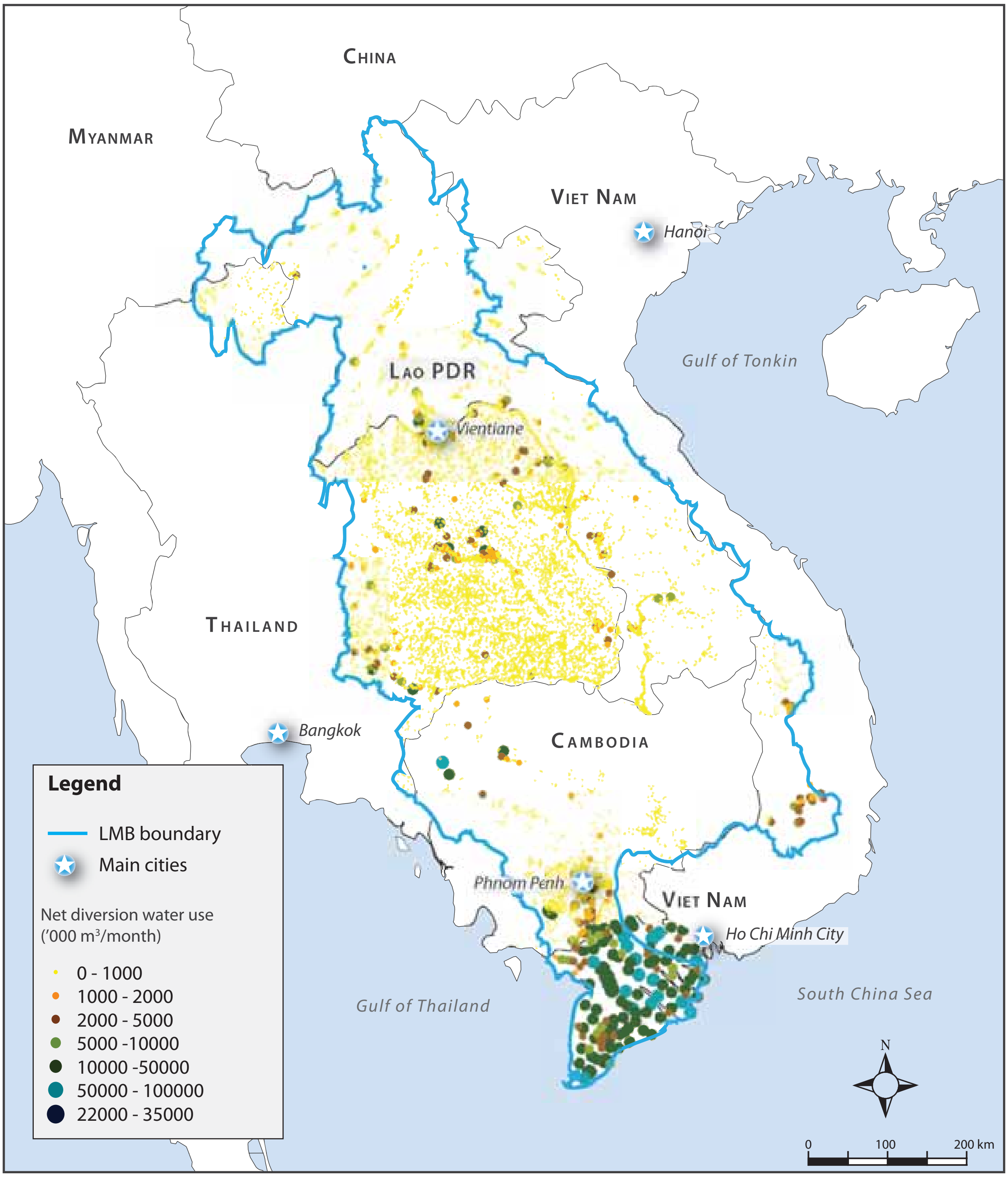
Appendix 3. Total diversion water use in the LMB region during the month of February



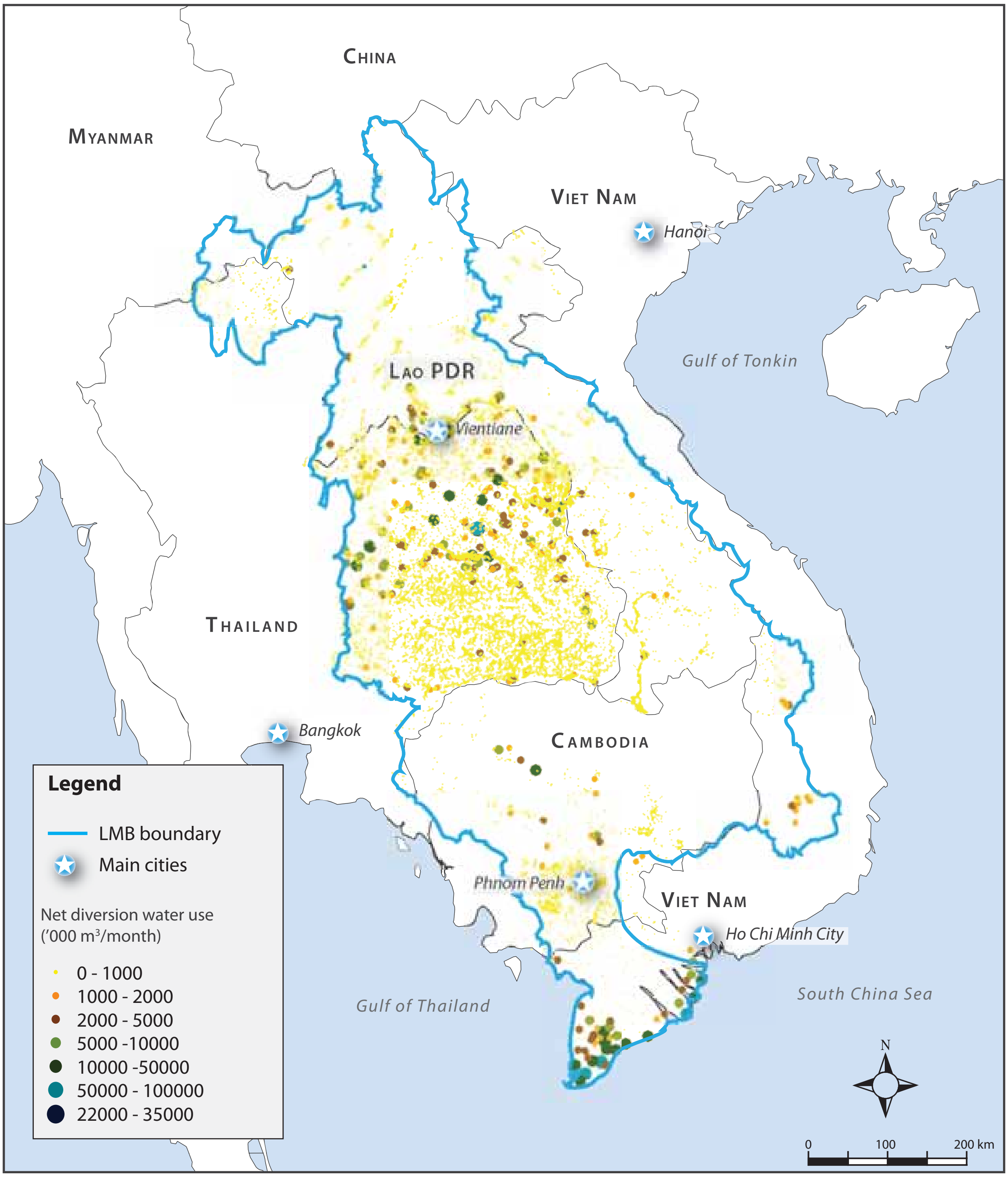
Appendix 4. Total diversion water use in the LMB region during the month of October



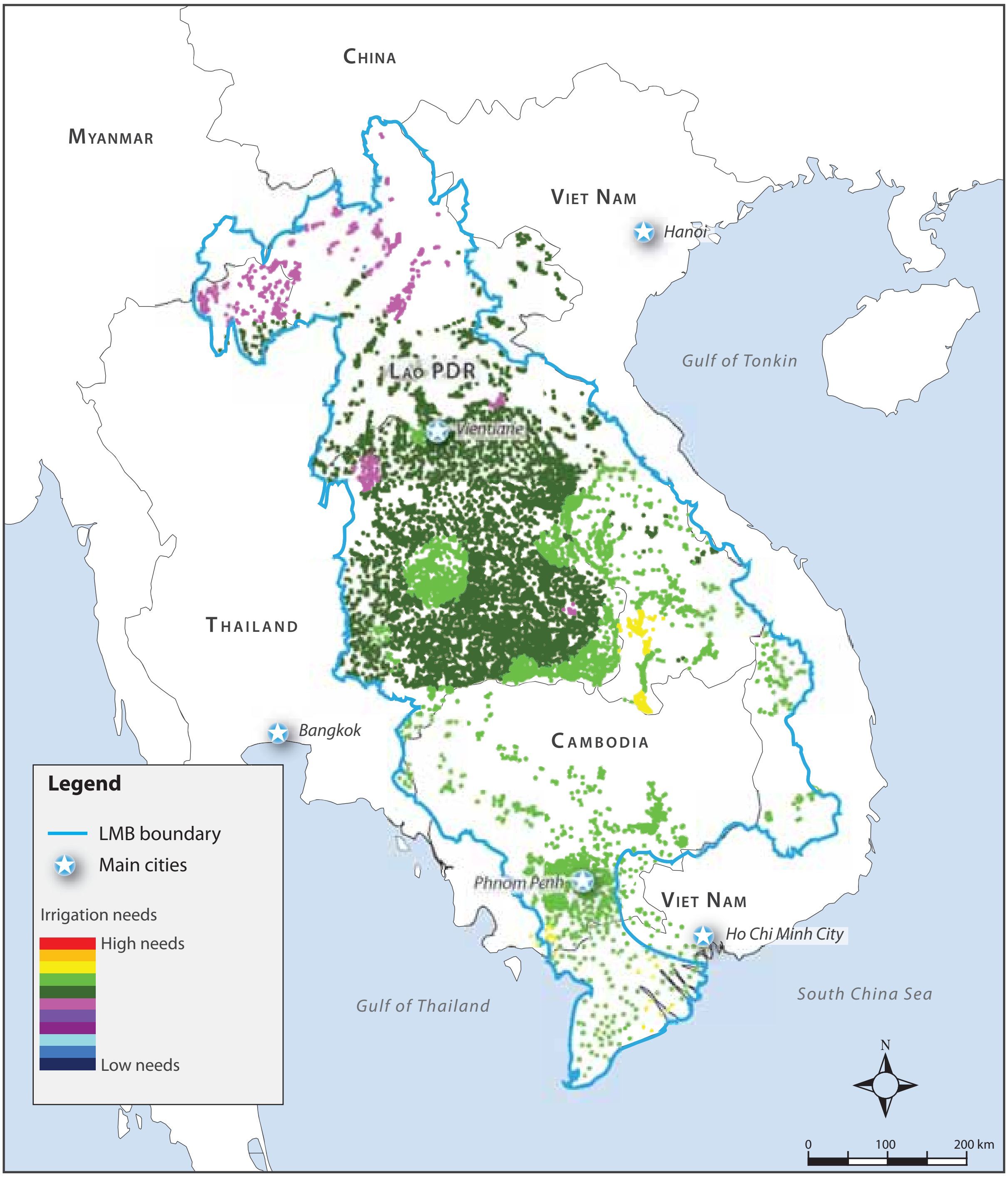
Appendix 5. Net diversion water use in the LMB region during the month of February



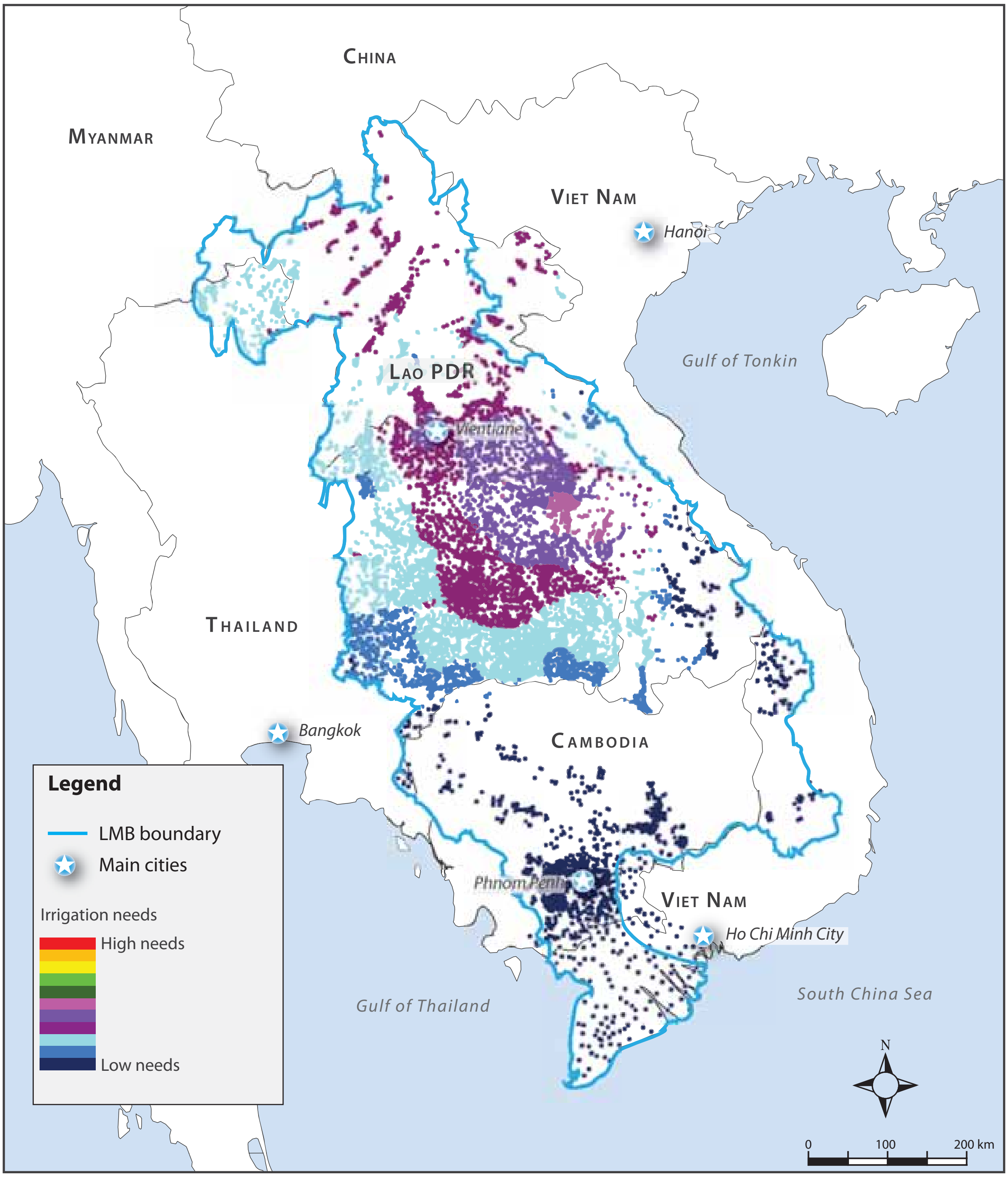
Appendix 6. Net diversion water use in the LMB region during the month of October



Appendix 7. Irrigation requirement (Eto-Effective rainfall) in the LMB region during the month of February



Appendix 8. Irrigation requirement (Eto-Effective rainfall) in the LMB region during the month of October



Some other papers in the MRC Technical Paper series:

MRC Technical Paper No. 11 Hydro-acoustic survey of deep pools in the Mekong River of southern Lao PDR and northern Cambodia.

MRC Technical Paper No. 12 Tagging Fish - a case study from the Tonle Sap, Cambodia.

MRC Technical Paper No. 13 Biomonitoring of the lower Mekong River and selected tributaries.

MRC Technical Paper No. 14 Fish Migration Triggers in the Mekong River and other freshwater tropical systems.

MRC Technical Paper No. 15 Diagnostic study of water quality in the Lower Mekong Basin.

MRC Technical Paper No. 16 Fish Consumption and the Yield of Fish and Other Aquatic Animals from the Lower Mekong River Basin.

MRC Technical Paper No. 17 Socio-economics of the fisheries of the lower Songkhram River Basin, northeast Thailand.

MRC Technical Paper No. 18 Yield and value of the wild fishery of rice fields in Battambang Province, near Tonle Sap Lake, Cambodia.

MRC Technical Paper No. 19 An Assessment of water quality in the Lower Mekong Basin.

MRC Technical Paper No. 20 Biomonitoring of the lower Mekong River and selected tributaries, 2004 – 2007.

MRC Technical Paper No. 21 Flood situation report, August 2008.

MRC Technical Paper No. 22 Report on the 2006 biomonitoring survey of the lower Mekong River and selected tributaries.

MRC Technical Paper No. 23 Report on the 2007 biomonitoring survey of the lower Mekong River and selected tributaries.

MRC Technical Paper No. 24 Adaptation to Climate Change in the Countries of the Lower Mekong Basin.

MRC Technical Paper No. 25 Report on the 2005 biomonitoring survey of the lower Mekong River and selected tributaries.

Mekong River Commission
P.O.Box 6101,Vientiane 01000,
Lao PDR.Telephone: (856) 21 263 263 Facsimile: (856) 21 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org