

© WWF-Canon/Elizabeth KEMF



Literature Analysis

Challenges to Sustainable Development in the Mekong Delta: Regional and National Policy Issues and Research Needs

Editors:

Tran Thanh Be, Bach Tan Sinh and Fiona Miller

Literature Analysis Challenges to Sustainable Development in the Mekong Delta: Regional and national policy issues and research needs

Tran Thanh Be, Bach Tan Sinh and Fiona Miller

The Sustainable Mekong Research Network





Publisher: The Sustainable Mekong Research Network (Sumernet)
Copyright: ©The Sustainable Mekong Research Network 2007

This publication may be reproduced in whole or in part and in any form of educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. Sumernet would appreciate receiving a copy of any publication that uses this publication as a source. No use of this publication may be made for resale or for other commercial purposes whatsoever without the prior permission in writing from Sumernet.

Editors: Tran Thanh Be, Bach Tan Sinh and Fiona Miller
Publishing coordinators: Dararat Weerapong and Tatirose Vijitpan
Designer: Pafon Next Step Company
Printer: Siam Tongkit Company
Available from: The Sumernet Secretariat
15th Floor, Witthyakit Building,
254, Chulalongkorn University
Chulalongkorn Soi 64, Phyathai Road
Pathumwan, Bangkok 10330 Thailand
Tel: +66 (0)2 2514415-8 Fax: +66 (0)2 2514419
www.sumernet.org

Table of Contents

	Page
Acknowledgement	4
Foreword	5
Christer Holstberg	
Preface	6
Johan Rockstrom	
Introduction	7
Tran Thanh Be, Bach Tan Sinh and Fiona Miller	
Chapter 1: Floods and Salinity Management in the Mekong Delta, Vietnam	15
Le Anh Tuan, Chu Thai Hoanh, Fiona Miller and Bach Tan Sinh	
Chapter 2: Livelihoods and Resource Use Strategies in the Mekong Delta	69
Nguyen Duy Can, Le Thanh Duong, Nguyen Van Sanh and Fiona Miller	
Chapter 3: Transboundary Challenges for Fisheries Policy in the Mekong Delta: Implications for Economic Growth and Food Security	99
Vo Thi Thanh Loc, Le Xuan Sinh and Simon Bush	
Chapter 4: Water Use and Competition in the Mekong Delta	143
Dang Kieu Nhan, Nguyen Van Be and Nguyen Hieu Trung	
Sustainability Challenges to Address in the Mekong Delta	189
Authors	193
Sumernet Partners	202

Acknowledgement

The editors of this publication would like to warmly thank Matthew Chadwick, Muanpong Juntopas, Dararat Weerapong, Tatirose Vijitpan and Marnie Graham of SEI for their assistance in the preparation of the manuscript. We would also like to acknowledge the professionalism of the authors of each chapter in working to tight deadlines and undertaking revisions of the chapters.

We also gratefully acknowledge the financial support of the Swedish International Development Agency (SIDA) and take this opportunity to state that whilst every effort has been made to ensure the accuracy of the information contained in this report whatever errors may remain are entirely the responsibility of the authors.

Tran Thanh Be, Bach Tan Sinh and Fiona Miller

November 2007

Foreword

This is the first of a series of publications which will examine the state of knowledge on specific regional sustainable development challenges facing the Mekong Region. The report includes an assessment of gaps in our understanding and an identification of further research needs. It also includes a number of concrete policy recommendations to governments, regional organisations and the societies at large.

The Mekong Region has since the beginning of the 1990s experienced a rapid economic and societal transformation fuelled by strong economic performance and helped by an extended period of relative peace. The population of the region has benefited from the economic development process. But the fruits of development have not been equally distributed. While the poverty rate has fallen, millions of people remain below the poverty line. It is also evident that rapid economic development is taking its toll on the natural resource base, upon which much of the economic development is dependent, casting doubts on the long term sustainability of the current development process. Increasing pressure on forest resources and competition over water, not least over the use of the Mekong River, is becoming accelerating. Economic integration, which has generally served the region well, also creates its own challenge. Cross-boundary demands give rise to both legal and illegal trade. With increasing mobility follows not only legal cross-boundary migration and but also increasing risks for trafficking. Climate change has only relatively recently materialised as another threat to continued development.

The countries on the Mekong River have a common history. They are also part of a shared regional ecosystem. What happens in one part of the system will have implications on other parts. This is particularly obvious with regard to the exploitation of the Mekong Region's water resources. The increasing regional competition over land resources is also becoming a cross-boundary concern. Despite the integration and inter-dependence among the countries across the region, national policy formulation is rarely reflecting transboundary dimensions of natural resource management and utilisation. Regional organisations are yet to be empowered to effectively address regional conflicts over natural resources. This is one of the main reasons behind the establishment of the Sumernet, which attempts to bring together a number of national research institutes and regional organisations to jointly address regional challenges over management and utilisation of common natural resources. Swedish Environmental Secretariat for Asia (SENSA) with financial support from Sida, is proud to be associated with this initiative.

It is my hope that the insights reflected in this and the forthcoming reports are discussed and seriously considered by decision makers in the governments, regional organisations, the research community and the civil society with the view to further sustainable development across the region. SENSA commit itself to ensure that the issues brought forward in this report (are brought) is being brought to the attention of decision makers across the region.

Allow me finally to congratulate the staff of the organisations behind this report for the hard work put in place to get it ready. My thanks go to Dr. Tran Thanh Be at the Mekong Delta Development Research Institute at Can Tho University, Dr Bach Tan Sinh at the Institute for Science and Technology Policy and Strategy Studies (NITSPASS) and Dr. Fiona Miller at Stockholm Environment Institute (SEI) and their colleagues. I must also take the opportunity to thank my friends at SEI-Asia, and in particular Ms Dararat Weerapong, Dr Matthew Chadwick, acting Director of SEI-Asia, Dr. Tariq Banuri, former Director of SEI-Asia, Ms Muanpong Juntopas and Ms Tatirose Vijitpan for making this great Sumernet idea a reality.

Christer Holtsberg
Director of Swedish Environmental Secretariat for Asia (SENSA)

Preface

The Sustainable Mekong Research Network or Sumernet is a network of 12 different institutions established in 2005. The network was the culmination of collaborative work and wider discussion based around increasing concern of the business-as-usual in policy analysis and advice. Such an approach has meant the intellectual community of the region have by in large remained rather isolated and consequently has also hampered the production of collective learning required to develop a coherent, sustained, and progressive vision for sustainable societies in the region. As succinctly described by one of the founders of Sumernet, this fragmentation and loss of capacity has particularly affected such longer term and emerging areas of concern as the environment.

The partner committed to collectively explore complex development issues in the region including amongst other things how the region is being transformed through the interactive impact of major drivers of regional change; what ecosystems, livelihoods and social groups are the most threatened by these transformations in the region, and what policy and management interventions hold greatest promise for addressing driving forces and impacts.

The result was the establishment of the “Sustainable Mekong” Programme and its related Sustainable Mekong Research Network or Sumernet. The network has an ambitious goal-to catalyse the transition to sustainability in the Mekong region. It seeks to achieve this through collaboration in policy research, network development, fundraising, outreach and dissemination, and capacity building. Clearly this in itself is unlikely to be sufficient but it is hoped that it will provide a guiding path for collaboration in research.

The network acknowledged that before it could begin the task of collectively developing such a vision they needed take stock, to develop a common, agreed state of knowledge on key issues for key areas of the Region. This report “Challenges to Sustainable Development in the Mekong Delta: A Regional Perspective on Policy Issues and Research Needs” represents one step in this process. It contains several papers drafted by partner organisations on key issues in the Mekong Delta. Each paper aims to provide a rapid assessment of the literature on a strategic issue, a bibliography, and a more detailed analysis of the topic, which would enable the addressing of regional issues and also help guide future collect research.

We hope that Sumernet publications such as this one generated by a regional research community will inform others and encourage and spur them to join us in building capacity to provide policy analysis and advice that brings us back on a path that leads towards a more Sustainable Mekong.

Support for the Sustainable Mekong programme, including the work and production costs involved in producing this publication, is provided by the Swedish International Development Agency (Sida), which the Stockholm Environment Institute and the other Sumernet partners greatly appreciate. However the views expressed in the publication do not necessarily reflect those of Sida.

*Johan Rockstrom
Executive Director
Stockholm Environment Institute*

Introduction



Tran Thanh Be, Bach Tan Sinh and Fiona Miller



1. Introduction

The purpose of this Report on conditions in the Mekong Delta, consisting of four detailed chapters that address flooding and salinity management, livelihoods and resource use strategies, fisheries policy, and competition for water use, is to set out the background to how a transition to sustainable development in the Mekong region might be achieved. Indeed, it is the purpose of the Sumernet Programme, under which these studies have been conducted, to catalyse this transition. The chapters presented here review the current state of knowledge on key challenges to sustainable development in this dynamic and productive, yet vulnerable, region of the Mekong Delta. From a national perspective the Mekong Delta is crucial to the economic development of Vietnam, in terms of rice, fruit and aquatic products, and for other natural resource-based livelihoods. From a regional perspective the delta is often perceived as vulnerable to the transboundary impacts of wider developments in the Mekong Basin. Livelihoods in the delta are strongly influenced by regional environmental processes, especially those concerning water resources, and are integrated into regional economies through trade relations. This report brings together an analysis of how livelihoods, economic development and natural resources management in the delta have been influenced by national policy changes, integration into the international market economy and concomitant regional processes to understand the current state of knowledge on key challenges for sustainable development.

Whilst the focus of the chapters is on the Vietnamese Mekong Delta, many of the issues analysed in this report are pertinent to other parts of the Mekong Region that confront similar sustainability challenges associated with intensification of resource use, competition over scarce resources, resource degradation, international commodity chains, trade networks, cooperation for natural resources use at multiple levels, decentralization, and vulnerability to natural hazards and environmental change.



2. Aims of the Report

The overall aims have been to:

- review and analyse existing literature to produce a “state of knowledge” on specific issues;
- identify where there is consensus; lack of consensus and why, on key issues;
- identify where there are information and knowledge gaps, with the aim of identifying topics to be addressed in future research;
- provide a “regional perspective on each issue”;
- make the policy linkages of each issue more explicit.

The chapters follow a very similar format, usually containing:

- a description of relevant geographical locations within the Mekong region;
- selected key issues for investigation;
- a survey of the current state of knowledge on these issues;
- conclusions on the issues selected;
- contested issues;
- research gaps and priorities;
- conclusions linked to policy formulation requirements:



3. Sumernet

The purpose of the Sumernet programme is to **catalyze the transition to sustainability in the Mekong region** through actions that will lead to the sustained production of independent, policy-relevant knowledge on key dimensions of sustainable development, especially on regional and transboundary issues. The particular vehicle for the programme is support for the Sustainable Mekong Research Network (Sumernet), an association of 12 research and policy institutions based in the Mekong region. The proposed programme comprises a combination of applied research, network development, fundraising, outreach and dissemination, and capacity building.

The ultimate aim of the programme therefore is squarely to contribute to the building of individual and collective capacities of the region-wide independent policy research community in the Mekong region. There are four key activity areas: applied research (on trans-boundary and regional issues); network development; outreach and dissemination (especially to a policy audience); and capacity building (including fundraising).

The purpose is to facilitate a more effective engagement of the network with key policy forums in the region as well as international expertise, research networks, global public policy networks, and networks and resources mobilized by SENSА.

4. Role of Policy Research

Policy research explicitly addresses recognised challenges for policy and problems affecting society at large, such as sustainable wealth creation, and poverty and vulnerability reduction. For policy research to effectively contribute to progressive change it needs to address problems that are relevant to particular policy or knowledge communities. As such, policy research is more likely to be successful when it is a result of a dialogue between researchers, policy makers and relevant community stakeholders, allowing for shared problem definition.

The term “knowledge community” refers to individuals who have an interest in particular policy domains despite differences in background, interests, or skills, and have the ability to produce knowledge relevant for solving problems in this domain. In the Mekong region, this community can broadly be categorized into three groups (though there is some overlap between them):

- *Civil society and non-government organisations*: e.g., research and advocacy NGOs, international organizations and public policy institutions and networks.
- *Academic and research institutions*: e.g., universities, independent research institutions, independent experts, the mass media, and research arms of government agencies, donor organizations and financial institutions.
- *Decision-makers*: i.e., government departments, regional agencies, donor organizations, the private sector and financial institutions.

The Mekong Region comprises a number of distinct cultural and political environments, with policy development occurring in quite different ways in each context and at different times. This reflects the constant negotiation of the different roles played by research community, civil society and government in the policy process, with the policy environment varying greatly from ones where a nascent civil society plays a growing role in policy review and development, as in Cambodia, to the situation of Thailand, where civil society's previously active role in policy is being rolled back as a result of military government. The situation of Laos, Vietnam and China is influenced greatly by their socialist governments; science and research are increasingly being considered as part of the policy process, and often through policy research civil society perspectives and experiences of policy can be documented and communicated.

In the Vietnamese context there are emerging opportunities for research to influence the development and review of policy. Independent research, as undertaken by universities and research institutes is increasingly being brought into the policy process through high-level workshops, assessments and reviews, commissioned studies, and education and training. Researchers also play a crucial role linking local community concerns with higher-level decision makers, through the use of participatory research methods. Such methods can also ensure rigour is brought into the research process.

5. Description of the Delta

The Vietnamese Mekong Delta forms the most downstream portion of the Mekong River basin. With a population of over 17 million inhabitants, some 21% of the national population, inhabiting an area of under 4 million hectares (12% of the country area) it is the most densely populated agrarian region within the basin.

Whilst cultivation in the Delta is a relatively recent practice, with wet season floating

rice cultivated prior to paddy rice, the delta has fast become the most important agricultural region for the country, contributing more than 50% of staple food crops and 60% of fish production in Vietnam, and it now contributes 27% of the total GDP of Vietnam. Besides rapid agricultural growth, the industrial sector has recently also grown rapidly, particularly in agro-processing and manufacturing.

With an area of 3.96 million ha, agricultural land use occupies 3.21 million ha, divided into 1.85 million ha for rice land, 0.22 million ha for fruit trees, 0.22 million ha for annual industrial crops, 0.63 million ha for aquaculture, and 0.39 million ha for forestry.

6. Regional context and linkages

A recognition that the delta is highly vulnerable to the impacts of upstream developments, especially dry season water diversions, water quality deterioration, and severe floods, has influenced the negotiation of regional policy agreements and cooperation between Vietnam and other riparian countries, especially within the Mekong River Commission.

The primary transboundary impacts posed to the delta are elaborated in the chapters in this report, highlighting in particular the transboundary nature of water and fisheries resources. Yet, developments in the delta, especially the infrastructure developments supporting the intensification of land and water resources, have created their own transboundary environmental impacts for countries upstream of the delta. Flood protection dykes in the upper delta have contributed to the banking up of floodwaters in the Cambodian part of the Vietnamese delta. Modification of the floodplain and the decline in wetlands, as well as the steady rise in the use of agrochemicals in the delta, has also contributed to a decline in fisheries, some of which are migratory.

Recent global climate change has contributed to changing flood regimes that go beyond the coping strategies of local communities.

The growing integration of the economies of the region has also contributed to a rise in cross-border trade and migration, especially between Vietnam and Cambodia.

7. Report Structure

The report has four chapters:

Chapter 1: Floods and Salinity Management in the Mekong Delta, Vietnam

Le Anh Tuan, Chu Thai Hoanh, Fiona Miller and Bach Tan Sinh

This chapter provides a literature review of the two main transboundary environmental problems confronting the people of the Mekong Delta: floods in the rainy season and salt water intrusion from the sea in the dry season. The local people have generally considered these as natural phenomena not disasters and tried to adapt their lives to them. The chapter describes the current state of knowledge on these phenomena and how approaches to their management have changed over time before concluding with some recommendations and the identification of research priorities.

Chapter 2: Livelihoods and Resource Use Strategies in the Mekong Delta

Nguyen Duy Can, Le Thanh Duong, Nguyen Van Sanh and Fiona Miller

This chapter provides a review of literature to assess changes in farmers livelihoods, resources-use strategies and the impact of government interventions, in order to identify research needs that can contribute to generating appropriate recommendations on resource use and livelihood development strategies. The chapter aims to outline how farmers deal with a very dynamic (natural, economic and policy) environment and goes on to generate strategic recommendations for water resources management, rural development and poverty reduction efforts.

Chapter 3: Transboundary Challenges for Fisheries Policy in the Mekong Delta: Implications for Economic Growth and Food Security

Vo Thi Thanh Loc, Le Xuan Sinh and Simon Bush

The overall objective of this chapter is to review the state of knowledge on fisheries in light of the transboundary nature of the Mekong Delta. By understanding the complex transboundary nature of natural resources, production systems and trade at national, regional and international scales the goal of the chapter is to identify gaps in fisheries policy that need to be addressed through future research in order to assist with the sustainable development of the fisheries sector. In order to systematically review the current knowledge on fisheries in the Delta the chapter focuses on literature and policies related to fisheries and aquaculture, trade and livelihoods. In doing so the aim is to:

- (i) assess the implications of national and international fisheries policy for the economy of the Mekong Delta;
- (ii) identify and elaborate on key transboundary challenges for fisheries;

(iii) assess the implications of national and international fisheries policy on food security, quality and safety in the Mekong Delta.

Chapter 4: Water Use and Competition in the Mekong Delta

Dang Kieu Nhan, Nguyen Van Be and Nguyen Hieu Trung

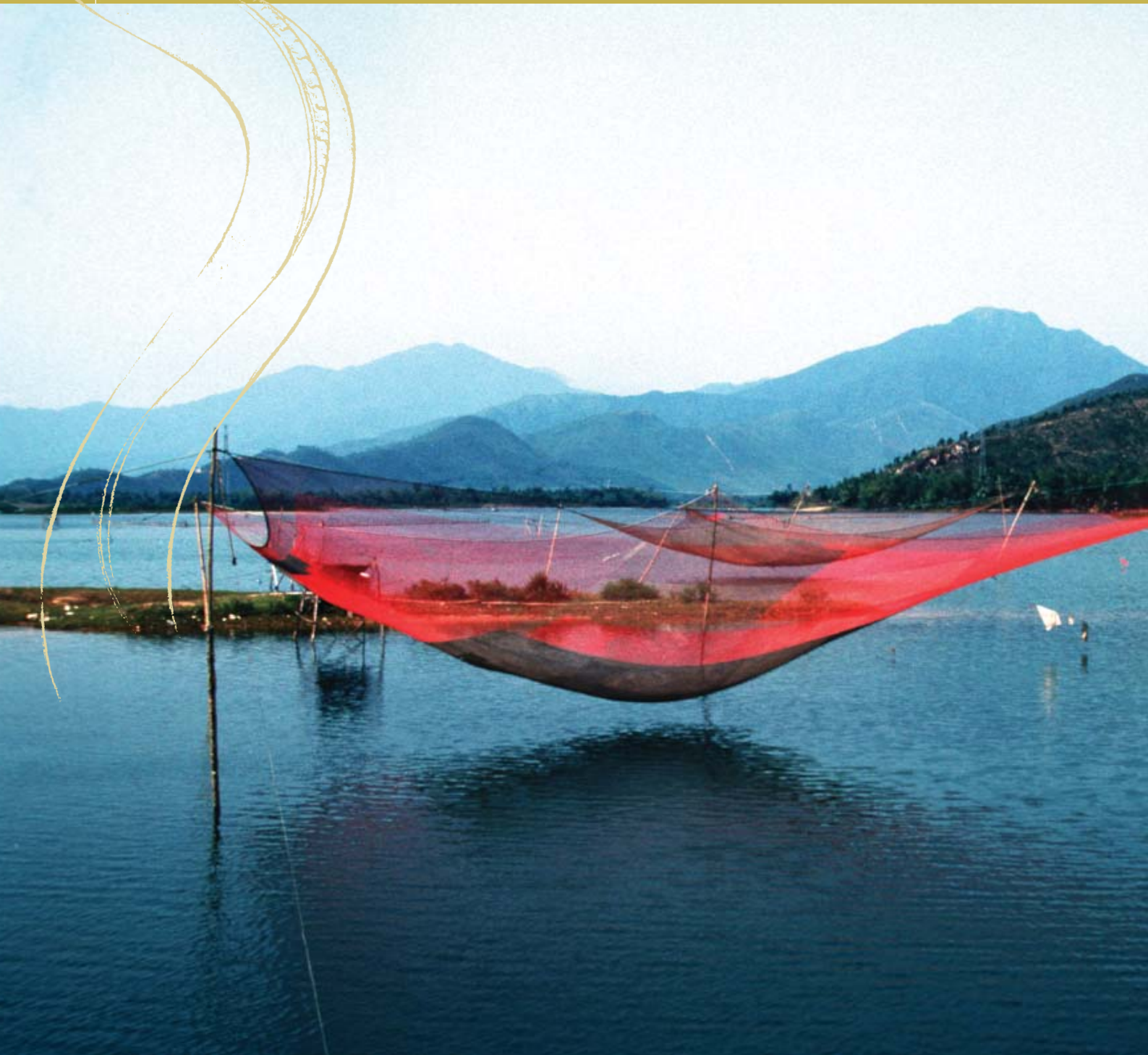
This chapter analyses water conflicts among water users in the Mekong Delta and identifies possible options to contribute to more efficient and equitable arrangements in the major agro-ecological zones of the delta. Special attention is paid to the impacts of the water demands of the current intensive rice farming and aquaculture practices. Impacts of the current intensive rice and aquaculture farming systems and institutional constraints on water access and sharing among different water users are identified in the three major agro-ecological zones of the Mekong delta:

- (i) upper irrigated,
- (ii) acid sulphate soil,
- (iii) downstream coastal zones. Possible solutions and constraints are analysed in each specific context for policy recommendations, and further investigations and recommendations are suggested to support policy-making for sustainable water resources management in the delta.

The report concludes with a brief section outlining the major sustainability challenges confronting the Mekong Delta. Key findings and research priorities coming out of the analysis contained in the report are discussed.

Chapter 1:

Flood and Salinity Management in the Mekong Delta, Vietnam



Le Anh Tuan¹, Chu Thai Hoanh², Fiona Miller³, Bach Tan Sinh⁴

¹*Department of Environmental and Water Resources Engineering, College of Technology,
Can Tho University, Vietnam. E-mail: latuan@ctu.edu.vn*

²*International Water Management Institute-SEA, Penang, Malaysia. E-mail: c.t.hoanh@CGIAR.ORG*

³*Risk, Livelihoods and Vulnerability Programme, Stockholm Environment Institute, Sweden.
Email: fiona.miller@sei.se*

⁴*Department of Science Policy Studies, National Institute for Science and Technology Policy and Strategy Studies,
Ministry of Science and Technology, Vietnam. Email: sinhanh@hn.vnn.vn*



Chapter 1 :

Flood and Salinity Management in the Mekong Delta, Vietnam

1. Introduction	18
1.1 The Mekong River Basin	18
1.2 The Mekong Delta in Vietnam	19
2. Key issues for investigation	25
3. Current knowledge	28
3.1. Floods in the Mekong Delta	28
3.1.1. State of the floods	28
3.1.2. Flood damages and benefits	33
3.2. Saline Intrusion in the Mekong Delta	39
3.2.1. The State of the saline intrusion	39
3.2.2. Positive and negative effects of saline intrusion	41
3.3. Flood and salinity management	42
3.3.1. Flood management	45
3.3.2. Salinity management	47
4. Major conclusions	48
5. Emerging issues and research priorities	49
6. Policy linkages	50
References	51
Appendix 1: The Mekong Delta flood damage	60
Appendix 2: Flood year 2000	62
Appendix 3: Water levels in the main branches of the Mekong	63
Appendix 4: Integrated water management projects	65
Appendix 5: Disaster and water management	67
Appendix 6: The major components of an early warning system	68



Abstract

The great variation in water flow of the Mekong River drives the productivity of the agro- and aqua-ecological systems of the basin, yet also forms a key constraint to intensive production systems. The Mekong River has special ecological and hydrological characteristics that are important to the riparian countries. Floods in the rainy season and salinity intrusion in the dry season form the two main physical problems for sustainable development of the Vietnam Mekong delta. The high floods, as in the year 2000, caused deep inundation and severe damage to infrastructure and production in the delta. Salinity intrusion, which is caused by sea water flowing inland when not enough fresh water flows to the estuaries, also causes problems for production and human health. However, people in the delta consider these processes to be normal natural phenomena and have generally adapted their lives to their presence. This paper offers an analysis of current state of knowledge of the subject drawn from a broad spectrum of nearly 100 publications. From this, the paper then identifies research gaps on floods and saline intrusion in the Mekong Delta to be undertaken in order to better inform a policy debate and decision-making on water resources management to ensure sustainable development and equitable management in the delta and Mekong Basin as a whole.



► Table 1 : Lower Mekong Mainstream mean annual flow (1960 to 2004) at selected sites

Mainstream Site	Catchment area (km ²)	Mean annual flow as			as % total Mekong
		Discharge (m ³ /s)	Volume (km ³)	Runoff (mm)	
Chiang Saen	189,000	2,700	85	450	19
Luang Prabang	268,000	3,900	123	460	27
Chiang Khan	292,000	4,200	133	460	29
Vientaine	299,000	4,400	139	460	30
Nongkhai	302,000	4,500	142	470	31
Nakhon Phanom	373,000	7,100	224	600	49
Mukdahan	391,000	7,600	240	610	53
Pakse	545,000	9,700	306	560	67
Stung Treng	635,000	13,100	413	650	90
Kratie	646,000	13,200	416	640	91
BASIN TOTAL	760,000	14,500	457	600	100

(Source: MRC, 2005b)

1.2 The Mekong Delta in Vietnam

The Mekong Delta section of the delta in Vietnam is the last country through which the Mekong River reaches out into the East Sea. The catchment area of the Mekong River Basin in Vietnam is 65,000 km² (20% of total Vietnamese area). The delta has four million hectares of cultivable land for nearly 18 million of Vietnam inhabitants (about 22% of the whole population of the country). Actually, the Mekong Delta represents a great potential for agriculture and aquaculture production.

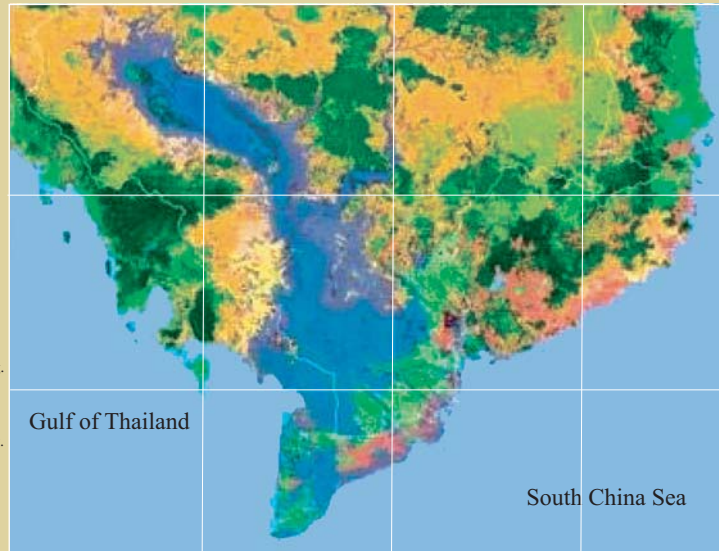
The river network of the Mekong as it reaches the Delta is rather complicated with 9 estuaries and a dense canal network. The Mekong meets Tonle Sap River west of Phnom Penh, then splits into the Tien and Hau Rivers. The Mekong then flows across the border of Vietnam. Especially from the Tonle Sap River in Cambodia to the East Sea of Vietnam, the Delta is covered mostly with water in the flood season (**Figure 2**). The Tien River branches into six tributaries and the Hau River into three tributaries and together they form what is called in the Vietnamese language the “Nine Dragons” (Cuu Long). This is shown in **Figures 3** and **4**. The River discharge at Tan Chau is 3-5 times larger than that of Chau Doc (Nguyen, 2006). The Vam Nao, connecting river 20 km downstream of Tan Chau and Chau Doc, conveys water from the Tien River to the Hau River, augmenting flow downstream of this point.

The Mekong Delta comprises a vast flood plain with an elevation of 0-4 m above mean sea level. It is formed of eroded sediments from the upper basin that are deposited in the lower basin (Fedra, 1991). There is an extensive network of canals that has been constructed in the last 300 years. The structures comprise 7,000 km of main canals, 4,000 km of secondary canals on-farm systems, and more than 20,000 km of protection dykes to prevent early floods (MARD, 2003).

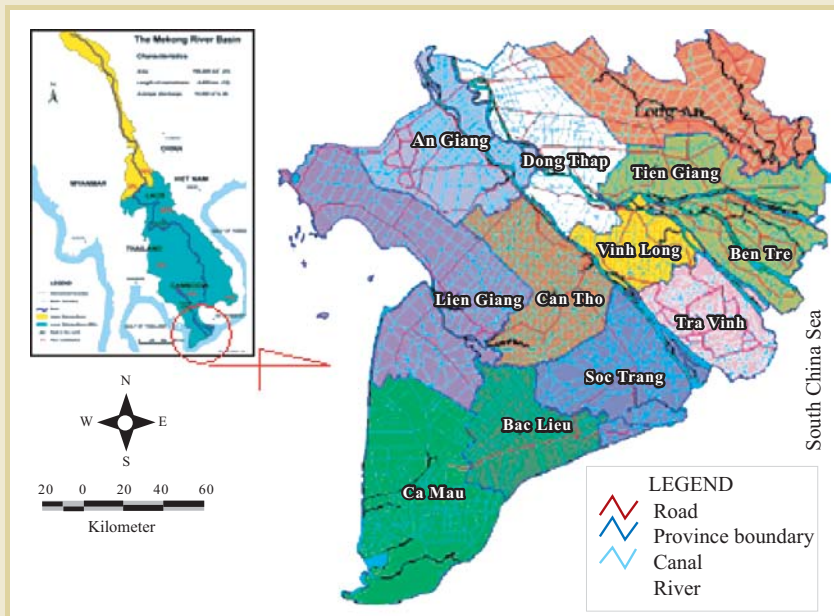
Land Map of Cambodia and the South of Vietnam

Legend

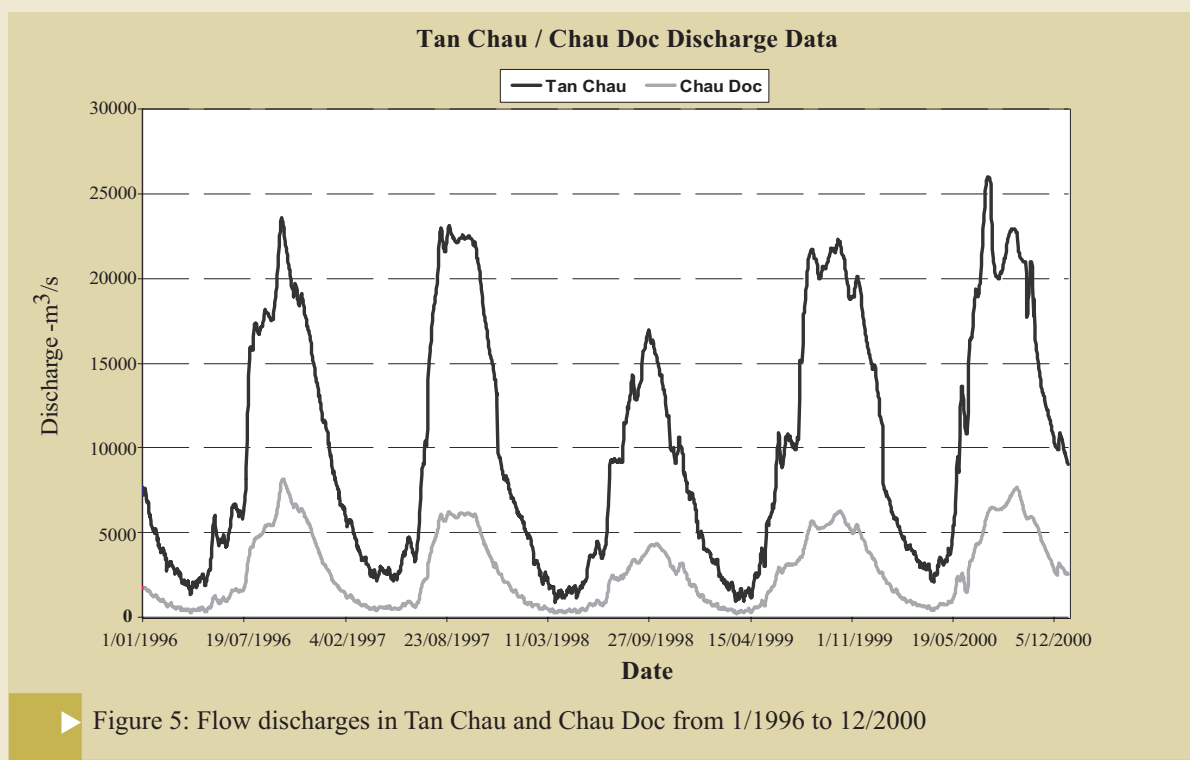
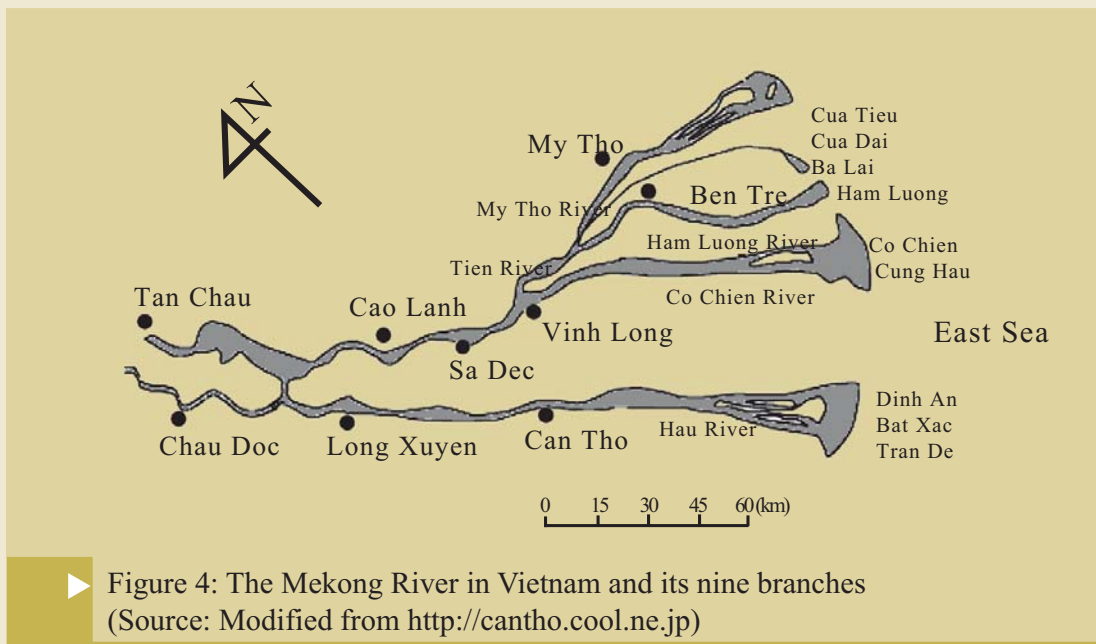
- Thick Forest
- Secondary Forest
- Forest Under Smoke
- Scrubland - High land
- Scrubland - Low land
- Settlement - Scrubland
- Settlement - Low Veg.
- Settlement - Mixed Veg.
- City - Cleared Area
- Paddy
- Paddy + Other Crops.
- Paddy - Crops. - M. Veg.
- Water | Sea
- Cloud
- Flooded regions (Accumulated from 1999 to 2005)



► Figure 2: The Mekong River from Cambodia to South China Sea (Source: Modified from UNU, 2006)



► Figure 3: Mekong Delta in Vietnam and provinces coverage



In 2000, agriculture occupied 85% of the total area of the Mekong Delta. In the past 20 years, the area of cultivable land has grown rapidly, aided by the expansion and increased density of the irrigation and drainage canals system. Since 1976 to 1990, agricultural areas in the Delta increased by approximately 20%, whilst total production doubled (Hoanh, 2003). Rice cultivation areas have increased yearly by more than 100,000 ha during the period 1995 -1999 (Tuan, 2004a). In 1993, the delta had 2.4 million hectares of rice cultivation, representing about 50% of the paddy production in Vietnam (NEDECO, 1993). The area under rice cultivation has increased from 3,210,800 ha in 1995 to 3,861,200 ha in 2005. Meanwhile the rice crop yield has increased from 12,831,700 tons to 19,298,500 tons in 2003 (Vietnam General Statistics Office, 2007). In 1985, Vietnam was still a net rice importing country, but in 1989, it exported 1.4 million tons of rice and the export amount was highest in 1999 with 4.6 million tons. The Mekong Delta distributes more than 90% of rice exported from Vietnam.

The life of Vietnamese is linked with water bodies as typical rice-water agriculture is practised. Irrigation and drainage systems have been usually built anywhere that Vietnamese communities live. Historically, the delta was sparsely populated before large scale settlement by the Vietnamese began 300 years ago. In 1818, the Mandarin Nguyen Van Thoai received an order from the King Nguyen to construct a canal from Long Xuyen to Rach Gia (Brocheux, 1995). The study by Biggs (2004) of the hydraulic history in the delta discusses how the first canals were built from 1820. In the late 19th century to early 20th century, the French continued to construct a large-scale canal network (Cho Gao Canal, Xa No Canal) through dredging and settlement measures. In addition, many water control projects were constructed by central government from 1975 onwards. These include floodgates, saline protection dams and dykes, sluices, and pumping stations. Channel density is about 20 - 30 m/ha and the channel area occupies 9% of the delta area (An, 2002). Presently, the interlacing rivers and dredged canals have been connected together with a total length approaching 5,000 km (Ministry of Transportation, 1993). In fact, the waterways within the MD have formed a unique hydrological system. This can be seen as boats can transport from the Long Xuyen Quadrangle to the Ben Tre Estuaries or from the Plain of Reeds to the Ca Mau Peninsula and the Gulf of Thailand.

The Delta's total population is estimated at nearly 18 million people (in 2006) who contribute more than 50% of the staple food and 60% of the fish-shrimp production of Vietnam (Minh, 2000). Normally, the population settled along the river and canal levees, creating the River-Water Civilization (*Van minh Song Nuoc*). Traditional ways of life are based on intensive river water use, from transportation and commerce to irrigation, aquaculture, and fishing and to domestic and industrial uses. Almost all the

delta people's activities and infrastructure are highly dependent on the river water regime. Mekong Delta farmers are very adaptable to the changes in water regime and apply sustainable production techniques. Compared with other Asian countries (Middle Asia, North-East Asia regions) annual average runoff volume per capita representing the water resource in the Mekong Delta is very high, at least four times that in other regions, and according to data recorded in 1990, this was about 35, 000 m³/capita (Can, 2000).

Each year, from July to December, a large part of the delta is inundated from both the overflow from the Mekong River and local rainfall. Due to the effect of the tropical monsoon, flood flows are about 25-30 times greater than dry season flows which occur between March and April (Ojendal, 2000). In the North West of the Mekong Delta, approximately 200-250 km from the East Sea, the Long Xuyen Quadrangle (covering mostly An Giang province) and the Plain of Reeds (Dong Thap and Long An provinces) have poorly drained depression areas with inundation lasting up to 4-6 months. In the dry season, the low discharge of the Mekong River combines together with the lower groundwater table leading to serious shortages of fresh water for rice cultivation and domestic drinking water. The big expansion of dry season rice in the last 15 years (now dry season rice in Mekong Delta is reaching 3.8 million ha - more than three times than other Lower Mekong Basin countries combined) contributes to water shortage - and induces more saline intrusion. Closer to the East Sea, the river width gradually expands and its flow velocity decreases progressively. Saline water from the East Sea and the Gulf of Thailand flows into the mainstream and the canal network covers a wide area in the coastal zone that is largest at high tide. The saline affected area expands throughout the Mekong Delta in two main zones: (i) the Eastern coastal zone running from Vam Co River through the Hau River, with an affected total area of 780,000 hectares; and (ii) the Ca Mau peninsula with 1.26 million hectares (CTU and DANIDA, 1996) that constitute one-third to a half of the total cultivable land of the delta.

The goal of this paper is to review and analyse, from a great number of publications on the subject, the current state of knowledge on flood and salinity intrusion in the Mekong Delta including establishing the causes, and the effect of its extent and the trends that experts have agreed upon to date. It also summarises the measures and responses to flood and salinity, identifies what has been effective and what has not, as well as the reasons behind this. Finally, the paper aims to identify critical research areas that might help to inform planning and decision-making for more effective prevention and mitigation of flooding and salinity intrusion in the delta.

The specific objectives are as follows:

Review and analyse the existing research and establish points of agreement and contentious issues on:

- Causes of flooding and salinity: both on-site and the upstream-downstream relations of the Mekong;
- Effects of flooding and saline intrusion; the extent and scale of these two phenomena by quantifying costs and benefits in terms of economic, social and environmental factors;
- Trends of flood and salinity intrusion in the delta, especially in the last two decades: is it improving or deteriorating, and why?

Summarize and synthesize the preventive, interceptive and remedial measures used to date by various actors to determine which have been effective and why:

- Summarize measures (structural and non-structural) to control flooding and saline intrusion, including adaptation measures taken by people;
- Review and analyze, from available literature, the effects of the water control projects and government strategies and policies in managing water in the Mekong Delta;
- Identify outstanding questions and contested issues; and,
- Provide recommendations for a future research plan.

The method employed in this paper is:

- (i) to synthesize existing hydrological data, status maps, social-economic reports and technical documents through a detailed literature review;
- (ii) to analyze flood and salinity characteristics mainly in Long Xuyen, Dong, Tra Vinh province and Ca Mau peninsula; including subsequent response measures and their effectiveness to date; and,
- (iii) to identify research gaps.

2. Key issues for investigation

In many river basins around the world, how to manage water efficiently whilst maintaining the natural resource base is one of the most important factors influencing regional sustainable development. During the last three decades, many water control works have been invested in the Mekong Delta for crop irrigation, flood drainage, saline prevent and soil improvement. Annually, about 10 percent of the state budget, as well as labour contributed by the people, is used for irrigation development (Tu, 2002). However, these water control infrastructure systems suffer from many shortcomings and challenges in terms of both their structure and management. These are elaborated on in this section.

Generally, there are two water quantity problems and three main water quality problems that are the principal limiting factors of agricultural production and these also influence human health in the delta (Tuan, 2004b):

1. *Salinity intrusion*: About 2.1 million hectares of the Mekong Delta coastal areas (50%) are affected by salinity during the dry season (from December to May).

2. *Floods*: Discharge of the Mekong River during the wet season averages 39,000 m³/sec. High flow rate from upstream combined with high rainfall and high tidal levels from the sea simultaneously lead to high floods in the Mekong Delta. About 1.2 - 1.9 million hectares of the south-western part of the Delta is under annual flood.

3. *Acid sulphate soils (ASS)*: Large areas of Long Xuyen Quadrangle and the Plain of Reeds and other scattered lands have soils with high iron sulphide content, covering 1.6 million hectares (40%) of the Mekong Delta. Floods can transport toxic water from ASS areas to other non-ASS areas (see paper 5 in this monograph for further discussion).

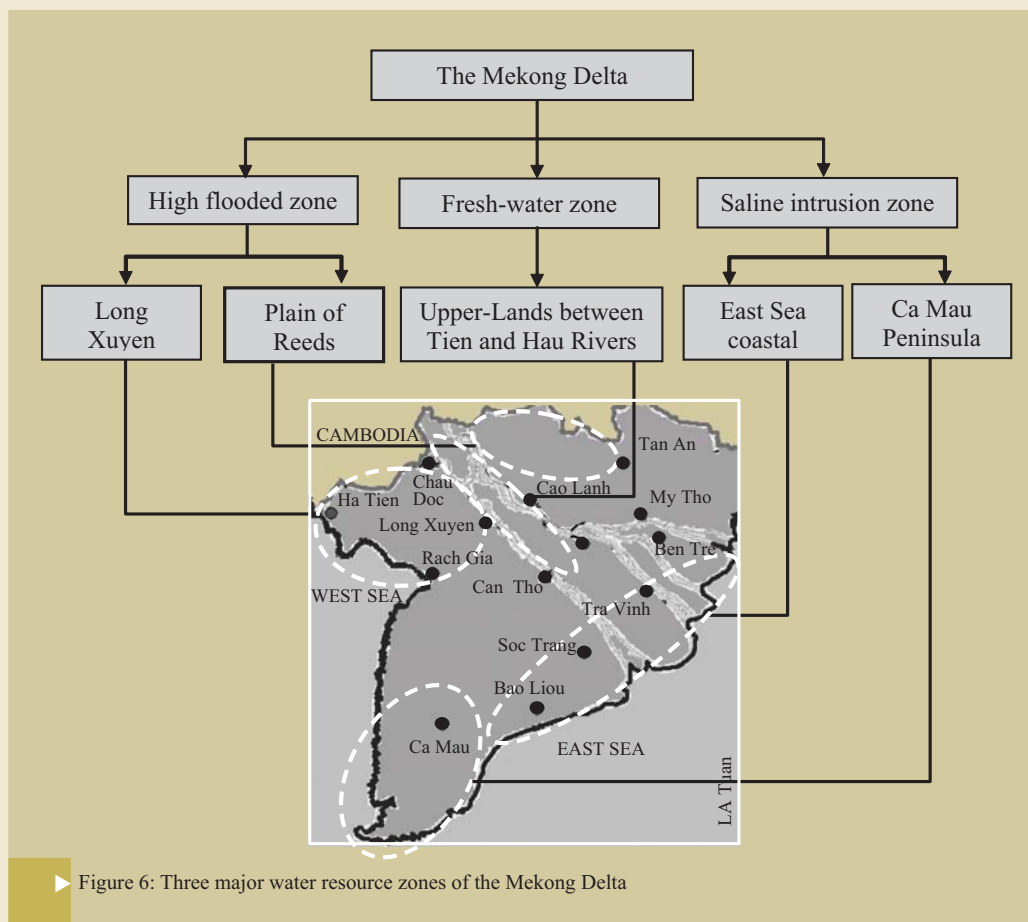
4. *Polluted water*: The Mekong River is facing more and more water pollution from agricultural and industrial chemicals and domestic untreated wastewater. In some places, the polluted water is seriously threatening public health and socio-economic development.

5. *Fresh water shortages*: In the dry season, the average discharge of the Mekong River is under 2,500 m³/s, and even as low as 1,700 m³/s, with the groundwater table lowering by 2 - 3 m in some places. Water scarcity for irrigation affects nearly 1.5 million hectares of cultivable land in the dry season.

This paper sets out to review and analyze publications written on the first two subjects in order to establish the current knowledge. The paper will thereby at the end of the review, suggest new areas of knowledge to study in order to clarify issues around them and to supply better information to decision-makers for better water management and sustainable development in the delta.

Actions within the delta, as well as upstream of the delta, influence the severity of the above problems. Whilst floods and salinity intrusion are identified as the main water (quality and quantity) problems limiting socio-economic development in the delta, they are not considered as serious hazards by most people in the delta. These include not only residents who live in the towns and cities but also farmers who cultivate rice or shrimp in rural areas. The dynamics of flooding and salinity have a close relationship with changes in other water problems, such as runoff from acid sulphate soils, freshwater scarcity and polluted water. Floods may transport and distribute acidity from ASS lands and pollutants from industrial and urban areas downstream (White, 2002; Tuong and Minh, 1995).

Based on the natural conditions, the Vietnam Mekong Delta can be divided into three major water resource zones (**Figure 6**):



In the Vietnamese language people distinguish between several kinds of floods: *lu* (flood), *lut* (inundation) and *ngap* (submergence). *Flood* occurs when excess water upstream flows over river banks or dykes to the floodplain. *Inundation* is affected by floods. *Submergence* is a phenomenon that occurs when water levels in the plain (fields or land of the inner dyke or depression areas or wetlands) are higher than the ground surface level, at a certain period. Submergence may be caused by high floods and/or heavy rainfall and/or a strong tide or uprising groundwater. Flood water may be freshwater from upstream or saltwater from the sea due to the tide. The word *bao lu* (storm-flood) refers to a serious disaster when the basin is affected by strong storms and continuous heavy rainfall. Storm-floods frequently occur in North and Central Vietnam, but rarely in the South.

Historically, till the present time, people in the Mekong Delta call the yearly September-October flood period *mua nuoc noi* (water rising season), and *Nuoc son* (reddish water) referring to the water colour of heavily silt-laden water from upstream. *Nuoc bac* (silver water) refers to greenish and transparent water that flows from fields with acid surface soils.

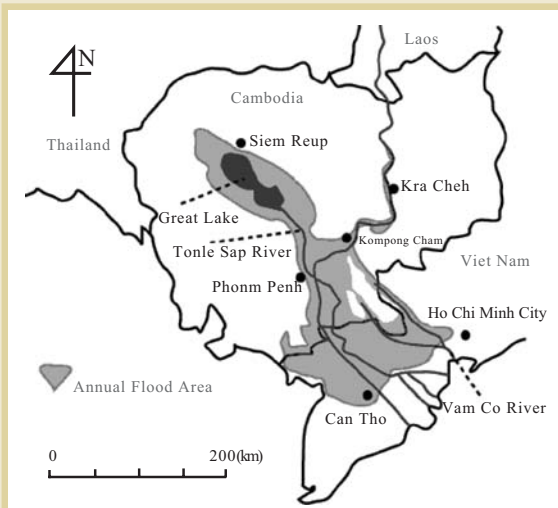
3. Current knowledge

3.1. Floods in the Mekong Delta

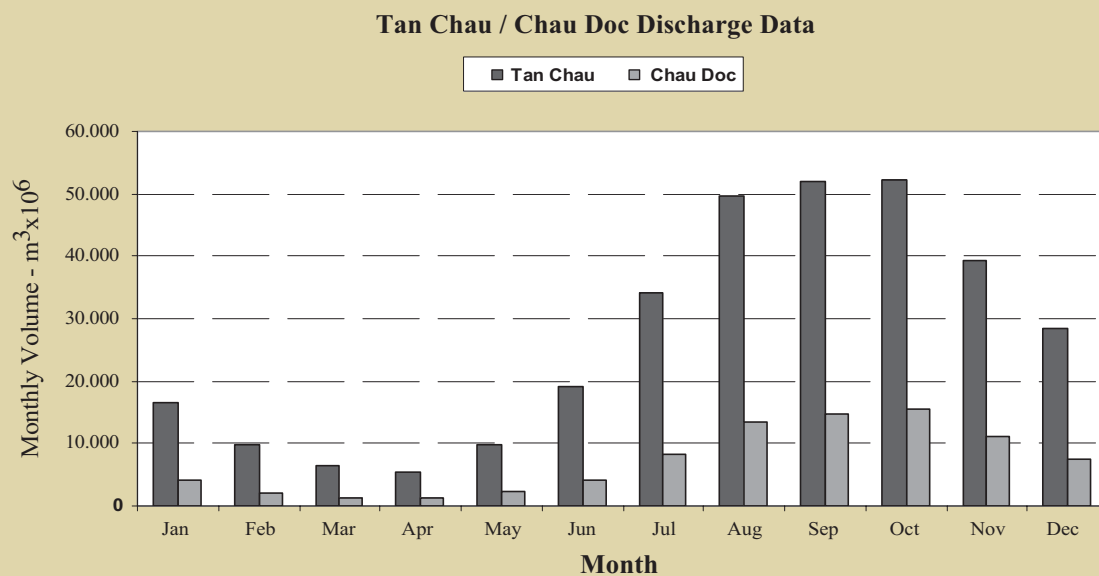
3.1.1. State of the Floods

Excessive flooding is a worldwide problem which in many countries results in severe loss of life and extensive damage to infrastructure and agricultural production (FAO, 1998). In the Mekong delta, annual floods are always a part of the life of nature and people. Due to its location in the most downstream part of the basin, the Mekong Delta receives the total volume of floodwaters from upstream. A vast plain, mainly in the northern parts of the Mekong Delta, is affected by annual flooding by overflows from the river and overland from Cambodia across the Vietnam border (**Figure 7**). Long Xuyen Quadrangle (An Giang and Kien Giang provinces) and the Plain of Reeds (Dong Thap and Long An provinces) are damaged by flood from July to December.

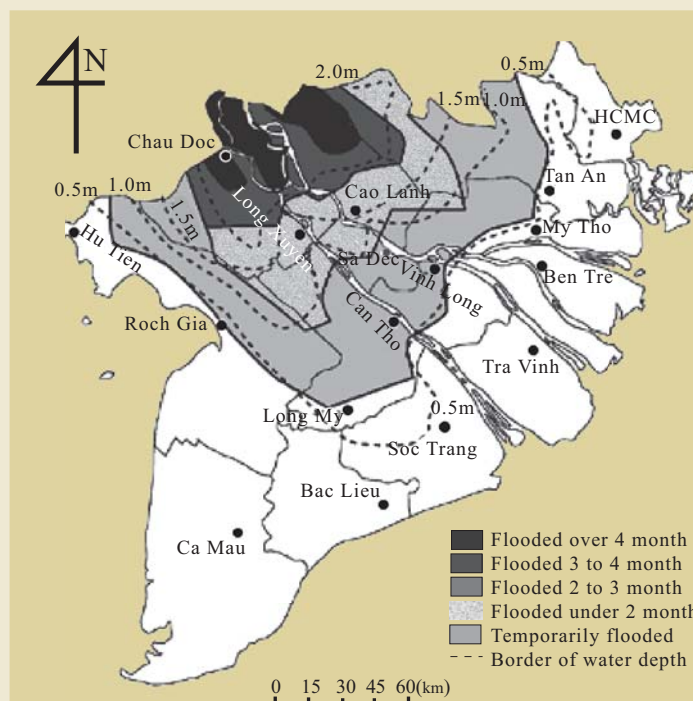
The flooded area ranges from 1.2 to 1.4 million ha in years of low and medium flooding, and around 1.9 million ha in years of high flooding (SRV, 2005). The flood season in the delta starts from July, increases gradually in August-September, and peaks in October before falling in November (**Figure 8**). **Figure 9** shows the flooded area, the depth and duration in the Mekong Delta. Combined with the flood season in the Mekong Delta, the weather situation in Central Vietnam is characterized by wind storms, heavy rains or low atmospheric pressure. About 50 percent of the Mekong delta experiences flooding and these areas are also susceptible to serious damage by floods about every five years (Sneddon et al, 2001). In general, floods in the delta have low discharge capacity; however, they cause prolonged deep inundation, river bank erosion, and transportation difficulties (SRV, 2005).



► Figure 7: Flood area in Cambodia and the Mekong Delta (Source: Yamashita, 2005)



► Figure 8: Monthly mean flow volume in Tan Chau and Chau Doc (1996-2000)



► Figure 9: Flood inundation in the Mekong Delta (Source: Yamashita, 2005)

Based on the peak water level at Tan Chau Gauging Station of An Giang province in 1978, the General Department of Meteorology and Hydrometeorology of Vietnam distinguishes three flood warning levels, as outlined in **Table 2**. However, hydrologists consider that a **low** flood occurs when the flood peak in Tan Chau is less than 4.0 m, **moderate** floods occur when the flood peak is between 4.0 and 4.5 m, and **high** floods occur when the flood peak is more than 4.5 m.

High floods are caused when three simultaneous factors happen: large water discharges occur originating from upstream as affected by typhoons or tropical low pressures; long and heavy rainfall occurs in the Mekong Delta itself; and, high tides that lead to high water levels in the rivers and canal system prevent easy drainage.

► Table 2: Warning Water Levels (in m) for flood events in the Mekong Delta

Levels	Gauging Station		Descriptions
	Tan Chau (Tien River)	Chau Doc (Hau River)	
I	≤ 3.0	≤ 2.5	Possible flood condition - River water level is high; threat to low height embankments; flooding of very low lying areas; infrastructure safe.
II	≤ 3.6	≤ 3.0	Dangerous flood condition - Flood plain inundation expected; towns and cities still generally protected by flood defences; high velocity river flows pose danger of bank and dyke erosion; bridge foundations at risk from scour; infrastructure generally safe.
III	≤ 4.2	≤ 3.5	Very dangerous flood condition - All low lying areas submerged, including low lying areas of cities and towns; safety of River protection dykes in jeopardy; damage to infrastructure begins.
Over III	> 4.2	> 3.5	Emergency flood condition - General and wide spread uncontrollable flooding; dyke failure a certainty and probably uncontrollable; damage to infrastructure severe.

In the 20th century the Delta had 11 very high floods recorded as equal to or higher than 4.50 m above mean sea level (MSL) at Ha Tien Datum (reference level 0.00 m), in 1904, 1923, 1937, 1961, 1966, 1978, 1984, 1991, 1994, 1996, 2000 (**Figures 10 and 11**). Based on Water Warning Level III (i.e. more than 4.20 m at Tan Chau), the Mekong Delta has exceeded emergency flood conditions 22 times in the last 80 years from 1926 - 2006 (see data in **Table 3**). There is a very close linear correlation of peak water levels and flow discharges between Tan Chau and Chau Doc (**Figure 12**). About 65% of the flood volume is concentrated in the months of August, September and October (CTU, 1996).

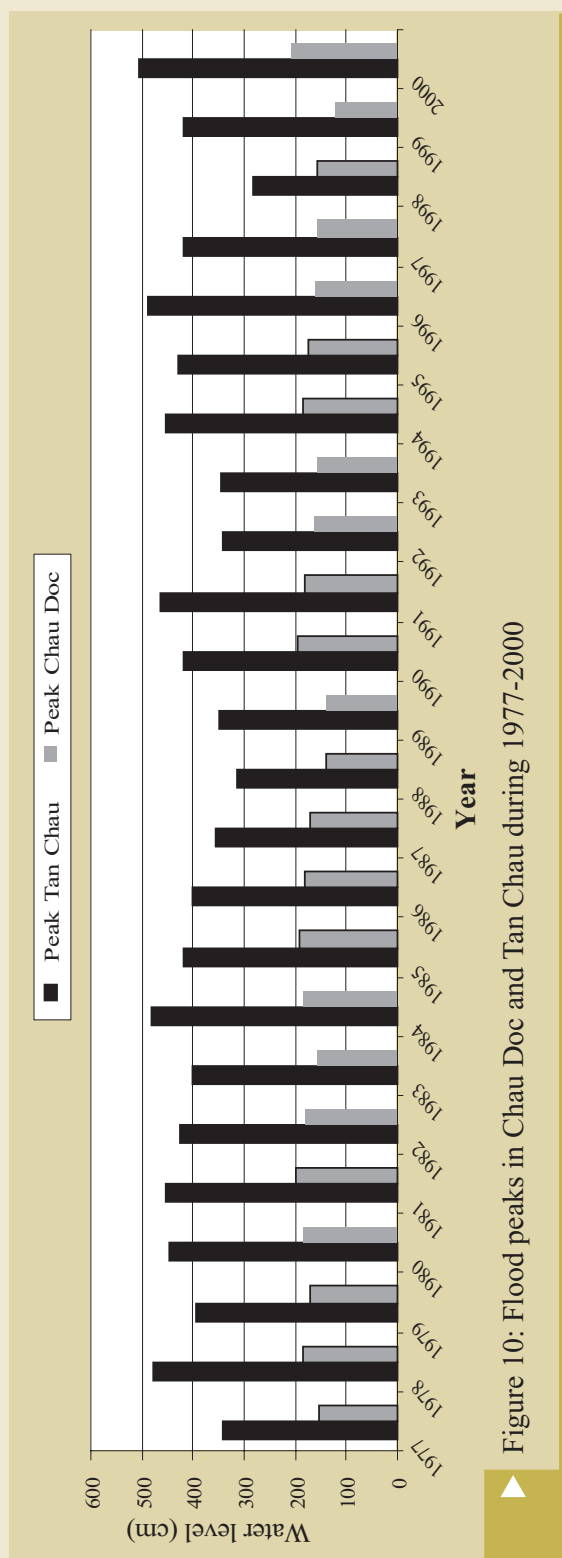


Figure 10: Flood peaks in Chau Doc and Tan Chau during 1977-2000

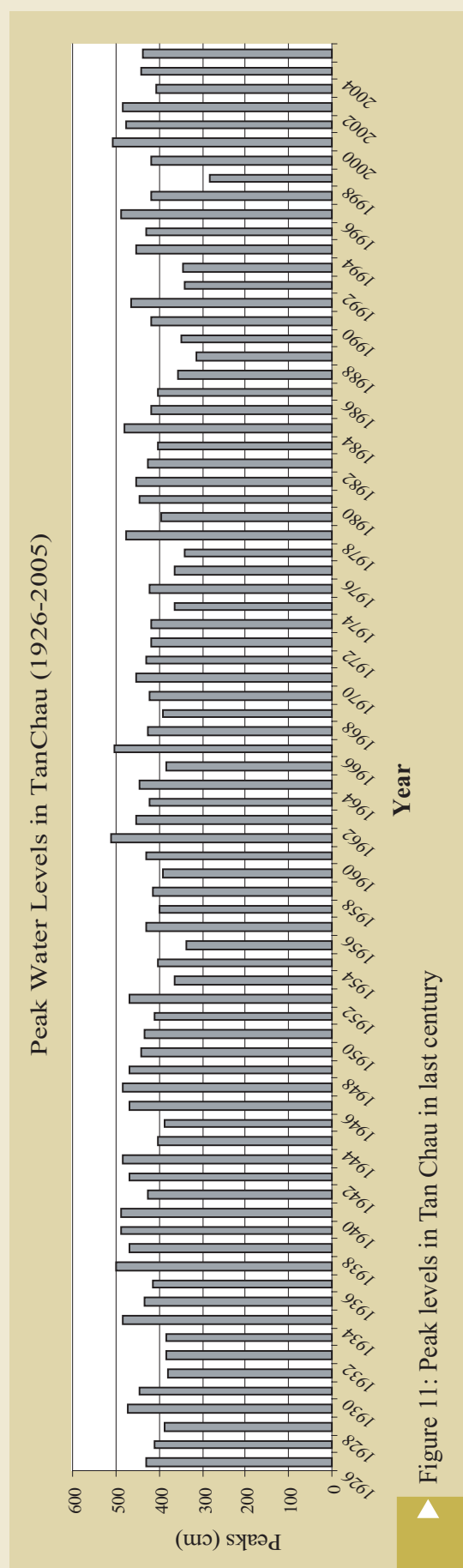
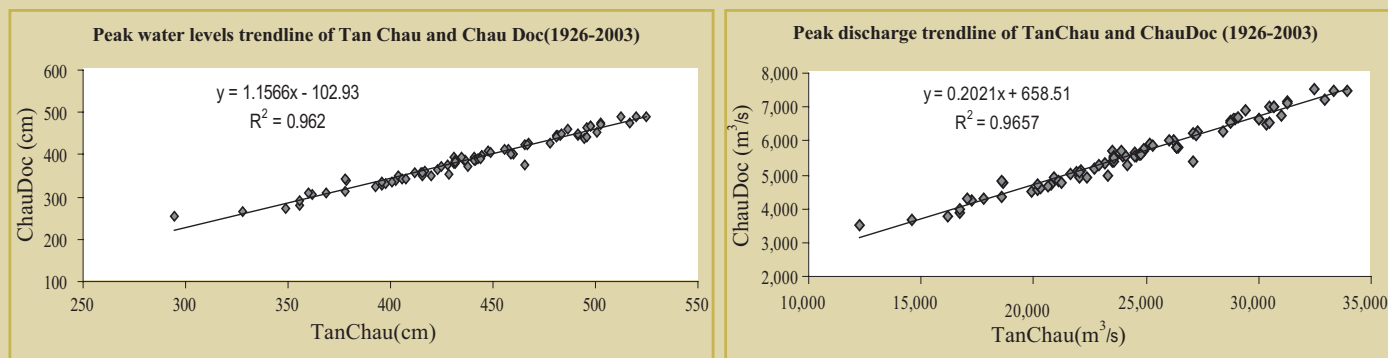


Figure 11: Peak levels in Tan Chau in last century

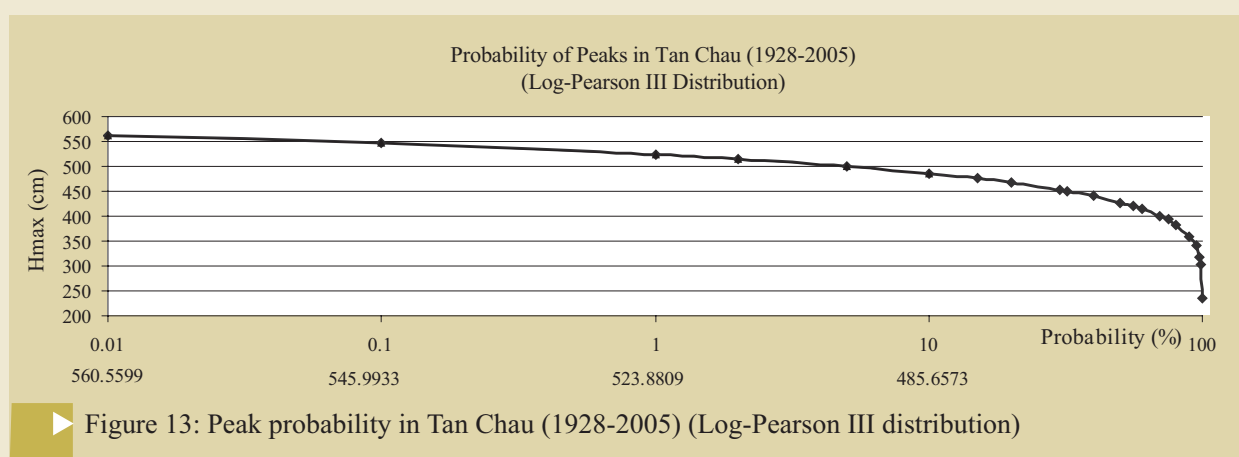
► Table 3: High flood peaks (WL > 420 cm) at Tan Chau Station

No.	Flooding year	Cycle (years)	Peaks (cm)	Diff. (+/-) (cm)
1	1929		489	
2	1934	5	500	11
3	1937	3	515	15
4	1939	2	505	-10
5	1943	4	498	-7
6	1947	4	500	2
7	1952	5	486	-14
8	1956	4	447	-39
9	1961	5	527	80
10	1964	3	462	-65
11	1966	2	519	57
12	1970	4	468	-51
13	1975	5	437	-31
14	1978	3	494	57
15	1981	3	468	-26
16	1984	3	497	29
17	1991	7	479	-18
18	1994	3	467	-12
19	1996	2	487	20
20	2000	4	506	19
21	2001	1	478	-28
22	2002	1	482	4
23	2004	2	441	-41
24	2005	1	436	-5



► Figure 12: Linear correlation of peaks of Tan Chau and Chau Doc

A worsening trend is apparent in flood patterns in the delta. Using the Log-Pearson III distribution for analyzing the probability of peaks in Tan Chau (1928 - 2005), it is found that the Water Warning level of 4.20 m has a probability of 55.8364%, as shown in Figure 13. So major flooding is now likely to occur in the Mekong Delta even more frequently than the “once in two or three years” average. An emerging question is whether adjusting the Water Warning levels is necessary or not when every 2 or 3 years the Mekong Delta meets a high flood warning level III as a normal occurrence.



3.1.2. Flood Damages and Benefits

3.1.2.1. Flood damage

It is hard to produce an exact inventory and comparison of historical flood damage in the Mekong Delta. Information sources of damage evaluation data are different, based on the different official authorities' reports (see **Appendix 1.1**). As in other places in Vietnam, high floods in the Mekong Delta result in loss of life, especially amongst children, and cause millions of dollars worth of damage including to houses, infrastructure and crops. A comparison of damage due to floods in 1978 to 1997 is given in **Appendix 1.2**. The loss of life and damage costs depend on flood levels in each year, however, there is a hazy trend between the flood peaks with the loss and the damage. Higher economic development and increasing population in recent years results in higher costs of damage and life. The flood peak in 1994 was 4.67 m - lower than the flood peak in 1978 (4.94 m) but the loss of life and the estimated damage cost in 1994 were 87 deaths and 2,284 million VN dongs respectively - higher than in 1978 with 407 deaths and 1,261 million VN dongs (data from Thien, 1998).

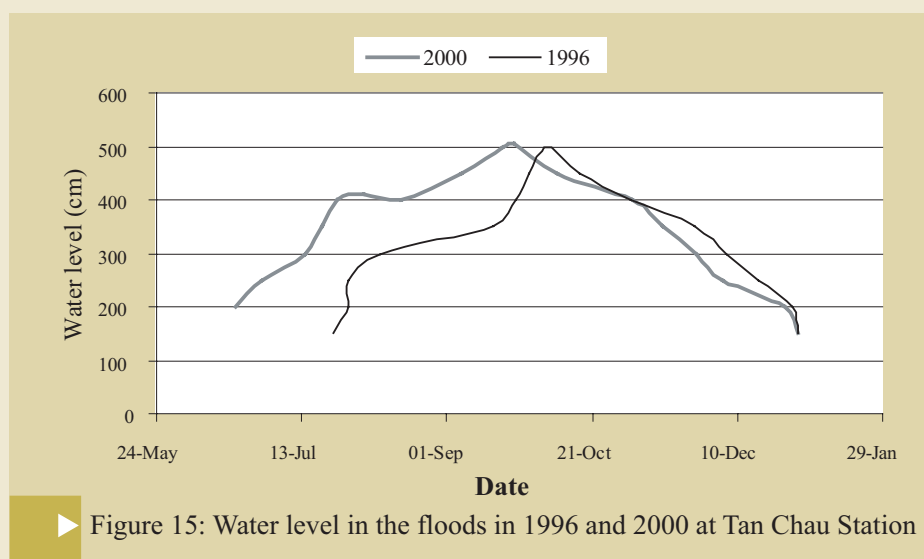
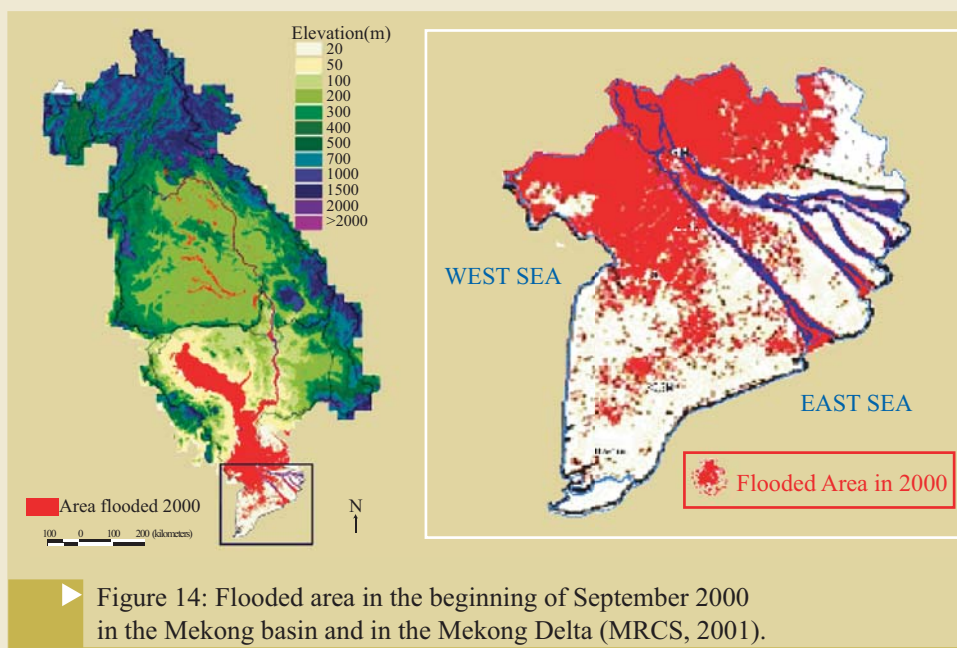
In 2000, the Mekong Delta faced a historically high flood, as severe as that of 1961 and the most destructive flood in 70 years (**Figure 14**). The flood in 2000 was extreme, not only in terms of its very high peak level and discharge but also in the earlier than usual arrival of the flood, approximately 4-6 weeks (**Figure 15**) (MRC, 2005a). The peak of the water level in 2000 was 19 cm higher and 12 days earlier than the flood recorded in 1996. Especially, the flood event in 2000 had two peaks, the first one on 3 August with the water level reaching over 4.0 m, then one month and 21 days later it was followed by a second peak of 5.06 m on September 24th, very close to the highest peak observed in 1961. The measured maximum discharges and total water volumes in 2000 from the Tien and Hau Rivers to Long Xuyen Quadrangle and the Plain of Reeds are distributed

as shown by the scheme in **Appendix 2**. As such, the flood in 2000 had a volume of 420 million m³, distributed between the main stream flow and runoff volumes from Cambodia as 17% to the Hau River, 65% to the Tien River, 3% to the Long Xuyen Quadrangle and 15% to the Plain of Reeds. Flood water levels in the Plain of Reeds area, and in the Long Xuyen Quadrangle area were 30-50 cm higher than the ones recorded in 1961, 1978, and 1996 (SRV, 2005).

Certainly, the flood of 2000 was the worst experienced in terms of social and economic damage, mainly in rural poor-farmers groups living in low land settlements. Over 300,000 households were reportedly submerged with over 2,900 houses destroyed and 1.3 million people affected, and 211 children were among the 280 people killed (ADRC, 2000). An estimated economic loss of USD 182 million occurred, according to ADRC (2000), although another report estimated the economic damage to be more than USD 400 million (Juergen, 2005). The difference in estimated costing may be due to the difference sources of damage declaration.

In addition to direct damage, indirect damage such as economic losses due to the interruption of economic activities, intangible effects such as anxiety, inconvenience, ill health and loss of cultural significance are considered (Gupta et al, 2004). Potential flood damage to different categories in the delta are shown in **Table 4** and **Figure 16**. Considering this, if a return period of high flood happens every five years (flood probability of 20%), the Mekong Delta will experience damage of nearly USD 50 million. Compared to the cost of damage in the commercial sector (more than 97% of the total), the costs of other items are minor.

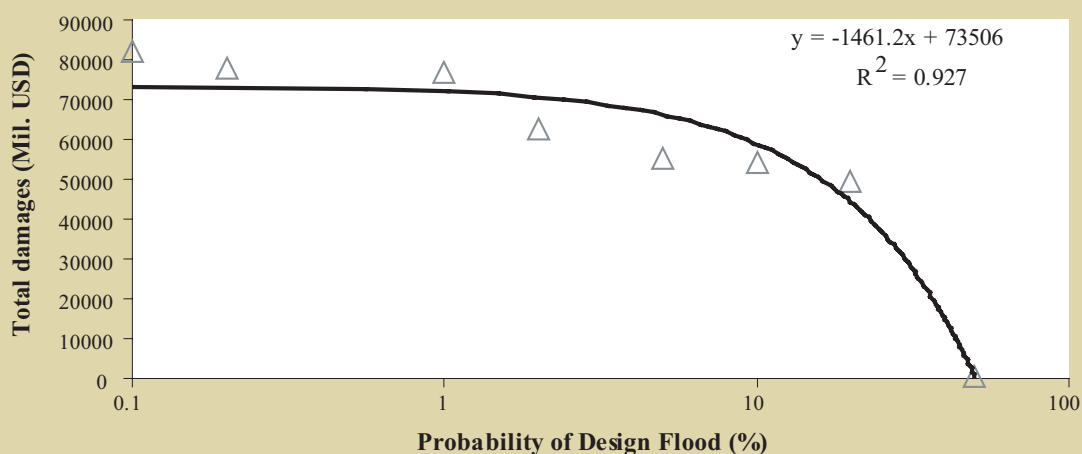
Table 4 should be reconsidered in light of flood adaptations taken to reduce damage in recent years.. The 2005 flood report (MRC, 2005) estimated damage in the Mekong Delta (**Table 5**), which had a probability of approximately 45% and recorded less damage. The losses of life are great but hard to evaluate if looked at from a social perspective. The damage costs to the residential and agricultural sectors largely affect the poorer sections of society.



► Table 4: Estimated damage of different sectors

Probability of design flood (%)	Residential		Commercial		Agriculture		Infrastructure		Total damages
	10 ⁶ \$	%	10 ⁶ \$	%	10 ⁶ \$	%	10 ⁶ \$	%	10 ⁶ \$
50	24	3.51	0	0.00	272	39.77	388	56.73	684
20	218	0.44	48,202	97.86	299	0.61	538	1.09	49,257
10	232	0.43	52,830	97.84	322	0.60	613	1.14	53,995
5	243	0.44	54,262	97.73	341	0.61	678	1.22	55,522
2	260	0.41	61,450	97.83	353	0.56	749	1.19	62,810
1	280	0.37	75,235	98.07	403	0.53	795	1.04	76,712
0.2	295	0.38	76,072	97.88	413	0.53	939	1.21	77,719
0.1	305	0.37	80,610	97.92	432	0.52	975	1.18	82,321

(Source: Gupta *et al*, 2004, percentage is added)



► Figure 16: Estimates of total damage versus flood probability

► Table 5: Estimation of damage of the flood 2005 at Mekong River Basin level
(Consolidation of data considered as sufficiently coherent for comparison)

	Lao PDR	Cambodia	Thailand	Vietnam	Total
People affected					
No of provinces affected	16	4	5	8	33
No of districts affected	84	35	23	2	144
No of communes affected	NA	195	234	NA	NA
No of villages affected	2,510	NA	NA	NA	NA
No of families affected	85,553	29,549	78,121	NA	NA
No of people affected	480,913	14,408	NA	NA	NA
Houses severely damaged/collapsed	NA	NA	1,275	4,303	NA
Deaths from floods (2)	4	19	0	77	100
People evacuated to safe places	356	4,805	NA	NA	NA
Agricultural production					
Rice planted (ha)	687,555	NA	NA	NA	NA
Paddy field loss (ha)	55,955	9,906	39,538	3,876	109,275
Loss of livestock (Unit) (1)	2,124	28	0	0	2,152
Loss of fishponds (ha)	296	NA	759	NA	NA
Damages to infrastructure	(only scattered information is available - consolidation for MRB may not be done)				
Total estimate of damage US\$ mil.	28.56	NA	NA	15.27	NA

(1) includes buffaloes, cows, pigs, goats

(2) data regarding flash floods not available (due to a large and vary flat basin, the Mekong Delta almost has no flash floods)

(Source: data and comments related to data from country reports MRC, 2005)

There are other flooding damages recorded affecting rural communities and the commercial sector directly:

Bank erosion: Many villages in 70 sites along the Tien and Hau Rivers face severe bank erosion due to floods, especially in Dong Thap and An Giang provinces. It was reported (VNN, 2002) that soil erosion in Dong Thap during the 2000 flood season caused 200 ha of severe erosion. Meanwhile, An Giang province had nearly 120 ha of land vulnerable to bank erosion.

Navigation hazards: Sedimentation in the Mekong delta is 7- 8 times higher than for the Red River (the North of Vietnam), estimated at 160 million ton/year (Milliman and Syvitski, 1992) resulting in an inherently dynamic channel system. Sedimentation due to floods makes river channel changes which cause hazards and challenges for navigation in the Hau River mouth for ships larger than 3000 Dead Weight Tonnes (DWT) travelling to Can Tho port. Every five years, VND1 billion have been paid for dredging the Hau river mouth bed.

Pests: Receding flood waters often reveal plagues of Golden Apple Snails (*Pomacea canaliculata*) that threaten serious damage to the country's main rice crop. After the 2003 flood, total 31,770 ha of Winter-Spring (*Dong Xuan*) rice fields were affected by golden apple snails, with an associated problem being leaf borers (MARD, 2003).

Invasive exotic plants: Flood flows may disperse invasive exotic plant species such as Giant Mimosa (*Mimosa pigra*) and water hyacinth (*Eichhornia crassipes*). In 2005, the Mimosa infested over 1,600 ha of the Tram Chim National Park, Dong Thap, threatening the grasslands including the feeding habitat of the Eastern Sarus Crane, the *Eleocharis ochrostachys* grassland (Vinh, 2006).

Health Risks: Specific health risks related to floods reported by Roger *et al* (2004) include 3 main categories of disease: water-borne diseases (typhoid, dysentery and cholera); mosquito-borne diseases (*Dengue fever*) and skin diseases (fungal skin disease, eye infections and gynaecological infections).

3.1.2.2. Positive effects or benefits of flood

Floods, however, are perceived by many farmers and scientists not only as a “disaster”. Historically, it may be confirmed that the natural form of the Mekong River delta region is always linked with annual floods although they can be damaging to loss of life and property. There are multiple replenishing and revitalizing benefits

from floods. A workshop in March 2002, conducted by the Mekong River Commission [MRC] (MRC, 2002) and World Wildlife Fund (WWF), provides a summary of available information on preserving the ecological functions reliant on the natural flood regime as well as suggestions to guide WWF's further analyses of the natural flood regime (Johnston *et al*, 2003). It was concluded, that:

- *Fertile sediment*: Floods carry a large amount of sediment from upstream and then deposit suspended solids on fields as natural fertilizer for crops and fruit. Most river-derived sediments are trapped within the deltaic system, including around the Ca Mau Cape (Oanh *et al*, 2002). The estimated deposition rate of the Mekong delta was about 45 m/y before 2500 years ago and 20 to 30 m/y for the last 2500 years (Yoshiki, 2002). Each year, the Ca Mau Cape has grown in surface area by about 80-100 m towards the sea. Water quality data in some current years gives the average sedimentation in the flooding seasons as 500 g/m³ in the Tien River and 200 g/m³ in the Hau River (Truong, 2006).

- *Fish spawning*: The flood season also brings young fish from the Tonle Sap to the Hau and Tien rivers. With a high flood of the Mekong River in 2005, fish and prawns followed the water stream in considerable quantity and people were able to make big catches. Floodwater brings beneficial nutrients for fish species in the rivers.

- *Aquatic products*: The flood season is also the period for farmers to catch snakes, apple snails, rats and some floating vegetables as a way of coping with food and getting higher prices in markets.

- *Flushing effect*: Parallel with natural fertilizer sediment deposit, flood water flushes out the toxins from the acid surface soil areas as well as farm pollutants such as agro-chemicals. High flood in a previous year will lead to a production increase in the next year.

- *Pest control*: Flood flow induces decreases the density in rate and insect populations in rice fields.

- *Water quality*: Floods improve water quality in the Mekong delta after several months of the dry season by flushing acidity from acid sulphate soils as well as reducing the salinity of coastal soils from farm land.

- *Water provision*: Floods provide fresh water for crop irrigation and drinking water, and replenish groundwater storage.

- *Reduce fire risk*: Floods may reduce forest fire, especially in *Melaleuca* forests.

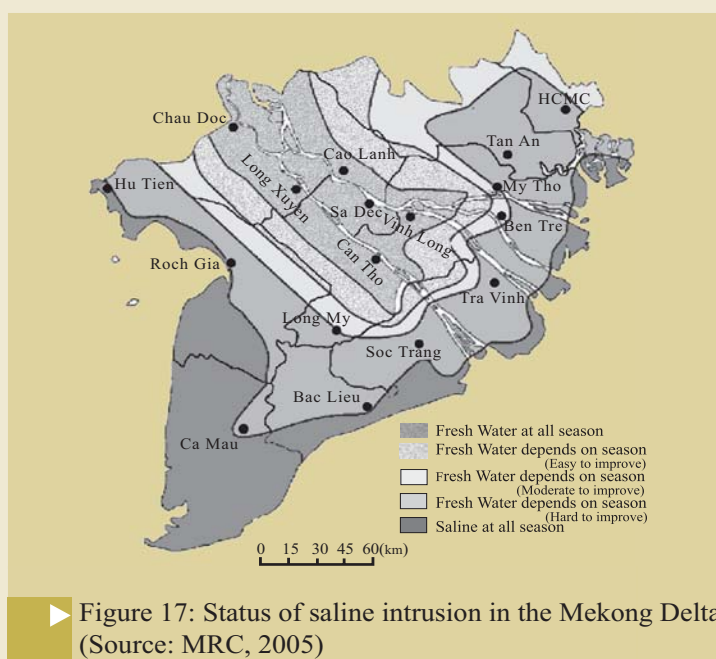
- *Ecological drivers*: Floods also play an important role as key drivers of ecosystems, especially in the Tonle Sap - Great Lake, the Long Xuyen Quadrangle, and the Plain of Reeds. The wild floating rice variety is naturally maintained due to yearly flood. Floods make these large zones fresh water wetlands that are rich in biodiversity.

3.2. Saline intrusion in the Mekong Delta

3.2.1. The state of the saline intrusion

In the Mekong Delta approximately 1 million ha are affected by tidal flooding and 1.7 million ha (about 45% of the delta area) by salt water intrusion (Reiner *et al*, 2004) from both the East Sea and the Gulf of Thailand to open waterways and estuaries for some period during the year, with much of this land exposed for a duration of over six months.

During the dry season, when flow rates in the Mekong River are at their lowest, especially in April, saltwater intrudes into the delta causing saline conditions in vast areas of cultivated land (MRC, 2005b). *Gio chuong*, a south-eastern wind from the East Sea, blows strongly in December-January seriously affecting the Winter-Spring (*Dong Xuan*) rice crop and water supply. All the provinces in the Mekong Delta coastal region are vulnerable to salinity (**Figure 17**).



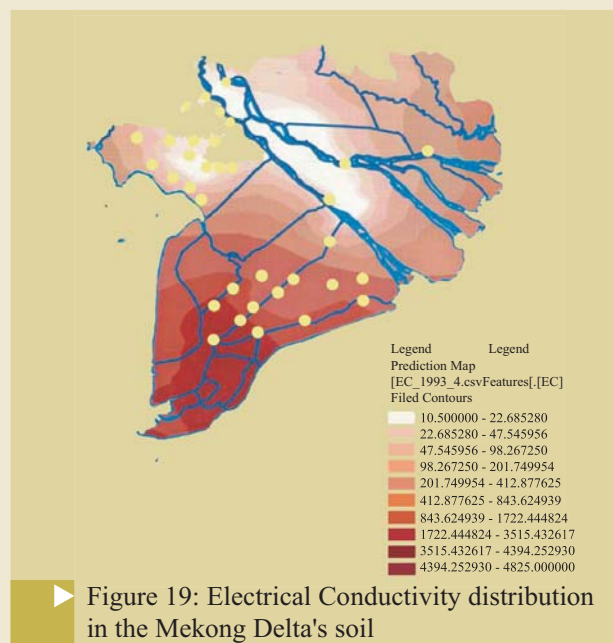
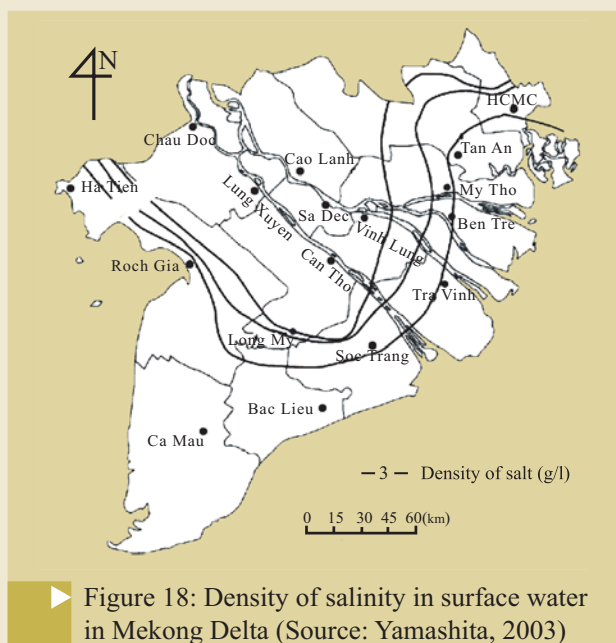
The greater part of the delta is tidal (MRC, 2005c). With a 600-kilometre coastline, saline intrusion in the river branches in the MD is very complicated. According to the classification of Davis and Hayes (1984), the MD's coast is as a mixed-energy (tide-dominated) environment. The Mekong River branches and canals from the North of Ben Tre province to the Ca Mau Cape are influenced strongly by the irregular semi-diurnal tides of the East Sea with a large tide amplitude of 3.0-3.5 m (see **Appendix 6** and **Appendix 7**). From the Ca Mau Cape to Kien Giang offshore, tides are diurnally irregular with a tidal range of about 0.8- 1.2 m. The tidal amplitude offshore of the East Sea is between 3.0-3.5 m, the tidal range is reduced to lower than 3.0 m when translating to the Delta River, not only due to the river discharge flowing downstream but also to the affects of the moon periods, as data shows in **Table 4**. In the dry season, the tidal range at Can Tho (90 km from the sea) is recorded as 1.50 - 2.0 m and at Tan Chau and Chau Doc (190 km from the coast) as 1.0 m (MRC, 2005c).

► Table 6. River discharge and tidal range data in the Mekong estuaries

Estuary name	Date	River discharge (m ³ /s)	Tidal range (m)
Hau	8 April 2005	1064	2.89
	9 April 2005	1038	2.90
	21 May 2005	930	2.62
	22 May 2005	975	2.75
Co Chien - Cung Hau	21 April 2005	655	2.07
	22 April 2005	680	2.14

(Source: Nguyen, 2006)

Physically, salinity intrusion occurs when not enough river discharge is flowing to the low-lying estuaries and instead salt water flows into the land. The numerous canals and local drainage systems allow the intrusion of seawater into many parts of the delta away from the main channels (Hashimoto, 2001). The saline intrusion factors are affected by the amplitude and period of tides in the East Sea and the Gulf of Thailand, the amount of local rainfall and runoff, the slope of the river bed, the wind velocity and direction and the depth of the estuary. Salt water intrudes inland from the Hau and Tien river mouths and the Ca Mau peninsula's estuaries from December to May, being strongest from February to April (**Figure 17**). Due to the difference in water volumes at each mouth of the tributaries, the distances and levels of saline intrusion in each province are different. Salinity penetrates inland through various branches of the Mekong and canals over 20 to 65 km from the shore (Trung, 2006). As indicated in **Figure 8**, from the sea to the Hau River in April, the density of salinity of 3 g/l is 45-50 km, 60-65 km at the Co Chien River and 75-80 km at the My Tho River. Strong tides cause intrusion up to 70 km inland (ADB, 2000). Especially in the case of the Ca



Mau Peninsula, influenced by tides from both directions of the East Sea and the Gulf of Thailand simultaneously, there is a problem of the formation of many stagnant water zones. In these zones, water exchange is very low, limiting economic and human uses of water, as well as leading to many environmental problems.

Seawater from the sea also affects soils (Lang *et al*, 2004). **Figure 19** gives the distribution of electrical conductivity (EC) values in the Delta's soil in 1993. In agriculture and water utility sections, isohalines of 4 ppt NaCl in river water are referred to as a warning of potential damage to crops and domestic water supply.

3.2.2. Positive and negative effects of saline intrusion

Coastal areas are home to mangroves and saline intrusion maintains these and other ecosystems, such as tidal mudflat habitats, estuaries, small offshore islands, large coastal brackish and saline lagoons, large areas of salt pans and aquaculture ponds (Molle and Tuan, 2001). The Mekong River Delta forms the biggest wetland forest in the Mekong region at 191,800 ha (Tuan *et al*, 2005) with about 1,600 fauna and flora species living under the canopies of these mangrove forests.

The damage costs of saline intrusion to farmers are very hard to quantify. Soil salinity is one of the principal limiting factors in crop production, especially for rice, as crops are intolerant of salinity in the soil and water beyond 0.4% or 4 grams per litre. During the annual saline intrusion period, from March to May, vegetables and other crops are scarce in the affected areas. Salinity intrusion also restricts the use of canal water for domestic and industrial uses and causes corrosion of all metal materials in engines, construction artefacts and elsewhere.

As an impact, more saline intrusion has to lead more salinity in groundwater layers. Salt water infiltration into ground water is very common in the coastal areas of the Mekong Delta (Tuan, 2003), especially to the normal exploitation layer of 80-120 m for household wells. Many wells have experienced quality problems of some kind - pH, high iron content, salinity and odours being the most common - almost all water supply plants for the future are based on increased groundwater withdrawal. Lower water levels at 400-500 m is better quality for groundwater plants but is more costly to exploit. Nevertheless, deeper drilling is necessary (Tuan, 2003).

Salinity intrusion has a positive effect for reducing acidity in potential acid sulphate soil land; hence pH in water is higher. When lacking saline water in fields, such as occurs with saline protection dikes in some districts of Bac Lieu and Kien Giang, soil acidification occurs in the dry season (Tinh, 1999) making soil much less productive and limiting agricultural yields.

Miller (2003) notes that the presence of brackish and saline water is considered by some coastal shrimp farmers and fishers to be a positive occurrence for their livelihoods. Choosing to adapt their activities to correspond with salinity intrusion, salt water enables farmers to implement a more varied production scheme to raise shrimp during the dry season. The marine and coastal region contributes more than half of the exported aquatic value for Vietnam. However, further expansion of the shrimp industry will have a negative impact on the environment (e.g. salinisation), affecting local livelihoods (Binh, 2004).

3.3. Flood and salinity management

Under the flood management and mitigation programme of the Mekong River Commission (MRCS, 2001, 2002), it is recommended that the development of an improved early warning system is the highest priority for the region (Plate and Insisiengmay, 2002). At present the Ministry of Agriculture and Rural Development (MARD) has a high responsibility for water resource planning and management (See **Appendix 9**). Under the MARD, the Southern Institute for Water Resources Planning (SIWRP) and the Southern Institute for Water Resources Research (SIWRR) are key research institutes on water management issues in the Mekong delta. At provincial level, the Department of Water Resources Management, an office under the Provincial Department of Agriculture and Rural Development (DARD) and under the Provincial People's Committee, has been responsible for water management in provinces, districts and hamlets. Water control works, after approval, are built and managed with the supervisors of DARD.

All the hydro-meteorological data are monitored and processed for flood forecasting by the General Hydro-meteorological Office. Primary flood control works, such as floodgates, drainage canals or flood dykes are surveyed, designed, approved and supervised by the MARD. After building, the provincial officers will manage and exploit these works, and local governments at district and commune level maintain these works. Farmers may give their demands and comments to local officers. Non-structural measures are implemented by provincial policies and NGO support.

People receive flood and storm information via the mass media (television, radio and newspapers) and announcements from the Provincial, District and Commune People's Committees. In the Central Government, the National Committee for Flood and Storm Prevention, Search and Rescue has the highest responsibility in steering activities concerning national and local disasters. Lower levels have responsibility for local action. The Southern Region Hydro-meteorological Centre, located in Ho Chi Minh City, via its network of hydro-meteorological stations, plays an important role in monitoring and forecasting the changes of weather and hydrological situations. Other information sources referred to include the Mekong Secretariat (water data from the Mekong River upstream via radio transmitter), the Internet, and the Weather Forecasting Centres in nearby countries. According to Apirumanekul (2002), during the flood season (June-October), five-day flood forecasting and flow forecasts are conducted at 19 stations along the Mekong mainstream and updated daily at <http://www.mrcmekong.org>, while seven-day river monitoring during the dry season (November-May) is provided.

It is necessary to model river and canal systems as complex as the Mekong in order to understand changes in water quantity and quality over time. Computer modelling is widely used as a powerful tool in water resources engineering. An extreme flood or severe saline intrusion in the Mekong Delta can be estimated in many scenarios to assist with decision-making in water planning and management. Since the 1960s, numerous mathematical models have been applied in the hydrological computation for the Mekong River Basin to compute various alternatives for short-term flood and salinity control as well as predicting the changes in hydrological regimes and water quality impacts (**Table 6**). More information is available in *Flood management and mitigation in the Mekong River Basin, Technical Session III: Flood forecasting and river modelling* (1999). These data and information are helpful for a strategy for reducing the damage to life and property of the people in the Mekong Delta.

For modelling, the collection and processing of routine hydrological and meteorological data is an expensive and difficult task (Piper *et al*, 1991). In a hydrodynamic model, flow data used relates to physical data such as river and canal cross-sections, banks or fields. One of the objectives of such mathematical models is the improved description of the flood propagation over the floodplain, water exchange between the floodplains and the river channels, the effect of topography and infrastructure on flooding, morphological changes and bank erosion potential and changes over time. Concerning saline intrusion, the low slopes of the Mekong and its tributaries' river beds and the complex of a two tidal regime affects, the salinity intrusion problem for whole system makes modelling complicated.

The results received from some of these models may be used as a technical prerequisite for development of a regional strategy and action plan to prepare for flood loss prevention and salinity management for the vulnerable agricultural sector. With a more dense and frequent river monitoring network and a stronger computer system, modelling developers are improving existing models and adapting them for long-term flood and saline intrusion forecasting.

► Table 7: Some hydrological, hydraulic and water quality models used in the Mekong Delta

Model names	Developers	References
SSARR	US Army Corps of Engineers, US	(Shafiee et al, 2004; USCE, 1975)
SOGREAH	SOGREAH Hydraulics Lab., France	(SOREAH, 1972)
MASTER MODEL	NEDECO, the Netherlands	(Delft Hydraulics, 1991)
VRSAP	SIWRP, Vietnam	(SIWRP, 2000; Hoanh et al, 2006)
SAL	SIWRP, Vietnam	(Dac, 1996)
KOD	SIWRR, Vietnam	(Nien and Xo, 2001)
HYDROGIS	Hydro-Meteorological Service of VN	(Nhan et al, 2001)
ISIS	Halcrow Cons. Co., UK.	(Thuc and Tuyen, 2005)
MIKE 11	Danish Hydraulics Institute (DHI)	(Fujii, 2003)

3.3.1. Flood management

In recent years, the people of the delta have prepared for flood control as dyke building and irrigation development have received investment. Also, public awareness campaigns aimed at reducing child casualties have been promoted. Full flood protection dykes or partial protection dykes may act to protect crops. Crop damage has been minimal, given that the Summer-Autumn rice crop is usually harvested just before the floods occur.

An action plan for reducing flood risks and keeping the flood benefits for sustainable development is captured in the saying ‘Avoiding the Floods, Living with Floods and Controlling the Floods’ (Truong, 2000). According to this motto:

- ‘*Avoiding the Flood*’ is a secondary alternative, it is applied to alert people at risk and to evacuate local people out of flood areas when high water levels occur.
- ‘*Living with the Flood*’ is understood as an integrated solution for adaptation and protection of human life and property, to maintain safe and sustainable housing for local people and to maintain social security.
- ‘*Controlling the Floods*’ includes infrastructure engineering works to protect the stability of aqua-agricultural production and increase the land-use coefficient and ensure the safety of local people.

First of all, based on the historical data records from the hydro-meteorological monitoring network, flood risk analysis and flood vulnerability assessment should be identified. Depending on natural and socio-economic conditions floods can be controlled by both structural and non-structural measures.

Structural measures for flood control include technical works such as constructing flood protection dykes, widening/deepening drainage channels to the sea, raising evacuation of foundations, roads, bridges and houses. Since 1996, high dykes have been raised further, especially in many districts in An Giang and Dong Thap provinces. As a result, most farmers have steady, year-round rice, fruit and fish crops and landless people have paid employment as well. In many villages, farmers built temporary embankment systems (or so-called “August embankment” or “*Do bao thang Tam*”) for protecting Summer-Autumn crops from early floods. The Vertiver floating weed (*Phragmites vallatoria* L.) barrier is also one of the effective ‘soft’ structural measures for protecting against bank erosion from the floods (Dung *et al*, 2003).

Non-structural measures mainly include strengthening the capability of flood reduction: upgrading the hydro-meteorological monitoring network, data processing and modelling, providing mass public communication and education, diversifying the crop production calendars, establishing Daytime Childcare Centres or “flood kindergartens” as described by Tinh (2003), “health-care boats” to take care of children and sick people during the flood time, raising awareness of risks, swimming lessons, and promotion of the use of life jackets and various types of life buoys (VNRC, 2002).

However, in some local regions, solving the flood problems still narrowly emphasises the technical construction aspects that other problems have created. Some examples follow.

There are some unofficial complaints that high full protection dykes upstream may become barriers or blockages to floodwaters leading to a slow drainage process, thereby prolonging floods downstream by about two to three weeks if compared with floods before 1995.

Intensive farming inside flood protection dykes may not be sustainable without the annual replenishment of nutrient silt deposits from the flood, and with increasing insects and rats in rice fields. Yields have gone down over recent years (Howie, 2005), in some cases decreasing 25-50 kg/*cong* (one *cong* is a tenth of a hectare or 1000 m²). Farmers pay more investment costs for chemical fertilizers and insecticides that have caused harm to the natural environment.

Resettlement of poor people to new residential sites to avoid floods may provide them limited opportunities to earn benefits from floods and face some new sanitation problems. Many of them say they are finding less small wild fishes, such as *ca linh* and *ca long tong*.

It was found that an invasive weed, named “*Mai Duong*” or Mimosa weed (*Mimosa pigra* L.) has appeared in high densities in many new residential settlements and high enclosure dyke areas, threatening the flood plain habitat. Mimosa has the potential to harm a wide number and variety of different types of primary agricultural production. The Mimosa weed is now found in all 12 provinces of the Mekong Delta, mostly in the freshwater region influenced by floodwater from the Mekong River (Triet *et al*, undated).

High, full protection dykes may constrain river and canal transportation.

Earth dyke maintenance and repair is difficult work in the Delta: it is hard to find suitable soil for embankments and it is costly to protect them from bank erosion.

3.3.2. Salinity management

The Provincial Division of Water Resources Management, under the DARD and the Provincial Hydro-meteorological Stations (PHMS) are official agencies responsible for saline intrusion monitoring. They principally report to the Provincial People's Committee and are involved in translating the action strategy into field practice. These Provincial DARD agencies also are local salinity construction project managers.

To limit saltwater intrusion into agricultural areas, saline water intrusion floodgates were installed or are planned for much of the lower Mekong River (White, 1996). During the last two decades, many saline control projects have been built, as described in **Appendix 8**.

The main structures in the saline intrusion zone are sea and estuarine dike systems, canal embankment systems, pumping stations and sluices. They were built not only for saline intrusion protection but also to keep freshwater for production and domestic use. Many years after construction, a large area previously affected by salinity intrusion is protected to allow production of two rice crops each year. However, in current years, the development of brackish aquaculture has quickly lead to a new utility requirement for salt water. Thus, such control may cause conflicts between rice farmers and shrimp farmers, as in the case of Bac Lieu Province (Hoanh *et al*, 2003). The local government wanted to keep freshwater for rice production but the shrimp farmers required brackish water for their shrimp cultivation environment. In the western part of Bac Lieu, the intensification of rice cultivation has become more difficult in the western part, despite larger areas being freed from salinity intrusion (Kam, *et al*, 2001). Wherever potential acid sulphate soils are exhibited, human disturbance of the natural environment, such as preventing the saltwater intrusion, has increased the extent and the severity of the problem (Hashimoto, 2001). So, shrimp farming on agricultural land in the long term must also be understood in terms of its negative effects, even though it is still a lucrative business for some and an important source of national income.

Several international research collaborations have been done in the salinity zone by Can Tho University and the Cuu Long Delta Rice Research Institute looking for drought-resistant and/or saline-resistant rice varieties (Lang *et al*, 2004; Tinh, 2001), integrated mangrove-aquaculture farming systems (Minh, 2001) or the integrated production with the practice of rice-shrimp farming in the coastal areas (Brennan *et al*, 2002). In the freshwater-brackish water environment zones, many farmer models have evolved such as rice-shrimp rotation systems to maximize returns through both rice and high-value, extensive or semi-intensive shrimp production (Xuan, 1993).

Perhaps one of the most important concerns for salinity management are controllable methods by which these harmful effects may be mitigated, by replanting mangrove forests that were destroyed by shrimp farms.

4. Key conclusions

Water is life for people and nature, not only in present years but also in the future. In general, to protect the people and their property for stable development conditions and to limit the damage of unusual natural disasters, there should be a flexible response system from the central to local levels. Flood and saline intrusion in the Mekong Delta may be looked at from different views if compared with other places in Vietnam and other countries. Within the delta, water management issues should be approached from various angles. The best people can do is to try to anticipate the flood and be prepared to live with the floods, both when the floods are beneficial and when they are harmful (Plate and Insisiengmay, 2002).

Flood and salinity intrusion are natural phenomena, not disasters. They are part of the typical images people evoke when speaking of the characteristics of the Delta. Both have given positive and negative impacts on natural habitats, human life, people's aqua-agricultural production, and infrastructure. They only become "disasters" when a great number of a valuable property is damaged and the life of people is endangered. This is due the increased industrial development and expansion of human settlement in the flood prone area as the delta is one of the most resource rich in the country. An Early Warning System and participatory water management are needed to reduce the disaster risks related to flood.

Conceptually, normal flood and saline intrusion in the Mekong Delta are not considered serious disasters to the people who are living and facing these event from year to year. For this reason, flood and salinity management in the Delta has emerged differently to other regions in the North or Centre of Vietnam. Thus the strategy appropriate for the delta is a *mitigation strategy* or '*living with flood and flood control*' with specific solutions such as planning of residential clusters, construction of irrigation systems for supplying clean water and preventing salt invasion, and construction of low embankment system for preventing salt invasion (Vietnam, 2005).

Water resources planning in the Mekong Delta is still quite "top-down". Villagers and farmers play a very minor role in water planning and natural prevention projection processes; even among them, many grass-roots people have little voice. Approved water plan information is not clear for the project affected people.

5. Emerging issues and research priorities

There is an urgent need for research on trans-boundary water cooperation and on environmental problems, rather than only technical problems.

The impact of hydropower dams in Yunnan province, China, on the downstream hydrology and ecology is a growing concern.

Within the Delta, environmental impact assessments of the effects of full-flood protection dykes in the upstream area, as well as downstream, are required. This would be an important policy, decision-making cooperative action among the regions utilising water in the delta. It is foreseen though that it is difficult to unite everybody under the common interest of protecting the stability of agricultural production and increasing land and water productivity.

Climate change compounds the existing challenges of managing floods. Sea level rise could have a major impact on flood risks in the coastal zone (Manuta and Lebel, 2005). Research still remains to be done on the effects of global warming on water and land resources and human activities in the Mekong Delta.

Some other detailed studies that require further work include:

- Establishing an Early Warning System (**Appendix 6**) in Vietnam as a recommendation of Asian Disaster Preparedness Centre (Garcia, 2002).
- Building flood and salinity hazard maps.
- Adjusting water management for multiple-use rather than only for irrigation.

The aqua-industrialisation processes in the delta are occurring rapidly, with surface water resources under severe threat of contamination from organic substances or salinity. The main objective of water resources project planning, especially in the period 1975-1990, was almost entirely focused on rice crop irrigation, without consideration for aquaculture and other activities. After 1990, water resources development projects have focused on multi-purpose and integrated agricultural production and socio-economic development.

- Limiting over-exploitation of ground water resources in major urban and rural areas that may lead to land depression in the coastal areas or arsenic contamination in some villages in An Giang and Dong Thap provinces.
- Conservation of wetland ecosystems in the Mekong Delta.
- Studying suitable domestic and industrial wastewater treatment systems for cities and towns in the Mekong Delta to reduce the pollution of river water.

- Raising awareness throughout the community of the urgent need to protect the Mekong Delta water resources.
- Designing rural house models and materials adapted to flood inundation conditions.
- Providing guidelines to rural people to secure their life and property against disasters.
- Offering loans to invest in activities and infrastructure that will help to avoid inundation.
- Protecting infrastructure works.
- Improving drinking water supply and sanitation conditions for the poor in the flood and saline intrusion regions.
- Applying the water law and environment protection law.

6. Policy Linkages

Vietnam, under pressure to improve its economic development, seems to be overlooking the environmental costs of development (Quy, 1997). The highest priority in all policies, in the case of high floods, should be to ensure the safety of people's lives. Secondly, water management policies should focus on adopting measures to ensure the stability of life and to protect the environment in the long term. To manage floods and salinity in a way that ensures sustainable socio-economic development, under conditions of limited financial and human resources, is a complicated and challenging task. It is very important that government policy in water conservation in the Mekong River occurs in an 'environmentally friendly' manner.

Vietnam has no Master Plan for National Water Resources Development or equivalent guidelines. There are two laws that are important for achieving suitable and effective water resource use and water environment protection; the Law on Water Resources (approved on 1998, effected on 1999) and the Law on Environmental Protection (1993, revised on 2001). There are a number of other laws and regulations to support the implementation of these laws, many of which have been developed by MARD.

Although there is a natural disasters warning organisation, from the central to local levels of government, it seems the lack of an Early Warning System in the region remains. The Mekong Delta is not a highly disaster prone region but the unusual weather in recent years may seriously affect the lowlands of the Delta.

For better policy linkages, a National Strategy and Action Plan for Disaster Management should provide assessment training programmes for provincial and district officials and staff and establish a linked internet reference database for a nation-wide communications network.

References

- An, N.T., (2002) *Mekong Delta water quality and sustainable aquaculture development*. Proceedings of the Workshop held in TraVinh, Vietnam, March 2002: Shrimp farming sustainability in the Mekong Delta, Environmental and Technical Approaches. IFREMER, France.
- Apirumanekul, C., (2002) *Management Issues in the Planning and Implementation of Flood Forecasting and Disaster Reduction Projects in an International River Basin*. Mekong River Commission, Regional Flood Management and Mitigation Centre, Phnom Penh, Cambodia.
- Asian Development Bank (2000) *Environments in Transition: Cambodia, Lao PDR, Thailand, Vietnam*. Asian Development Bank, Manila, Philippines. 114p.
- Asian Disaster Reduction Centre (2000) *Vietnam: Flood 2000/0. Natural Disaster Data Book - 2005*. Available online at: http://web.adrc.or.jp/publications/databook/databook_2005_eng/eng.html [Accessed 7 April 2007].
- Be, T.T., (1994) *Sustainability of rice-shrimp farming system in a brackish water area in the Mekong Delta of Vietnam*. M.Sc. (Hons.) thesis in Systems Agriculture, School of Agriculture and Rural Development, University of Western Sydney-Hawkesbury, N.S.W., Australia.
- Biggs, D.A., (2004) *Between the Rivers and Tides: A hydraulic history of the Mekong Delta (1820 - 1975)*. PhD. Thesis. Department of History, University of Washington, USA.
- Binh, T.N.KD., Vromant, N., Hung, N.T. Hens, L., and Boon, E.K. (2004) *Land Cover Changes between 1968 and 2003 in Cai Nuoc, Ca Mau Peninsula, Vietnam*. Paper in GIS Workshop: Geospatial Information and Sustainable Natural Resource in the 21st Century. 13 August 2004. Nong Lam University, Thu Duc, Vietnam.
- Brennan, D., Preston, N., Clayton, H. and Be T.T. (2002) *An evaluation of Rice-Shrimp Farming Systems in the Mekong Delta*. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Work in Progress for Public Discussion. The Consortium. 10p.
- Brocheux, P. (1995) *The Mekong delta: Ecology, Economy, and Revolution, 1860-1960*, University of Wisconsin-Madison, Center for Southeast Asian Studies, USA. 269p.
- Can, L.T., (2000) *Vietnam, a Country of the Mekong Sub-Region with its Water Resources and Dams*. The Fourth Regional Consultation of the World Commission on Dams in Hanoi, 26-27 Feb. 2000. Hanoi, Vietnam.
- CanTho University (CTU) and DANIDA (1996) *Flood Forecasting and Damage Reduction Study in the Mekong Delta*. Can Tho University, Can Tho, Vietnam.

- Commonwealth Scientific and Industrial Research Organization (CSIRO) (2003) *Sustaining prawns in the padi*. CSIRO Marine Research. Available online at: <http://www.marine.csiro.au/LeafletsFolder/58padiprawns/index.html>. [Accessed 16 April 2007]
- Cuc, N.S., (2007) Overview of Vietnamese Economy in 2006 and Prospect in 2007. *Communist Review* 31 Jan. 2007.
- Dac, N.T., (1996) *SAL - The model Flood in Mekong Delta*. Ho Chi Minh City, Vietnam.
- Davis, R.A. and Hayes, M.O. (1984) What is a wave-dominated coast? *Marine Geology* 60:313-329.
- Delft Hydraulics (1991) *MEKONG MASTER MODEL*. Vol.:1, 2, 3, 4. Delft, the Netherlands.
- Dung, L.V., Danh, L.T. Phong, L.T. and Truong, P. (2003) *Vetiver system for wave and current erosion control in the Mekong Delta, Vietnam*. Proceedings in the third International Conference on Vetiver and Exhibition, Guangzhou, P.R. China, October 6 - 9, 2003. pp. 356-364
- Fedra, K., Winkelbauer, L. and Pantulu. V.R. (1991) *An Application in the Lower Mekong Basin*. RR-91-19. International Institute for Applied Systems Analysis. A-2361 Laxenburg, Austria 169p.
- Fred P., (2004) Chinese dams blamed for Mekong's bizarre flow. *New Scientist* 25 March. Available online at: <http://www.newscientist.com/article.ns?id=dn4819>, [Accessed 25 April 2007].
- Food and Agriculture Organization (FAO) (1999) Preface: *Flood management and mitigation in the Mekong River Basin*. FAO publication 1999/14. Vientiane, Lao PDR. Available online at: <http://www.fao.org/docrep/004/ac146e/AC146E00.htm> [Accessed 8 March 2007].
- Food and Agriculture Organization [FAO] (1997) *Fisheries management. FAO Technical Guidelines for Responsible Fisheries. No. 4*. Food and Agriculture Organization, Rome 82p.
- Fujii, H., Garsdal, H., Ward, P., Ishii, M., Morishita, K., and Boivin, T., (2003) Hydrological Roles of the Cambodian Floodplain of the Mekong River. *International Journal of River Basin Management*, 1(3): 1-14
- Gupta, A.D., Babel, M. S. and Ngoc, P. (2004) *Flood Assessment in the Mekong Delta, Vietnam*. Proceedings of the Asia Pacific Association of Hydrology and Water Resources (APHW) 2nd Conference, Singapore.
- Garcia, L. (2002) *Overview of Early Warning Systems for Hydro-Meteorological Hazards in Selected Countries in Southeast Asia (Cambodia, Indonesia, Lao PDR, Philippines and Vietnam)*. Asian Disaster Preparedness Center [ADPC], Bangkok, Thailand.

- Hashimoto, T. R., (2001) *Environmental Issues and Recent Infrastructure Development in the Mekong Delta: Review, Analysis and Recommendations with Particular Reference to Large-scale Water Control Projects and the Development of Coastal Areas*. Working paper series (Working paper No. 4). Australian Mekong Resource Centre, University of Sydney, Australia, 70p.
- Hoanh, C.T., Phong, N.D., Gowing, J.W. Tuong, T.P. Hien, N.X. and Dat, N.D. (2006) Predicting Impacts of Water Management in Coastal Zones by Hydraulic and Salinity Modeling. Proceedings of the iEMSs Third Biennial Meeting: "Summit on Environmental Modelling and Software". In: Voinov, A., Jakeman, A., Rizzoli, A. (eds). *International Environmental Modelling and Software Society*, Burlington, USA. Available online at: <http://www.iemss.org/iemss2006/sessions/all.html>. [Accessed 2 March 2007].
- Hoanh, C.T., Guttman, H., Droogers, P. and Aerts, J. (2003) *Water, Climate, Food, and Environment in the Mekong Basin in Southeast Asia*. Available online at: http://www.geo.vu.nl/~ivmadapt/downloads/Mekong_FinalReport.pdf. [Accessed 24 February 2007].
- Hoanh, C.T., Tuong, T.P., Gallop, K.M., Gowing, J.W., Kam, S.P., Khiem, N.T. and Phong, N.D. (2003) Livelihood impacts of water policy changes: evidence from a coastal area of the Mekong River Delta. *Journal of Water Policy* 5: 475-488.
- Howie, C., (2005) High dykes in the Mekong Delta in Vietnam bring social gains and environmental pains. *Aquaculture News* No. 32, October.
- Interim Committee for Coordination of Investigations of the Lower Mekong Basin, (1988) *Perspectives for Mekong Development*. Committee Report. Bangkok, Thailand.
- John V., (2004) Dammed and dying: The Mekong and its communities face a bleak future. *The Guardian* 25 March. Available online at: <http://www.guardian.co.uk/china/story/0,7369,1177292,00.html>. [Accessed 25 April 2007].
- Johnston, R., Rowcroft, P., Hortle K.G., and McAllister, C. (2003) *Integrating environmental values into resource allocation - MRC's approach in the LMB*. Paper presented at Workshop on Integrating Environmental Impacts into Water Allocation Models of the Mekong River Basin, 15 December 2003, University of Economics, Ho Chi Minh City, Vietnam.
- Juergen, W., (2005) *From the Field: Flood Disaster Mitigation in the Mekong Delta*. The 7th European Sociological Association Conference, "Rethinking Inequalities", 9-12 September, 2005, Torun, Poland. Available online at: <http://www.erc.gr/english/d&scrn/>. [Accessed 13 March 2007].
- Kam, S.P., Hoanh, C.T., Tuong, T.P., Khiem, N.T., Dung, L.C., Phong, N.D., Barr, J. and Ben, D.C. (2001) *Managing water and land resources under conflicting demands of shrimp and rice production for sustainable livelihoods in the Mekong River Delta, Vietnam*. DFID-R7467c project document.

- Khue, N.N. (1986) *Modelling of tidal propagation and salinity intrusion in the Mekong main estuarine system*, Report of the Mekong Delta salinity intrusion studies, Mekong Secretariat, Bangkok, Thailand.
- Lang, N.T., Ky, B.X. Kobayashi, H. and Buu, B.C. (2004) *Development of salt tolerant varieties in the Mekong delta*. JIRCAS Project, Can Tho University, CanTho, Vietnam
- Lu, X.X. and Siew, R.Y. (2005) Water discharge and sediment flux changes in the Lower Mekong River. *Hydrol. Earth Syst. Sci. Discuss.*, 2: 2287-2325.
- Ministry of Agriculture and Rural Development, Government of Vietnam [MARD] (2003) *Atlas of Some Selected Hydraulic Works of Vietnam*. Hanoi, Vietnam.
- Manuta, J and Lebel, L. (2005) *Climate Change and the Risks of Flood Disasters in Asia: Crafting Adaptive and just Institutions*. An International Workshop: Human Security and Climate Change. Holmen Fjord Hotel, Asker, near Oslo, 21-23 June 2005.
- Mekong News (2003) One river, many needs to fill. *The Newsletter of the Mekong River Commission*. January - March 2003/1.
- Mekong River Commission [MRC] (2006) *Annual Flood Report 2005*. Mekong River Commission, Vientiane Lao PDR, 82pp.
- Mekong River Commission [MRC] (2005a) *Overview of the Hydrology of the Mekong Basin*. Mekong River Commission, Vientiane, November 73pp.
- Mekong River Commission [MRC] (2005b) *Saltwater Intrusion in the Mekong River Delta*. MRCS Environment Training Program Case Studies. Vientiane, Lao PDR.
- Mekong River Commission [MRC] (2005c) *Overview of the Hydrology of the Mekong Basin*. Mekong River Commission, Vientiane, November 73pp.
- Mekong River Commission [MRC] (2002) *Establishing the Economic Value of the Flood in the Mekong Basin*. Summary of Workshop held in Phnom Penh. March 20-21, 2002. Internal report, Mekong River Commission, Phnom Penh, Cambodia.
- Mekong River Commission Secretariat [MRCS] (2001) *Consultation workshop on formulation of a regional strategy for flood management and mitigation in the Mekong River Basin*. Mekong River Commission (MRC), Phnom Penh, Cambodia
- Mekong River Commission Secretariat [MRCS] (2002) *International expert meeting on early warning for the Mekong River*. Proceedings. Mekong River Commission, Phnom Penh, Cambodia.
- Milliman, J.D. and Ren, M.E., (1995) River flux to the sea: impact of human intervention on river systems and adjacent coastal areas. In: Eisma, D. ed (1995) *Climate Change: Impact on Coastal Habitation*. Lewis Publications, Boca Raton, Florida pp 57-83.

- Milliman, J.D. and Syvitski, J.P.M. (1992) Geomorphic/tectonic control of sediment discharge to the ocean: the importance of small mountainous rivers. *Journal of Geology*, 100: 525-544.
- Miller, F. (2003) *Society-Water Relations in the Mekong Delta: A Political Ecology of Risk*. PhD thesis. University of Sydney, Australia.
- Miller, F. (2000) Watershed. *Mekong Articles: Mekong Region*, February 17
- Minh, L.Q. (2000) *Environmental Governance: A Mekong Delta case study with downstream perspectives*. CanTho University, CanTho, Vietnam.
- Minh, T.H., Yakupitiyage, A. and Macintosh, D.J. (2001) *Management of the Integrated Mangrove-Aquaculture Farming Systems in the Mekong Delta of Vietnam*. ITCZM Monograph No. 1, 24 pp.
- Minister of Agriculture and Rural Development [MARD] (2003) *Ten-day Crop and Market Report, Vietnam*. Hanoi, Vietnam.
- Ministry of Transportation (1993) *Mekong Delta Master Plan, Rehabilitation and Improvement of the Main Waterways in the Mekong Delta*. Feasibility Study, Volume 2: Main Report. Government of Vietnam, State Planning Committee, World Bank, Mekong Secretariat, United Nations Development Programme.
- Molle, F. and Tuan, D.T. (2001) *Water control and agricultural development: Crafting deltaic environments in Southeast Asia*. Paper presented at the IWHA 2nd conference: "The Role of Water in History and Development", August 2001, Bergen, Norway.
- NEDECO [Netherlands Engineering Consultants] (1991) *Mekong Delta Master Plan (VIE/87/031)*, Working Paper No. 5, Forestry.
- NEDECO [Netherlands Engineering Consultants] (1993) *Master Plan for the Mekong Delta in Vietnam*. Summary Report. Government of Vietnam, World Bank and UNDP
- Nien, N.A. and Xo, L.Q. (2001) *Phan tich cac mo hinh tinh toan thuy luc sir dung cho Dong bang song Cuu Long (Analysis the hydraulics modeling applied for the Mekong Delta)*. Proceedings on Scientific and Technology Researches in 2001. The Southern Water Resources Science Institute. Agriculture Publishing House. Ho Chi Minh City, Vietnam.
- Nhan, N.H., Duc, P.V., Cong T.T. and Diep, H.N. (2001) *The Applied Assistant Software HYDROGIS for Modelling Flood and Mass Transport in Lower River Delta (Version 2.1)*, Hydro-Meteorological Service of Vietnam. Proceedings on International European - Asian Workshop: Ecosystem & Flood, June 27-29, 2000, Hanoi, Vietnam.
- Nguyen, A. D. and Savenije, H. H. G. (2006) Salt intrusion in multi-channel estuaries: a case study in the Mekong Delta, Vietnam. *Hydrol. Earth Syst. Sci.*, 10: 743-754.

- Oanh, T.T.K., Lap, N.V., Tateishi, M., Kobayashi, I., Tanabe S., and Saito, Y. (2002) Holocene Delta Evolution and Sediment Discharge of the Mekong River, Southern Vietnam. *Quaternary Science Reviews* 21: 1807-1819.
- Ojendal, J., (2000) *Sharing the Good - Models of Managing Water Resources in the Lower Mekong River Basin*. Department of Peace and Development Research, Goutenborg University, Sweden. 297p.
- Ojendal, J. and Torell, E. (1997) *The Mighty Mekong Mystery*. Stockholm Environmental Institute, Stockholm, Sweden
- Piper, B.S., Gustard, A., Green, C.S., and Sridurongkatum, P. (1991) *Water Resource Developments and Flow Regimes on the Mekong River*. Proceedings of the Vienna Symposium: Hydrology for the Water Management of Large River Basin in August 1991. IAHS Pub. No. 201
- Plate, E.J. and Insisiengmay, T. (2002) *Early Warning System for the Mekong River*. Keynote Lecture. Flood Defence, Wu et. al. eds, Science Press, New York
- Quy, V. (1997) Environmental issues in Vietnam. In: H. Mecker and V.P. Hoang (Eds.). *Environmental Policy and Management in Vietnam* Public Administration Promotion Centre, Berlin, Germany, pp 5-30.
- Reiner W., Hien, N.X., Hoanh C.T., and Tuong, T.P. (2004). Sea Level Rise Affecting the Vietnamese Mekong Delta: Water Elevation in the Flood Season and Implications of Rice Production. *Climatic Change* 66: 89-107
- Roger F., Tran P.G., and Hong, B.T.T. (2004) *Living with floods: Health Risks and Coping Strategies of the Urban Poor in Vietnam*. Research Report. Tyndall Centre for Climate Change Research. Technical Report 17. 27p. Available online at: http://www.tyndall.ac.uk/research/theme3/final_reports/t3_31.pdf [Accessed 25 March 2007].
- SOGREAH (1972) *Les modeles mathematiques du delta Mekong*. Publ. de l'UNESCO, Paris.
- Sneddon, C. and Binh. N. T. (2001) Politics, ecology and water: the Mekong Delta and development of the Lower Mekong Basin. In: Adger, Kelly, and Ninh eds. *Living with Environmental Change*. Routledge New York, pp 234-262.
- Sub-Institute for Water Resources Planning [SIWRP] (2000) *VRSAP: User's Manuals*. Ho Chi Minh City, Vietnam.
- Shafiee, M., Ahmad, A., Hassan, F., Yaakub, M.A., Sing, L.K., Fatt, C.S., Dom, N.M., Samsinar, N.A., Osman, S., Hashim, Z., Amin M.Z.M. and Aun, T.S. (2004) *Development of an Operational Monsoon Flood Management System*. Paper presented at the Third National Microwave Remote Sensing Seminar, 28 September 2004, MACRES, Kuala Lumpur, Malaysia
- Tin, H.Q., Berg T., and Bjornstad, A(2001) Diversity and adaptation in rice varieties under static (*ex situ*) and dynamic (*in situ*) management. *Euphytica* 122: 491-502

- Tinh, D.Q. (2003) *Flood Kindergarten: Community Need to Community Solution*. Department of Dyke Management, Flood and Storm Control, Ministry of Agriculture and Rural Development, Hanoi, Vietnam
- Tinh, T.K. (1999) *Reduction Chemistry of Acid Sulphate Soils: Reduction rates and influence of rice cropping*. Doctoral Thesis. Swedish University of Agriculture Sciences, Uppsala, Sweden
- Thien, L.T.T. (1998) *Review of flooding and flood management: Viet Nam country statement*. Proceedings of the Regional Workshop: Flood management and mitigation in the Mekong River Basin. FAO publication. Vientiane, Lao PDR. Available online at: <http://www.fao.org/docrep/004/ac146e/AC146E00.htm> [Accessed 2 April 2007].
- Thuc, T and Tuyen, H.M. (2005) *Hydraulics Computations for the Lower Mekong River Basin to study Flood Drainage for the Plain of Reeds in Viet Nam*. Proceedings on the Workshop: Role of Water Sciences in Trans-boundary River Basin Management, Thailand
- Triet, T., Kiet, L.C., Thi N.T.L, and Dan, P.Q. (Undated) *The invasion by Mimosa pigra of wetlands of the Mekong Delta, Vietnam*. Available online at: http://www.ento.csiro.au/weeds/pdf/mimosa_symposium/07Trietetal.pdf [Accessed 26 April 2007].
- Trung, N.H. (2006) *Comparing land use planning approaches in the Mekong Delta, Vietnam*. PhD Thesis. Wageningen University, Wageningen, the Netherlands.
- Truong, T.V. (2000) *Tu tran Lu lich su 2000: Nhin lai va Dieu chinh Quy hoach Kiem soat lu o Dong bang song Cuu Long (in Vietnamese). (From the Historical Flood in year 2000: Looking backward and Adjusting the Planning for Flood Control in the Mekong River Delta)*. Southern Institute for Water Resources Planning (SIWRP), Ho Chi Minh City, Vietnam
- Truong, T.V. (2006) *Nhan dang, Du bao va Kiem soat Lu o Dong bang song Cuu Long (in Vietnamese). (Identification, Forecasting and Control the Floods in the Mekong River Delta)*. Agriculture Publishing House, Hanoi, Vietnam. 472p.
- Tu, D.T. (2002) *Land and water investment in Viet Nam: past trends, returns and future*. Proceedings in the Regional Consultation: Investment of Land and Water. Food and Agricultural Organisation, Bangkok, Thailand
- Tuan, L.A., Viet, L.H. and Huynh, D.N. (2005) *An Inventory of Vietnam Marine and Coastal Economic and Environment*. Training Document. CanTho University, CanTho, Vietnam.
- Tuan, L.A., Wyseure, G., Viet L.H. and Haest, P.J. (2004a) *Water Quality Management for Irrigation in the Mekong River Delta, Vietnam*. International Conference on Agricultural Engineering,, Leuven, Belgium.
- Tuan, L.A., Wyseure G. and Viet, L.H. (2004b) *Sustainable Water Management for Rural Development in the Mekong River Delta, Vietnam*. The second International Symposium on Southeast Asian Water Environment, Hanoi, Vietnam.

- Tuan, L.A. (2003) *An Overview of the Drinking Water Supply Situation in the Mekong River Delta, Vietnam*. Oral Presentation on the Workshop: Water Supply in the Mekong River Delta. CanTho University, CanTho, Vietnam.
- Tuong, T.P. and Minh, L.Q. (1995) *Contamination of surface water as affected by land use types in acid sulfate soils*. Collected papers presented at the Workshop on Acid Sulfate Soil: Development and Management, Ho Chi Minh City, 18-20 October, 1995, Vol. I & II.A. Report for the Mekong River Commission. Southern Institute of Water Resources Research, Ministry.
- US Corps of Engineers (1975) *Program description and users manual for SSARR model*. US Corps of Engineers, North Pacific Office.
- United Nations University (2006) Mekong Basin Research Network. *Land cover map of the Lower Mekong River Basin*, with its accumulated flooded regions from 1999 to 2005. Available online at: http://www.mekongnet.org/Main_Page [Accessed 2 April 2007].
- Vietnam News Agency [VNN] (2002) *Soil Erosion Pose Threat to Mekong Delta Residents*. VNN Press release July 30
- Vietnam, S.R. [SRV] (2005) *National Report of Disaster Reduction in Vietnam*. The World Conference on Disaster Reduction. Kobe-Hyogo, Japan.
- Vietnam General Statistics Office Website (2007) *Production of paddy by province*. Available online at: http://www.gso.gov.vn/default_en.aspx?tabid=469&idmid=3&ItemID=6480 [Accessed 17 October 2007]
- Vietnam Red Cross [VNRC] (2002) *Lessons from the Floods: Voices of the people, local authorities, and disaster management agencies from the Mekong Delta in Viet Nam*. Discussion paper for the Viet Nam Red Cross and the International Federation of Red Cross and Red Crescent Societies, Koos Neefjes, July 2002.
- Vinh, N.X. and Andrew, B.W. (2006) *Situation Analysis: Plain of Reeds, Vietnam*. A publication of the Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme. Mekong Wetlands Biodiversity Use Wisely. Available online at: http://mekongwetlands.org/Common/download/VietNa_Situation_Analysis_web_PDF.pdf, [Accessed 8 April 2007]
- White, I. (2002) *Water Management in the Mekong Delta: Changes, Conflicts and Opportunities*. IHP-VI, Technical Documents in Hydrology, No. 61, UNESCO, Paris.
- White, I. (1996) *Possible Impacts of Saline Water Intrusion Floodgates In Vietnam's Lower Mekong Delta*. Seminar on Environment and Development in Vietnam, December 6-7, 1996. Australian National University, Australia.
- World Wildlife Fund [WWF] (2004) *Seven from Mountain to Sea: Asia Pacific River Basin Big Wins*. WWF International, Switzerland.

- Xuan, V.T. (1993) Recent advances in integrated land uses on acid sulphate soils. In Dent, D.L. and van Mensvoort, M.E.F. eds. *Selected Papers of the Ho Chi Minh City Symposium on Acid Sulfate Soils*. International Institute of Land Reclamation and Improvement, Wageningen, 53: 129-136.
- Yamashita A. (2005) *Zoning for risk assessment of water-related natural disasters in the Mekong Delta*. Master Thesis. Can Tho University, Can Tho, Vietnam.
- Yoshiki S. (2002) *Deltas in Southeast And East Asia: Their Evolution And Current Problems*. Marine Geology Department, Geological Survey of Japan. Tsukuba, Japan.

Appendix 1: The Mekong Delta Flood Damage

Appendix 1.1: The Mekong Delta Flood Damage in 2000

Personal Injury	Material Damage
Source: UNICEF 2000/10/27 (http://www.unicef.org/emerg)	
- Over 200,000 families (approximately 1 million people) are lacking food to date, and some 700,000 households (3.5 million people) may ultimately need food assistance over the next five months. - Over 60,000 households (approximately 300,000 people) remain in need of evacuation, with another 12,500 households (60,000 people) in need of further evacuation	- Approximately 825,000 homes have been inundated, rendering 4 million persons homeless or without adequate shelter. - Some 3,000 schools have been inundated as well, and considerable quantities of teaching materials have been damaged or lost. The Government estimates that over 800,000 children are currently missing school. - Total economic losses from the floods are estimated to be US\$ 257 million.
Source: OCHA Situation Report No. 5 2000/10/13 (http://www.reliefweb.int)	
- On 8 October 315 people, of whom 234 were children, were reported to have died in the floods. On 10 October the UNICEF office in Hanoi gave the figure of 319 deaths due to the floods, and on 12 October the media reported as many as 340 deaths from the floods. - Approximately 5 million people (815,000 households) have been affected by the disaster. Some 350,000 have been relocated, and another 335,000 people are still in need of relocation. In addition, 110,000 people need to be re-evacuated to safer areas.	Over 815,000 houses have been inundated and damaged. Over 70,000 ha of summer/autumn and third seasonal rice fields have been destroyed or damaged together with over 70,000 ha of subsidiary crops and fruit trees.
Source: AFP No.2 2000/09/22 (http://www.reliefweb.int)	
The floods, caused by heavy rains beginning in late July, have left more than two million people homeless.	- Floods caused an estimated 30 million dollars worth of damage. - Officials said a total of 400,000 homes were under water and some 500,000 people were short of food, water and medicine. - Some 300,000 hectares (741,000 acres) of rice fields have been flooded in the Mekong

(Source: ADRC website)

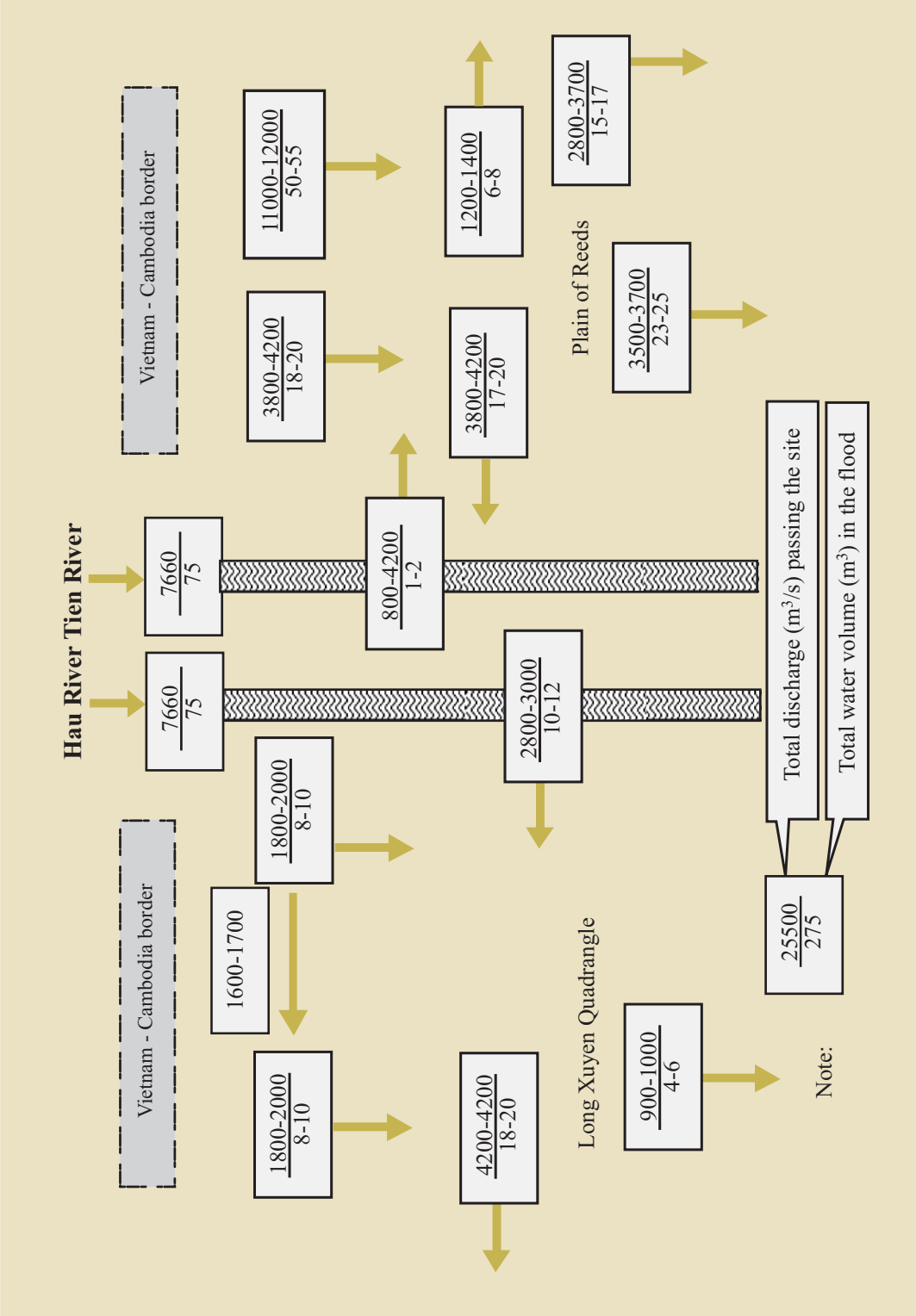
Appendix 1.2 : Total damage of severe flooding 1978-1997

No.	Damages	Unit	1978	1984	1991	1994	1995	1996	1997
1	Total human loss (Number of children loss)	Person	87	105	158	407 (265)	199 (180)	250 (160)	607
2	Damaged house	Family	57 005	41 835	185 127	593 107	26 326	42 150	99 238
3	House carried away by flood	Family	9 005	8 219	12 350	2 799	28 240	839 686	74 368
4	Households migrated	Family	245 500	10 744	15 600	20 125	11 431	39 378	
5	Rice areas entirely damaged	Ha	307 100	175 626	171 898	26 868	11 101	60 368	19 758
6	Rice areas with yield decrease	Ha	113 600	111 879	88 873	202 186	62 399	132 309	251 341
7	Estimated damage	Billion VND	1 261	1 247	883	2 284	700	2 673	6 966

* The data of 1997 include the damage caused by flooding and by typhoons. (Source: Thien, 1998)

Appendix 2: Flood Year 2000

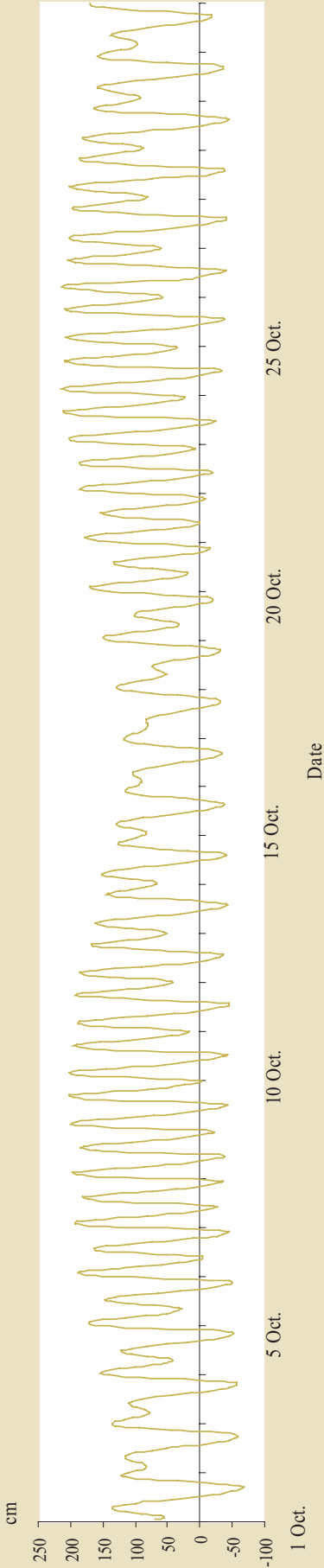
Appendix 2.1: Tien Rien River and Hau River into Long Xuyen Quadrangle and the Plain of Reeds (Data from SIWRP, Truong, 2000). Measured maximum discharges and total water volumes



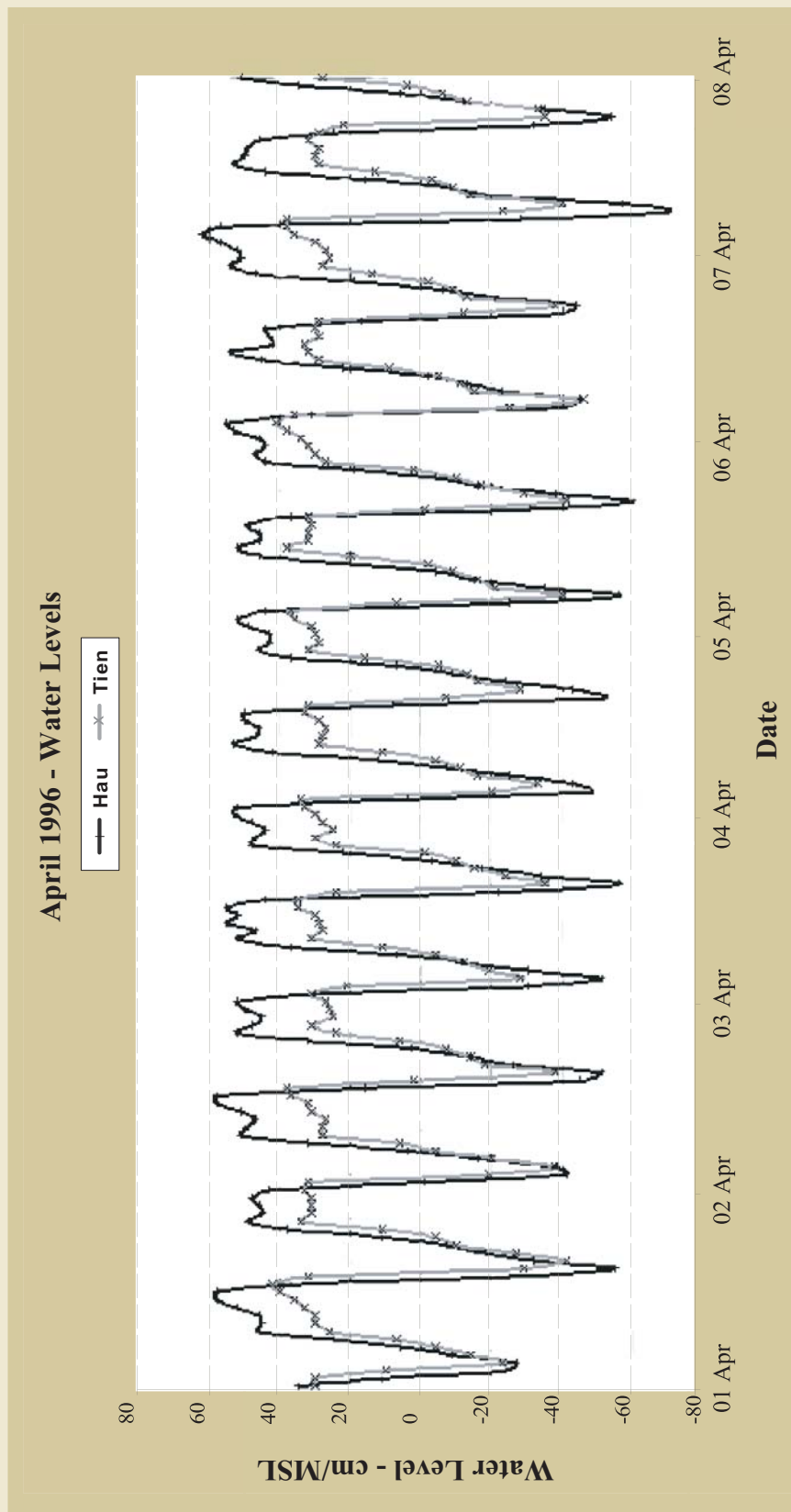
Appendix 3: Water Levels in the Main Branches of the Mekong

Appendix 3.1: Water level in Dai Ngai Station (from 01 Oct. 1991 to 31 Oct. 1991)

Water level in Dai Ngai Station (1-31 Oct. 1991)



Appendix 3.2: Water level in My Thuan (the Tien River) and Can Tho (the Hau River), 1 - 8 April 1996



Appendix 4: Integrated water management projects

Appendix 4.1: Flood control project in Vietnam Mekong Delta

Project name	Location	Project aims
Long Xuyen Quadrangle	An Giang and Kien Giang	To research for construction: (a) Dykes, dams, sluices for controlling flood water flowing overland from Cambodia; (b) Gates, dyke system for controlling salinity intrusion from the west sea; (c) Canals for irrigation and drainage; and (d) Road system and safe areas of settlement for people in the flooding season;
North Vam Nao	An Giang	To assist An Giang Province establish and operate an effective water management system in North Vam Nao which is socially and environmentally sustainable and benefits the local economy by assisting in the alleviation of poverty; to strengthen the capacity of provincial agencies in the An Giang Province to plan, operate, and maintain an integrated water control system in North Vam Nao that is efficient and effective and meets the requirements of multiple users.
Tan Chau - Hong Ngu	An Giang	To research on riverbank erosion and sedimentation
Plain of Reeds (Tan Thanh-Lo Gach flood control system)	Dong Thap and Long An	To built flood control system from the border area to the West Vam Co and the Mekong Rivers. Work system for year-around flood control at the southern areas of the Nguyen Van Tiep canal, industrial tree areas and east of Bo Bo canal are planned
Western Bassac River area	Kien Giang, Ca Mau	A flood control system along road 80 from the Long Xuyen Quadrant to the West Bassac River area, dredging flood drainage canals to the Cai Lon River and salinity protection system along the Cai Lon River are to be constructed for year-around flood control
O Mon - Xa No Sluices	Can Tho and Hau Giang	To control flood all year for the area of 45,430 ha, protect agricultural production in 3 stable crops, protect fruit juice and infrastructures; to create hydraulic system for irrigation, drainage, flush acid water, prevent salinity, taking alluvium reclaims soils for 38,800 ha of agricultural land; to supply water for domestic use and fresh rural water; to contribute road and water way transportation, filling residential foundation; and improvement of environment

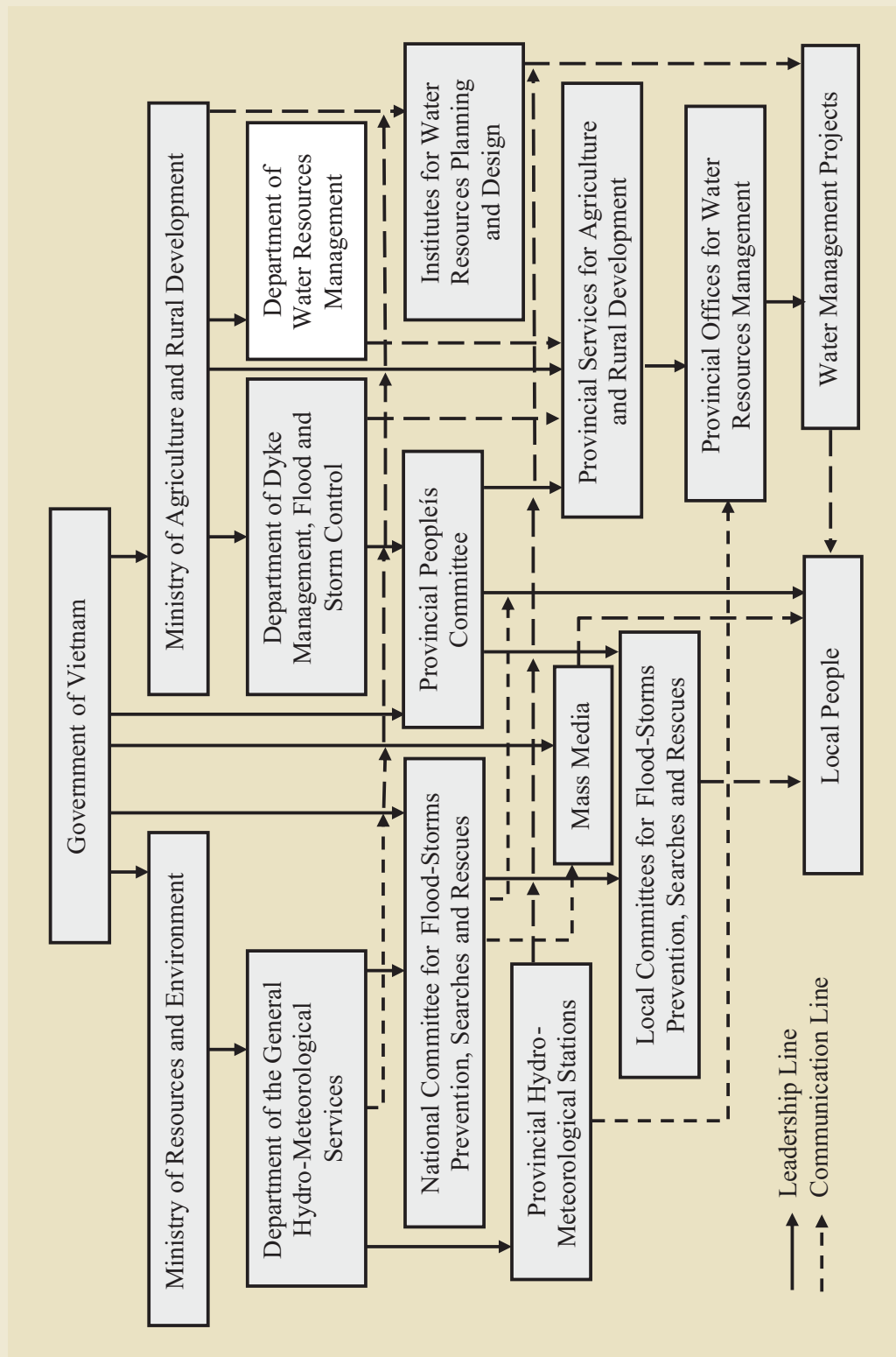
* The data of 1997 include the damage caused by flooding and by typhoons. (Source: Thien, 1998)

Appendix 4.2 : Saline intrusion control project in Vietnam Mekong Delta

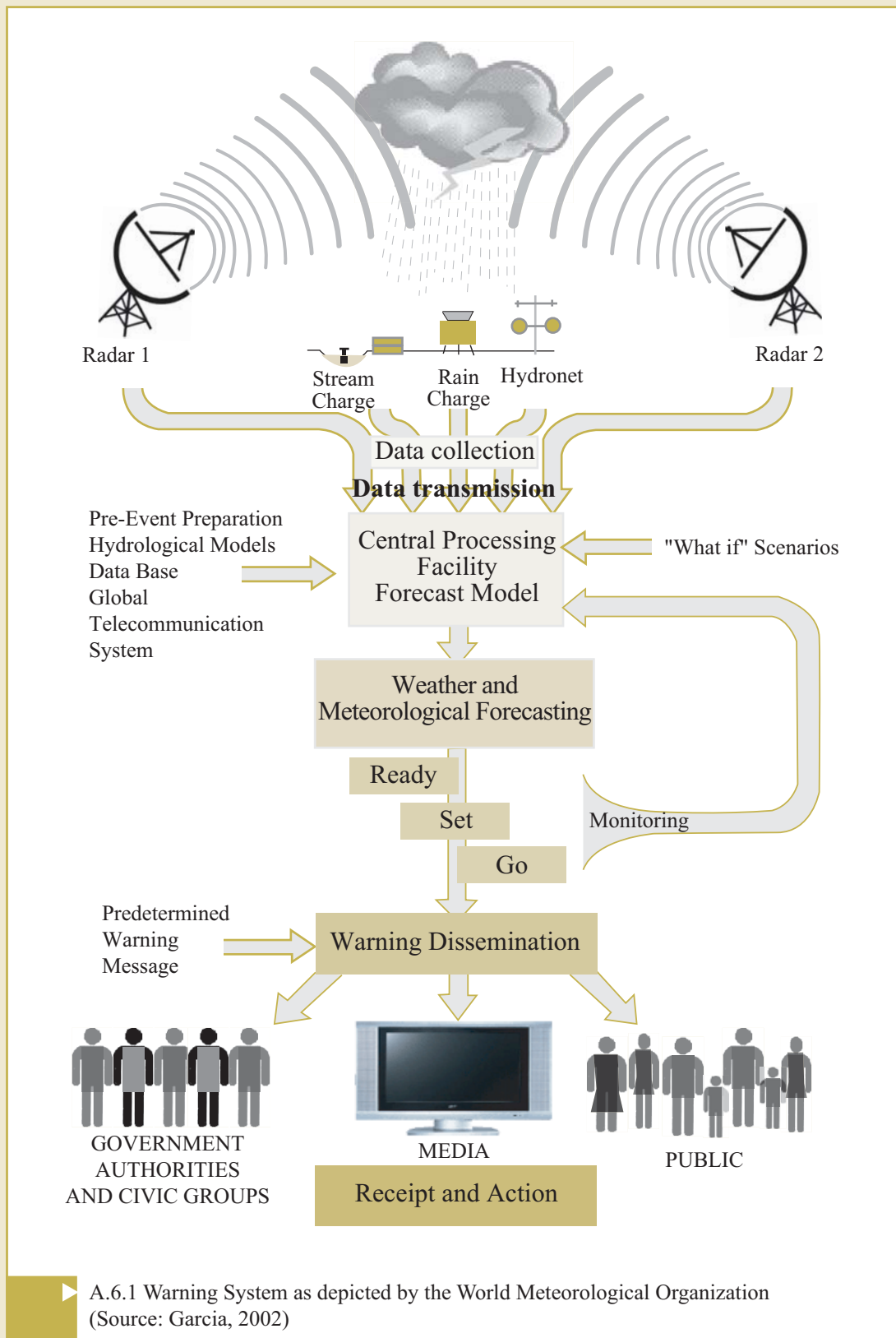
Project name	Location	Project aims
Tam Phuong Water Control Project	Tra Vinh	To irrigate and drain more than 17,000 ha of cultivated area, including 5,980 ha within the Tam Phuong project area itself, and 11,000 ha of adjacent areas which will benefit from the project.
South Mang Thit Water Resources Project	Most of Tra Vinh and part of Cuu Long	To support primary sector development through increasing agricultural production; to raise rural income and generate employment; and to reduce poverty in the project area by improving living conditions. This integrated water resources development project involves infrastructure works for irrigation, drainage flood control, saline water intrusion control, navigation and rural water supply.
Tiep Nhat Salinity Control Sluices	Soc Trang	To control salinity, take and remain fresh water, drain, flush acid water and reclaim soils for a total area of 204,818 ha of cultivated land and 263,743 ha of gross area; to supply water for domestic use of the local people; to remain and develop the aquaculture products; to contribute to the development of road and water way transportation, and improvement of environment.
Quan Lo - Phung Hiep Water Control Project	Hau Giang, Bac Lieu, Ca Mau	To supply fresh water from Hau River and to prevent the saline intrusion in the coastal areas in Bac Lieu and Ca Mau.
Ba Lai Dam	Ben Tre	To protect saline water and provide water to farmers in four districts and a part of Ben Tre town, Ben Tre Province

Appendix 5: Disaster and Water Management

Appendix 5.1: Organizational Scheme for Projects in Vietnam



Appendix 6: The major components of an Early Warning System



Chapter 2:

Livelihoods and Resource Use Strategies of Farmers in the Mekong Delta



Nguyen Duy Can¹, Le Thanh Duong², Nguyen Van Sanh³ and Fiona Miller⁴

¹Mekong Delta Development Research Institute, Can Tho University, Vietnam. Email: ndcan@ctu.edu.au

²Mekong Delta Development Research Institute, Can Tho University, Vietnam. Email: ltduong@ctu.edu.vn

³Mekong Delta Development Research Institute, Can Tho University, Vietnam. Email: nvsanh@ctu.edu.vn

⁴Livelihoods and Vulnerability Programme, Stockholm Environment Institute, Sweden. Email: fiona.miller@sei.se



Chapter 2 :

Livelihoods and Resource Use Strategies of Farmers in the Mekong Delta

1. Introduction and background	72
2. Key issues	73
2.1 Use of sustainable livelihoods framework	73
2.2 Agro-ecological zones of the Mekong Delta	74
2.3 The regional context of livelihoods in the Delta	77
3. Livelihoods and resource use strategies of farmers in the Mekong Delta	77
3.1 Historical changes in livelihoods	77
3.2 Overall changes in government policies	78
3.2.1 From rice intensification to livelihood diversification	78
3.2.2 Effective land use	79
3.2.3 Land and water use conflicts	79
3.3 Livelihood capital assets	79
3.4 Changes in production systems and resource use strategies	82
3.4.1 The Freshwater alluvial zone	82
3.4.2 The Plain of Reeds	84
3.4.3 The Long Xuyen-Ha Tien quadrangle	84
3.4.4 The Trans-Bassac depression zone	84
3.4.5 The coastal zone	85
3.4.6 The Ca Mau peninsula zone	86
3.5 Livelihood outcomes	87
3.6 Impact of external environment on livelihoods	89
4. Discussions and contested issues	90
5. Research priorities	91
5.1 Community-based natural resources management	92
5.2 Strengthening livelihood assets	93
6. Conclusions	93
List of text abbreviations	95
References	96



Abstract

The Mekong Delta, which lies at the southern tip of Vietnam, has seen rapid changes in agricultural production systems and socio-economic conditions since the 1990s when the government made reforms in the agricultural sector. Attempts on restructure agriculture and increase the economic value of farmlands was the main focus of government policy and investment. In order to promote the intensification of rice production, the government invested in building a series of dikes and canal systems to prevent floods in the upstream parts of the delta, thus allowing 2-3 rice crops per year. At the same time, in the coastal zone the government invested in a series of coastal embankments and sluices to control salinity intrusion. This agenda for agriculture-led growth has had a large influence on the livelihoods of farmers in the delta.

This paper 1) reviews and analyzes publications in order to establish the current state of knowledge on the impact of the government's policy and development interventions on farmers' livelihoods and resource-use strategies; 2) this will allow for the identification of gaps in research and the studies needed to contribute to appropriate actions on resource use, poverty reduction and securing sustainable livelihoods in the Mekong Delta.

Government intervention in preventing flooding upstream was indeed successful in its primary aim of increasing rice production but it caused environmental pollution and the degradation of soil fertility. This has become a serious concern and could undermine the sustainability of livelihoods. In the coastal zone, government efforts have promoted agricultural diversification and contributed to the improvement of farmers' livelihoods. The economy of the delta remains at a low level of development and it is concluded that the government should invest more in the asset base of the rural poor.



1. Introduction and background

The dynamic relationship between land, water and other ecological factors in the Mekong Delta support a rich variety of livelihoods for over 17 million people. Many of these livelihoods tend to be rice-oriented, although other agricultural systems, together with aquaculture and fisheries, have developed to make use of the diverse natural resources and economic opportunities.

The two main physical factors determining land use in the delta are hydrology and soil type. The interaction of different soil types in the delta (alluvial, saline and acid sulphate) with seasonal variations in water flow, rainfall and tides combine to create diverse agro-ecological zones throughout the delta. Such differences allow for important niches for resource-based livelihoods. The significant seasonal variations in water availability mean that floods in the wet season and water scarcity and salinity intrusion in the dry season provide considerable constraints (and opportunities) for livelihoods. People have to deal with seasonal and spatial differences in water quality and availability (flood, drought, salinity and pollution), which are influenced by processes within and upstream of the delta. Rice and fish production are the predominant livelihoods of most households in the flood prone areas, while in the brackish water ecosystems of the coastal areas most households rely on shrimp and rice farming activities.

It is widely known that the Mekong Delta is the “rice bowl” of Vietnam. It is significant for national food security and national export earnings. Annually, the delta produces about 19.23 million tons of rice (accounting for 54% of total national production), with an average yield 5.03 t ha⁻¹ (CSO, 2005; GSO, 2004). The delta produces rice not only for domestic consumption but also for export; with about 90% of total national rice exports originating from the delta (Duong et al, 2005). Agricultural production, especially rice and shrimp production, continues to play a dominant role in the economy, accounting for 46% of GDP at current price levels (GSO, 2005). Attempts to restructure agriculture and increase the economic value of farmlands are the main focus of government policy and investment, as well as farmers’ own efforts (Duong et al, 2005). To increase agricultural production, particularly rice, from the early 1990’s the government invested in the construction of flood dikes and diversion systems to prevent floods. This allowed 2-3 rice crops per year. In the coastal zone, the government has also invested in the development of freshwater canals and the construction of embankments and sluices to maintain freshwater for rice cultivation by preventing salinity intrusion. In 2000, the government put in place a new policy that encouraged farmers to use agricultural land more effectively (Can, 2005), hence loosening the strong focus on intensive rice production.

Flood control and salinity control infrastructure, together with the introduction of new agricultural and aquacultural techniques, have been the key government interventions to change production systems in the Mekong Delta. Wider economic changes have also supported more independent and market-oriented production since the late 1980s. However, these interventions and their livelihood impacts are not sufficiently understood. There are uncertainties in regard to:

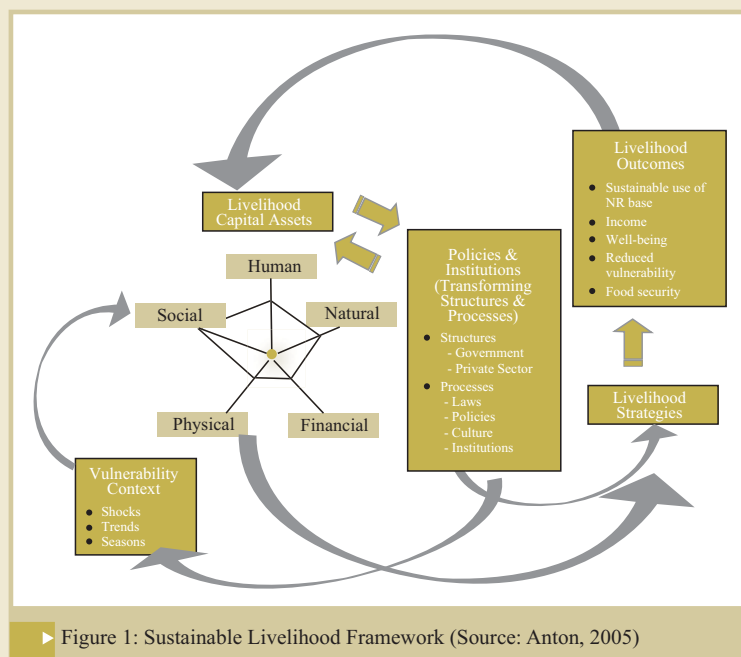
- opportunities for improved economic benefits from more diversified land and water use;
- the appropriateness of intensive rice production in different parts of the delta;
- the resolution of land and water-based conflicts in the coastal zone;
- the emergence of different livelihood strategies in different parts of the delta and tension/trade-offs over water use.

This study reviews the literature to assess changes in farmers' livelihoods, resource-use strategies and the impacts of government interventions, in order to identify research needs that can contribute to generating appropriate recommendations on resource use and livelihood development strategies. A livelihoods approach is adopted due to the benefits it offers in terms of a more holistic understanding of people's everyday lives and means of making a living. Through this paper the authors aim to study how farmers deal with a very dynamic (natural, economic and policy) environment so as to generate strategic recommendations for water management, rural development and poverty reduction.

2. Key issues

2.1 Use of Sustainable Livelihoods Framework

The Sustainable Livelihoods Framework (SLF) is used for the investigation of farmers' livelihoods (Gallop et al, 2003; Anton, 2005; Can, 2005; Hossain et al, 2006). The SLF helps to generate a holistic approach to the following issues: how farmers might be vulnerable to external environmental threats and shocks, and from where these emanate; how assets and resources, which are categorized into five forms of 'capital' (human, physical, natural, financial and social capital) might help farmers thrive and survive; the policies and institutions (e.g. organizations, levels of government, private sector behavior, laws, policies, culture and institutions) impact on farmers' livelihoods; how farmers respond to threats and opportunities; and what outcomes farmers aspire to, such as more sustainable use of the natural resource base, more income, increased well-being, reduced vulnerability and improved food security (**Figure 1**).

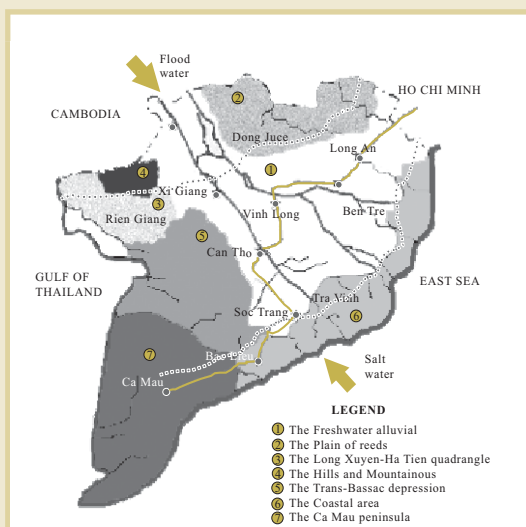


The SLF starts with five elements of livelihood capital assets and understandings of how farmers use them as a means of livelihood strategy (Hossain et al, 2006). These five assets may be visualized in the following way: (i) human capital, e.g. skills, knowledge & information, ability to work, health; (ii) natural capital, for example, land, water, wildlife, biodiversity and the environment; (iii) financial capital, e.g. savings, credit, remittances and pensions; (iv) physical capital comprising the basic infrastructure (transport, shelter, water, energy and communications); and (v) social capital, for example networks, groups, trust, access to institutions.

The livelihood outcomes are indirectly determined by policies and institutions (transforming structures and processes) that are beyond the control of the household (Hossain *et al*, 2006), thus the consideration of such factors in this paper. The vulnerability context includes shocks, trends and seasonal fluctuations that influence people's livelihoods and their belongings, but are out of their control.

2.2 Agro-ecological Zones of the Mekong Delta

The Mekong Delta is situated in southern parts of Cambodia and Vietnam. The Vietnamese portion covers an area of 3.9 million ha. The region was settled by major ethnic groups: Vietnamese, Khmer, Chinese and a small number of Cham people. Of the total population of the delta the labour force comprises 10.9 million persons and about 80% of the population live in rural areas (CSO, 2005). Population density is high, about 434 persons/km² in 2005. The Mekong Delta consists of 12 provinces and a city, three of which are areas subject to considerable flooding, and seven of which are bordered by the East Sea. About 5 million inhabitants live in flood prone areas and about 7 million inhabitants live in coastal areas.



► Figure 2: Map of the Mekong Delta with the different zone under investigation

To increase agricultural production, particularly rice, the government constructed a complex dike system to prevent floodwater in order to produce double and triple rice crops per annum in the upper part of the Mekong Delta. While in both Ca Mau peninsular and the coastal zone, from 1994 to 2000 the government progressively constructed a series of dikes and sluice gates to prevent saltwater intrusion. As a result, the canal water (sourced from intake points further upstream) has progressively become fresh, supporting an increase in cultivated rice areas at an average rate of 4.2% per annum in the period 1995-2000 (Duong et al, 2005).

Based on geographic and physical features, the Mekong Delta can be classified into six important agro-ecological zones, excluding hills and mountainous areas (Duong et al, 2005). These zones are either affected by flood or salt-water intrusion as indicated by the demarcating lines in **Figure 2**.

- *The Freshwater Alluvial Zone (FAZ)* is situated along the Trans-Bassac and Mekong rivers of the central parts of the delta. It is characterized by alluvial soil types, covering an area of about 900,000 ha, with freshwater; the environment has scarcely changed much in recent years. In this zone, people make their livelihoods by diversifying agricultural activities, as they practise double or triple rice crops, fruit trees, vegetables, and/or integrated rice-fish systems.

- *The Plain of Reeds (PRZ)* lies in Dong Thap province and parts of Long An province, covering an area of about 500,000 ha. This is the upstream but lowest part of the delta (0.5m below mean sea level). The zone is characterized by acid sulphate soils. Water and associated environmental factors were partly controlled by the flooding and acidic toxicity. People in this zone earn their living by practising rice farming and integrated rice-aquaculture.

- *The Long Xuyen-Ha Tien Quadrangle Zone (LXZ)* lies in the middle of An Giang and Kien Giang provinces, covering an area of 400,000 ha. It is also dominated by acid sulphate soils. Water and environmental factors changed from acidic ecology to freshwater ecology after 2000. Rice is the major crop and rice-based farming is the predominant activity.

- *The Trans-Bassac Depression Zone (TBZ)* lies to the west of Can Tho, covering an area of about 600,000 ha. This is the low depression area of the delta. This zone is not seriously affected by flooding and the intrusion of saline water, presenting good conditions for intensive and diversified crop production. People earn their living by practising double or triple rice crop cultivation.

- *The Coastal Zone (CZ)* is found along the eastern parts of the Mekong Delta, covering an area of about 600,000 ha. Large areas of this zone have acid sulphate soils. Since 1998 parts of this zone have experienced changed water and environmental conditions, from brackish water ecology to permanently freshwater ecology. In this zone people make their livelihoods by practising shrimp and rice farming.

- *The Ca Mau Peninsula Zone (CPZ)* is situated in the southernmost part of the delta, covering an area of about 800,000 ha. This zone is characterized by seasonally saline-affected soils presenting various rice-based farming systems under rainfed conditions. Since 1998, large areas of this zone have experienced changed water and environmental conditions to permanent freshwater ecology. At present, shrimp farming is the predominant activity.

To assess the impact of the government's intervention on people's livelihoods and resources-use strategies in different ecosystems of the Mekong Delta under a dynamic natural, policy and economic environment, a number of researchers conducted participatory rural appraisals (PRA) in order to obtain a general picture, and conducted household surveys to gather data on the operation of the household economy and to understand livelihood strategies (Gallop *et al*, 2003; Can *et al*, 2005; Hossain *et al*, 2006; Thanh *et al*, 2006; Be *et al*, 2006).

Previous studies show some degree of difference in livelihood systems and resource use of farmers among the agro-ecological zones in the Mekong Delta. In this study we also use this classification and focus on areas of the upper and downstream parts of the Mekong Delta of Vietnam: upstream (An Giang, Dong Thap), and downstream (Soc Trang, Bac Lieu, Ca Mau). This allows a picture to emerge of different aspects of the operation of household economies and in particular of the ecological zones that are most severely affected by floods and salinity intrusion.

2.3 The Regional Context of Livelihoods in the Delta

The Mekong Delta forms the most densely populated and agriculturally productive region within the Mekong Basin. Livelihoods in the delta, compared with other parts of the basin, are very resource intensive, compared with the extensive upland agriculture of many parts of Laos and the extensive rainfed and flood-recession agriculture of Cambodia. Much of the land resources are intensively cultivated and water withdrawals are high, estimated at 915 m³/cap/year, compared with 98 for Cambodia and 559 for Thailand (Ringler, 2001).

Income levels are also higher in the Mekong Delta compared with other parts of the Mekong countries, such as Cambodia and Laos. The market orientation of livelihoods in the delta has progressively strengthened with the process of *doi moi*, and has contributed to making livelihoods in the delta some of the most internationally market-integrated in the basin. The strong orientation of livelihoods in the delta towards national and international markets, especially in rice and aquatic products, has brought benefits in terms of economic returns but has also exposed farmers to new risks associated with the vagrancies of international commodity markets.

3. Livelihoods and resource use strategies of farmers in the Mekong Delta

3.1 Historical Changes in Livelihoods

Generally, changes in livelihoods of people in the Mekong Delta can be reflected through changes in agricultural systems, which are closely associated with its physical conditions (soil and water), the settlement process, canal excavation, as well as the socio-economic situation and government policy (Sanh *et al*, 1998; Can, 2002). The evolution of agrarian systems in the Mekong Delta can be divided into six stages, indicating that from very early on once settlements were established, people earned their living by practising rice farming.

Since the large-scale settlement of the delta from the late 19th century, livelihoods in the delta have shifted from fairly extensive, independent production systems with low inputs, to increasingly intensive, high-input and more organised production systems (Chiem 1994; Xuan and Matsui, 1998). Livelihoods have also become increasingly inter-dependent as water resources have become more regulated by pumps, gates and other structures requiring greater levels of cooperation at the local and more macro levels for water access (Miller, 2006a). The evolution of agrarian systems in the delta is summarized in **Box 1**.

Box 1: Evolution of agrarian systems in the Mekong Delta (Source: Can, 2000)

Rice farming in the Oc-ao period (roughly before 1857): Collection of wild rice for food and cultivation of floating rice; under the Nguyen dynasty when canals were dug, the development of canal systems attracted migrants to exploit land along canals for rice cultivation.

Traditional rice farming system period (roughly 1857-1966): The mode of farming was predominantly by tenant farming. Canals were excavated and land reclaimed for rice cultivation; various rice growing methods were practised, floating rice in deep water flood areas, single and double transplanting of rice; high yielding varieties (IR5 and IR8) were introduced in 1966.

Transition from traditional rice to high yielding rice farming period (roughly 1966-1975): High yielding rice (IR5 & IR8) was cultivated under irrigation; double rice cropping was practiced.

Rice-based farming system development stage (roughly 1976-1988): After the war farmers went back to their villages for rice production (rice land was 2 million ha, areas of double rice cropping increased); collective farming and later on contract farming were established; plantation of fruit trees and upland crops were developed. Policy reform “Doi moi” took place in 1986.

Intensification of a rice-based farming system stage (roughly 1988-1999): Rice farming shifted to more intensification and diversification, areas under triple and double cropping increased; a range of rice-growing methods were applied; privatisation and commercialisation in agricultural production.

Sustainable (ecological) farming system stage (beginning from 1990s onwards): “Sustainable agriculture” terminology began to be used in government policy from the late 1990s; strengthening the management of agricultural and other resources to improve livelihoods; new government policy on “change in the economic structure of agricultural systems” was released (2000); incorporating agribusiness management for rice production (2001).

3.2 Overall Changes in Government Policies

A number of studies indicate that farmers in the Mekong Delta live in a very dynamic environment, with policy changes impacting upon the natural resource base and ultimately, on the livelihoods of the rural poor (Xuan and Matsui, 1998; Hoanh et al, 2003; Tuong *et al*, 2003). There are three key policy and economic changes that have lead to livelihood changes in the delta.

3.2.1 From rice intensification to livelihood diversification

Following the Government's policy of increasing rice production in the early 1990s, many communities in the flood prone area had constructed dike systems to prevent floods in order to produce 3 rice crops per year (Thanh *et al*, 2006; Be *et al*, 2006). In the coastal areas, a system of sluices and dikes was also constructed in stages to protect these areas from salinity intrusion (Gallop *et al*, 2003; Hoanh et al, 2003; Tuong *et al*, 2003; Can, 2005). This resulted in rapid expansion of intensified rice cultivation. During 2000 the demand for rice production dropped and farmers focused more on diversified farming to increase their income. For instance, flood prone farmers in the FAZ, PRZ and LXZ applied integrated systems with rice, raising fish in flood waters, while farmers in brackish water in the CZ have applied innovations in shrimp farming that provide opportunities for farmers to increase their income (Brennan *et al*, 2002).

3.2.2 Effective land use

In 2000, the Government instituted a new policy that encouraged farmers to use agricultural land more effectively (Gallop *et al*, 2003; Hoanh *et al*, 2003; Tuong *et al*, 2003; Can *et al*, 2005; Thanh *et al*, 2006; Be *et al*, 2006). This policy has had a tremendous impact on agricultural production and farmers' livelihoods. As a result, some rice areas have been converted to shrimp farming and shrimp cultivation has expanded in the salinity intrusion zone of the downstream part of the CZ of the Mekong Delta, while diversified rice-based farming and maintaining the areas of intensive rice production upstream (FAZ and PRZ).

3.2.3 Land and water use conflicts

In the CZ, however, increasing salinity protection has led to social conflict between shrimp farmers and rice farmers, who depend on freshwater to irrigate their fields. The situation has prompted the government to re-examine the policy of emphasising rice production and to explore alternative land uses in the Mekong Delta (Gallop *et al*, 2003; Hoanh *et al*, 2003; Tuong *et al*, 2003; Gowing *et al*, 2006).

These policy and economic changes have allowed for key livelihood changes throughout the delta. A case study from the CPZ also showed a great change in land use systems, as over 125,000 ha of rice land and some other crops and tree areas had been converted to shrimp farming in 2003 (Can, 2005). This resulted in a more restricted freshwater ecological zone and a more extensive saline ecological zone.

3.3 Livelihood Capital Assets

Information on the livelihood capital assets was obtained mainly from case studies through a household survey in six agro-ecological zones of the Mekong Delta, conducted by Thanh *et al*, (2006) and Be *et al*, (2006). It is noted that this was the first comprehensive piece of livelihoods research in the Mekong Delta, covering all major six agro-ecological zones, although the number of samples was limited to 327 households.

Human capital is an important asset in the region. In the rural area, the household size ranged from 4 to 6 persons. Previous case studies indicated some differences in household size among the six zones, being higher in LXZ (5.76 persons) and lower in PRZ (4.24 persons). As a whole, the proportion of males was 49% and females 51%. The labour-active age group (16-55) constituted 66% of the population. Hossain *et al*, (2006) reported that the average number of workers per household was 3.3 for the CZ,

85% of them being engaged in agriculture. The education attainment of the household head showed that CPZ had a higher proportion of household heads passing secondary school (64%), while in PRZ households had a higher proportion of people passing high school (42%). The level of skills of the workers was unequally distributed. Average years of experience in shrimp farming for the household head (manager) was 9.2 in the CZ and 4.5 in the CPZ (**Table 1**), reflecting the pattern of aquaculture development in the delta.

The gender of the household head was considered to be important, influencing household livelihoods. Previous case studies also showed some differences of household heads where these were female, but the majority was male (**Table 1**). Hossain *et al.*, (2006) reported that the incidence of poverty was substantially higher for the households managed by women than those with a male head.

Natural capital was considered to be a predominant asset. The land owned by a household was different among the six agro-ecological zones. In the CZ, the average size of land owned by households was the highest (2.51 ha), compared with 1.15 ha for the Mekong Delta and 0.72 ha for Vietnam as a whole (Hossain *et al.*, 2006). This figure also reflects the lower productivity of land in this part of the delta compared with elsewhere. In the CZ and CPZ, a large proportion of land owned was used for aquaculture (raising shrimp or fish), very little land being used for orchards and the homestead. In the FAZ, PRZ, LXZ and TBZ, the land was mainly used for growing rice, some land for orchards and very little land used for the homestead (**Table 1**). Households that cultivated no land was present in six zones, but were unequally distributed, e.g. with 16% of all households with no land in the CZ (Hossain *et al.*, 2006), whereas there was about 10% in the CPZ.

► Table 1: Endowment of capital per household by zone

Capital item	FAZ	PRZ	LXZ	TBZ	CZ	CPZ
Natural capital:						
Land owned (ha)	1.36	1.83	1.40	1.75	2.51	2.08
Rice land (ha)	1.02	1.46	1.29	1.19	-	-
Shrimp/fish land (ha)	-	0.02	0.01	0.26	2.37	1.95
Orchards (ha)	0.28	0.32	0.06	0.23	0.07	0.08
Homestead (ha)	0.06	0.03	0.04	0.07	0.06	0.05
Human capital:						
Household size (units)	4.93	4.24	5.76	5.47	5.01	5.00
Labor age (16-55) of household (units)	3.11	2.33	3.79	3.95	3.43	3.41
Labors engaged in non-farm activities (units)	1.88	1.05	2.71	2.50	2.05	2.12
Labors engaged in off-farm activities (units)	0.64	0.05	0.42	0.28	0.29	0.34
Experience in shrimp farming (years in farming)	-	-	-	-	9.2	4.5
Education of head (% passed primary school)	6	12	18	7	9	7
Education of head (% passed secondary school)	34	37	21	58	43	64
Education of head (% passed high school)	29	42	40	25	39	24
Gender of head (% female)	16.2	2.4	5.3	0	6.3	4.9
Financial capital:						
Enough production capital (% household)	26.3	52.4	28.9	40.0	18.0	19.6
Loan received (% household)	44.2	42.9	71.1	71.7	85.5	90.2
Physical capital:						
Pump machine (% household owned)	74.7	76.2	78.9	50.0	91.4	27.4
Boat (include motor boat) (% household owned)	38.0	76.2	71.0	85.0	21.4	72.4
Rotate fan (% household owned)	1.2	4.8	13.2	0.0 6	7.2	13.7
Sprayer (% household owned)	73.6	57.2	68.4	63.3	2.9	0.0
Social capital:						
Member of mass organization (% of head)	6.9	5.5	9.5	10.7	14.3	11.4

(Source: from household survey, MDI (Thanh et al, 2006; Be et al, 2006))

The physical capital and financial capital of households among the six zones were still at a low level. A large proportion of households reported having a lack of the means for production. For instance in the CPZ, only 27% households had pump machine whilst in the freshwater zones (FAZ, PRZ, LXZ), over 70% households had a pump (**Table 1**). In the CZ and CPZ where rotate fans were used as a main tool in shrimp farming, only 13.7% and 67.2% households had rotate fans, respectively. About 30% of households had enough capital to operate their production economically. Nearly 70% of households received loans from institutional sources, especially in the CZ and CPZ, about 90% households borrowed money. The amount of money borrowed from different sources varied from US\$220 to US\$1000, depending on the production activities (Hossain *et al*, 2006; Can, 2005). So, in the CZ and CPZ there appears to be higher levels of indebtedness and landlessness, especially amongst the poor.

The level of social capital was measured by membership of the households in different organizations and networks. Over 10% of the households reported membership of mass organizations for the TBZ, CZ and CPZ, and less than 10% for the FAZ, PRZ and LXZ. Mass organizations, which included the Farmers' Association, the Women's Union, the Veteran's Union and the Farmers' Club, had a significant influence on farmers' livelihood as they supported micro-credits and shared information.

3.4 Changes in Production Systems and Resource Use Strategies

Farmers use their capital assets and resources in different ways to make their living. Table 2 provides information on production systems and resource use of farmers in six agro ecological zones. It was noted that this information is based on mainly the two case studies conducted by the Mekong Delta Development Research Institute (MDI) of Can Tho University (Thanh *et al*, 2006; Be *et al*, 2006).

3.4.1 The Freshwater Alluvial Zone (FAZ)

Before 1995, farmers used to cultivate two rice crops in paddy fields and grew mixed trees of low economic value in their gardens. After 1995, when canal water and dike systems were improved progressively, the production system changed. In the upper part, as many surrounding dike systems were built to prevent flooding, the area allocated to third crop of rice quickly increased. For example, in An Giang, the area of a third crop of rice increased from 21,000 ha in 2000 to 80,340 ha in 2004. In Dong Thap, this increased from 18,840 ha in 2000 to 62,840 ha in 2004 (CSO, 2005). However, as the price of rice fluctuated, farmers saw very low returns from rice production, and then began to diversify.

► Table 2: Changes in production systems and resource use strategies of farmers by agro ecological zones

Agro ecological zone	• Production systems and resource use strategies of farmers before 2000	• Production systems and resource use strategies of farmers after 2000
The Fresh water alluvial zone (FAZ)	• Monorice with double or triple cropping; some areas applied rice-upland crop or rice-fish systems • A few area with specializing in upland crop • Less investment in fruit tree garden and mixed fruit tree garden	• Intensive rice farming with double or triple cropping; Increased areas applied rice-upland crop or rice-aquaculture systems • Increased areas with specializing in upland crop • High investment in fruit tree garden and focused growing high quality fruit tree
The Plain of Reeds (PRZ)	• Monorice with only one or two cropping • A few area with specializing in upland crop, growing lotus • Some areas with melaleuca tree and fallow	• Intensive rice farming with double or triple cropping; rice-fish systems • Diversity of upland crops and trees (vegetables, yam, pineapple, lotus, sugar cane, malaleuca tree)
The Long Xuyen-Ha Tien quadrangle (LXZ)	• Monorice with double cropping • Traditional rice- upland crop (maize, sesame), traditional rice- fallow	• Monorice with double or triple cropping; Two rice- upland crop systems; Rice- fresh water shrimp systems • Some areas with specializing in upland crop; Fruit tree garden
The Trans-Bassac depression zone (TBZ)	• Cultivation of one or two rice cropping; A few area with rice-upland crop • Cultivation of pineapple, sugar cane • A few areas with fruit tree and fallow	• Double or triple rice cropping (predominant); Rice-upland crop; Rice-fish systems • Cultivation of pineapple, sugar cane • A few areas with fruit tree
The coastal zone (CZ)	• Extensive shrimp culture with natural juveniles; Traditional rice-shrimp systems • Mangrove forest-shrimp system • A few areas with fruit tree and fallow	• Intensive shrimp farming (industrial and semi-industrial shrimp farming); Rice-shrimp systems • Mangrove forest-shrimp (integrated fish and crab) system • A few areas with fruit tree
The Ca Mau peninsula zone (CPZ)	• Semi-intensive shrimp farming; Mangrove forest-natural shrimp system • Traditional rice-wild fish or two rice- wild fishsystems • Malaleuca- wild fish	• Intensive shrimp farming (industrial and semi-industrial shrimp farming); Rice-shrimp/fish systems • Double rice-fish system • Forestry-shrimp system

Source: Thanh et al (2006); Be et al (2006)

The peak of these changes occurred during 2000 to 2002 as the government released the Decree No 09/2000/NQ-CP to encourage farmers to change production systems and consumption of agricultural products (Thanh *et al.*, 2006; Be *et al.*, 2006). On areas less favourable to rice, people started growing maize, vegetables, and watermelons, obtaining higher profits. The area allocated to aquaculture also expanded rapidly. For instance, in Can Tho City, the area used for raising freshwater fish increased from 7,104 ha in 2000 to 10 893 ha in 2004. The same trend was found for An Giang and Dong Thap. On the relatively

high land, farmers grew fruit trees as the area became flood-free. The natural catch of fish from rivers and canals decreased substantially as a result of dike construction and a reduction of wild fish, leading to a decline in employment and income from fisheries, especially amongst poor households. For instance, in An Giang, the amount of natural catch of fish decreased from 91,268 tons in 2000 to 58,062 tons in 2004 (CSO, 2005).

3.4.2 The Plain of Reeds (PRZ)

According to previous studies, before 1990 swampland occupied a large area. Farmers used to cultivate one to two rice crops, mixed garden, melaleuca, or fallow in this swampland. These production systems were changed to be more diversified from 2000 to 2001 (Thanh *et al*, 2006; Be *et al*, 2006). After the government had supported in some programmes such as reclaiming and digging canals, farmers tried further intensification by growing two to three rice crops, applying an integrated rice-fish system, or two rice crops integrated with lotus. Most of the fallow land was converted to growing yams, pineapple or sugar cane.

3.4.3 The Long Xuyen-Ha Tien Quadrangle Zone (LXZ)

Before 1995, farmers used to cultivate one traditional rice crop, or traditional rice with an upland crop. Two rice crops were grown in areas where there was freshwater for irrigation. Since 1995, the production systems were changed as the Vinh Te canal was introduced. With the increased availability of freshwater, rice cropping in the LXZ shifted from one traditional variety to double or triple cropping by using short duration rice varieties. Farmers also tried out rice-upland crop and an integrated rice-aquaculture system (particularly rice-freshwater shrimp). On the relatively high land or dike, they grew fruit trees and forest trees.

3.4.4 The Trans-Bassac Depression Zone (TBZ)

The production systems in the TBZ started to change from 1996, thanks to freshwater canal programmes, particularly the Quan Lo Phung Hiep canal which provided freshwater to the Ca Mau peninsula; Mang Thit canal introduced freshwater to south Mang Thit in Tra Vinh, and canal systems diverted flood waters to the Gulf of Thailand. With the increased availability of freshwater, rice cropping from one or two rice crops per year shifted to double or triple cropping. Some farmers practised integrated rice-upland crop, integrated rice-aquaculture systems (e.g. rice-shrimp/fish), and they also expanded areas of fruit trees, sugar cane and pineapple. Poor households that had no land worked as hired labour in agricultural activities and caught natural shrimp and fish, although these are less plentiful now due to the impact of agrochemicals.

3.4.5 The Coastal Zone (CZ)

Before 1990, as the freshwater canal systems were undeveloped, wetlands covered a large area with abundant supplies of natural fish and shrimp (Hossain *et al*, 2006). From 1997 the salinity in the “freshwater project zone” decreased and freshwater has been found in canals all year round. Since then, most swampland in this zone was converted to rice land. Some farmers tried further intensification by growing two to three rice crops, diversifying agriculture by growing more vegetables and upland crops in the dry season. While outside of the “freshwater project zone” farmers experimented with intensive or semi-intensive shrimp farming. From 2000, as the decree No. 09/2000/NQ-CP was promulgated, the land-use strategy of farmers changed. As a result, the area for culturing shrimp increased rapidly, while at the same time, the area growing rice decreased significantly (**Table 3**). A large area of rice land with low yields was converted to shrimp ponds. Farmers had tried many ways of getting saline water in to raise shrimp but, as the yield for each season dropped some farmers became bankrupt and lost essential assets, such as land. The natural catch of shrimp and fish decreased as a result of environmental changes that led to decline in income from fisheries for poor households. However, the intensification of rice farming and shrimp farming generated opportunities for hired labour, especially for landless farmers (Hossain *et al*, 2006).

► Table 3: Changes in shrimp and rice areas in selected coastal provinces of the Mekong Delta

Selected coastal provinces	Year				
	2000	2001	2002	2003	2004
Changes in shrimp production area (ha)					
Ben Tre	-	19,103	28,228	29,469	33,731
Tra Vinh	9,512	12,910	12,910	15,820	18,800
Soc Trang	33,280	48,673	34,729	41,280	48,879
Bac Lieu	54,017	82,967	101,690	112,345	118,538
Ca Mau	153,373	217,898	239,398	248,028	248,174
Changes in rice production area (ha)					
Ben Tre	101,617	100,817	99,496	95,538	90,511
Tra Vinh	238,525	238,411	235,224	235,164	234,551
Soc Trang	370,385	348,764	354,865	349,552	315,205
Bac Lieu	217,393	177,978	169,811	150,439	137,212
Ca Mau	248,241	131,570	130,563	107,009	131,659

Source: CSO (2005)

3.4.6 The Ca Mau Peninsula Zone (CPZ)

Before 1995, farmers used to practise extensive shrimp farming, integrated forest-natural shrimp farming, traditional rice-wild fish and integrated melaleuca-fish farming. After 1995, the production systems changed. The extensive shrimp farming (by natural culture) was replaced by semi-intensive culture system and was quickly followed by the development of intensive shrimp farming. The shrimp boom took place from 2001 to 2003, and then shrimp farming moved further inland. A large number of new farms were constructed during this time. This led to the emergence of serious environmental problems in the shrimp aquaculture sector during 2001-2003 such as mangrove deforestation, disease increase, water pollution and soil degradation (Binh *et al*, 2005; Tho *et al*, 2006; Sels, 2004; Gowing *et al*, 2006). Shrimp yields fluctuated dangerously, resulting in high farm risk levels. Farmers tried polyculture aquaculture (shrimp, crab, fish) instead of shrimp monoculture (Can *et al*, 2005). The development of shrimp farming had generated opportunities for hired labour for landless farmers. Labourers, mostly poor and landless farmers, from different provinces migrated to this zone for hired work.

Table 4 reveals some similarities in livelihood strategy among the six zones. A large proportion of workers were dependent on farming, except in the PRZ, indicating a positive effect of agriculture diversification on employment generation. Engagement for agriculture wage labour was marginal. The high engagement in non-agriculture activities is presumably due to the effect of urbanisation and newly-generated opportunities for hired labour.

The data on the structure of household income indicates the importance of the involvement of households in many economic activities (**Table 5**). Farmers reported income generation from catching fish, raising livestock and selling their labour, which contributed significantly to the total household income. In terms of the contribution to household income, rice-based farming were the most important activities (47-92%) in the FAZ, PRZ, LXZ and TBZ, whereas shrimp farming ranked the top (57-75%) in the CPZ and CZ, but was high risk. Many farmers reverted to extensive or semi-intensive shrimp farming in order to avoid these risks.

► Table 4: Source of employment of workers by zone, 2005

Primary and secondary occupation	FAZ	PRZ	LXZ	TBZ	CZ	CPZ
Agriculture (%)	76.1	56.2	73.1	77.3	74.3	77.0
- Farming	63.1	55.0	65.8	72.2	68.5	68.2
- Agriculture wage labor	13.0	1.2	7.3	5.1	5.8	6.8
Non-agriculture (%)	38.1	24.8	47.0	45.7	40.9	42.4
Total	114.2	81.0	120.1	122.0	115.2	119.4

^a The total exceeds 100 because workers are counted twice if they are engaged in a secondary occupation.
 FAZ = Fresh water alluvial zone, PRZ = Plain of Reeds, LXZ = Long Xuyen-Ha Tien quadrangle zone,
 TBZ = Trans-Bassac depression zone, CZ = Coastal zone, CPZ = Ca Mau peninsula zone
 (Source: authors' estimate from sample household survey, MDI)

► Table 5: The structure of household income from sources (in %) by zone, 2005

Sources of income	FAZ	PRZ	LXZ	TBZ	CZ	CPZ
Agriculture	72.0	100.0	85.4	67.8	91.0	80.0
Rice-based farming	57.5	92.3	75.9	47.1	0.0	0.0
Fisheries/Shrimp	0.0	0.0	0.0	0.0	75.2	57.4
Catching fisheries	1.0	1.0	2.5	5.8	3.2	13.9
Livestock	12.2	3.7	3.1	13.5	2.4	1.1
Agriculture labor	1.2	3.0	3.8	1.4	10.2	7.6
Non-agriculture	23.8	0.0	11.4	15.5	6.8	20.0
Other (remittance)	4.2	0.0	3.2	16.6	2.3	0.0
All sources	100.0	100.0	100.0	100.0	100.0	100.0

FAZ = Freshwater Alluvial Zone, PRZ = Plain of Reeds, LXZ = Long Xuyen-Ha Tien Quadrangle Zone,
 TBZ = Trans-Bassac Depression Zone, CZ = Coastal Zone, CPZ = Ca Mau Peninsula Zone
 (Source: authors' estimate from sample household survey, MDI)

3.5 Livelihood Outcomes

Livelihoods can be understood as resulting in multiple outcomes in terms of income levels, well being, security and sustainability. In terms of income, as a whole, the average income earned by a household during the year was estimated at USD1745. This compares favourably with the national average of USD1937 for the whole country¹, indicating the household income in the Mekong Delta remains at a lower level (GSO, 2005). There is a large variation in income in the six zones (**Table 6**). Per capita income was highest in the FAZ and CZ compared to other zones. Per capita income was US\$466 in the FAZ, indicating the large income contributed by diversifying agriculture and rice farming. At the same time, for the CZ per capita income was US\$424, reflecting the large income contributed by shrimp farming. Per capita income was low in the LXZ, TBZ and CPZ, compared to the national average of USD387.

Per capita income in the CPZ was nearly less than half of that in the CZ. The transition from extensive to intensive shrimp system and the shrimp boom has indeed had a negative impact on livelihood. The income from shrimp farming was less, which pushed down the average household income in the zone. Low shrimp yields could be attributed to the environmental problems and shrimp diseases (Sels, 2004; Can *et al*, 2005; Tho *et al*, 2006; Gowing *et al*, 2006). Can *et al* (2005) also reported the incidence of risk was very high for shrimp farming. Particularly between the periods 2001-2003, per capital income fell from USD635 to USD448 due to declining of shrimp incomes. About 33% of shrimp farming households was estimated to be unsuccessful in 2003.

Since the level of income was not high, and it was unequally distributed, the incidence of poverty in the Mekong Delta was high, and equal to the national average poverty rate of 19.5%. According to GSO (2004), poverty rate was calculated by monthly average expenditure per capita and the poverty line used by the Vietnamese government and the World Bank with monthly average expenditures for 2004 at 173,000VND (equal to USD 11.5). About 5.1% of the Mekong Delta population was estimated to be in a condition of food poverty, compared to the national average of 7.8% (GSO, 2005).

► Table 6: Average incomes from the source for households (US\$/annum) by zone, 2005

Sources of income	FAZ	PRZ	LXZ	TBZ	CZ	CPZ
Agriculture	1,652	1,592	1,482	1,052	1,932	937
Rice-based farming	1,321	1,470	1,318	731	0	0
Fisheries/Shrimp	0	0	0	0	1,598	673
Catching fisheries	22	16	44	90	69	163
Livestock	281	59	54	209	50	13
Agriculture labor	28	47	67	22	216	89
Non-agriculture	548	0	198	241	144	234
Other (remittance)	96	0	56	258	48	0
All sources	2,296	1,592	1,736	1,551	2,124	1,171
Family size	4.93	4.24	5.76	5.47	5.01	5.00
Per capita income	466	375	301	283	424	234

FAZ = Fresh water alluvial zone, PRZ = Plain of Reeds, LXZ = Long Xuyen-Ha Tien quadrangle zone, TBZ = Trans-Bassac depression zone, CZ = Coastal zone, CPZ = Ca Mau peninsula zone

Source: sample household survey, MDI (Thanh et al., 2006)

Considering livelihood outcomes can not only be evaluated as income levels, the sustainability of livelihoods needs to be considered. The sustainability of current livelihoods is influenced by the favourability of market returns on investments (i.e., the price of inputs vis-a-vis commodity prices), environmental impacts of production activities, particularly on water resources and biodiversity, and the vulnerability to economic and environmental shocks. Considering this, the sustainability of livelihoods remains a challenge for many in the delta, particularly small producers who face marginal returns from rice and those subject to severe floods and water scarcity in the lower delta. The decline in water quality in particular poses a problem for human health and sensitive production systems, such as fisheries and aquaculture.

3.6 Impact of external environment on livelihoods

Government efforts in investment in flood control projects in the flood prone zones, and the construction of dykes and sluices to prevent salinity in the coastal zone could be considered as an external force to promote agricultural intensification and diversification. It is widely accepted that natural capital (land and water resources) and human capital (labourers) are important assets; as such intervention has a large impact on the improvement of productivity of land and labour.

According to Thanh *et al* (2006), the FAZ, which produces three rice crops a year, obtained a total rice production of 13.5t/ha/year, valued at US\$1940 and net returns to the household resources of US\$1096. Continuous cultivation of three rice crops, however, has led to harmful effects on the environment and the degradation of soil fertility. In the PRZ, the other zone in the flood prone area, farmers grew two rice crops and one upland crop a year. This gave a net return to the household of US\$1189 per year. This information suggests that there was a positive impact from government intervention.

Semi intensive shrimp farming in CZ and CPZ yielded about 904 kg/ha/year, equivalent to 39 tonnes of rice. The net return from shrimp farming per ha was estimated at US\$1598 per year. For those engaged in a rice-shrimp system, the “preferred” system by most farmers, the shrimp yield was 222 kg/ha/year, equivalent to 9.7 tonnes of rice. In addition, farmers harvested rice in the wet season from the same land and obtained a yield of 4.0 t/ha. The total net annual return to a household was estimated at US\$1969 per ha. The existing rice-shrimp system in the CZ provided almost twice the income compared with the most intensive rice system that the government intervention had induced in the zone. However, continuous cultivation under rice-shrimp system may affect the land quality in the long term.

Hossain *et al* (2006) reported that shrimp prices were more favourable than those of rice. This attracted farmers to raise shrimp and caused them to ignore the risks, both

environmental and economic. One kg of shrimp was equivalent to 55 kg of paddy. Both rice and shrimp prices fluctuated from year to year, but the shrimp market was more volatile. Even if the price of shrimp had declined by 50% from the level of 2001, the rice-shrimp system would remain more profitable than intensive rice.

To conclude, in the upstream parts (FAZ, PRZ, TBZ, LXZ), the investment in water management intervention together with promulgating appropriate policies encouraged farmers in an intensification and diversification of agriculture and contributed to an improvement in agricultural productivity. However, in the downstream parts (CZ and CPZ), the intervention seemed to be limited to improving agricultural productivity, an important element of livelihood outcomes.

As discussed in other papers in this monograph, water resources are strongly influenced by the activities of upstream Mekong countries. An increase in water use, especially in the dry season, as is consistent with current agricultural intensification strategies in Laos, Thailand and Cambodia, poses a risk for dry season water needs in the delta (Miller, 2006b). A decline in water security is likely to pose challenges for livelihoods reliant on intensive water use in the dry season, as is the case in the double and triple rice cropping areas of the mid-delta.

Moreover, further modification of the floodplain in Cambodia, as has already occurred in the Mekong Delta in Vietnam, will result in further losses of important wetland habitats for fish. Migratory fish are of course reliant on floodplains for spawning. The decline in wild fisheries will particularly affect those households, especially poorer households, reliant on fisheries as a supplemental food and income source, as discussed by Loc *et al* (2007) in another paper in this monograph.

International rice market fluctuations are also a big influence on people's livelihoods. Rice price fluctuations can result in changes in people's livelihood activities, with people choosing to either invest in rice when the price is high or diversify into other areas when it is low.

4. Discussions and Contested Issues

The government intervention in water management, particularly in preventing floodwater for upstream parts and in controlling saline water intrusion into the coastal zone, was successful in its primary aim of raising rice productivity. This encouraged farmers in intensification and diversification of agriculture in the flood prone zones as they could grow a third rice crop or grow more of the upland crop. In the coastal zone, some areas successfully practised double or triple rice, induced by government intervention. However, management in the coastal zone is not easy as far as effective resource use for increasing income and sustaining of natural resources is concerned.

Most farmers remain directly dependent on a productive natural resource base for their livelihoods. In the early stages of intervention, salinity protection led to social conflict between shrimp farmers and rice farmers, who depend on freshwater to irrigate their fields. This led to the emergence of important social factors in the management of natural resources that link to the strategy of community-based interventions for natural resource management, sensitive to multiple resource interests.

The salinity protection in the CZ and CPZ had a negative impact on the livelihoods of the poor as they found it difficult to access information and advanced technologies, lacked access to land and other services, their livelihoods depending on these natural resources. Landless farmers or farms with marginal land also experienced negative impacts because they could not use advanced technologies and invest in farming since their capital assets were low. The institutional support, particularly extension services, had not paid enough attention to the poorer or landless farmers. Extension services have only offered technology-oriented solutions, and did not provide interventions on socio-economic issues, such as local institutional development. Capacity building for rural poor areas should not only help local people in technological aspects, but also socio-economically.

The effect of government investment on the construction of sluices to prevent saline water in the CZ reduced farm income during the transitional stage. Several households suffered heavy losses. This situation might improve over time as farmers gain experience with environmental changes and production system change. But this problem needs support from institutions, diffusing improved technologies and innovations, in order to prevent further losses.

Current government interventions, which aim to help the rural poor to improve their livelihood may sometimes ignore the negative impact of such intervention. So far, there are few studies that investigate this issue. It is suggested that there is a need for a further study to analyse pathways into and out of poverty in zones where the environment and resources management are serious casualties.

5. Research Priorities

The sustainable livelihoods of farmers are realised when they are not dependent on external support, can maintain long-term productivity of natural resources and stay resilient to shocks and stresses from external impacts. In relation to the current situation of farmers' livelihoods and resource use strategies the following key issues are identified as first priorities in the Mekong Delta region.

5.1 Community-Based Natural Resources Management (CBNRM)

Problems related to the sustainable management of natural resources are most critical in the flood prone and coastal areas of the Mekong Delta, where natural resource degradation can lead to irreversible loss of food productivity and the breakdown of ecosystems due to loss of habitats. A widespread process of the privatisation of natural resources, such as forests and coastal areas that were previously collectively managed, has been underway for close on 20 years. Privatisation may lead to productivity increases in the short term, but frequently it also increases poverty because poor people, who previously had access to these common resources, such as wetlands, fishers and forests, are now excluded.

CBNRM activities previously were implemented not only in the Mekong Delta region, but also in many other areas in Vietnam which formulated a Natural Resource Management Network (NAREMNET 1996-2002) whose nucleus body is the Mekong Delta Development Research Institute (MDI), formerly the Mekong Delta Farming Systems R&D Institute of Can Tho University. NAREMNET brings together six Vietnamese organisations and has as its general objective the development of human resource capabilities in Vietnam in CBNRM, building on the past farming systems research approaches and methods. Specific objectives include: to build and strengthen human resources in CBNRM methods; and to train faculty members, researchers, extension workers, local administrators, policy makers and farmer leaders in concepts, awareness and practices of CBNRM; and to form a national network of practitioners of CBNRM among the members of the Vietnam Farming Systems Research Network.

Traditional policies and research have often discounted the role of local people in designing and implementing measures and projects. Proposing an alternative approach, CBNRM works with the local men and women most directly involved with natural resource management. Often they are the poorest or belong to ethnic minorities, which are politically and economically isolated. CBNRM recognizes that these men and women may have an intimate knowledge of the local resource base, that they may have (countervailing) views on resource use and management and are motivated to improve productivity if they can be assured of reaping the benefits longer-term.

Although the MDI has implemented some research projects with application of CBNRM approach (funded by International Development Research Centre [IDRC]) Canada and Community Biodiversity Development Conservation programme [CBDC] global network), it is said that these efforts were just the preliminary inceptive research activities and focused on a farming system approach. Further investigation on CBNRM with regard to improving livelihoods of farmers, optimum use and better management of natural resource (land and water) are needed. Through the CBNRM

approach, the capacity of local people (resource-poor farmers and other related stakeholders) is built. This can support improvements in the livelihoods and resource use of those that are resource poor.

5.2 Strengthening Livelihood Assets

Several researchers use the sustainable livelihood framework (SLF) as a tool for the investigation of farmers' livelihoods, in order to learn holistically about farmers in terms of: how they manage vulnerability and crises; how they use their livelihood capital; how the policies and institutions impact on farmers' livelihoods; how they respond to threats and opportunities; and what outcomes they aspire to. The authors think the SLF is a powerful tool, not only for "investigation", but also for "implementation" to address rural poverty. Worldwide, there are some useful experiences from urban poverty reduction programmes, which use these strategies to enhance the asset base of the urban poor (Mitlin, 2003).

In the Mekong Delta, the asset base of the rural poor is very low. Strengthening assets, both in terms of amount, quality and security of access, should be a clear way to address rural poverty. It is necessary to formulate a research program with regard to use strategies to strengthen the asset base of the rural poor to secure poverty reduction within the broad framework of sustainable livelihoods.

6. Conclusions

Investment by the government in preventing floodwater by constructing the surrounding dikes for upstream parts was indeed successful in its primary aim of increased rice production. This encouraged farmers to intensify and diversify agriculture in the flood prone zones. However, the resulting environmental pollution and degradation of soil fertility is a serious concern that could undermine the sustainability of livelihoods and overall agricultural production. In the coastal zone, government efforts in the construction of embankments and sluices to control saline water intrusion could be considered as an external force to promote agricultural intensification and diversification. Some areas successfully practised double or triple rice cropping and in brackish-water shrimp ponds were utilised. Since human capital and natural capital are the dominant assets, these interventions are important to mark the first step towards livelihood enrichment by improving the productivity of land and labour.

The high value and higher profitability of shrimp production indicates that the brackish water in the coastal area is likely to be a more important natural resource than rice land. This finding may help local government in adjusting land use policies and water management strategies in this zone. On the other hand, the pollution of the

environment due to poor management of shrimp ponds causes shrimp death and disease. This may improve if the management could be based on a community basis.

The economy in the rural areas among the six zones of the delta remains at a low level of development, with natural (land and water) and labour as the dominant resources. Therefore, the government should invest more in the asset base of the rural poor.

List of text abbreviations

CBDC	Community Biodiversity Development Conservation Programme
CBNRM	Community-Based Natural Resources Management
CSO	Can Tho Statistics Office
CZ	Coastal Zone
CPZ	Ca Mau Peninsula Zone
FAZ	Freshwater Alluvial Zone
GSO	General Statistics Office
IDRC	International Development Research Centre
LXZ	Long Xuyen-Ha Tien Quadrangle Zone
MDI	Mekong Delta Development Institute
NAREMNET	Natural Resource Management Network
PRZ	Plain of Reeds
SLF	Sustainable Livelihood Framework
TBZ	Trans-Bassac Depression Zone

References

- Anton JI. (2005) *Introduction to sustainable livelihoods (SL) & its relationship to project work*. Paper presented in the Workshop held in Cantho University, Vietnam.
- Binh, T.N.K.D., Vromant, N., Hung, N.T., Hens, L., and Boon, E.K. (2005) Land cover changes between 1968 and 2003 in Cai Nuoc, Ca Mau Peninsula, Vietnam. *Environment, Development and Sustainability* 7:519-536.
- Can, Nguyen Duy (2005). Assessing of the status and analyzing of farming systems in areas of changing in farming systems of Ca Mau province: analysis sustainable livelihood framework. *Scientific Journal of Cantho University*.
- Can, Nguyen Duy, Dung, LC. And Tuong, TP (2005) *Comparing livelihood and resource-use strategies of farmers within and outside the salinity protected area of Bac Lieu Province, Vietnam. Working Paper: Act. 1.1b, CPWF Project # 10*.
- Can, Nguyen Duy (2002) Development of agricultural systems in the Mekong Delta of Vietnam: current rice cultivation and problems involved. In: *Proceeding of International Workshop on GMS Water Environment, organized by Alliance for global sustainability and GMS academic and research network. Bangkok, August 22-23, 2002*.
- CSO (Cantho Statistics Office) (2005). Socio-economic data of 13 provinces of Mekong Delta. Cantho Statistics Office, 2004.
- Duong, L.T., Can, ND. and Phan TT (2005) Current status of integrated crop-animal systems (ICAS) in Vietnam: a case study in the Mekong Delta. In: Sombilla, MA, and Hardy, B., eds. *Integrated crop-animal systems in Southeast Asia: Current status and prospects. IRRI Limited Proceedings No.11*. Los Banos, Philippines pp 46-62
- Gallop KM, Khiem, NT., Dung, LC., Gowing, JW (2003) *Changes in farmer livelihoods and land-use strategies during the project period 2000-2003. Working paper WP1-2, DFID - CRF Project - R7467C*.
- Gowing, JW, Tuong, TP. Hoanh, CT. and Khiem, NT (2006) Social and environmental impact of rapid change in the coastal zone of Vietnam: an assessment of sustainability issues. In: Hoanh, CT., Tuong, TP, Gowing, JW and Hardy, B eds (2006) *Environment and livelihoods in Tropical Coastal Zones: Managing agriculture-fishery-aquaculture conflicts*. pp 48-60.
- GSO (General Statistics Office) (2004) *Statistical Yearbook 2004*. Statistical Publishing House, Hanoi
- GSO (General Statistics Office) (2005) *Statistical Yearbook 2005*. Statistical Publishing House, Hanoi
- Hoanh, C.T., Tuong, T.P., Gallop, K.M., Gowing, J.W., Kam, S.P., Khiem, N.T., Phong, N.D (2003) Livelihood impacts of water policy changes: evidence from a coastal

- area of the Mekong river delta. *Water Policy* 5: 475-488.
- Hossain, M., TT. Ut and Bose, ML (2006) Livelihood systems and dynamics of poverty in a coastal province of Vietnam. In: Hoanh, CT., Tuong, TP, Gowing, JW and Hardy, B eds (2006) *Environment and livelihoods in Tropical Coastal Zones: Managing agriculture-fishery-aquaculture conflicts*. pp 30-47
- Miller, Fiona. (2006a) "Seeing "Water Blindness": Water Control in Agricultural Intensification and Environmental Change in the Mekong Delta, Vietnam" in Connell, John. and Waddell, Eric eds. *Environment, Development and Change in Rural Asia-Pacific: Between Local and Global*, Routledge, pp 196-207
- Miller, Fiona. (2006b) "Environmental Risk in Water Resources Management in the Mekong Delta: A Multi-Scale Analysis", in Tvedt, Terje. and Jakobsson, E. eds. *A History of Water: Water Control and River Biographies* Vol 1, I.B. Tauris, London, pp 172-193
- Mitlin, D. (2003) Addressing urban poverty through strengthening assets. *Habitat International* 27: 393-406
- Nguyen Huu Chiem (1994) Former and Present Cropping Patterns in the Mekong Delta. *Southeast Asian Studies* 31(4): 345-384.
- Nguyen Van Sanh, Vo-Tong Xuan, et al. (1998). History and future of farming systems in the Mekong Delta. In: Vo Tong Xuan and S. Matsui *Development of Farming Systems in the Mekong Delta of Vietnam*. Ho Chi Minh City Publishing House, Ho Chi Minh City: 16-80.
- Ringler, C. (2001) *Optimal Allocation and Use of Water Resources in the Mekong River Basin: Multi-Country and Intersectoral Analyses*. Peter Lang Europaischer Verlag der Wissenschaften, Frankfurt.
- Sels, A. (2004) *Shrimp aquaculture and the socio-economic situation of the Cai Nuoc district, Ca Mau province, Vietnam: application of the POET model*. Master, Free University of Brussels, Brussels.
- Thanh, D.N. et al (2006) *Impact of Government policy in changing agricultural production structure to people livelihoods in the Mekong Delta. Scientific report of the Mekong Delta Development Research Institute* (in Vietnamese).
- Tho, N., Vromant, N. Hung, N.T. and Hens, L. (2006) Organic Pollution and Salt Intrusion in Cai Nuoc District, Ca Mau Province, Vietnam. *Water Environment Research* 78:716-723.
- Tran Thanh Be et al (2006) *Assessing impacts of changes in farming systems to socio-economic in different areas in the Mekong Delta. Scientific report of the Mekong Delta Development Research Institute* (in Vietnamese).
- Tran Thanh Be, Clayton, Helena and Brennan, Donna (2003) Socioeconomic characteristics of rice-shrimp farms in the study region. In: Preston, Nigel and Clayton, H. eds. *Rice-shrimp farming in the Mekong Delta: biophysical and socioeconomic issues*. ACIAR Technical Reports No. 52e, 170 pp.

- Tran Thanh Be (1994) *Sustainability of Rice-Shrimp Farming System in a Brackish Water Area in the Mekong Delta, Vietnam*. MSc. (Hons) thesis. School of Agriculture and Rural Development, University of Western Sydney, Australia.
- Tuong, T.P., Kam, S.P., Hoanh, C.T., Dung, L.C., Khiem, N.T., Barr, J, and Ben, D.C. (2003) Impact of seawater intrusion control on the environment, land use and household incomes in a coastal area. *Paddy Water Environment*, 1: 65-73.
- Vo-Tong Xuan and Matsui, Shigeo (1998) *Development of Farming Systems in the Mekong Delta of Vietnam*. Ho Chi Minh City Publishing House, Ho Chi Minh City, Vietnam.

Chapter 3:

Transboundary Challenges for Fisheries Policy in the Mekong Delta, Vietnam: Implications for Economic Growth and Food Security



Vo Thi Thanh Loc¹, Le Xuan Sinh² and Simon Bush³

¹The Mekong Delta Development Research Institute, Can Tho University, Vietnam. Email: vtthloc@ctu.edu.vn

²College of Aquaculture & Fisheries, Can Tho University, Vietnam. Email: lsxinh@ctu.edu.vn

³ Environmental Policy Group, Wageningen University, The Netherlands. Email: simon.bush@wur.nl



Chapter 3 :

Transboundary challenges for fisheries policy in the Mekong Delta, Vietnam: Implications for economic growth and food security

1. Introduction	102
2. Key issues	105
2.1 Trans-boundary issues within the context of the Mekong River Basin	106
2.2 Fisheries production for global commodity chains	107
2.3 Domestic fisheries policy challenges	108
3. Regional trans-boundary linkages of fisheries within the Mekong River Basin	109
3.1 Regional fisheries ecology	110
3.2 Livelihood dependence within Agro-aquatic production systems	111
3.3 'Low-value' species in aquaculture feed	112
3.4 Regional fish trade	113
4. Status of fisheries supply chain management	113
4.1 Shrimp and fish supply chains and market channels	113
4.2 Integration in global fish trade and quality standards	115
4.3 The role of government and industry in food safety assurance	117
4.4 Food supply chain and its management	118
4.5 Quality problems of fisheries supply chain in the Mekong Delta	119
5. Status of fisheries related policy in the Mekong Delta	121
5.1 Structural rearrangement and development strategy of the sector	121
5.2 Use and management of land and water bodies for aquaculture	122
5.3 Exploitation and protection of natural aquatic resources	122
5.4 Environmental management and control of diseases on aquatic species	123
5.5 Support organizations for fisheries development	124
5.5.1 Credit supply	124
5.5.2 Extension and technology transfer	125
5.6 Major input materials for aquaculture development	125
6. Contested issues, research priorities and policy linkages	127
6.1 Contested issues	127
6.2 Research priorities	128
6.3 Further research - the priorities	130
7. Conclusions	130
7.1 Fishery challenges and trans-boundary impacts	131
7.2 Fisheries supply chain	132
7.3 Fisheries policy	132
List of text abbreviations	134
References	135



Abstract

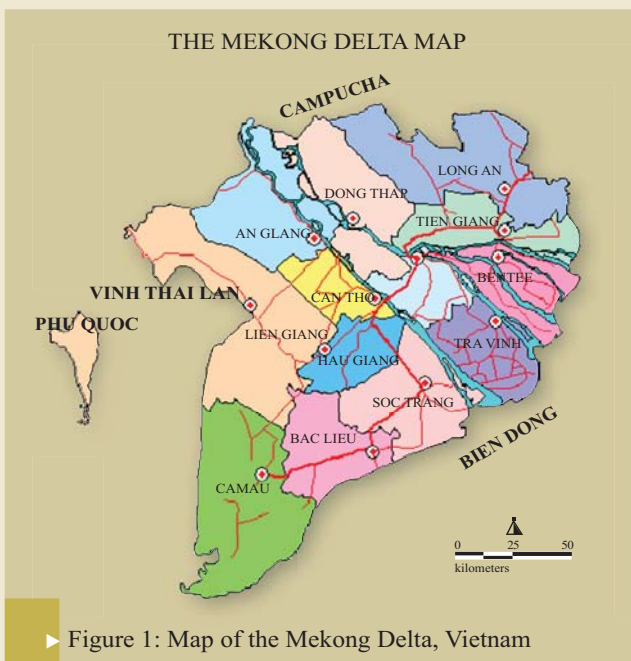
The Mekong Delta is one of seven ecological regions in Vietnam as well as an essential habitat within the Mekong River Basin. The natural resources of the delta are an important source of income and nutrition to the local population as well as contributing increasingly to the export led economy of Vietnam. The fishery sector, dominated by aquaculture, covers 75-80% of total area of the Delta, contributing 60% of total export value of aquatic products from Vietnam and growing at around 14% per year. The fishery sector has been a major focus of government policy following a number of policies and regulations in 2000 that started a process of rural economic and development restructuring by promoting further integration with international markets. Despite the seeming advantages the delta appears to enjoy it remains one of the less developed regions of Vietnam with a GDP 20% lower than the national figure. The failures of ensuring that the wealth of the fisheries sector contributes to the sustainability of rural livelihoods in the delta can, in general terms, be linked to the lack of government policy that can adequately respond to the combined influence of trans-boundary pressures, including the regional control and management of fisheries and water and growing pressure from regional and international markets. This paper reviews the state of knowledge on fisheries policy in light of the trans-boundary nature of the Mekong Delta with the key implications and food safety trade-offs for economic growth and food security. The aims are: (i) to show the trans-boundary linkages of fisheries within the Mekong River Basin; (ii) to describe the fisheries supply chain management; (iii) to analyse the impacts of policy changes on the aquaculture area and production, quality and food security, as well as the trade-off between aquatic products and its contribution to livelihoods in the delta; and (iv) to identify the research gaps and to propose the research needs in relation to policies and regulations for a sustainable development of fisheries of the delta.



1. Introduction

Covering some 12% of the total area of Vietnam the Mekong Delta (**Figure 1**) is a vital source of agricultural and fisheries production for both domestic and export markets. The delta is also strongly dependent on aquaculture and agriculture with both sectors representing 53% of the region's total economy, especially rice and shrimp production. These continue to play a dominant role in the economy, accounting for 46% of GDP at current price (GSO, 2005). Traditionally the tropical monsoon climate and low lying land has enabled wet rice and vegetable cultivation all year round. Indeed, the area has long been considered the 'rice basket' of the country, producing 53.8% of the country's total rice production (Delta Yearbook, 2004). The opening up of the country following market reforms within the government's economic policy of 'Doi Moi' in the mid-1980s led to the rapid diversification of agricultural production which fed initially into the growing domestic economy and subsequently led to producers in the delta entering global export markets (Sinh, 2004).

Coastal fisheries in the delta also entered into global markets with the rapid rise in the value of shrimp during the 1980s. Recognizing the potential of aquaculture the government set forth a series of agro-economic reform directives to provincial and commune governments from 1998-2002 to expand the area of aquaculture in the delta (Sinh, 2004). Intensification techniques saw a transition from essentially extensive rice-shrimp aquaculture to intensive production systems and by 2006 Vietnamese shrimp (*Penaeus monodon* and *Penaeus vannamei*) held a 2.6% share of the world market with an annual value of US\$1.46 billion (VASEP, 2006).



► Figure 1: Map of the Mekong Delta, Vietnam

The domestication and subsequent intensification of the native freshwater catfish, *Pangasius hypophthalmus* and *Pangasius bocourti*, has markedly increased the delta's profile in global markets. Pangasius brought US\$1.15 billion worth of revenue to Vietnam in 2006; 66.5% more than the previous year (VASEP, 2006). The Delta contributes over 50% of the total volume and 60% of the total value of national aquaculture production (Loc, 2006). In 2005 alone the economic growth rate for aquaculture in the Delta was 24.9% compared to 19.5% for the entire country contributing to the highest regional economic growth rate in the country of 14.4% - 5.4% higher than national economic growth (Provincial Yearbooks, 2005).

Despite the importance of this expansion for economic growth the rapid development of aquaculture has not been without consequences, having led to a number of technical and environmental problems which have translated into considerable socio-economic challenges, such as land use conflicts and a rise in disparities in wealth.

In broad economic terms, the delta remains a less developed economic region of Vietnam. In 2005 Gross Domestic Product (GDP) per capita was US\$510, lower than the national figure (US\$638) despite having increased 16.2% per annum from 2001-2005 compared to a national growth rate average of 8.86% over the same period (Provincial Yearbooks, 2005). The vulnerability of producers to global market perturbations and policies has also increased, as evidenced by the 2000 anti-dumping case of *Pangasius* catfish in 2003 and the ongoing difficulties shrimp farmers face in maintaining both the value and volume of production to repay both formal and informal debt (Sinh, 2005).

While both *Pangasius* and shrimp remain important to diversified systems, carried out by both large and small scale producers, the capability to meet the needs of increasingly global oriented processing companies, the complexities and risk of formal financial arrangements and the investment required to manage both feed and disease means that small-scale producers in the sector continue to face considerable challenges. Environmental impacts from both shrimp and *Pangasius* aquaculture have also emerged. More than 20% of mangroves have been cleared for shrimp production in coastal areas in some parts of the delta and the incidence of acid-sulphate soils has increased dramatically (Graaf de and Xuan, 1998). Cage culture of *Pangasius* and snakehead (*Channa striata*) have been linked to nutrient blooms in the mainstream of the Mekong, in tributaries and canals, and increasing attention has turned to the impact of low value species fish, both from coastal areas of Vietnam and inland areas of Cambodia, being used as feed (APFIC 2005).

Ecologically the delta is inextricably linked to the upstream countries and ecosystems of the Mekong River Basin. The flow of water and the migration of several commercially important fish species from between Thailand, Laos and Cambodia

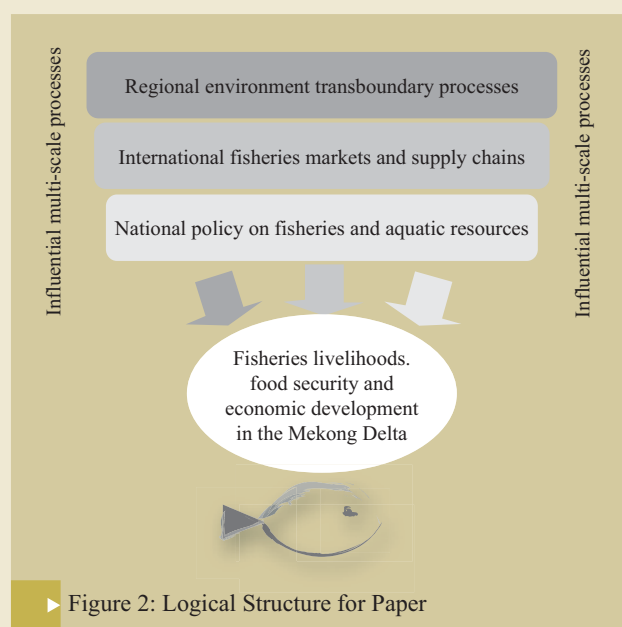
renders Vietnam inter-dependent on the policies and activities of upstream countries. The vulnerability of the delta to flooding is of explicit concern to policy makers, having set out measures for flood mitigation. While most of the attention to flood control has been to minimize the damage to rice production (Miller, 2003) the investment in land-based aquaculture is now also of major concern to policy makers. Native fish production is highly dependent on the flood-based hydrology of the Mekong River system and there is increasing evidence to show that the delta environment along the border of Vietnam and Cambodia is a key breeding ground for a number of commercially important fish species (Poulsen *et al*, 2002). Furthermore, there is growing evidence that small and juvenile 'low value' fish provide an essential source of both protein and income to rural poor communities (APFIC, 2005).

Fish consumption in Vietnam at the beginning of the 1990s was estimated at 21 kg/person/yr, making up 60% of animal protein (Sinh, 2005). Recently refined to include the full range of aquatic animals and processed products the average annual consumption is now estimated at 60.2 kg/person/yr in the delta (van Zalinge *et al*, 2003). Policy pertaining to the access and management of such resources is only now being developed, and remains an area for further development with considerable trans-boundary importance.

The natural resources of Mekong Delta provide an imperative source of income and nutrition to the local population, an important source of national export-led economic development as well as being a significant habitat within the Mekong River Basin. As such, the delta, like so much of Vietnam's market transition, is located within the intersection of a social, economic and ecological processes operating at a range of national, regional and international scales (Adger *et al*, 2001). Framing the delta within the simultaneous contexts of a regional riverine ecology, global trade networks and locally diversified livelihoods provides a framework to assess how ongoing shifts in governance and policy in Vietnam must continue to respond to a range of complex trans-boundary processes. As essentially local production systems are increasingly scaled up to meet the demand of national and international scales, policy needs to respond to the concurrent increase exerted on the natural resource base and the consequences this holds for local rural livelihoods. The growth rate of aquatic products has placed considerable pressure on the capacity of policy makers at all levels of government to ensure continued economic well-being for the people of the delta, as well as ensuring the responsible use of land and water resources.

The overall objective of this paper is to review the state of knowledge on fisheries policy in light of the multi-scale changes from national, international and regional processes to understand the key implications and trade of fisheries for economic growth and food security. By understanding the complex trans-boundary nature of natural resources, production systems and trade across national, regional and international

scales our goal is to identify gaps in fisheries policy that need to be addressed through further research in order to assist with the sustainable development of the fisheries sector in the delta. In order to systematically review the current knowledge on fisheries in the delta, focus of this literature are policies related to aquaculture, fisheries-trade and livelihoods. Three main objectives, as represented in **Figure 2**, guide our analysis: first, to identify a key set of trans-boundary challenges for fisheries, especially related to regional environmental processes; second, to assess the implications of international fisheries markets and supply chains; and third, to assess the implications of national policy on fisheries, food security, quality and safety in the delta.



The paper begins with an overview of the current constraints to the development of the fishery sector in the Delta with respect to the production and trade of both capture fisheries and aquaculture. The paper then outlines different sections: key issues related to fisheries; overview of regional trans-boundary issues within the context of the Mekong River Basin; challenges of global markets on the management of supply chains within Vietnam; and overview of existing domestic policy to trans-boundary issues that impact economic growth and food security in the delta.

2. Key issues

Bringing together three main areas of analysis in this paper exposes a series of interrelated challenges to both domestic policy-makers as well as those involved in the fishery sector, including a broad spectrum of producers, traders, processing and export companies. Understanding how these actors are related requires an understanding

of what key issues influence decision-making related to fisheries production within the Mekong Delta. This section outlines three such key ‘scaled’ issues: the *regional* environmental transboundary context of the Mekong Basin; the development of *global* commodity chains; and the challenges faced by *domestic* fisheries policy.

2.1 Transboundary issues within the context of the Mekong River Basin

The Mekong Delta sits physically within the geographical context of the Mekong River Basin. As such, both the producers and ecosystem functions of the delta are strongly linked to activities upstream of Vietnam in Cambodia, Thailand, Laos and China. As a ‘downstream’ country Vietnam is vulnerable to changes in water flows, including issues of flooding, which influence the productivity of both aquaculture and capture fisheries. Where aquaculture is affected by annual flooding, in much the same way as rice production, capture fisheries (re)production is closely related to the size and extent of flooding (Junk *et al*, 1989; Payne *et al*, 2005). As an ‘upstream’ area, the flooded habitats of the delta are important for a number of migratory fish species which reproduce in freshwater environments, or move into the South China Sea as part of their lifecycle (Sinh, 2005; Beasney *et al*, 2005). The passage and maintenance of habitat for these fish species is important not only for subsistence and commercial fisheries within the Delta but also for upstream fisheries – most notably the highly productive fisheries of Cambodia.

In addition to ecological ‘flows’ of water and fish, the delta is also linked to the Mekong Basin through both import and export cross-border trade of fish and other aquatic animals. A variety of ‘high-value’ capture and aquaculture species are traded for human consumption as well as a number of ‘low-value’ species, which are used for aquaculture feed. This regional trade of fish is an important source of income for a wide variety of ‘fish dependent’ people (such as fishermen and fish farmers) and ‘fish related’ people (including traders, brokers, transporters and processors) (Bush, 2004). Of the estimated 176,420 and 323,440 tonnes of low value fish used for aquaculture in Vietnam a proportion is traded from the highly abundant Dai fisheries of Cambodia (APFIC, 2005; Bush and Le Nguyet Minh, 2006). Although providing considerable income to the people of the delta, this regional trade also places increasing pressure on fishery resources.

It is therefore increasingly recognized that localized production activities in the delta are linked directly to both the human and natural trans-boundary ecology of the Mekong River Basin, both as a recipient and source of fish migration and trade. A key challenge for the governments and producers alike is to ensure that the regional trade of fish continues to provide a source of income while not endangering the sustainability of the resource base through over-exploitation. Within the context of the 1995 Mekong Agreement (MRC, 1995) Vietnam has established certain obligations and rights

related to the trans-boundary use of water, and related linkages to fish ecology and production. The following sections of this paper further discuss the implications of the wider influences on fishery production in the delta by considering how both national and provincial level policy is tied to upstream decisions made within the Mekong Basin and what, if any, improvement in regional relations could further assist the development of the sector.

2.2 Fisheries production for global commodity chains

The increasingly global focus of aquaculture production in the delta has had considerable consequences for the use and management of both natural and human resources. What were once essentially local markets and trading relations for fishery products have now grown into global commodity chains and networks feeding into lucrative European and US markets. With this ‘up-scaling’ of markets and trade there has been a comparable increase in the number of actors operating within these commodity chains, which increasingly poses considerable challenges for state policy and governance (Bush and Oosterveer, 2007). Indeed, fishery production, including aquaculture, remains one of the primary production systems that is most challenging to understand because of the complex interrelations between inputs and outputs, and the diversity of actors involved (Thorpe *et al*, 2005). As fish are caught, processed and transferred from local to national and international markets they pass through a series of scaled networks, each with formal and informal norms, rules and regulations that control and manage activities and social relations. Producers and traders alike are located first within communities with interrelated sets of social, cultural and familial norms, practices and expectations, and then, secondly, within formal state legislation and formal and informal rules and regulations set by non-government institutions. Together these scaled networks and their associated governance arrangements influence the flow of the commodity up the chain and information down the chain (Bush and Oosterveer, 2006). It is therefore important to understand the spatiality of the system to determine the geography of the trade, the source and influence of information and the relevance of governance systems which mediate access and control over resources in the delta.

As the trade of fishery products from the delta continues to globalize, greater pressure is being placed on guaranteeing the safety and quality of food, to ensure that the conditions of production meet the required standards in the sites of consumption (Oosterveer, 2007). While forces of global governance, such as certification, have improved considerably in recent times there has been continued failure to effectively target and improve production processes in information-poor countries such as Vietnam where rules, norms, values and control over production are neither clear nor easily amenable to modern auditing and traceability practices. Nevertheless, to ensure continued access to lucrative international markets the government of Vietnam has

placed considerable emphasis on acquiring international certification, including EurepGAP and the Global Aquaculture Alliance (GAA). While these certification schemes provide guidelines for sustainable production, the government needs to continue to provide clear and relevant policy. As such, a series of problems related to the management of domestic supply chains and networks need to be addressed for better coordination of a range of actors including processing companies, feed suppliers, traders and middlemen and both large and small scale producers (Loc, 2006).

If the delta is to sustainably supply aquatic products to global markets then both the national and provincial governments must continue to provide managerial assistance to commodity chain coordination. To achieve this, better coordination of national policy with global market-based governance systems needs to be better understood. Section four specifically elaborates on each of the above challenges with respect to the current knowledge available on supply chain management in the delta.

2.3 Domestic fisheries policy challenges

The policies, laws and regulations for fishery sector management in Vietnam have been largely developed and implemented through a top-down process aiming to facilitate multi-sector integration (Sinh, 2004). Various policies and regulations - issued in cooperation between the Prime Minister's office, and relevant Ministries - have assisted this process by building a policy framework for the fishery sector that includes fishing, aquaculture, processing and marketing of aquatic products. The framework has also been revised and updated through the market orientation or "*Doi Moi*" process since the end of 1980s and again through the more recent orientation to export-led economic development. There has been considerable input into policy development in Vietnam since the 1990s with support from international institutions such as the EU, DANIDA and ACIAR.

At the provincial level, if the fishery sector contributes about or more than 20% of total GDP of a province then a Department of Fisheries office is established, otherwise fisheries remains a sub-sector in the Department of Agriculture and Rural Development. Although promoting some efficiency, this institutional arrangement has led to a number of barriers in the development of the fishery sector. Most notable has been the difficulty in developing a coherent division of responsibilities and different approaches between agriculture and fisheries in aquaculture fisheries management and extension. A number of problems have also become apparent in the wider fishery policy environment as many issued regulations have either been inefficient or not enacted at all.

Considerable progress has been realized at the national and provincial levels in the provision of legal and policy documents to guide the management of fisheries,

aquaculture, processing and trade, as well as for setting food safety standards and disease control. Like in many Asian countries, Vietnam faced considerable problems in ensuring that aquaculture is effectively regulated and legislation enforced. The improvements made in establishing use rights for land/water bodies, the management of supply of major inputs (e.g. feed, seed, credit) and the marketing of outputs (especially those for export) are all important. Nevertheless, further regulations and policies at regional and provincial levels are needed that better enable effective implementation of national policies and legislation. Three specific challenges that need further attention in domestic policy at all levels are: 1. the establishment of extension methodologies that ensure production improvements translate into poverty reduction and food security; 2. the improvement of farmer's capability to better access local, regional and international markets; and 3. the further development of assurance mechanisms for product safety and quality.

Vietnam also faces a series of challenges in ensuring further international and regional integration. Within the wider context of the Mekong River Basin Vietnamese domestic policy is still being developed that meets the obligations set out under the 1995 Mekong Agreement on the use and management of shared water resources. Construction of irrigation, water diversion systems and hydro-electricity in upstream countries, and also the central highlands of Vietnam, will greatly affect the ecology of the floodplains and delta of the lower Basin. How to respond to these developments is a matter for foreign policy, especially through the Vietnamese Mekong Committee. Collaboration with neighbouring countries was also emphasized through the 1997 off-shore fishing program, which highlighted the extent natural marine resources of Vietnam are shared with neighbouring countries. Finally, the US anti-dumping duties on *Pangasius* catfish in 2003 and on *Monodon* shrimp in 2004 have made policy makers aware of the importance of international relations in maintaining access for aquaculture products of Vietnam.

3. Regional trans-boundary linkages of fisheries within the Mekong River Basin

As well as adjusting to a changing national policy context and responding to new opportunities and demands from the international market, fisheries in the Delta is also confronted by challenges with trans-boundary environmental issues. This section outlines regional fisheries ecology, fisheries relevant livelihood, low value species in aquaculture feed and regional fish trade.

3.1 Regional fisheries ecology

Balancing the benefits and impacts of flooding remains an important social and environmental imperative for policy makers throughout the Basin and one that has received much attention in the 1995 Mekong Agreement. According to the agreement each country has the sovereign right to use water but should do so in a way that minimizes negative impacts to other riparian countries. Water and fish are both trans-boundary resources that tie the delta ecologically, economically and politically to the rest of the Basin. Water remains one of the most contested areas of cooperation between the Mekong countries. Vietnam, as the furthest country downstream, is acutely aware of the implications of both restricted flow and flooding to the agro-ecology of the delta. Indeed, flood mitigation is characterized by the interplay between state policy and the perpetual management of risk and vulnerability for the farmers of the delta (Miller, 2003). Fisheries have had a prominent position with the Mekong River Commission, and remain a key area of technical and policy cooperation between the countries of the Basin. Overall, however, statistics on the status of fish stocks, and especially shared fish stocks remain scarce in nearly all of the riparian countries (Coates, 2002).

It is widely recognized that the health of the Basin's fisheries is dependent on the maintenance of water flows both within and between the riparian countries. The so called 'flood-pulse' links the productive capacity of river-floodplain environments to the extent and duration of flood events (Junk et al, 1989; Junk and Wantzen, 2003), and has become increasingly used to promote the maintenance of 'ecological flows' of both temperate and tropical river systems (Richter *et al*, 2003). Like in many rivers of the world there is considerable evidence that fish migration in the Mekong Basin is triggered by the discharge rate of water and so closely linked to the hydrological flood-cycle (Baran, 2007). The flood-pulse from June to October in the delta also triggers a series of upstream migrations that feed into wider ecology for migration of wild fish. To date three main migration systems have been found in the Mekong Basin: the upper, middle and lower systems (Sverdrup-Jensen, 2002). The lower migration system, extending from the Khone falls in Laos to the South China Sea, is characterized by the intimate relationship between deep pools and the extensive floodplains in Cambodia and the delta. A key characteristic of the lower migration system comprises of the dry-season refuge in the north of the Vietnam Mekong delta, and the feeding and breeding habitats located in the Vietnam's wet-season expanded flood areas.

Lateral migrations from the mainstream and tributaries into flooded areas, including lakes, seasonal wetlands and intermittent streams, are important for reproduction and feeding throughout the Basin (Sverdrup-Jensen, 2002). Many of the floodplain fisheries in the northern parts of the delta, particularly in Dong Thap and An Giang



► Figure 3: Migration Systems in the Mekong
(Source: Reproduced from Baran, 2007,
as adapted Poulsen *et al*, 2002)

provinces, are directly linked to the wider ecology of the Basin. The smaller species that these lateral migrations focus on provide an important source of income and nutrition for rural Vietnamese communities. Some 65% of the basin is thought to be dependent on these fish for survival are intricately linked (Sverdrup-Jensen, 2002).

The delta is also important for some of the large and endangered species such as *Pangasianodon gigas* and *Probarbus jullieni*. Larval studies suggest that many species do not spawn in the delta, but rather that the larvae drifts to these wetland environments from habitats further upstream (Sverdrup-Jensen, 2002). The importance of these species for riparian communities in Cambodia, Laos and Thailand links the floodplain habitats of the delta in Vietnam to a wider, complex ecology of the Basin as a whole. As such, the regulation and management of floodplain fisheries, flooding, navigation and aquaculture all affect the health of both upstream Mekong fish and fishers alike.

3.2 Livelihood dependence within Agro-aquatic production systems

Fishing activities are very important to rural livelihoods in the Mekong River Basin in general and in the delta in particular. In 1998, fishing activities were conducted by about 70% of the total number of farm households settling in the flood-prone areas, and wild fish contributed more than 10% of income obtained from fish farming activities. One working day for fishing brought to local people an average income of \$US1.76 while that of other off-farm activities was between \$US1.1 - \$US1.36. Fishing therefore is an important source of employment (directly and indirectly) providing a significant source of income to rural communities, especially during the flooding period when unemployment is more serious (Sinh, 1995; Sinh *et al*, 1997a; and Sinh *et al*, 2000).

At the current time, education on natural resources conservation and development is still a new concept for local communities. Therefore, a “free riding” situation occurs and each household with fishing activities tries to capture as much wild fish as possible in the rice field and common canals or rivers. Even though the natural fish stock is replenished annually from upstream fish and natural reproduction in the delta, wild stocks are declining at an estimated rate of 10-13% per year (Sinh, 1995 and Sinh *et al*, 2000). This trend was confirmed by 89.7% of the respondents involved in the investigation conducted by Sinh *et al* (2000). These results indicate that the inland fishery of the Delta is an important source of food and income to rural communities. While there is currently less attention on the management of these inland resources in the delta lessons may be learnt from the development of community-based management systems in near-shore coastal fisheries. Applying these methods to inland fisheries, in both mainstream and floodplain environments may prove an important activity for strengthening both fisheries ecology and the improvement of rural livelihoods.

3.3 ‘Low-value’ species in aquaculture feed

The use of ‘low-value’ fish as aquaculture feed for *Pangasius* in the delta is another important trans-boundary policy issue. As the *Pangasius* catfish industry (including both *Pangasius bocourti* and *Pangasius hypophthalmus*) has grown, pressure has been placed on low value wild fish as a source of protein for feed. These fish are sourced from either coastal areas of the delta, such as Kien Giang, from flooded areas in Dong Thap and An Giang, or increasingly from Cambodia (Bush, 2006).

Up to 2002, 99% of the total number of *Pangasius* farmers still used home-made feed, 20-30% of which was made up of low-value fish. Because of the insufficient supply of low-value fish and the impact of their use on largely juvenile fish and small migratory species *Pangasius* farmers have shifted to using commercial feeds. With further declines in the amount of low-value freshwater fish farmers started sourcing fish from coastal marine areas. In 2004 it was also estimated that about 100,000-120,000 tones of low-value marine fish were being used for *Pangasius* culture. In response to the further decline of this source of low-value fish around 65% of farmers now use commercial feed, indicating a somewhat forced transition to the more expensive inputs (APFIC, 2005).

The over-exploitation of low-value fish has come at the expense of poorer rural communities in the delta. As the commercial *Pangasius* farming is more often conducted by wealthier farmers and companies, the use of low-value fish disproportionately affects the income, food and employment of poor communities, who together make up approximately 25-30% of the total population of 17.5 million people (Sinh, 2005).

3.4 Regional fish trade

The development of regional trade of fisheries products in the delta has been facilitated by increased investment in infrastructure by governments, processing companies and farmers alike. At the regional level, the Asian Development Bank (ADB) funded Greater Mekong Subregion programme has implemented an extensive regional infrastructure programme to link all the countries of the Basin with a road network, thereby facilitating growth in trade (ADB, 1996; Rigg, 1997). The development of infrastructure has enabled relatively stable trading networks to develop, facilitating the smooth transfer of fish products from most parts of the Delta to local, regional and international markets.

Although infrastructure plays an important role in the further development of trade in the delta, little recognition has been given to the socially embedded nature of fish trade networks such as complex debt-tied relations and social obligations (Bush, 2006). It is increasingly recognized that in order to address issues of market access and improved management of fishery production in the context of greater regional integration of trade government policy must further understand the socially embedded nature of trade - especially of the poor and disenfranchised. Now that physical infrastructure is largely in place, the development of an export-led economy in Vietnam is now dependent on how well the social infrastructure of local trade networks can respond to the needs of international supply chain management.

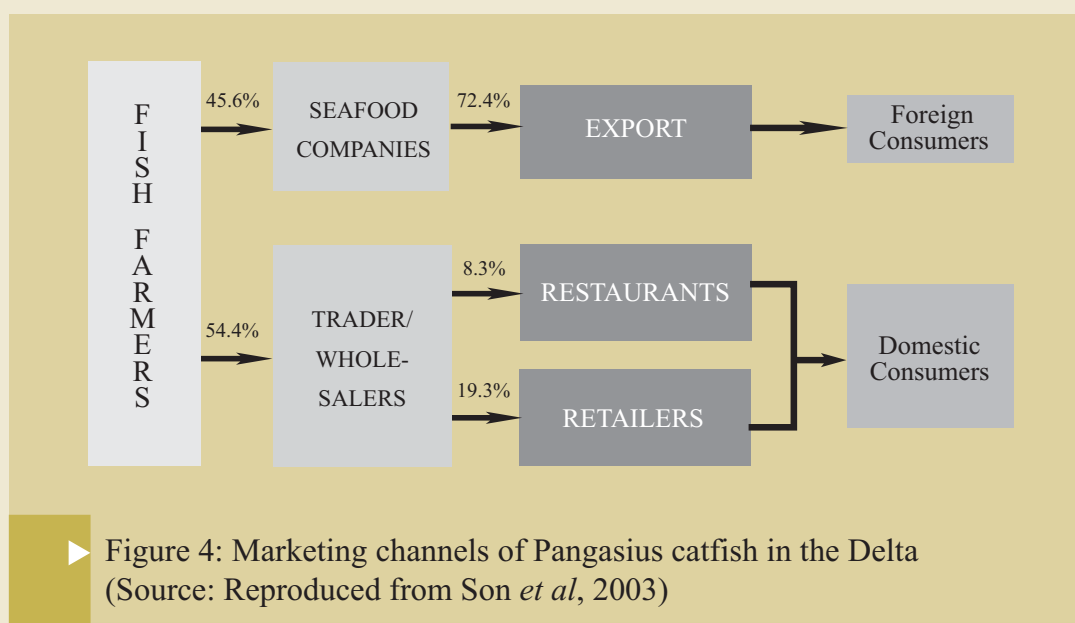
4. Status of fisheries supply chain management

Meeting fisheries quality and safety standards for integration in global trade chains requires further cooperation and development of government and industry assurance systems. This section outlines the challenges of global integration, the importance of supply chain management, and how the Vietnamese government and industry is currently addressing the problems of chain management in the delta.

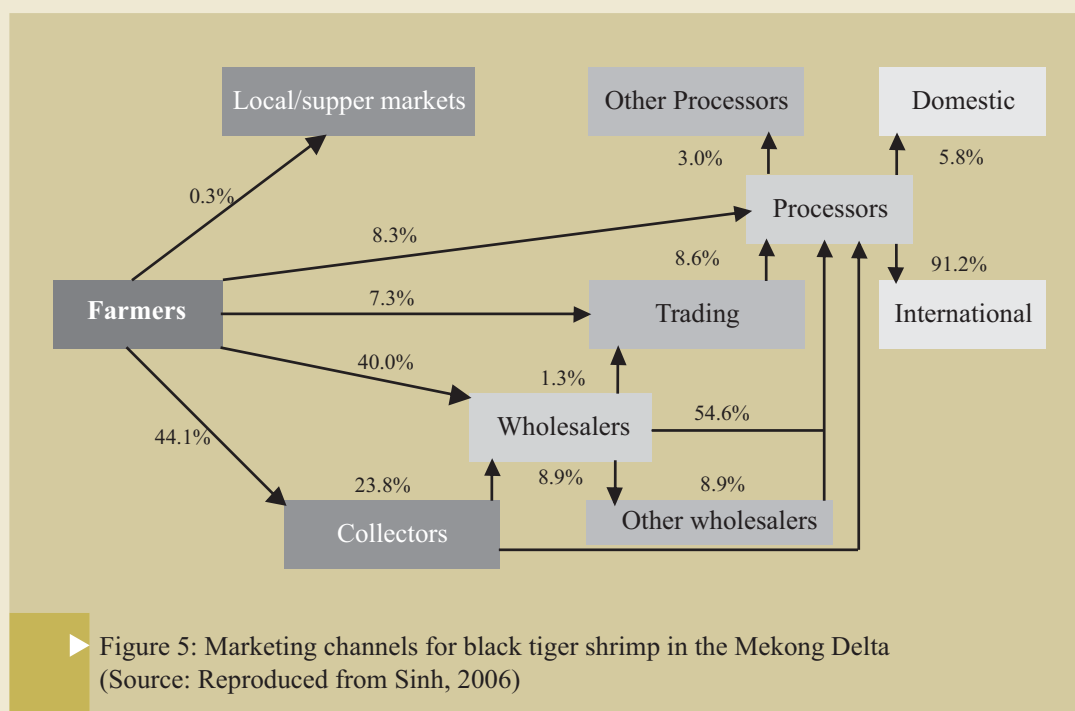
4.1 Shrimp and fish supply chains and market channels

Pangasius catfish and *Monodon* shrimp are the two main globally traded fisheries products from the Delta. In 2000 approximately 65% of the total production of *Pangasius* was exported and this proportion has continued to grow to around 75% by 2003, and 89% by 2006 (Ministry of Fishery, 2000, 2003, and 2006; Son *et al*, 2003). The remaining proportion of catfish are sold either in the local markets or are supplied to restaurants in the delta or Ho Chi Minh City

(Figure 4). Shrimp trade shows a similar pattern with approximately 92% of shrimp sent to export (Figure 5).



Despite the success of the export led economy within the fishery sector a number of problems affecting quality have emerged. First, exporters have had to deal with a growing global attention on high food quality standards. Complicating matters further, requirements and expectations, including product weight and size, differ between markets making it difficult to respond quickly to market changes and meet customer needs. Second, stricter controls and testing by importers for micro-organisms and antibiotic residues have been imposed. Japan, the US and EU all now use modern technology and equipment to test for Chloramphenicol, Nutrofuram, Fluoroquinolones, and other antibiotics in seafood products, with zero tolerance for quality deviations. Third, Vietnam producers face increasing competition from Thailand, Ecuador, and Indonesia in terms of price and quality. Trade disputes have also emerged over labelling and trade-marks. The most high profile case of this has been the catfish trademark dispute with the US, through which Vietnam has been precluded from using the “catfish” to label *Pangasius*. Lastly, antidumping tariffs to the US market on both Vietnamese shrimp and *Pangasius* (between 36.8% and 63.8%) have caused further concern about the long term competitiveness of the sector.

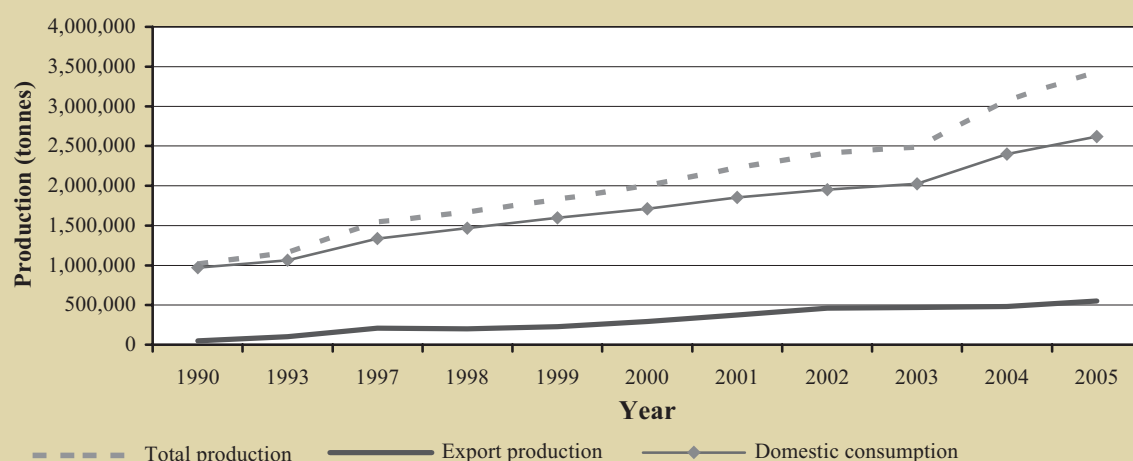


4.2 Integration in global fish trade and quality standards

Before the mid-1990s, there were very few legal documents on the marketing and trade of aquatic products, except some of those relating to the export of shrimp products. Many policies have been issued by different institutions aiming to regulate the trade of goods including aquatic products. The marketing and trade of aquatic products has become essential to the development of the fisheries sector, especially to its diversification and economic efficiency. Decision 251/1998/QĐ-TTg dated 25/12/1998 by the Prime Minister to approve the development programme for the processing and export of aquatic can be seen as the first and most important policy that helps to improve the capability of the processing to adjust with the development of the fisheries sector, as well as the penetration and development of international markets for Vietnamese aquatic products. Domestic consumption continues to play the essential role in marketing aquatic products (contributing 95.2% of the total aquatic production in 1990 and 81.2% in 2003) but the export production has increased through time, from 4.8% of the total production in 1990 to 12.0% in 1997, 14.6% in 2001 and reached 16.0% in 2005 (**Figure 6**) (Ministry of Fisheries, 1991, 1998, 2002 and 2006).

The experience of Vietnam in 2001 US anti-dumping case for *Pangasius* has led to further awareness of potential problems faced with integration into international markets. Vietnam's accession to the World Trade Organisation (WTO) in 2004 has been an important landmark for ensuring security in international markets. Nevertheless, as raised by Oxfam (2004) there are still points of concern that need to be addressed in domestic policy.

First, a significant challenge faced by Vietnam after WTO membership will be the Sanitary and Phyto-Sanitary Agreement (SPS Agreement). As outlined by Oxfam (2004): “Poor farmers will struggle to understand what these standards are, never mind comply with them. If tough new standards are imposed upon accession without (external technical) support, a large number of poorest Vietnamese farmers will no longer be able to produce for export. Fresh fruits and the fisheries and seafood sectors will probably be most affected”. In WTO negotiations, Vietnam is requesting a transition period and technical assistance to implement SPS measures; such an approach seems amply justified considering the dominance of small-scale farmers, the difficulties in communication and extension, as well as fragmented market chains. Ultimately, the development of national standards to international levels will enable Vietnam to take better advantage of seafood export markets; however, substantial capacity is required.



► **Figure 6: Trend in the domestic consumption and export production of aquatic products**
(Source: Sinh, 2006, summarized from the Ministry of Fisheries [1991, 1998, 2001, and 2006])

Second, negotiations to date include a request that Vietnam adopt a bill to amend the Law on the Promulgation of Legal Documents to include procedures for publication and public comment. Oxfam consider that increased transparency will be good for increasing accountability in the decision-making process and improving transparency and accountability that will benefit the Vietnamese people, including poor women and ethnic minorities.

Finally, WTO members can apply safeguards against imports from each other in cases of “market disruption”. The standards for application are much lower than in the WTO Agreement on Safeguards, and Oxfam consider that this provision may lead to an increase in anti-dumping measures affecting Vietnam.

The impact of joining the WTO will only increase as the trade of aquatic products from Vietnam access new markets. The number of importers of Vietnam’s aquatic products has already increased from 60 in 2003 to more than 120 countries and territories in 2005 (VASEP, 2005; and Sinh, 2006). The changes have resulted in a significant development of the fishery sector, especially on *Pangasius* catfish and Monodon shrimp farming. Complying with WTO rules means that those involved in the Vietnamese fishery sector, (fishermen, farmers, traders and processors operating small-scale farms or businesses) must effectively manage supply chains, directly engaging international food quality standards in order to maintain and build market share.

4.3 The role of government and industry in food safety assurance

In order to improve food quality and safety, the roles of the government and industry are very important. Food safety experts from Asia, Africa, Latin America, and Europe, as well as international organizations such as the World Bank, Food and Agricultural Organisation (FAO), WHO, and members of the European research community emphasize that food quality control cannot be applied successfully in each country without the support of government and industry (Hanak *et al*, 2002). In working with industry, governments are increasingly responsible for: (i) mandating the regulatory requirements; (ii) establishing mandated critical limits when necessary; (iii) establishing criteria, methods and sampling plans when necessary; and (iv) verifying that in individual facilities Hazard Analysis and Critical Control Points (HACCP) plans are adequate in order to assure food safety (Kvenberg *et al*, 2000; Hanak *et al*, 2002; Jill *et al*, 1999; Billy, 2002; and Ababouch, 2000). Additional government activities should be to use epidemiological and scientific data to identify hazards and conduct risk evaluations. There are also many measures that the food industry can use to manage food safety in a more efficient manner and reassure public confidence in the food supply. Such measures include regulations and policies, guidance on hazards, risk communication and education, and incidents and crisis management (Lee & Hathaway, 1999; Motarjemi and Mortimore, 2005).

Fearne (1999) indicates that the food industry has a vested interest in supplying better information along the length of the supply chain. Governments have both a duty and interest in facilitating the process. Besides support from the government, the food supply chain itself, which consists of production from processing to marketing, should be supported by the food industry, support organizations, local departments and

other chain stakeholders in order to achieve product quality control objectives. Furthermore, Suwanrangsi (2002) notes that the interaction between provincial government agencies and the fisheries industry is vital for promoting the sector's development through the introduction of new technologies, extension, research, training, regulation and inspection. Finally, McDonough (2002) also concludes that government has a role to play in its successful introduction, and that this can be a challenging undertaking for all parties concerned.

For Vietnam in general and the delta in particular, fisheries safety and quality cannot be free from hazards without a contribution by government and industry. Because quality programs have not been implemented in primary production, the role of government and industry is vital. The Ministry of Fisheries is the highest authority for the issuance of all decrees and regulations. These include fields of food safety and quality, environmental protection, fisheries resource development and protection, veterinary drug use and production, and training on food safety and quality. At the local level, the Department of Fisheries is responsible for implementing and expanding the decrees and regulations to other relevant departments, lower management authorities, sea food companies (SFCs), and farmers, as well as receiving their feedback (Loc, 2006; Son *et al*, 2003).

4.4 Food supply chain and its management

Global consumers nowadays are more concerned about the safety of their food in general and seafood in particular because of a series of food scandals and incidents that have occurred over the last decade. The solution called for is higher food quality and integrity, safety guarantees and transparency. The responses are two-fold: governments are imposing new legislation and retailers are making new demands on their supply chains. Food supply chains are reacting by implementing systems to improve their product quality in an attempt not only to guarantee the safety of the products, but also to raise the consumer community's awareness of their efforts. Such efforts are performed at the level of either an individual company or a complete supply chain network (Van Dorp, 2004; Beulens *et al*, 2005). Food safety, therefore, is currently considered to be an important issue for all stakeholders in the area of food production as well as for governments in setting new legislation.

The limitations regarding managerial knowledge and technological investment to ensure supply chain seafood safety are especially big challenges for SFCs in Vietnam in general. The development of food safety management systems in developing countries emphasise how prominent food scares and change in the international trading environment have brought food safety to the forefront of international agri-food policy concerns, as well as toward process-based standards in the food supply chain (Orris and Whitehead, 2000; Hanak *et al*, 2002; and Van Veen, 2005).

In Vietnam the relationship between government and industry is an area of attention, and crucial for setting realistic performance quality standards, negotiating regulatory issues, and implementing improved inspection, audit and risk assessment systems throughout the whole chain (Loc, 2006; Ministry of Fisheries, 2003).

Food supply chain management covers the management of the food supply system from the farm, to food manufacturing, to retail and wholesale markets, and to consumer issues (Bourlakis & Weightman, 2004; Eastham *et al*, 2001). In particular management should ensure food quality management attains quality and safety standards stemming from customers' requirements and expectations, and (furthermore) that these requirements and expectations are transformed into the company's performance quality objectives (Luning *et al*, 2002). To implement these objectives, partnership relationships between food companies and their chain actors, and even with loyal customers are crucial. So far, SFCs in the delta do not satisfy the managerial and technological conditions and lack the financial possibilities to implement the above aspects of food chain management. For instance, internal competition among SFCs still exists, chain actors' quality knowledge is low, chain information is insufficient and, especially, relationships between SFCs and their chain stakeholders are still weak (Loc, 2002; Son *et al*, 2003; Tuan, 2004). Moreover, quality standards, such as Good Manufacturing Process (GMP), Sanitation Standard Operation Procedures (SSOP), Safe Quality Food (SQF), British Retail Consortium (BRC) and especially HACCP, have not yet been sufficiently applied by the SFCs (Loc, 2002).

In recent years Vietnam has paid particular attention to seafood quality, safety and hygiene. The Ministry of Fisheries has issued several policy directives and regulations along with financial loan priority for quality improvement, so that local governments and SFCs can improve seafood materials and finished products that can meet customer expectations. To meet customer needs, seafood exporters are all trying to develop and promote quality improvement in the supply chain of aquaculture, marine catch, processing, and distribution.

4.5 Quality problems of fisheries supply chain in the Mekong Delta

Generally, the fisheries supply chain in the Delta includes five stages - hatchery, farm/capture, collector/wholesale buyers, the SFCs and distributors. According to Loc (2006), although all stages of the chain are supported by the Vietnamese government and Fisheries Industry in terms of loan priority, policies and regulations and export document activities to improve and ensure seafood quality and safety, fisheries supply chain quality management is still limited and fisheries products still face quality problems (see **Box 1**). As a result, there are weekly warnings on hazard infections, as well as Vietnam's fisheries import refusal from main export markets (EU, US and Japan)

The main issues for fishery supply chain in the delta include: (i) farm planning and infrastructure; (ii) application of chemicals and antibiotics; (iii) environment of management and monitoring; (iv) high quality fingerlings supply, (v) weak vertical integration; (vi) product quality uniformity, (vii) traceability, (viii) social responsibility issues, (ix) U.S. anti-dumping tariffs and bond issue, (x) international competition, (xi) declining trend of international market price, (xii) value-addition by culturing and processing, (xiii) distribution channels for fisheries, and (xiv) branding and country image building (Dung, 2006; Ha and Trieu, 2007).

These issues have impacted both the efficiency of trade and producers who are increasingly dependent on this trade for their livelihoods. Production arrangement, disease spread, environmental degradation and food safety and hygiene assurance were identified as the key issues for further attention as concluded at an international workshop entitled “Safety and quality of Vietnam’s *Pangasius* in accessing global markets” in June 2006. However, translating these international standards to farmers has also opened up a series of primary production issues that farmers are facing, including ensuring the quality of fingerlings and other inputs, the limitations of small-scale production and the lack of capacity at the commune level to assess and manage product quality.

Despite the current attempts to broaden the scope of chain management, most attention continues to be directed to reducing the prevalence and impact of disease infection (Loc, 2006; Sinh, 2001; Son *et al*, 2003; and Tuan *et al*, 2004). Approximately 25% of the companies said that their products were infected by microbiological hazards (*E.coli*, Coliform, and Salmonella). In addition, 15.6% and 9.4% answered that the products were infected by chemical (Chloramphenicol and Sulfite) and physical hazards (pieces of metal). Although processing companies have good control over the temperature and the hygiene of the equipment in the purchasing process, they are not able to control or audit the level of antibiotic infection or the ice hygiene, even though they maintain good relations with the suppliers. In practice, both processors and suppliers lack equipment necessary to uncover these hazards, and producers and processors alike are constrained by a series of logistical barriers (see **Box 1**). Nevertheless, as seen with the case of the antibiotic contamination of Shrimp in Thailand, auditing practices in the US and EU is raising food quality standards. The implications for producers in Vietnam are considerable, forcing improvements in supply chain management under considerably difficult production conditions.

Box 1: Common Hazards related to fisheries production

Marine capture fisheries

After having been caught, shrimp/fish are stored on a boat offshore. The average time that they are kept offshore is 5 to 7 days (minimum 3 days, maximum 15 days). The materials are then sold to the collectors/wholesale buyers who within a day sell them on to the SFCs and domestic markets. In general, fisheries are seldom infected by micro-organisms and antibiotics after catching. They can, however, become infected during storage, before they are bought onshore. The factors that may affect the original quality of raw materials are methods and techniques to maintain raw materials of food safety as well as storage means during transportation.

Aquaculture

Aquaculture is directly affected by the quality of fingerlings and culture techniques employed by farmers. Poor quality fingerlings are more sensitive to fluctuations in water quality, lower concentrations of pathogens, and inappropriate application of chemicals and antibiotics. Success for many farmers is related to production techniques. As such improvements in quality control, including environmental pollution from intensive cultivation, feed, and harvest methods, can lead to more successful production.

Quality control problems related to the manufacturer

Quality control problems include lack of equipment and technology, quality management, and quality knowledge:

- Lack of quality control equipment to check materials and finished product: Currently almost all SFCs in Vietnam lack the modern equipment to test input materials (from suppliers) and the finished products.
- Processing time: The entire process - from receiving materials to the finished product (input-output process) - takes several days. A longer input-output process leads to a reduction in weight and quality.
- Processing technology: Out-of-date technology creates long processing times and reduces product quality (changing colour and decreasing weight).
- Simple processing techniques: This is a critical stage in ensuring a high quality product. During processing, material is cleaned by hand and in a wet environment, with chemical hazards occurring easily during this process. Antibiotics used by workers to clean their hands in order to prevent fungal diseases may be transferred to the final product.
- Inventory time: Chemical hazards (salmonella) can occur if conditions of facilities are poor.

5. Status of fisheries related policy in the Mekong Delta

This section provides a review of the main policies and legislations related to the fisheries sector. It identifies several key policy areas relevant to management of both aquaculture and capture fisheries, including: structural re-arrangement and sectoral development strategy; use and management of water bodies; exploitation and protection of natural aquatic resources, environmental management disease control; credit supply; extension and technology transfer; supply of feed and chemicals; and fisheries quality, trade and global integration. The following builds on earlier work by Sinh (2004) by further investigating those areas of legislation and policy that highlight ongoing areas of fisheries development in the delta. The main point of this section is to demonstrate how the policies and regulations in fisheries have been made and implemented, as well as to assess their effectiveness.

5.1 Structural rearrangement and development strategy of the sector

Before the end of the 1980s, capture fisheries and aquaculture in Vietnam were mainly for subsistence or for household consumption due to the richness of natural aquatic

resources and the lack of marketing aquatic products. Following the process of *Doi Moi* (1986) and the initial successful operation of Seaprodex model, in 1993 the Communist Party identified fisheries as a priority sector for further development. This resulted in the promulgation of Decree 43/2003/ND-CP dated 2/5/2003 on the functions, responsibilities and organization of the Ministry of Fisheries. The policy making process at different levels has been improved since the 1990s through the combination of both top-down and bottom-up processes. However, the participation of the communities in the planning and policy making process is still emerging. As a result of changes accompanying economic restructuring and international integration, the Central Government then required provinces to revise their provincial development strategies and plans (Decree 01/2004/NQ-CP dated 12/01/2004). These documents have recently been revised by each province. The development strategy for the fisheries sector to 2015 and the vision to 2020 was published in 2006. This is a good reference for detail planning of the sector at provincial and lower levels.

5.2 Use and management of land and water bodies for aquaculture

There are a number of outstanding issues relating to land use. It is not clear, however, of their application to water bodies used for aquaculture. Sea surface areas can be used for aquaculture but not certificated. The mangrove ecosystems along the coasts in the delta have been divided into 3 zones for management: full-protected, buffer and economic zones. Fragmentation of lands from 1980s to 1990s as well as the concentration of lands since 1990s have been important issues. This pattern of land ownership and exploitation carry important implications for the fishery and agriculture sectors, as well as overall rural development.

Despite the revision of the Land Law in 2003, and subsequent implementation guidelines, many questions relating to the performance of Land Law remain unanswered. The situation now shows that it is not easy to make appropriate planning, design, construction and operation of aquaculture at commune and higher levels. This is particularly true for aquaculture farming areas, due to the multi-purposes and conflicts of different target groups on this scarce resource.

5.3 Exploitation and protection of natural aquatic resources

Traditionally, the fisheries sector in Vietnam was based on natural aquatic resources, with regulations focusing mainly on protection of natural aquatic resources. Yet, even though natural aquatic resources are very important to the sector their management has only recently been considered. Late application of strict policies is the main reason for many illegal activities and over-fishing, and subsequent rapid depletion of natural aquatic resources. Other reasons include the lack of man-power, financial support and facilities for management of the resources. Up to 1999, only 6 of 32

inland provinces had the Division of Aquatic Resources Protection and Development (Ministry of Fisheries, 2005).

Natural aquatic resources play an important role to the local communities, especially poor households in the delta. Results of recent studies show that for farming household in fresh water area wild fish capture contributes 10-15% of the total income from aquaculture, increasing to 20 to 35% in the coastal areas (Sinh, 1995 and Sinh *et al*, 2004). Improved management of natural aquatic resources contributes to significant improvement in the household incomes, especially for the poor as a decline in natural aquatic resources most severely affects poor households. From the end of the 1990s, some provinces were pioneering the release of shrimp post larvae and fish fingerlings into the open water bodies in order to improve natural aquatic resources (Ministry of Fisheries, 2005).

Against this background, in Vietnam while a clear development and protection strategy for aquatic resources was neglected for a long time, things are gradually changing. For instance, in July 2004 the Prime Minister approved the Protection and Development of Aquatic Resources Program to 2010, and the protection and development program for inland aquatic resources was issued in June 2007. These provided a clear strategy for sustainable development of the sector. The challenge now is to see this implemented.

5.4 Environmental management and control of diseases on aquatic species

From the beginning of the 1990s, spontaneous and rapid development of shrimp culture raised a number of big problems for the environment and society. Recently, questions have been raised about the increasing intensive level in *Pangasius* fish and shrimp farming, as well as exploitation of the central coast for sandy-soil shrimp farming, more broadly. However, no complete development strategies and plans have been prepared and no successful management schemes have been applied. Consequently, environment in the *Pangasius* shrimp farming areas has degraded leading to poor water quality and the spread of disease. The Ministry of Fisheries released the regulations to manage the environment in the concentrated farming areas in 2001 for shrimp farming and for *Pangasius* farming in 2003, but these can work well only when the planning of aquaculture farming areas is completed in association with other supportive regulations. In order to improve the management of environment relating to aquaculture, the Minister for Fisheries established two Centres for Environmental Warning and Prevention and Treatment of Diseases on Aquatic Species in Central and South regions from 2003 (Ministry of Fisheries, 2003). It can be stated that the environmental and social aspects have been left behind in the rapid growth of the fisheries sector, both in terms of fishing and aquaculture,

for a long time. Increasing demand and requests for certification of origin, especially for export markets, have made the related stakeholders give more concern to environmental issues. Production, trade and application of seed, feed and chemicals/drugs, as well as the use and management of public water and treatment of different types of wastes must be given first priority.

5.5 Support organizations for fisheries development

Two main areas of support are necessary for fisheries development. One is financial support in the form of loans and the other is technology transfer by an extension service.

5.5.1 Credit supply

Capital is one of the most important constraints for aquaculture development, both for poor and rich households. The demand for credit has increased with economic restructure and regulations supporting the conversion of low, economically inefficient land into aquaculture development (Sinh *et al*, 2000; Cuc, 2003; Cantho University, 2004; Ket *et al*, 2006). Financial support for aquaculture has increased since the end of the 1990s. In 2000, priority for loans was given to successful fish farmers, then to farmers with a land certificate and lastly to other groups of farmers. Overdue loans are said to be less common in the northern and central region than in the southern region, where more than 10% of the respondents admit having had an overdue loan from 2000 to 2003. The loan amount is commonly insufficient. Shrimp farmers with land certificate can borrow up to 60 millions Dong and those without land certificate up to 10 millions Dong respectively. For a shrimp hatchery, a total loan of VND 50 million is too small for its operation. (1 USD is about 16,000 VND in Nov 2007).

A significant demand for credit for future investments for the expansion and improvement of fish farming is noted. Non-collateral credits are limited but the policy and regulations have been generally improved. The Ministry of Fisheries commented that the lack of credit supply institutions in rural areas is common and other reasons kept 50% of the total number of households in rural areas away from the banks (DANIDA, FAO, and MOF, 2003). Only about 12-15% of the private, small and medium businesses in rural areas could borrow money from the banks. At the national level, the total amount borrowed by private businesses and companies was less than 10% of the total amount of money borrowed. This is a very low rate compared to that of 18% in the poorest country and 85% in the other Asian countries.

5.5.2 Extension and technology transfer

The Extension Centre plays an important role for disseminating reports and regulations regarding fisheries sustainable development as well as training and technology transfer to farmers. In 2000 the Central Aquaculture Extension Centre was established, and later in 2003 renamed the National Aquaculture Extension Centre. Six extension programs were implemented for the period of 1996-2000 with hundreds of training courses for each: (1) reproducing seed of aquatic products; (2) shrimp culture (*Penaeus monodon*); (3) freshwater aquaculture; (4) brackish water and marine water aquaculture; (5) off-shore fishing and protection of aquatic resources; and (6) preservation, processing and improvement of product quality for export.

Horizontally, the extension networks were expanded from 1996 to 2000. Department of Fisheries offices were established in the provinces where natural fisheries and aquaculture have an important role in the provincial economy. There is an extension centre under this department. Otherwise, activities are managed through the Department of Agriculture and Rural Development. All extension activities are combined under the management of the division of agriculture/forestry and fisheries at district and commune levels. At present, extension staff are key information providers to commune authorities and farmers, as far as market issues are concerned, to help farmers assess opportunities and risks, as well as to choose input suppliers and options for output sales.

5.6 Major input materials for aquaculture development

Use of seed, feed and chemicals/drugs has increased over time for many reasons; expansion of aquaculture; farmers' expectations, higher intensity levels, extension, and marketing of suppliers. These inputs have rapidly increased from the 1990s when intensive farming increased and strict quality standards was applied to the quality of aquatic products. Recent studies show that the three most important items in the total production costs for shrimp and fish culture are: (i) feed (about 50-70% of the total production costs); (ii) seed (15-20%); and (iii) chemicals/drugs (4-15%). Therefore, both suppliers and users give most of their attention to these inputs (Sinh & Nga, 2004).

Seed for aquaculture farming often plays an important role, especially to the systems with a higher level of intensification and those with new species. At provincial level, the management of hatcheries is difficult and the provinces where there are major shrimp seed producers (like Camau, Khanhhoa and Ninhthuan) may have their own regulations on seed production and inspection. It was found that 10% of the total seed samples imported from the Central region to the delta were infected by White Spot Syndrome (Ministry of Fisheries, 1999; and Sinh, 2003). In addition, most of

the sectoral standards can be considered as “window-dressing” because they are inappropriate and their application is often very difficult or impossible. Therefore, there is still a big gap between the extension program on seed production and development plans on it. Diversification of aquaculture requires a better development of seed supply including species, quantity, quality and seasonal conditions (Sinh, 2003; and Sinh et al, 2006).

Feed costs to produce shrimp in Vietnam were reported to be higher than that of Thailand (USD 0.9/kg compared with USD 0.75/kg). Feed costs to produce cage Tilapia in Vietnam were USD 0.8/kg higher than that in the Philippines (USD 0.69-0.75/kg). To meet the demand of feed about 40,000 tonnes (45%) of feed is imported from Thailand, Hongkong and Taiwan (Ministry of Fisheries, 2000-2003). The remaining was imported by unidentified or unregistered suppliers. Informal data show that there were about 120 types of feed traded in the market in 2003, but only about 70 types have been tested or registered before being traded (Huong & Nhung, 2004).

Regarding chemicals/drugs, in 2003 NAFIQUVED reported that there were 1,361 registrations for the production and 199 registrations for the import of chemicals/drugs for aquaculture. Despite of Decree 18/202/QD-BTS dated 3/6/2003 by the Ministry of Fisheries on the procedure of testing and checking the seed, feed and chemicals/drugs used for aquaculture, only 53 products were reported up to the end of 2003. In addition, after being tested, checked and reported, the name and function of some of these products have been changed when being traded (Thanh, 2004).

The Ministry of Fisheries issued lists of permitted, limited and prohibited chemicals/drugs for aquaculture in May 2002. In August 2005, 11 products of Fluoroquinolones group in the limited list became prohibited for the US and Canadian markets (Decision 26 in 2005 by the Ministry of Fisheries). Studies conducted by Trinh (2004), Nga (2004) and Tuan (2004) show an increasing level in the use of chemicals/drugs for aquaculture, especially for intensive shrimp farming along the coasts and intensive culture of *Pangasius* catfish in the ponds and cages in the freshwater areas. Increasing the level of application of chemicals/drugs was reported by 83.3% of the fish farmers with the main reasons being the lower quality of the public water supply.

In short, along with increase in quantity and culture area, farmers have used more input materials such as seed, feed and chemicals/drugs. However, the quantity and quality of these inputs have not been sufficiently managed and controlled by local government authorities. As a result, final fisheries products are still hazardous.

6. Contested issues, research priorities and policy linkages

6.1 Contested issues

The delta is said to have great potential in natural and human resources. It is a cradle for Vietnam's agricultural production, especially fisheries, for national sufficiency and for export. It is, however, still at a low level of development compared with other regions of Vietnam despite the government's attention to the development of policy and regulation. Fisheries policies are frequently updated for meeting market needs but there are still problems of management and inspection. Many researchers focused on different issues regarding regional trans-boundary linkages of fisheries in the Delta Basin, international fisheries markets and supply chains, and national policy on fisheries and aquatic resources.

The first issue relates to different policies regarding water and fish trans-boundary resources as well as infrastructure development in the Mekong River Basin. These issues need to be solved through the cooperation on technical and policy aspects between the countries within the Mekong River Basin region in order to develop regional fisheries ecology. Particularly, floodplain fisheries in the Northern parts of the delta, such as Dong Thap and An Giang provinces, are directly linked to the ecology of this area. Moreover, the flood-pulse in the delta triggers a series of fish migrations and maintenance of fish stock that is crucial for livelihood, income and nutrition of the delta community.

The importance of wild capture fishery has been largely downplayed in the Lower Mekong countries as a whole, despite that the wild capture fishery far exceeds the total yield from aquaculture. In addition the wild capture fisheries play important for the food security of the vast poor, while aquaculture is beyond their reach. The total fish products of the four lower Mekong countries is assessed at 2 million tons per year; 1.75 mil. tons from wild capture and only 0.25 mil. tons from aquaculture. (MRC, 2004) This point is rather important as one of most the contested issues at the lower Mekong basin (LMB) regional level. The key points of debates focus on why the LMB government had put in little effort to maintain the wealth of wild fisheries resource, proven by most of national fishery budget goes to aquaculture activities. Similarly, at the regional scale of the LMB, regional cooperation in maintaining the region's wild stock has not been vigorous, while all other sectors have secure the top priorities (e.g. hydro power cooperation, irrigated agriculture etc.).

Second, greater attention is needed on improving the supply chain management for international markets. Further attention needs to be given to assure product quality in its

supply chain and meet international market standards. In particular, farmers still have limited knowledge on the application of improved production technologies in the delta, as well as understanding of product quality, market, competition and sustainable production from the farmers. Overall, fisheries production in the Delta is on a small scale and individual basis, and faces capital shortages, underdeveloped infrastructure, and limitations of technological application, as well as creating environmental pollution, low quality products, high costs of production, and a lack of an efficient input-output process. Furthermore, fisheries products are facing trademark and labelling problems, technical barriers and anti-dumping threats in three main markets - Japan, EU and the US. Consequently, aquatic products from Vietnam are difficult to compete in these markets in terms of the quality, quantity and competitive price. In the domestic markets, fish for the poor is very important while there is an increasing demand for a better quality of fish products, especially via the network of supermarkets.

The last area of concern focuses on the ability of policy makers to deal with a wide variety of complex issues at local, regional and global levels to make effective net gains from fisheries development in the delta. These include environment and social issues as much as economic efficiencies. Important considerations, in policy making and resource planning, must be given to issues of land and water allocation for aquaculture while keeping balance with protection of the delta environment and its natural aquatic resources. Although the policies regarding the above issues have gradually improved over the last years, conflicts between the use of land and water still exist; environmental pollution has worsened, credit supply and technical transfer remain limited, and contamination of fish products remains a challenge for export.

6.2 Research priorities

There are several research areas where a concerted research effort would result in a broader understanding of fishery resources and their sustainable development. Some of these are related to issues at the Mekong Basin level as a whole, some beyond the Vietnam Delta. These include the impact of both social and environmental transboundary influences. The following lists key questions for further research and would complement the further development of domestic policy aimed at balancing the economic growth of the sector with both environmental and social development imperatives.

First, with respect to *regional transboundary management challenges* in the Delta the following questions are proposed:

- 1) How can regional fisheries ecology be better integrated into water and fisheries management schemes in the Mekong Delta?

2) What steps are necessary to strengthen all stakeholders' understanding on the use and impact of regional sources of low-value fish for aquaculture feed?

3) How can a wider understanding of the social aspects of transboundary trade in aquatic products in the delta be improved and other issues of flow regime change the impacts throughout the Mekong Delta?

4) Study of Impact of flow regime change from upper Mekong to the Vietnam delta. What would this flow regime change (dams, regulation of water, Lower flood peak and wetter dry season) mean in term of wild fishery stocks? And what implication this may have for agriculture and aquaculture?

Secondly, questions related to *supply chain management for regional and global trade* include:

1) What are the impacts of poor seed quality management on both the quality of raw materials and final products?

2) How can better control over fisheries quality and safety at the level of collectors/wholesale buyers be developed?

3) How might SFCs be combined in the Delta for purchasing input materials to improve quality?

4) What are the costs and benefits of a lack of fisheries supply chain transparency?

Third, the following key questions related to the further *development of domestic policies* relate to trans-boundary issues of the fisheries sector in the Delta are proposed:

1) What extension techniques are necessary for the sustainable development objectives of the fisheries sector?

2) What is needed to ensure a better supply and quality management of fingerlings/seed at national and local government level?

3) How can improvements be made in the supply and application of chemicals/drugs for aquaculture farming activities, while ensuring safe levels of preservation and processing?

4) What managerial methods might improve understanding between chain

stakeholders about the importance of their roles and responsibilities in terms of quality assurance, pollution and sustainable development?

5) What incentives or programmes would encourage farmers to voluntarily form larger scale production groups to achieve more effective and efficient production?

6) What measures and policies are needed to both conserve and develop natural aquatic resources to ensure food security and agricultural land for rural communities, especially small-scale and poor households, as well as the reproduction of endangered species?

7) What is the impact of the increasing aquaculture on poverty reduction in the delta ? is the aquaculture for export policy compatible with poverty reduction strategy and plan?

6.3 Further research - the priorities

Based on the contested issues and research gaps two areas of research are prioritized for the further improvement of managerial policies for fisheries resources as well as for sustainable development of the fisheries sector among countries in the Mekong River Basin:

1. Measures for a better regional policy integration of fisheries ecology, trans-boundary sources of aquaculture feed and for improvement of trans-boundary trade of aquatic products in the delta region; and,
2. Assessment of regional value chains for promoting sustainable fisheries development in the Mekong Delta.

These research topics are suggested as being useful for the Vietnamese Government, Ministry of Fisheries, the local governments, VASEP and NAFIQAVED, as well as for all fisheries chain stakeholders in order to help to further develop the fisheries sector, taking into consideration both social and environmental factors. Research on these topics will improve appropriate fisheries policy, fisheries quality and safety throughout the whole value chain and also will reduce the challenges and meet the standard needs for both international and domestic markets.

7 Conclusions

Today, sustainable development of the fisheries sector in each country relates not only to itself but to the requirements and development integration of regional policy and international standards that have created big changes in fisheries livelihoods. In fact,

natural fishery resources of the Mekong River Basin in general, and in the delta in particular, have contributed to significant changes in the growth of the regional economy, income and livelihood improvement of the people. These results stem from regional, environmental, trans-boundary processes in policy integration for fisheries development, exploitation and protection of natural resources and infrastructure. In addition, the international standard requirements for fisheries products have imposed big changes on the national policy environment in both fisheries and quality that lead to a quality improvement in primary production, processing and distribution (the fisheries supply chain), as well as fisheries sustainable development in the delta to meet the market needs. Moreover, regional and global trans-boundary influences over fisheries production have huge implications for the ongoing development of trade and population livelihoods. Reviews of the literature suggest both achievements and a lack of information and understanding of the trans-boundary challenges for fisheries policy and its implications for economic growth and food security in the delta where a large proportion of the population rely on aquatic resources. The main conclusions on these issues follow.

7. 1 Fishery challenges and transboundary impacts

This paper indicates some of the challenges policy makers face when balancing the economic well-being of the people of the delta with responsible land and water resources use. It is clearly important for decisions to be made within the context of production activities within the delta as well as within the wider framework of the Mekong Basin. How to achieve this balance and move towards a more integrated understanding of production activities at local scales, within the wider social, economic and ecological processes of the delta and Mekong Basin remains a central challenge for policy makers.

It is increasingly clear that farming communities within the delta are reliant on wild caught fish for food and income. Although much of this paper has focused on the implications of international supply chain management of aquaculture fish, there is increasingly a recognition that wild fish also play an important role in both the economic development of the delta as a whole by supporting the livelihoods of farming communities. Artisanal production within the delta remains poorly understood and, as such, undervalued within planning and policy circles. The importance of trans-boundary movement of fish is also relatively little understood, but there is growing motivation for management based on emerging evidence that fish caught within flooded areas of the delta migrate elsewhere. In the absence of such information it may be appropriate for more precautionary approaches in decision making. Given the complex mixture of agro- and aqua-production systems throughout the delta, decision makers are placed in a precarious position when balancing flood mitigation and ecological flows for fish production. Considerable

support is needed to develop adequate mechanisms to balance water and fish production not only in response to development imperatives within the delta but also in response to imperatives throughout the Basin as a whole.

The MRC remains the most relevant platform for the ongoing management of the transboundary resources in the scope of the Mekong Basin. While the MRC has proven ineffectual over key resource disputes in recent years further investment by the government of Vietnam remains a central strategy for continued engagement over fair and equitable use of shared resources. The ongoing effectiveness of platforms such as the MRC lies in its ability to engage national Mekong Committees to ensure that problems that are transboundary in nature are mitigated within the context of sovereign national territories. The interdependent nature of each of the countries of the Basin for the health of migratory fish stocks provides a case in point: regional management of fish stocks must begin with better coordination of water flows and maintenance of fish habitat within each of the countries. Trade, as a key motivator for fisheries exploitation and aquaculture production, also needs further attention by such regional bodies. Much like the ecological flow of fish stocks, equitable trade of fish and fish products begins with a strong national prerogative before extending to a regional scale. Supply chain management and government policy that encourages cleaner and more efficient production provide important starting points for the improved governance of fisheries production in the Delta. Nevertheless, it remains to be seen how state regulation, WTO rules, third party certification and the 1995 MRC agreement will collectively improve the management of fisheries production, ensuring continued economic development of delta, maintaining food security of vulnerable rural communities and fostering ongoing stewardship of the Delta environment for both capture and culture fisheries.

7.2 Fisheries supply chain

There is a growing customer demand for stable and high quality products. Therefore, manufacturers and traders have no choice but to supply good products and to control product quality. But, hazards are still not free from fisheries products because there are many quality problems occurring in the entire fisheries chains, as this paper has detailed. These problems affect product quality and the value added of each stage of the supply value chain system.

7.3 Fisheries policy

The analysis reveals that policy environment has not been well suited to the development of the fisheries sector in practice. The main elements are as follows:

1. The late restructuring of the fisheries sector and lack of appropriate strategies and development plans has slowed down the growth of sector.

2. Protection and development of aquatic resources, is regulated but many of these regulations are ineffective and unimplemented. Lack of strict regulations, insufficient man-power and facilitation, as well as a low level of education of the communities are the most important reasons.

3. Multidisciplinary management of environment, land and water bodies, as well as quality standard performance of policy making and regulation is difficult.

4. Lack of capital is a common constraint for aquaculture, but the improvement in procedure and the amount of loans seems to be difficult for credit supply institutions to change so that the development of aquaculture is encouraged and diversification takes place.

5. Both domestic and international markets are important to the development of the fishery sector, but international markets have especially encouraged the development of fishery sector. Diversification in aquaculture depends on the physical conditions, available technology and major inputs. International trade laws are important for most of the stakeholders in the sector, especially big producers and exporters.

6. Extension must be improved and overlapping institutional arrangements need to be removed. In addition, methods of technology transfer and knowledge on the use of chemicals/drugs, as well as market information need to be encouraged.

7. Lack of timely and strict regulations on the supply and use of major inputs like seed, feed and chemicals/drugs have made these complicated and difficult to manage. Appropriate development plans at different levels should go hand in hand with the strict registration and inspection of these inputs. Further studies on marketing and efficient use of these inputs for specific farming systems could assist the establishment of appropriate policies.

8. Traditionally, the fishery sector was privately owned. State management was revealed to not be appropriate for aquaculture, fisheries and processing, except where there has been the establishment and operation of regional centres for seed production and technical and environmental services. Cooperation among stakeholders is a good option, which needs the support from government at different levels depending on the specific community.

Therefore, all of the related aspects should be considered to achieve a better policy-making environment and improved policy performance. Significant improvement in the policies and regulations on aquaculture has slowly been achieved over the last decade.

List of text abbreviations

ACIAR	Australian Centre for International Agriculture Research
BRC	British Retail Consortium
EC	European Council
EU	European Union
FAO	Food Agriculture Organization
GAA	Global Aquaculture Alliance
GAP	Good Agriculture Practice
GDP	Gross Domestic Product
GMP	Good Manufacturing Practice
HACCP	Hazard Analysis and Critical Control Points
MRC	Mekong River Committee
Delta	Mekong Delta
NAFIQAVED	National Fisheries Quality Assurance and Veterinary Directorate
OXFAM	Oxford Committee for Famine Relief
SFCs	Seafood Companies
SQF	Safe Quality Food
SSOP	Sanitation Standard Operation Procedures
US	United States
VASEP	Vietnam Association of Seafood Exporters and Producers
WHO	World Health Organization
WTO	World Trade Organization

References

- ADB (1996) *Economic Cooperation in the Greater Mekong Subregion*, Asian Development Bank: 18.
- Adger, W. N., Benjaminsen, T. A., Brown, K. and Svarstad, H. (2001) Advancing a Political Ecology of Global Environmental Discourses. *Development and Change* 32:681-715.
- APFIC (2005) *APFIC Regional workshop on Low value and “trash fish” in the Asia-Pacific region*. Food and Agriculture Organisation of the United Nations, Regional Office for Asia and the Pacific, Bangkok 37p.
- Baird, I. G. and Flaherty, M. (2005) Mekong River Fish Conservation Zones In Southern Laos: Assessing Effectiveness Using Local Ecological Knowledge. *Environmental Management* 35(1):1-17.
- Baran, E. (2007) *Fish migration triggers in the Lower Mekong Basin and other tropical freshwater systems*. MRC Technical Paper No.14 Mekong River Commission, Vientiane.
- Beasley, I.; Sinh, L.X., and Hodgson, A. (2006) Investigating the occurrence of Mekong Irrawaddy Dolphin status in the Vietnamese Delta *Special number of Scientific Magazine*, Cantho University, April pp 291-300.
- Bush, S. R. (2004) Scales and Sales: changing social and spatial fish trading networks in the Siiphandone fishery, Lao PDR. *Singapore Journal of Tropical Geography* 25(1): 32-50.
- Bush, S. R. (2006) *Livelihoods, markets and governance: market access and value adding for small-scale fishers in the Lower Mekong Basin*. Oxfam America, Phnom Penh, Cambodia.
- Bush, S. R. and Le Nguyet, Minh (2006) Fish trade, food and income security: an overview of the constraints and barriers faced by small-scale fishers, farmers and traders in the Lower Mekong Basin. *Fish for the People* 4(2): 8-16.
- Bush, S. R. and Oosterveer, P. (2006) Intersecting governance and trade in the space of place and the space of flows. In Shriver, A. ed, *Proceedings of the Thirteenth Biennial Conference of the International Institute of Fisheries Economics & Trade: Rebuilding Fisheries in an Uncertain Environment*, July 11-14 IIFET, Portsmouth, UK pp. 12.
- Bush, S. R. and Oosterveer, P. (2007) Environment, governance and global markets. In Zijpp, A.J. van der Verreth, J. A. J., Le Quang, T., van Mensvoort, M.E.F., Bosma, R. H. and Beveridge, M. C. M. eds *Fishponds in Farming Systems*, Wageningen Publishers, Wageningen, pp. 203-210.
- Can Tho University (2004) *Survey of the farming systems in the buffer zone of Tra vinh, Soc trang, Bac lieu and Ca mau provinces*. Report prepared by College of Aquaculture and Fisheries, College of Agriculture. CWPDP Project World Bank. October 2003 - April 2004. 2.

- Can Tho University (2004) *Survey of the farming systems in the buffer zone of Travinh, Soctrang, Baclieu and Camau. Consultant report of Coastal Wetlands Protection and Development project (CWDP) of the World Bank in Vietnam.* Vietnam.
- Coates, D. (2002) *Inland capture fishery statistics of Southeast Asia: Current status and information needs.* Asia-Pacific Commission, Bangkok 113p.
- Cuc, N. S. (2003) *Agriculture and Rural areas of Vietnam in "Doi moi" process.* Statistical Publishing House, Hanoi.
- Department of Agriculture & Rural Development (2006) *Research on harmful residues to aquaculture in Cantho-measures and sustainable fisheries development, Research report.* Department of Agriculture & Rural Development, Cantho City, Vietnam.
- Department of Legislation-Ministry of Fisheries (2004) *The Government Decree of the State management of products quality,* September 11.
- Dinh Nam (2006) *Agriculture in WTO integration: Opportunities and challenges* June 1.
- Doan Ngoc Bong (2006) *WTO: Agricultural opportunities and challenges,* VCCI, VNExpress.net, January 12.
- Edmonds, C. (2002) The role of infrastructure in land-use dynamics and rice production in Viet Nam's Mekong next term River Delta. *ERD Working Paper Series Issue 16:* 1-25.
- Edwards, Peter, Tuan, Le Anh, Allen, Geoff L. (2004) *A survey of marine trash fish and fish meal as aquaculture feed ingredients in Vietnam,* Australian Center for International Agricultural Research.
- FAO, DANIDA, Ministry of Fishery (2003) *Fisheries marketing and credit in Vietnam.* Ministry of Fishery, Hanoi.
- Food and Agriculture Organization of the United Nations (2003) *WTO agreement on Agriculture: the implementation experience developing country case studies.* Commodity Policy and Projections Service, Commodity and Trade Division, Rome.
- Garces; R. Agbayani; and Genio, E. (1997) *Marketing Freshwater Table-Fish in the Central Area in the Mekong River Delta.* WES-Aquaculture Program, Cantho University.
- General Statistics Office (2003) *Statistical Yearbook.* Statistical Publishing House, Hanoi.
- Graaf de, G. J. and Xuan, T. T. (1998) Extensive shrimp farming, mangrove clearance and marine fisheries in the southern provinces of Vietnam. *Mangroves and Salt Marsh 2:* 59-166.
- GSO (General Statistics Office) (2005) *Statistical Yearbook 2005.* Statistical Publishing House, Hanoi, Vietnam.
- Ha Van and Dong Trieu (2007) *Opportunities, challenges and solutions for development of main agricultural sub-sectors in the Delta, Vietnam to the WTO, Internal Workshop March 7-16 2007 in Can Tho.*
- Hai, N.N. (2004) *Survey of Tra nursery techniques and application of chemicals/drugs.* Bachelor dissertation, Faculty of Aquaculture & Fisheries, Can Tho University, Vietnam.
- Hong Minh, Nguyen (2006) Challenges of fisheries development. In *Quan Doi Nhan Dan* Newspapers, December 21, 2006.

- Jerndal, R. and Rigg, J. (1999) From Buffer State to Crossroads State: Spaces of Human Activity and Integration in the Lao PDR. In Evans, G. ed. *Laos Culture and Society*, Silkworm Books, Chiangmai, pp. 35-60.
- Johnson, G. I. and Hofman, P. J. (2003) *Agriproduct Supply-Chain management in Developing Countries*, Australian Center for International Agricultural Research.
- Junk, W. J. and Wantzen, K. M. (2003) The flood pulse concept: New aspects, approaches and applications - an update. In Welcomme, R. and Petr, T. eds. *Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries*. RAP Publication 2004/17. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, Phnom Penh, pp. 117-140.
- Junk, W. J., Bayley, P. B. and Sparks, R. E. (1989) *The flood pulse concept in river-flood plain systems*. Proceedings of the International Large River Symposium, Toronto, Ontario, September 14-21, 1986, Canadian Special Publication of Fisheries and Aquatic Sciences
- Karen, S. and Thach, P.N. (2003) *Risk issues and management strategies for Bacillary Necrosis Disease (BNP) and other factors for Pangasius spp. farming in the Delta Vietnam*. Social science report. Stirling University and Cantho University.
- Le Anh Tuan (2004) *Status of aquaculture and associated environmental management issues in Vietnam*, University of Fisheries, Nha Trang, Vietnam.
- Loc, V.T.T (2006) *Seafood supply chain quality management in the Mekong Delta, Vietnam*, CDS thesis No.17. University of Groningen.
- Loc, V.T.T. (2001) *Description of seafood companies in the Mekong Delta*. Faculty of Organisation and Management, University of Groningen.
- Loc, V.T.T. (2002) *Primary data and the reports from 32 seafood companies in the Mekong Delta, Vietnam*.
- Loc, V.T.T. (2002) *Primary data and the reports from exploratory interviews of ten SFCs leaders in the Mekong Delta, Vietnam*.
- Loc, V.T.T. (2002) *The situation of the world's seafood market, Vietnam's and the Mekong Delta's*, Faculty of Organisation and Management, University of Groningen.
- Loc, V.T.T. (2003) *Shrimp supply chain in the Mekong Delta, survey results*.
- Loc, V.T.T. (2005) *Primary information from 34 chain stakeholders and experts in the Mekong Delta, Vietnam*.
- Lynch, R. (2003) *Corporate Strategy, 3rd ed.*, Prentice Hall Financial Times.
- Phillips, Michael, Nguyen Thanh Tung and Nguyen Van Thanh (2004) *Policy Research Implications of Liberalization of Fish Trade for Developing Countries, A Case Study of Vietnam*, Project PR 26109, FAO of the United Nations, Rome.
- Miller, F. (2003) *Society-Water Relations in the Mekong Delta, Viet Nam: A Political Ecology of Risk*. School of Geosciences., University of Sydney, Australia.
- Ministry of Fisheries (1998) *Strategy for the development of aquatic processing and export of aquatic to 2005*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (1999) *Strategy for the development of fisheries to the year of 2010*. Ministry of Fisheries, Hanoi, Vietnam.

- Ministry of Fisheries (1999a) *Aquaculture development program for the period of 1999-2010*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (1999b) *Summary report of 10 years of protection and development of natural aquatic resources (1989-1999)*. Ministry of Fisheries, Hanoi, Vietnam
- Ministry of Fisheries (2000) *Export program of aquatic products to 2005 & aquaculture 1999-2010*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (2000) *Situation report of & plan for aquaculture development in coastal province for the period of 2001-2005*. Ministry of Fisheries, Hanoi, Vietnam
- Ministry of Fisheries (2000-2006) *Annual reports and action plans for the following year*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (2003) *Fisheries extension in Vietnam: 10 years of operation and development*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (2004) *Fisheries activities in 2004 and workplan for 2005*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (2006) *Forbidding import and using anti-biotics and chemical substances to fisheries culture*. Ministry of Fisheries, Hanoi, Vietnam
- Ministry of Fisheries (2006) *Guidance Decree on Implementation of development policy to fisheries*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries (2006) *Report on control of using anti-biotics and chemical substances to Shrimp*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries and Farmer Association (2006) *Combination between MOFi and farmers in fisheries economic development in the period 2006-2010*. Ministry of Fisheries, Hanoi, Vietnam.
- Ministry of Fisheries, and Ministry of Foreign Affairs - DANIA (1997) *Master Plan Project for Fisheries Development to the year 2010*. Ministry of Fisheries, Hanoi, Vietnam.
- Mekong River Commission (1995) *Agreement on the cooperation for the sustainable development of the Mekong River Basin*. Mekong River Commission, Phnom Penh 13p.
- Murray, D. (1993) *From Golden triangle to Economic Hexagon - recent Development Proposals for Regional Economic Linkages in mainland Southeast Asia*. The Netherlands, Western Australia, The Indian Ocean Centre for Peace Studies, University of Western Australia 43p.
- NAFIQAVED, Branch 6 (2006) *Control program of harmful residues in aquaculture*.
- Nguyen Huu Dung (2006) *Some issue for sustainable development of fisheries farming in Vietnam, International conference paper June 11 in An Giang, VASEP*.
- Nguyen Ngoc De (2006) *Farmers, agriculture rural development in the Mekong Delta, Vietnam*, Education Publishing House.
- Nguyen Van Thuoc (2007) *The Mekong Delta's farmers in integration trend*. In *Cantho Newspapers*, February 24.
- Oosterveer, P. (2007) *Global Governance of Food Production and Consumption: Issues and Challenges*. Edward Elgar, Cheltenham.
- OXFAM (2004) *Analysis of Viet Nam's Accession to the WTO*. (Unpublished)

- Pathania-Jain, G. (2001) Global parents, local partners: A value-chain analysis of collaborative strategies of media firms in India, *Journal of Media Economics* 14(3): 169-187.
- Payne, A. I., Sinha, R., Singh, H. R. and Huq, S. (2005) *A Review of the Ganges Basin: Its Fish and Fisheries*. Second International Symposium on the Management of Large Rivers for Fisheries, FAO Regional Office for Asia and the Pacific, Thailand. RAP Publication 2004/16
- Phuong, N.T.; Thinh, N.Q.; Chau, H.H.; Anh, C.T.; Hau, N.M.; and Sinh, L.X. (2006) *Economics of different catfish feeding practices in Vietnam*. Paper presented in the training workshop 'Data processing analysis on the economic assessments of aquaculture feeding systems' organised by FAO/NACA in Bangkok, Thailand, 25-28 April 2006.
- Poluha, Rolf G. (2006) *Application of the SCOR Model in Supply Chain Management* Youngstown, New York
- Pomeroy, R.; Sinh, L.X.; Garces, A.; Agbayani, R.; Be, N.V.; and Pekar, F. (1997) *Ecotechnological and Socio-economic Analyses of Fish Farming Households in the Fresh Water Areas of the Mekong River Delta*. WES-Aquaculture Program, Cantho University, Vietnam
- Poulsen, A. F., Ouch Poeu, Viravong, S., Suntornratana, U. and Nguyen Thanh Tung (2002) *Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management: MRC Technical Paper No. 8: 62*. Mekong River Commission, Phnom Penh,
- Poulson, A. F. and Jorgensen, J. V. (2001) *Fish Migration and Spawning Habits in the Mekong Mainstream: A survey using local knowledge*. CD-ROM, AMFC/Mekong River Commission, Vientiane, Lao PDR
- Preston, N. and Clayton, H. (2003) *Rice-Shrimp Farming in the Mekong Delta: Biophysical and Socioeconomic issues*, Australian Centre for International Agricultural Research
- Rainbird, M. (2004) A framework for operations management: the value chain *International Journal of Physical Distribution & Logistics Management*. 34(3/4)
- Richter, B. D., Mathews, R., Harrison, D. L. and Wigington, R. (2003) Ecologically sustainable water management: Managing River Flows for Ecological Integrity. *Ecological Applications* 13(1): 206-224
- Rigg, J. (1997) Uneven development and the (re-) engagement of Laos. In Dixon, C. and Drakakis-Smith, D. ed. *Uneven Development in Southeast Asia* Ashgate Publishing Company, Aldershot, pp 148-165
- Sinh, L. X. (1995) *Roles of Aquaculture on the Farm Household Economy in Omon district, Cantho province, Vietnam*. Asian Institute of Technology (AIT), Bangkok, Thailand
- Sinh, L. X. et al. (1998) *Marketing Freshwater Table-Fish in the Central Area of the Mekong River Delta*. Paper presented at the Asian Fishery Society's Conference (AFOOD SAFETY), Chiangmai, Thailand, October 1998.

- Sinh, L. X.; Tuan, N. A.; Pomeroy, R.; Garces, A.; Agbayani, R.; and Genio, E. (1997) *Marketing Freshwater Table-Fish in the Central Area in the Mekong River Delta*. WES-Aquaculture Program, Cantho University, Vietnam.
- Sinh, L.X, Hien, H.V. and Chung, D.M. (2006) *Technical-economic efficiency in the hatchery of giant freshwater prawn (Macrobrachium rosenbergii) in the Mekong Delta. Special number of Scientific Magazine*. April, Cantho University, Vietnam pp 268-279.
- Sinh, L.X. & Khuyen, P.T.N. (2006) *Black tiger (Penaeus monodon) shrimp industry in the Mekong Delta: Consideration on the supply of raw materials for processing and export*. Paper presented in the International workshop on “Industrialisation & Modernisation of the Fishery Sector” held in Nhatrang University, Vietnam.
- Sinh, L.X. (2004) *A bio-economic modelling of a shrimp hatchery in the Mekong Delta of Vietnam*. PhD thesis, University of Sydney, Australia.
- Sinh, L.X. (2004) ‘*An overview of aquaculture in Vietnam*’ and ‘*Policy environment for development of aquaculture and diversification in Vietnam*’. Report submitted to the World Bank Group in Vietnam.
- Sinh, L.X. (2004) *Use of bio-economic modelling for planning and management shrimp hatcheries in the Mekong Delta. Scientific Magazine (Aquaculture) of Cantho University, Can Tho University, Vietnam* pp 349-361.
- Sinh, L.X. (2005) *Issues relating to sustainable farming of catfish (Pangasius spp.) in Vietnam*. Paper presented at the workshop “Socioeconomics of selected species for sustainable development of aquaculture” organised by the Oceanic Institute, Hawaii, USA, 17-19 October, 2005.
- Sinh, L.X. (2005) *Management and development of aquatic resources in freshwater wetland areas of the Mekong Delta of Vietnam: Can we adjust to a new situation?* Proceedings of the National Workshop on Environmental Economics and Evaluation of the Wetlands 4-6 May 2004, Vietnamese Association of Environmental Economics, Hanoi, Vietnam pp.76-97.
- Sinh, L.X. and Tuan, N.A. (1997) *Some of socio-economic aspects of integrated Rice-Fish farming systems in the central part of Mekong Delta of Vietnam*. Proceedings of the International Workshop on Rice-Fish Farming by Katholieke Universiteit (Belgium) and Cantho University (Vietnam) held at the Cantho University, September 1997, p.83-89.
- Sinh, L.X. and Tuan, N.A. (1997) *Some of socio-economic aspects relating to the protection and development of coastal mangrove eco-system in the Mekong Delta. Scientific Magazine of Cantho University (Agriculture)*. pp 192-200.
- Sinh, L.X. and Phuong, N.T. (2000) *Scientific Report on the “Feasibility study of the Application of Rice-Fish Systems in Flooding Water Area of the Mekong Delta*. Vietnam-Netherlands Research Program (VNRP)
- Sinh, L.X. and Nga, N.T.P. (2004) *Major assessments of the supply and use of chemicals and drugs for aquaculture in the Mekong Delta*. Proceedings of the National Workshop on Aquaculture 22-25 December, 2004, Ministry of Fisheries, Vungtau.

- Sinh, L.X., Chung, D.M and Hien, H.V. (2006) *Building of a bio-economic model of giant fresh water prawn (Macrobrachium rosenbergii) in the Mekong Delta* Ministry of Education & Training.
- Sinh, L.X., Khuyen, P.T.N., Hien, H.V., Chung, D.M. and Truyen, T.T. (2005) *Assessment of the social impacts of coastal aquaculture farming activities (shrimp farming) in the Mekong Delta. Special number of Scientific Magazine, Can Tho University, April pp 220-234*
- Statistical Office of Angiang Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Baclieu Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Bentre Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Camau Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Can Tho City (2005) *the Mekong Delta Statistical Yearbook 2004*.
- Statistical Office of Can Tho City (2006) *Statistical Yearbook 2005*.
- Statistical Office of Dongthap Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Haugiang Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Kiengiang Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Long An Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Soctrang Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Tiengiang Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Travinh Province (2006) *Statistical Yearbook 2005*.
- Statistical Office of Vinhlong Province (2006) *Statistical Yearbook 2005*.
- Sverdrup-Jensen, S. (2002) *Fisheries in the Lower Mekong Basin: Status and Perspectives*. Mekong River Commission, Phnom Penh 103p.
- Ta Quang Dung (2007) The key for fisheries export development, *Nhan Dan Newspapers*, March 15.
- Thorpe, A., Williams, S. and Zyl, J. V. (2005) The Post-Harvest Chain. In Kooiman, J., Bavinck, M.; Jentoff S.; and Pullin, R. S ed. *Fish for Life: Interactive Governance for Fisheries*, Amsterdam University Press, Amsterdam, pp. 109-132
- Trinh, N.T.T. (2004) *Survey of the use of chemicals and drugs in shrimp farming in Ngoc Hien district, Ca Mau province*. Bsc Dissertation, College of Aquaculture and Fisheries, Cantho University, Vietnam.
- Truong Tri Vinh (2006) Fisheries export in 2007 and “value” regarding US dollars. In *VNECONOMY*, December 20.
- Tuan, P.T. (2004) *Initial survey on the application of chemicals/drugs for Tra culture in Dongthap province*. Bachelor Dissertation, College of Aquaculture & Fisheries, Cantho University, Vietnam.
- Valbo-Jorgensen, J. and Poulsen, A. F. (2000) Using local knowledge as a research tool in the study of river fish biology: experiences in the Mekong. *Environment, Development and Sustainability* 2(3-4): 253-376
- Van Zalinge, N., Degen, P., Pongsri, C., Nuov, S., Jensen, J. G., van Hao, N. and Choulamany, X. (2003) *The Mekong River System, Contribution to the Second International Symposium on the Management of Large Rivers for Fisheries Phnom Penh, 11-14 February 2003*.

Vietnam Statistical Yearbook 2005.

Vietnamese Government Office (2006) *Decision on export development project in the period 2006-2010.*

Vietnamese Government Office (2006) *Decision on fisheries export development program between 2010-2020.*

Zweig, Ronald D., Thong, Ha Xuan, Luu, Le Thanh, Cook, Jonathan R. and Phillips, Michael (2005) *Vietnam: Fisheries and Aquaculture sector study.* Rural Development and Natural Resources East Asia and Pacific Region (EASRD).

Chapter 4:

Water Use and Competition in the Mekong Delta, Vietnam



Dang Kieu Nhan¹, Nguyen Van Be² and Nguyen Hieu Trung³

¹Mekong Delta Development Research Institute, Can Tho University, Vietnam. Email: dknhan@ctu.edu.vn

²Department of Environment and Natural Resources Management, College of Agriculture and Applied Biology,
Can Tho University. Email: nvbe@ctu.edu.vn

³Department of Environmental Engineering and Water Resources, College of Technology, Can Tho University.
Email: nhtrung@ctu.edu.vn



Chapter 4 :

Water Use and Competition in the Mekong Delta, Vietnam

1. Introduction	146
2. Relevant issues to water-based competition	148
3. Current state of knowledge	152
3.1. Upstream-downstream water competition	152
3.1.1 Rising water use in rice farming	152
3.1.2 Salinity intrusion	154
3.1.3 Water use and effluent discharge in fish farming	156
3.1.4 Possible solutions and constraints	158
3.2 Impacts of the reclamation of acid sulphate soils	161
3.2.1 Current uses of acid sulphate soils	161
3.2.2 Water acidification and metal pollution	162
3.2.3 Possible solutions	166
3.3 Water conflicts in coastal zones	168
3.3.1 Multiple values of water and its associated livelihoods	168
3.3.2 Local and regional water conflicts	169
3.3.3 Possible solutions	170
3.4 Constraints to water access and sharing	172
4. Conclusions on the major issues to be addressed	173
4.1. Upstream-downstream water competition	173
4.2. Impacts of acid sulphate soil reclamation	174
4.3. Water conflicts in coastal zones	175
4.4. Constraints to water access and sharing	176
5. Contested issues	176
6. Research priorities	177
6.1. Crop and field levels	177
6.2. Zone and regional levels	177
7. Conclusion: Policy linkages	178
References	181



Abstract

Safeguarding limited resources of water is a major challenge for sustainable food production. This study analyses water use and competition, identifies possible options to contribute to more efficient and equitable arrangements and gives recommendations to support policy-making for sustainable water resource management in agro-ecological zones within the Mekong delta. Rice farming and aquaculture development are recognised as major driving factors of water competition among water users in and between three major agro-ecological zones: (1) upper delta irrigated zone; (2) acid sulphate soil (ASS) zone; (3) downstream coastal zone. In the upper delta, intensive rice development abstracts a large quantity of freshwater and then results in salinity intrusion in the downstream delta during low flow periods of the Mekong River. Aquaculture expansion contributes to further water pollution in the downstream areas through flushing pond/cage effluents during water exchange. The reclamation of ASS for food production pollutes water in canals and shallow ground water by acidic substances, aluminium, iron and other heavy metals. In coastal zones, water has multiple values. Rice and shrimp development causes conflicts over water among crop and shrimp production, fishing and mangrove forests. Water access and sharing are determined by a wide range of local bio-physical and socio-economic settings and institutional aspects at household and community scale. Efficient and equitable arrangements of water use need both structural (technical) and non-structural (planning and institutional) solutions implemented at different spatial scales – from crop and field to community and regional levels. Water provides a range of goods and services, which greatly differ between users and locations. Possible options therefore need to consider the needs of all resource users at multiple scales rather than focusing on only one particular sector or scale. Strong evidence of water competition, however, is still inadequate in the Mekong delta. Further investigations are suggested to provide a clear picture of water conflicts, cause-effect relationships and guidelines to policy-makers and managers.

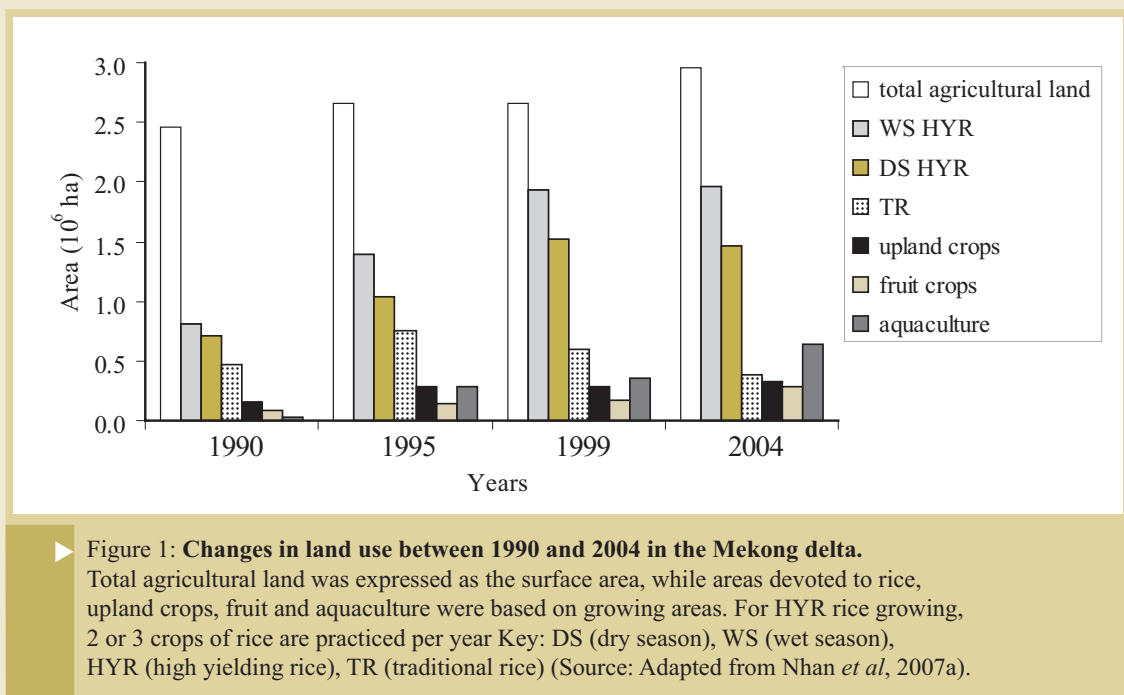


1. Introduction

In the 21st century, Asian agriculture faces two major challenges: improving total food productivity for food security and farmers' welfare while safeguarding the natural resource base, including water (Edwards, 1993; Cantrell, 2004; Bouman, 2007). As rice is the staple food in Asia, the great challenge is how to increase the current annual rice production from 545 million tons to more than 700 million tons to feed an additional 1.3 billion rice consumers by 2025. This increase will mainly rely on irrigated rice systems (Guerra *et al*, 1998; Cantrell, 2004). There are warnings that food production is likely to be seriously constrained by freshwater shortages in the next century. It is noted that the need for irrigation water is likely to be greater than currently anticipated, and the available supply of it less than anticipated (Smith and Gross, 1999). The available amount of water for irrigation, however, is becoming increasingly scarce due to decreasing resources, declining water quality and increasing competition among multiple water users and environmental factors in some Asian countries, including Vietnam (FAO/NACA, 1995; Pimentel *et al*, 2004; Rijsberman, 2006).

In the Vietnamese Mekong delta, soil and hydrology are the major physical factors determining agricultural land use. Combined local rainfall and seasonal discharges of the Mekong River cause seasonal and spatial variations in water availability within the delta. The upper region is subjected to prolonged and deep flooding in the wet season coinciding with the high flow period, while the coastal region downstream faces freshwater scarcity and salinity intrusion in the dry season during the low flow period (February-April). In 2004, about 74% of the delta surface was devoted to agriculture, and rice farming constituted about 70% of agricultural land (CSO, 2005). Over time, agriculture and aquaculture have shifted from subsistence- to market-orientated production and progressively intensified. Intensive rice culture expanded during the 1990s and is still the principal farming activity (**Figure 1**). Most rice growing areas are irrigated with about 80% of the total surface water volume diverted for agriculture uses, mostly rice, while only 5% is devoted to domestic consumption (White, 2002). Recognising the potential of aquaculture (as discussed by Loc *et al* and Can *et al* in this volume), since 1999 the Vietnamese government has promoted diversification in agriculture, aiming to increase the contribution of aquaculture to economic growth (Nhan *et al*, 2007a). Between 1999 and 2004, the growth rate of aquaculture production was rapid, annual growth rates of 31% for production and only 19% for farming areas (GSO, 2003; GSO, 2005) suggesting a gradual intensification of aquaculture. Coastal shrimp farming and intensive fish culture upstream have been the main drivers of this expansion of aquaculture production, but there are indications that this growth is not sustainable globally (Naylor

et al, 2000) nor regionally (see Loc *et al.*, this volume). Intensive rice farming and aquaculture practices are both water-intensive (Boyd and Gross, 2000; Cantrell, 2004; Tuong *et al*, 2005). Sustainable rice culture and aquaculture should be water-efficient. These farming sectors have to meet increasing demands for food supplies and income generation.



As demands and competition over water and related resources has increased, the spectre of conflict has emerged. In this context conflict is understood as interest incompatibility or livelihood loss among various water users as a result of access to water of inadequate quantity and quality (Ohlsson, 1995; Smith and Gross, 1999). Two levels of conflict are: international and within countries. In the Mekong delta conflict is identified mainly on the latter scale, community or region. Rivers and canals serve as both water supply and drainage, with the former function more important in the dry season while the latter is dominant in the wet season. Numerous studies have reported water conflicts in rice farming and aquaculture practices in irrigated, acid sulphate soil or coastal zones. The water conflicts relate to intensive water abstraction for rice farming in the upper delta (Tin and Ghassemi, 1999; Hashimoto, 2001), effluent discharges from aquaculture farming (Nhan and Be, 2005; Nhan *et al*, 2006), acidity and metals released from land reclamation in acid sulphate

soil zones (Minh *et al*, 1997), and water conflicts among crop culture, shrimp farming, mangrove forests and fishing in coastal zones (Tuong *et al*, 2003; Binh *et al*, 2005; Trung, 2006). Policies and infrastructure investments of the State and local government have encouraged intensification of agriculture and aquaculture, but the tensions between different water users and environmental impacts have not received sufficient attention. In the Mekong delta, rice farming and aquaculture will remain important for food production and economic development. Combined increases in urbanisation and industrialisation, as well as further agricultural intensification is likely to contribute to greater socio-economic differentiation and water conflicts unless careful attention is given to sustainable water resources management. Moreover, the Vietnamese Mekong delta is characterised as being at high risk to water-related natural disasters, due to the pressure from population growth and accumulative impacts of upstream interventions for irrigation and hydropower schemes in the Mekong Basin (Kristensen, 2001; White, 2002; Miller, 2003; Molle, 2005). Negative impacts of the development interventions schemes might contribute to changes in the flood regime, a reduction in dry season flows, an increase in water pollution, and changes in sedimentation. Appropriate solutions therefore need to be realised to improve productivity of production systems while safeguarding the environment and ensuring more equitable arrangements for water access among water users in order to reduce the vulnerability of the delta's inhabitants.

This study is based on a complete review of existing knowledge and information. This paper analyses water conflicts among water users and identifies possible options to contribute to more efficient and equitable arrangements in agro-ecological zones in the delta. Special attention is paid to impacts of the water use of the current rice farming and aquaculture practices. Further investigations and recommendations are suggested to support policy-making for sustainable water resources management in the delta.

2. Relevant issues to water-based competition

Impacts of the current intensive rice and aquaculture farming systems and institutional constraints on water access and sharing among different water users were identified in the three major agro-ecological zones of the Mekong delta: (1) upper delta irrigated zone, (2) acid sulphate soil (ASS) zone and (3) downstream coastal zone. Possible solutions and constraints were analysed in specific contexts for policy recommendations. In the study zones, rice and aquaculture farming systems are important activities and people's livelihoods are highly vulnerable to natural water-related problems, whether due to changes in quality or quantity. Surface water

is the focus of this paper because of its importance to Mekong delta people's lives, and increasing competition for its use within the delta. In addition, surface water is a trans-boundary resource and has a strong link with hydrology and development project interventions in upstream parts of the Mekong River. Therefore, understanding surface water uses in the study zones are of great importance for policy considerations to sustainable water resources not only within the Vietnamese Mekong delta but also the Mekong River Basin.

The overall question guiding this study is: based on a comprehensive review of the state-of knowledge on water, how are recommendations made to support policy-making to contribute to more efficient and equitable arrangements of water sharing in the study zones as well as the delta as a whole, in terms of economic, environmental and social welfare aspects? The study considers water conflicts between upstream and downstream areas, impacts of ASS reclamation for agriculture and recent aquaculture, competition among multi-values of water within the coastal zone, and common constraints to water access existing in the study zones. These issues were identified by the authors as priority concerns affecting sustainable water resources management in the delta. To answer the questions, six major issues are raised as follows:

First, *what evidence exists for a rise in competition between upstream and downstream water uses* in the delta? State and local policies and infrastructure investments for intensification of agriculture, including aquaculture, in the upper delta have resulted in positive impacts on food production and economic development, but contributed to an increase in tensions of water conflicts within and between users and zones. Intensification of high-yielding rice varieties with double and triple cropping ensures national and household food security and improvements in rice farmer income. Intensive rice culture, however, requires heavy application of agro-chemicals and a large amount of fresh water for irrigation (Berg, 2002; Cantrell, 2004). Rice farming that is practised during the dry season consumes a lot of water. Intensive abstraction of water for the rice farming in the upper delta might also exacerbate salinity intrusion downstream of the delta during low flow periods of the Mekong River, which in turn has negative consequences on agriculture and aquaculture, domestic water supplies and the environment (Sam, 1997; Hashimoto, 2001). For aquaculture, semi-intensive and intensive farming systems consume a large volume of water through water exchange in order to dilute metabolites within ponds or cages (Nhan *et al*, 2007a,b). Consequently, the farming practices discharge a large quantity of effluents, which might eutrophy surface water bodies in surrounding and downstream areas, in turn constraining fish culture, domestic water supplies and environment protection.

Second, *what are the impacts of acid sulphate soil reclamation* and to what extent do impacts still continue? The reclamation of acid sulphate soils, particularly in the Plain of Reeds, the Long Xuyen Quadrangle and the Ca Mau peninsula since 1975, has significantly contributed to increased food production and improved farmers' livelihoods at the expense of surface water pollution of acidity and heavy metals (mainly aluminium and iron), due to the oxidation of the sulphidic layer as the water table falls (Minh *et al*, 1997; Husson, *et al*, 2000). Water pollution poses adverse effects on aquatic organisms, aquaculture practices, potential risks to human health and estuarine ecosystems when the early rains wash out toxic substances from fields into drainage canals (Minh *et al*, 1997; Nhe, 2006). Some studies indicate that the level of acidity does decline with water flushing of fields after an initial peak, but the impacts can remain for decades (Husson, *et al*, 2000). Tradeoffs exist between improved soil fertility and enhanced crop productivity on the one hand and the environmental and social impacts on the other. So, benefits may be accrued privately yet the costs are dispersed to all, harming common natural resources.

Third, *what are the land and water conflicts identified in the coastal zone* and how have the conflicts been addressed at a local and regional level? Have these conflicts been successfully resolved, and if so how? The coastal zone is a highly vulnerable agro-ecosystem, and water has multiple values for crop and shrimp production, fishing and mangrove forests. On the one hand, crop farming Ò a freshwater farming activity, shrimp culture Ò a brackish water farming, and the wetland ecosystem require different land and water resources, making water resource management more complex (Gowing *et al*, 2006). Water competition depends highly on the water use in the upper delta, within the zone and the process of salinity intrusion. Salinity-control infrastructure was developed intentionally for rice farming, but presently attempts to adapt it for use by both rice and shrimp farming concurrently have occurred. A proper operation of this infrastructure for both purposes, agriculture and aquaculture, is not an easy task. More saline water taken in for shrimp farming results in losses of crop production in immediate communities or in upper parts of the river basin. In contrast, shrimp farming might suffer from fresh water diverted and field water discharges from crop production areas. On the other hand, the development of shrimp farming has resulted in significant losses of coastal mangrove forests, resulting in declined aquatic resources, on which livelihoods of the poor depend (Binh *et al*, 2005). Local authorities are confronting the challenge in order to achieve a compromise between agriculture and aquaculture. Nonetheless, development of aquaculture or agriculture is likely to impact adversely on the ecosystems. In the coastal zone, development plans for water resources were formulated at zonal level whereas water conflicts have to now be resolved at local community scale. Information on those conflicts and scenarios for further improvements at community and regional scales are still limited.

Fourth, *what are factors that affect the equity and efficiency of water access?* A wide range of local bio-physical and socio-economic settings and institutional aspects affecting water access have been recognized at household and community scale (Miller, 2003). Socio-economic and individual cooperation play an important role in water access at household level while coordination and participation of all local stakeholders, including authorities, are crucial at the community level. Participatory approaches, and good planning, coordination and regulation of local authorities are necessary, and contribute to greater equities in water access not only at the individual household level but also at the community level.

Fifth, *what are principles on which potential solutions are suggested in order to reduce water competition among water users while improving rice and aquaculture productivity to meet food security, economic growth and environmental conservation?* The major challenge for rice farming and aquaculture is how to increase productivity with less water use and rational discharge rates. Possible solutions include technical, planning and institutional principles at different scales; from crop, field to community and regional levels. For technical principles, the potential solutions can be identified by improving technology components and farming diversification to reduce water competition. In general, there are four major principles: (1) reducing non-beneficial depletion of water, (2) reducing water discharges, (3) maximising non-irrigation water inflow, and (4) using water from the storage effectively (Tuong *et al*, 2005; Bouman, 2007). Technological measures include crop variety selection (crop level), cropping technology, crop diversification and resource management practices (field and community level). For planning principles, at the community and regional level, water provides a wide range of goods and services. Different communities or regions have different options for using water to achieve different social, economic and environmental goals. Possible solutions therefore need to consider the needs of all resource users at multiple scales rather than focusing on only one particular scale. For institutional measures, participatory and bottom-up approaches, dialogue among various local stakeholders and their participation in decision-making, are required to support well-informed planning, management and policy options to ensure equities in water access and sharing. Participatory structures and the extent to which water use equity is based on these are important because of the need to represent and respond to local interests and needs.

Finally, *what are the research and development gaps?* Constraints for the potential solutions are identified. Further investigations are suggested to provide a clear picture of water conflicts, cause-effect relationships and guidelines to policy-makers and managers.

3. Current state of knowledge

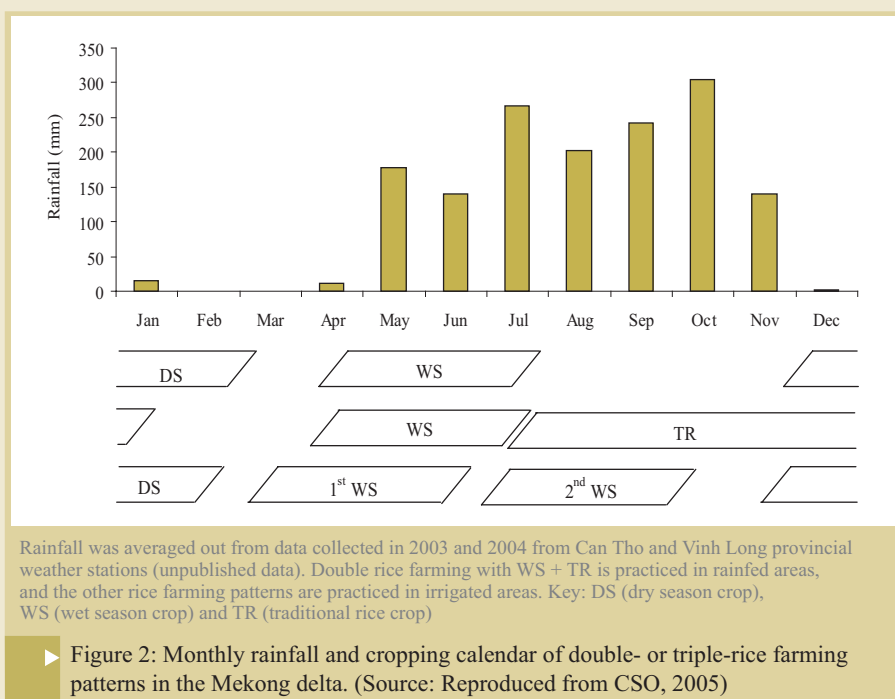
In this section we outline the state of knowledge on the three key axes of competition over water: between upstream and downstream areas; impacts of reclamation of acid sulphate soil areas; and, in the coastal zone. In each section, after the issue is described, potential ways forward to address the problem are introduced.

3.1. Upstream-downstream water competition

3.1.1 Rising water use in rice farming

Intensive-rice growing areas are mainly located in upstream and mid-stream provinces. During 2000 and 2004, the upper provinces Long An, Tien Giang, Dong Thap, An Giang, Kien Giang, Can Tho, Vinh Long and Hau Giang shared an average of 85% in the dry season crop and 73% in the wet season crop of the total rice farming area and productivity in the delta (CSO, 2005). Rice is mainly grown with two or three crops a year (CSO, 2005; **Figure 2**). The double rice farming pattern is practiced with high-yielding rice in the dry season crop plus the wet season crop in the irrigated or flood-prone areas, while the wet season crop plus traditional rice crop occurs in rain-fed areas. The triple rice farming is mainly practiced in areas with well-developed irrigation systems or well-controlled flood systems.

Intensification of rice production systems is highly reliant on water availability, as well as access to other key inputs (fertilizers, pesticides, seed, labour, etc.). Intensive rice farming consumes a large volume of water during the dry season. The specific water requirements of different cropping regimes in the delta are shown in **Table 1**, and discussed further in section 3.1.4.



► **Table 1: Estimated water productivity (kg rice m⁻³ water input) of rice production in the Mekong Delta.** Based on average rainfall and cropping seasons given in Figure 2 and calculated as kg rice per m³ water input from irrigation

Parameters	Rice crops		
	Winter-spring	Summer-autumn	Autumn-winter
Total water requirement (m ³ ha ⁻¹) ¹	8080	7520	6500
Rain water available (m ³ ha ⁻¹) ²	160	4000	7000
Irrigation requirement (m ³ ha ⁻¹)	7920	3520	-500
Average yields of rice (tons ha ⁻¹)	6.0	4.3	4.0
Water productivity (kg m ⁻³ water) ³	0.8	1.2	-

(Source: Reproduced from Sam, 1997)

There is limited information on actual water demands per crop and the following is based on total water requirement and analysis of rainfall. Water productivity is estimated at about 0.8 and 1.2 kg rice m⁻³ water input from irrigation for the winter-spring and the summer-autumn crops, respectively. These figures are in the range of the water productivity of continuous flooding rice farming but are much lower than that obtained from water-saving irrigation techniques (1.6-1.9 kg rice m⁻³ water input) in other tropical countries in Asia (Bouman and Tuong, 2001; Tuong *et al*, 2005). The water productivity of rice farming greatly varies with rice variety, growth duration, soil and hydrological conditions and farming practices (Bouman and Tuong, 2001). There is still room for further water efficiency improvements of rice irrigation in the Mekong delta.

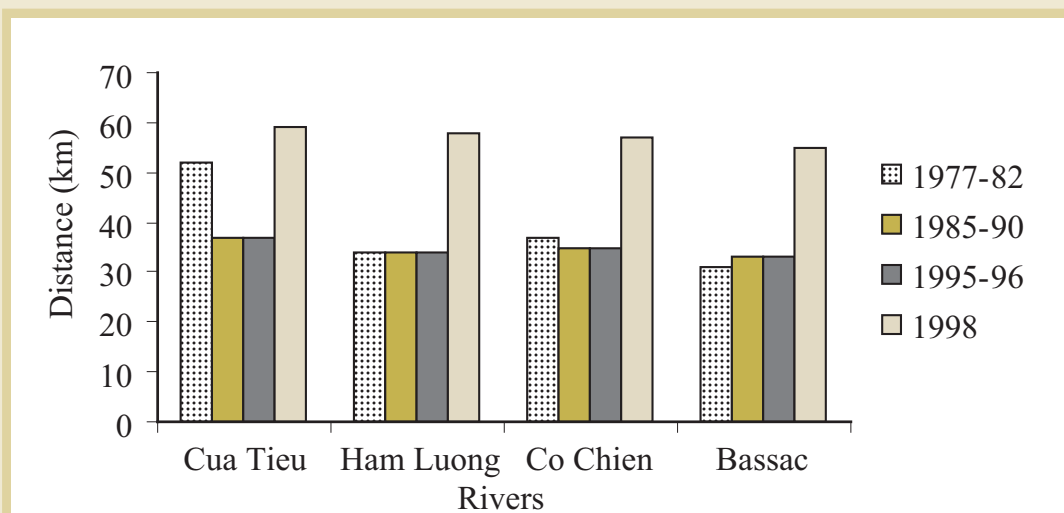
Water requirement for rice greatly varies with cropping calendars, cropping patterns and areas. The earlier the wet season rice crop is established, the more water is required to irrigate the rice during early periods of the crop (see **Figure 2**). In the early stages of the wet season rice crop, rainfall is low and field water losses through evapo-transpiration and percolation are significant, due to high air temperature, deep levels of the water table and soil cracks during field drying after the dry season crop. Therefore, rice cultivation consumes more water in the triple cropping than in the double cropping patterns. Sam (1997) estimated that the water requirement to irrigate the rice averages about 1470 mm in the upstream area (i.e. An Giang) and about 1060 mm in the central part (i.e. Can Tho). The water requirement is higher in the upstream area, due to the early establishment of the wet season crop and deep levels of the groundwater table. In the upstream provinces, rice irrigation is practiced by pumping mostly and irrigation costs share an average of 8% and 10% of the total input costs of the 1st wet season and the dry season crops, respectively (Nhan, unpublished data in 2000 and 2006). On the contrary, in the mid-stream provinces (i.e. Vinh Long), the irrigation is practiced mainly with gravity through the tidal effect from the estuary, making irrigation costs much lower.

Based on rice growing areas, irrigation requirements of the dry season and 1st wet season crops and rainfall records in 2004 (i.e. **Figure 2** and **Table 1**), it is estimated that rice cultivation in the upper provinces can abstract a water volume between 900 and 1200 m³ s⁻¹ from December to May. This water consumption by rice farming equals about one-half of flow rates of the Mekong during the dry season within Vietnam (Tin and Ghassemi, 1999). Water abstraction is greater if triple rice cropping is expanded and the wet season crop is established as soon as possible to avoid possible crop damages from flooding. Sam (1997) calculated irrigation water requirement for the whole Mekong delta to be about 400-900 m³ s⁻¹ in 1990-1991 period, and predicted an increase demand of 900-1100 m³ s⁻¹ by 2010. The intensive water demands in the upper and mid delta have implications for dry season water availability and related salinity intrusion in the coastal zone - a clear trade-off occurs between expansion of dry season rice production upstream and downstream impacts of salinity. This suggests that monitoring impacts of water extraction for rice farming in the dry season and appropriate solutions to improve water use efficiency in rice culture need to be considered.

3.1.2 Salinity intrusion

The intensive agriculture and coastal aquaculture development strategy pursued in the delta, reliant upon the provision of reliable and sufficient dry season flows, has made the delta increasingly vulnerable to a decline in dry season water flows and salinity intrusion. The salinity intrusion in the downstream part is a function of the discharge from the upstream of the Mekong River, tidal effects in the South China Sea and the Gulf of Thailand, surface water storages in the Tonle Sap, on river/canal systems and

backswamps within the delta, irrigation canal systems, coastal water-management infrastructure (i.e. canals, salinity-control dikes and sluice gates), morphology and coastal land uses. Over 85 % of the total annual discharge occurs during the flood season (Tin and Ghassemi, 1999), while in April the discharge of the Mekong river branches is less than 10% of the discharge in October (Wassmann *et al*, 2004). During the dry season, the low river flow period, the tidal influence extends throughout most of the delta. Seawater enters distributaries and intrudes into a range of 40-60 km upstream (**Figure 3**) (Wolanski *et al*, 1998). About 2.1 million ha was affected by saline water of 1 g l⁻¹ and about 1.7 million ha of 4 g l⁻¹ (Sam, 2006).



► Figure 3: Average maximum distance (km) of salinity intrusion (4 ppm) up Mekong and Bassac branches in April (Source: Reproduced from Miller, 2003).

Economical and ecological consequences of extended salinity intrusion are: insufficient freshwater for agricultural production and domestic water supplies, damaging the aquatic ecosystem and threatening bio-diversity. When such ecological changes occur, livelihoods of downstream communities are adversely affected, sometimes leading to conflicts. In estuaries on the east and west coasts and in Vam Co rivers during 1992-2004, the salinity was observed to be high in 1998, 2004, 1992, 1993 and 1995, and low in 2000, 2002 and 2003 (Sam, 2006). In 1998, the extent of salinity intrusion was high, 10-15 km further inland than the average for previous years, because of a serious drought in the region (Miller, 2003). Dry season rice expansions in the Plain of Reeds probably resulted in an increase in salinity intrusion in the Mekong and Vam Co rivers for the period 1977-1982 compared with the 1936-1940 period (Hoanh, 1987). In the 1990s, there was a trend of increasing salinity intrusion up the West Vam Co system and canals connecting the Bassac river with the western delta part (Truong, 1999). This spatial pattern of salinity intrusion is more

severe up smaller canals than in the main branches of the Mekong and Bassac rivers and is likely to accompany water resources development and a reduction in low flow (cited in Miller, 2003).

Rice intensification in the upper delta could increase the extent and the severity of the salinity intrusion in the downstream part, due to significant decrease in the river flows (Miller, 2003). In the past, flood water maintained in backswamp areas supplemented freshwater flow in main canals during the early dry season. For the last three decades, the development of canal systems and the expansion and intensification of the rice culture have reduced the flood-plain water storage, particularly in the Plain of Reeds and the Long Xuyen Quadrangle, while increasing the abstraction of the discharge in the upstream areas. Consequently, the discharge of main rivers and canals decreased, and hence saline water intruded further into many parts of the delta downstream (Hashimoto, 2001). This could increase the duration and extent of saline intrusion. Since the 1980s, salinity intrusion in canals or rivers of the Bassac and Mekong has generally increased in duration (Tin and Ghassemi, 1999). The salinity intrusion into the upstream is likely severe as the construction of new water-control structures, population growth, urbanisation and industrialisation will continue in the future (Hashimoto, 2001). Non-structural options are of great importance to ensure river flows are not further lowered and to make use of saline water efficiently through agricultural diversification and strengthened awareness of risks.

Salinity intrusion is not only influenced by processes within Vietnam, but also wider global climate changes and Basin water resources developments. Sea water rise and interventions in upstream countries are likely determinants. A rise of sea water level has already been observed along many shore lines in Southeast Asia, including Vietnam (Perez *et al*, 1996; Tuong, 2001). Combining intensive water withdrawal for agricultural irrigation in upstreams, a rise of the sea level might have an impact on salinity intrusion in the Mekong delta during the lowest flow periods. A further and growing threat is posed by ambitious schemes of dam and reservoir construction in the catchment upstream of the delta (Lang, 2005). The Tonle Sap in Cambodia plays an important role in the natural regulation of the river flow. An example of this threat is that an estimated average of monthly dry season flows (February- April) into the delta, in the absence of mainstream storage dams, would decrease by 37 per cent if dry season irrigation is expanded in upstream countries (cited in Miller, 2003).

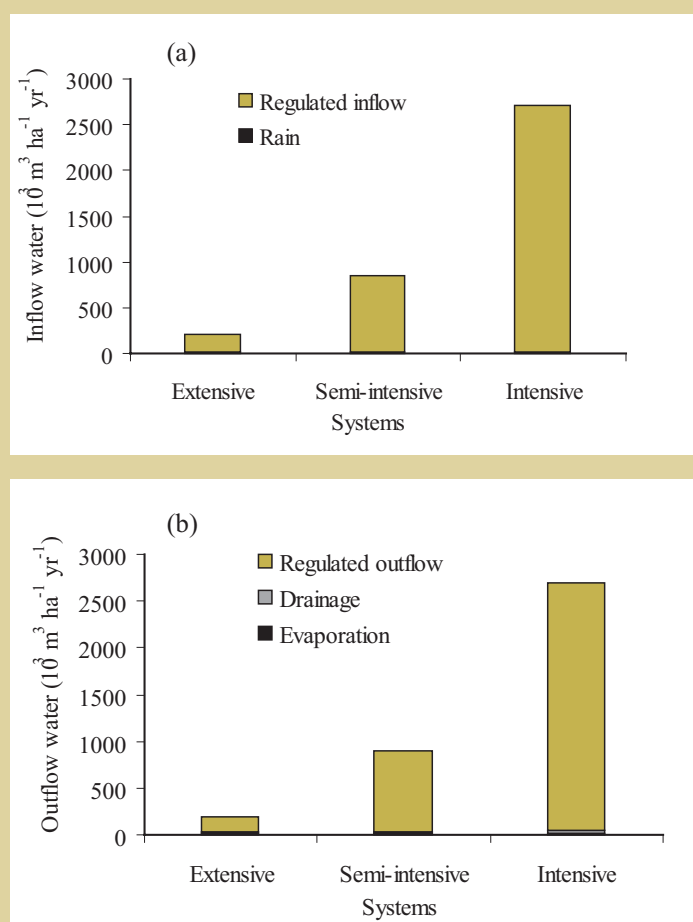
3.1.3 Water use and effluent discharge in fish farming

As discussed in other papers in this monograph the government has more recently promoted diversification to improve farmer incomes in the delta. Part of this strategy has been the promotion of fish farming. However, as with intensive rice production, fish farming has impacts on water, but these impacts are on water quality rather than quantity.

Access to high quality water and minimising effluent discharges is a key principle (and challenge) for sustainable aquaculture development in the Mekong delta. In freshwater areas, four major aquaculture systems are practised: (1) intensive cage/pen culture, (2) intensive pond culture, (3) semi-intensive pond culture, and (4) extensive or semi-intensive aquaculture integrated with rice culture systems (Nhan *et al*, 2004). Aquaculture is commonly practised in upper provinces and unlike rice farming, aquaculture systems do not “consume” water but pollute surface water bodies. Except for aquaculture integrated with rice farming (with low nutrient inputs and low water exchange rates) other systems have an impact on the aquatic environment from intensive water use and high rates of effluent discharge (Nhan and Be, 2005; Son *et al*, 2005; Hao, 2006; Nhan *et al*, 2006; Nhan *et al*, 2007a,b). This constrains the use of water for intensive aquaculture systems themselves and limits domestic consumption locally and downstream.

In general, farmers use water lavishly in aquaculture. Cage and pen culture systems can be considered as flow-through systems (Son *et al*, 2005). Semi-intensive and intensive pond farming systems are practised with high water exchange rates. The water exchange rate practised increases with increasing intensification levels of the pond to avoid water quality deterioration within the pond through high discharge rates of nutrient-rich effluents (**Figure 4**) (Nhan *et al*, 2007b). In the pond aquaculture systems, the intentionally regulated inflow or outflow usually accounts for about 80% (in extensive and semi-intensive systems) and 98% (in intensive systems) of the total inflow or outflow water of the pond. Nhan *et al* (2006) observed that in semi-intensive systems, about 1.5 times more nitrogen and organic carbon, and 3.1 times more phosphorus were discharged than the amounts received through inflowing water. Only about 11% food nitrogen input is recovered in fish and about 30% is discharged through the pond into surrounding canals (Nhan *et al*, 2007a). Unnecessary loss of pond nutrients as a result of high water exchange rates could reduce economic benefits to farmers while causing eutrophication in downstream ecosystems. This problem might result in “water scarcity” for aquaculture, industrialisation and domestic water supplies. For example, in An Giang province in 2006, the number of catfish (*Pangasianodon hypophthalmus*) cages reduced by about 40% compared with that in 2005, while catfish pond culture, where water intake for ponds was easier controlled, was expanded. One of major reasons is the increased pollution of the Mekong and Bassac river water. In the Mekong delta in 2005, about 5,000 ha were devoted to catfish pond culture, annually producing about 370,000 tons of fish, which was 4 times higher than that in 1997 (unpublished data). To 2010, this type of aquaculture is planned to expand to 10,200 ha, annually producing about 850,000 tons of fish. It is estimated that an average of 20 per cent of food nitrogen input is recovered in fish and about 45 per cent is flushed out to surrounding canals (Nhan, unpublished data). Based on this estimation, in 2005 about 13,300 tons of nitrogen and in 2010 about 30,600 tons of nitrogen would be flushed into surrounding rivers through pond water exchange. Therefore, proper management of effluent discharges from the aquaculture

farming practices could not only optimise nutrient use efficiency and economic benefits, but also improve farming sustainability and reduce water competition among users.



► Figure 4: Pond water inflows and outflows of freshwater aquaculture systems in the Mekong delta (Source: Nhan, unpublished data)

3.1.4 Possible solutions and constraints

On a global scale, the Challenge Program on Water and Food, coordinated by the Consultative Group on International Agricultural Research (CGIAR), recognises that increasing competition from different water users is creating an urgent need to improve water productivity of agricultural production (Cantrell, 2004). In the delta, increasing water productivity while retaining high incomes is identified as an important challenge that needs to be given special attention in order to alleviate water upstream-downstream competition. Water productivity is expressed as the ratio of food output derived from water use to water input. Water productivity can be increased

by producing more output per unit of water used or by reducing water losses (or discharges), or by a combination of both.

For rice farming, in general, there are four major principles contributing to improving water productivity (see section 2). There are several strategies and technologies or a combination of them for increasing water productivity. For irrigated rice farming, several water saving techniques have been reported and the potential for water savings is substantial (Bouman and Tuong, 2001; Belder *et al*, 2004; Tuong *et al*, 2005; Bouman, 2007). Possible solutions are:

- Appropriate **variety selection** and good **crop husbandry** that allow reduce water consumption. Rice varieties with high harvest-indexes, short-growth duration and good seedling vigour should be grown (Bouman, 2007).
- **Land preparation** period should be short to reduce water loss through evaporation and percolation (Bouman, 2007).
- **Alternative wetting and drying irrigation methods**, which reduce the duration that the field is flooded, would be advisable (refer to Belder *et al* 2004 for description of this practice in China, and Tabbal *et al*, 2002 for Philippines example).
- **Soil mulching** has also been shown to reduce water inputs and increase water productivity in rice, especially in combination with the alternative wetting and drying technique (cited in Tuong *et al*, 2005).
- Choosing the appropriate **cropping season** in order to maximise use of available soil water storage and rain water (Tuong *et al*, 2005). In the Mekong delta, for example, if the summer-autumn crop is established at an appropriate time, the rice crop can use rainfall more effectively than the commonly-practised method, which could abstract less fresh water diverted during low flow periods.
- **Integrating rice-based farming systems** with upland crops, as total water requirements for many upland crops are lower than rice (Sam, 1997). During low water flow periods, appropriate upland crops instead of rice could be practised.
- **Water pricing** could be an option (Fujimoto and Tomosho, 2003). Although water pricing has not been commonly applied for agriculture in the delta, it could be a possible solution to encourage farmers to adopt water conservation techniques.

The above proposed measures for increasing water productivity in rice farming, however, face challenges. The methods for reducing non-beneficial depletion and outflows of water are labour- or cost-intensive (Tuong *et al*, 2005). The alternative wetting and drying or keeping soil saturation techniques is likely to result in a reduction of rice yields (Bouman and Tuong, 2001; Tuong *et al*, 2005). Changes from flooded to partially aerobic soil conditions could result in the occurrence of weeds or grass in the field (Singh *et al*, 2003), in losses of phosphorus and nitrogen (Muirhead *et al*, 1989), in increased nitrous oxide, a greenhouse gas, and in nitrate leaching into groundwater (Dittert *et al*, 2002).

In the Mekong delta rice farming is small-scale, crop performance and water requirement differ from field to field, water saving techniques are likely not feasible at large-scales, unless the production is well-organised within a community or a zone. The most widely used irrigation cost system is commonly based on growing area per crop, sharing only about 9% of the total production costs (Nhan, unpublished data), which seems not to encourage farmers to apply water saving techniques. A system that is based on “water volume supplied” instead needs to be considered. Moreover, the harvest of the summer-autumn crop is highly vulnerable to floods. A delay of the crop establishment could increase the use of available rainwater and reduce freshwater consumption during the low flow periods at the expense of harvest losses by flooding. Therefore, the choice obviously depends on the economic effectiveness of the strategies. Soil type, labour cost and availability, existing irrigation infrastructure and markets for crop inputs and outputs are important factors. Possible solutions at a broader scale rather than at the field level therefore are likely to be more feasible and needs to be discussed with the appropriate stakeholders.

Unlike in rice farming, in aquaculture further improving fish yields or aquaculture incomes while minimizing effluent discharges is of great importance. Practically, flushing of ponds/cages with “clean” water from the river results in pollution of surrounding surface waters and a loss of nutrients, which otherwise could have been used for other products. “Ecological or sustainable aquaculture”, a new paradigm for aquaculture development, is therefore necessary in the near future as the following indicate (Costa-Pierce, 2002; Frankic and Hershner, 2003):

- Proper **fish species** combinations and **stocking rates** to allow for high yields and stimulate a healthy pond ecosystem (Delince, 1992).

- Pond (cage) **nutrient-rich effluents** can be re-used to produce an extra crop of fish, terrestrial or aquatic plants before discharge (Beveridge *et al*, 1997; McMurtry *et al*, 1997; Naylor *et al*, 2000; Yi *et al*, 2003). Fish or plants can extract nutrients from wastewaters while producing more food for human, fish or livestock. Although this proposed system looks promising, it has not been commonly practised by farmers in the delta. In contrast, the production of aquatic vegetables using wastewater is well established on the urban fringes of Ho Chi Minh City and other urban centers of Southeast Asia (Rigg and Salamanca, 2004). One possible reason is that a wastewater-fed wetland system consumes land at the expense of other more profitable or less risky farming activities. If applied, such approach could create more jobs, food and income for the poor and reduce environmental impacts.

- The **maximum allowable amount of pond/cage effluent** discharged needs to be determined. This depends on many factors, including the density of ponds/cages, distribution patterns and the absorptive capacity of the surrounding environment.

• **Water pricing or polluter pay policies** are possible options, but they are difficult to impose, especially with small-scale and resource-poor farmers.

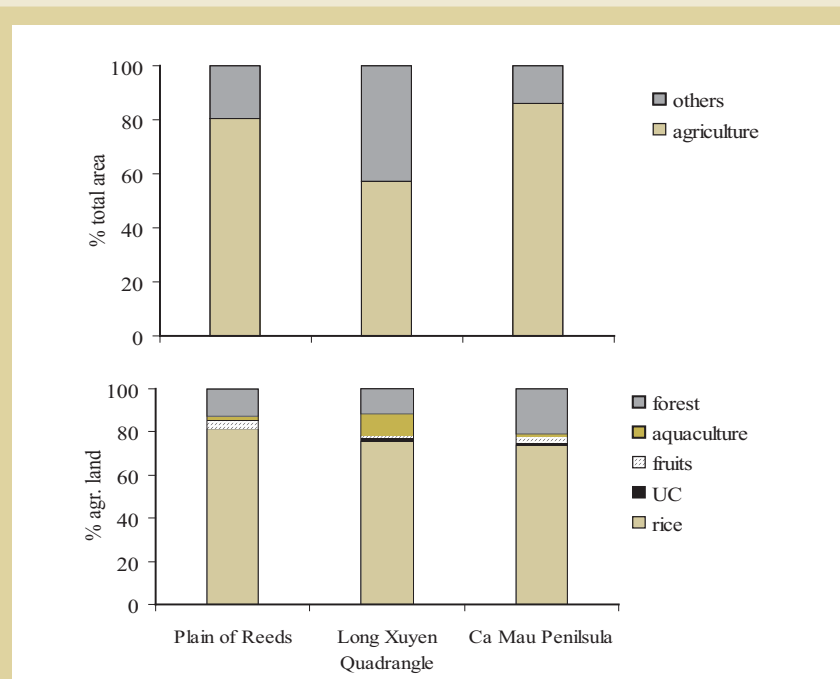
Like in rice farming, the proposed measures for reducing effluent discharges of aquaculture still face difficulties. Current aquaculture farming is mostly practised on a small-scale and in diverse forms. The proposed measures should be considered not only at a farm level but at larger scales.

3.2 Impacts of the reclamation of acid sulphate soils

3.2.1 Current uses of acid sulphate soils

Acid sulphate soils are a particular problem in newly formed riverine landscapes at the interface with the sea. Overall, in the Mekong delta acid sulphate soils have implications for water competition because acidity and metals released from the soil results in negative impacts on natural aquatic resources, agriculture and aquaculture and domestic water supplies downstream. Much has been written on acid sulphate soils, however, few authors have discussed this problem from the perspective of water competition or conflict.

Since the late 1970s, most of acid sulphate soil areas have been converted into agricultural areas, especially rice cropping, increasing the portion of actual acidic soils significantly. The acid sulphate soil zone, including the Long Xuyen Quadrangle, the Plain of Reeds and the Ca Mau Peninsula, are mostly located in low-lying backswamp areas far from main distributaries. The conversion of acidic soil low-lying backswamps into agricultural and aquaculture areas was encouraged by extensive development of canal systems and human settlement in combination with improved cropping practices. Consequently, larger areas of actual acidic soils are formed. In 2005, about 60% total surface area in the Long Xuyen Quadrangle and 80% in the Plain of Reeds and the Ca Mau Peninsula were devoted to agricultural and forestry activities (**Figure 5a**). Most of the agricultural land was used for rice farming, accounting for 74-81%, and a small portion for forestry, sharing 12-20% (**Figure 5b**). Upland crop and fruit production are not important activities in acid sulphate soil zones. Recently, in coastal regions of the Long Xuyen Quadrangle and the Ca Mau Peninsula, a large portion of rice growing areas has been converted into coastal shrimp farming. Between 2000 and 2005, the rice growing area decreased by 35% in Bac Lieu and 56% in Ca Mau province, while the coastal shrimp culture area increased by 184% and 62% in the respective provinces. During the same period in Kien Giang province, rice growing area increased by 10%, while the shrimp culture area increased five-fold (CSO, 2006).



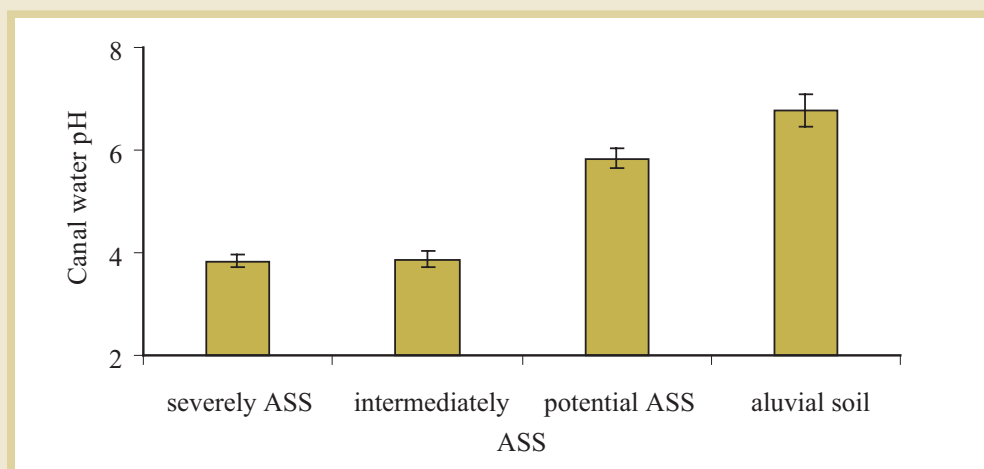
► Figure 5: Relative percentages of (a) agricultural land and (b) of crops, aquaculture and forestry (b) in some of the districts located in the major areas of acid sulphate soils. Moc Hoa, Vinh Hung and Tan Hung districts of Long An (the Plain of Reeds), Tri Ton of An Giang and Kien Luong of Kien Giang (the Long Xuyen Quadrangle), An Minh and Vinh Thuan of Kien Giang (the Ca Mau Peninsula). Key: UC (upland crops). (Source: Reproduced from provincial and district statistics, 2005)

3.2.2 Water acidification and metal pollution

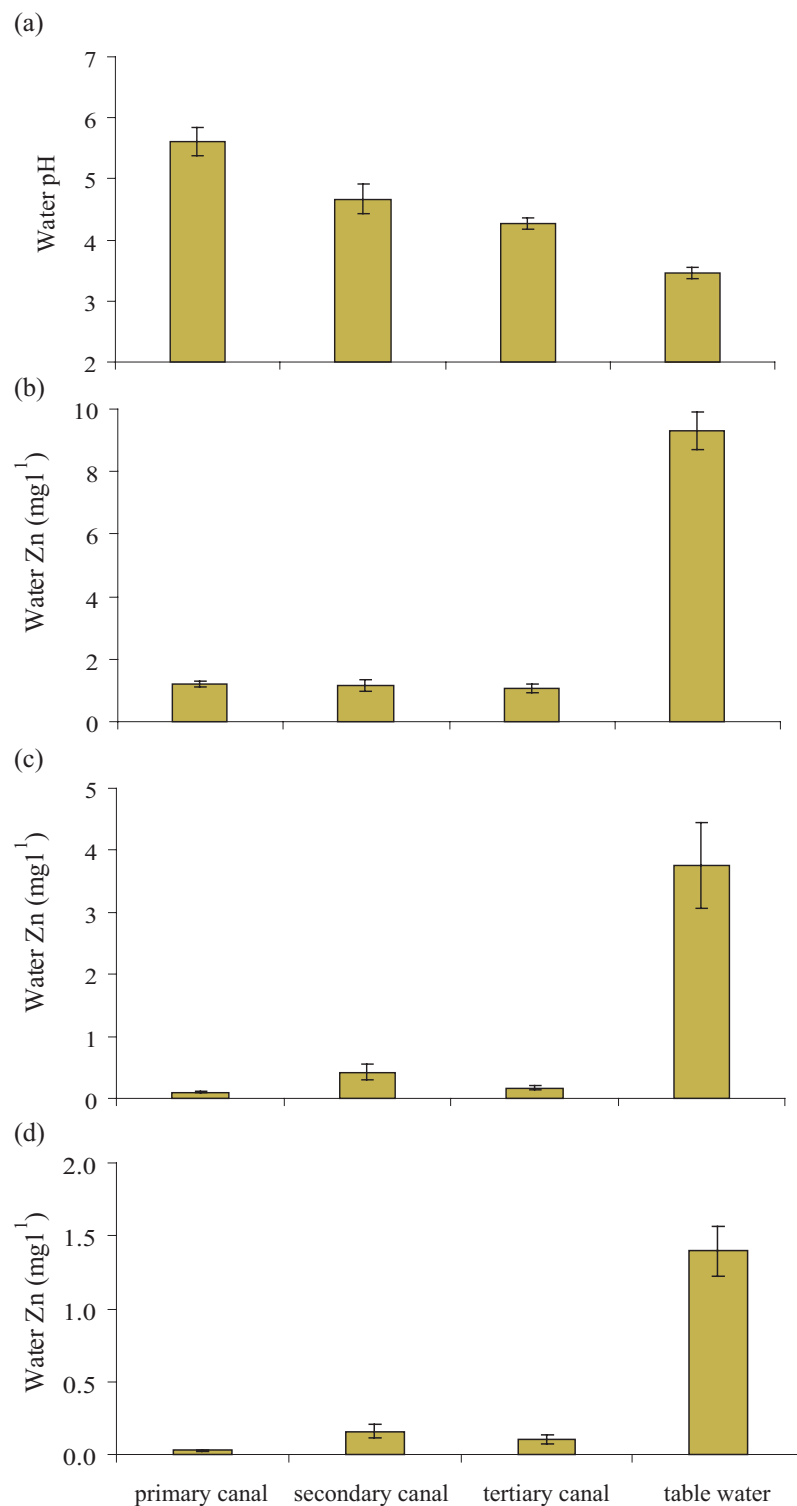
An important impact of actual acidic soils is the acidification of soils and water bodies (Tin and Wilander, 1995). The potential acidic soils becomes actual acidic soils when it is exposed to oxygen through a fall in water table during the dry season, deeper drainage of land, increased evaporation soil surfaces or canal excavation (Hashimoto, 2001). The acidification of soil and water results in the increased mobility of potential metals (i.e. iron, manganese, aluminium, arsenic, cadmium, etc.). When the flood recedes, the acidic substances and the metals are drained from fields into drainage canal systems. As a result, pH values in secondary canals suddenly drop (from 6 to less than 3.5) and metal concentrations increase (Husson *et al*, 2000b). During the dry season, the soils dry out and cracks form, resulting in oxygen penetrating to deeper layers and the oxidation of pyrite occurring. The evaporation results in acidic substances and metals moving upward through capillary action and concentrating at the surface (Minh *et al*, 1998). At the beginning of the rainy season (April-May), first rains can reduce the soil acidity or metals accumulating during the dry season to some extents, by leaching acidic products into field ditches. In May-June, the following heavy rains continue to flush a large quantity of acidic water with high concentrations of metals to irrigation/drainage canals (Tin and Wilander, 1995). As the rainy season progresses, the quantity of acidity flushed decreases gradually. In addition, farming practices also flush acidity

and metals from the field to canal water in order to prevent crop losses (Husson *et al* 2000a). These processes result in acidification and pollution of surface water bodies, detrimental to domestic water supplies, crop and aquaculture farming practices, and aquatic ecosystems in surrounding and downstream parts. Such degradation of water quality and aquatic ecosystems has serious consequences for resource-poor households, who depend more on open-access aquatic resources than better-off households with land for economic production. The impacts can last for many years (Husson *et al* 2000b).

Recent studies have provided evidence of impacts of acidic soil reclamation on surface water acidification. Husson *et al* (2000a) observed that pH values of the surface water are usually lower than 5 during the rainy season in the Plain of Reeds. Studying on quality of canal and shallow ground water in the Long Xuyen Quadrangle during May and July, Hoa *et al* (2006) and Nhe (2006) found that water pH values were below 4 in actual acid soils compared with above 6 in potential acidic and alluvial soils (**Figure 6**). pH values in canal water decrease in this order: primary canal > secondary > tertiary > ground table water; they are above 5 in primary canals while this is below 5 in secondary and tertiary canals, and below 4 in shallow ground water (**Figure 7a**). This has important implications for water access. Farmers tend to gain water directly from tertiary canals. In general, pH of water in secondary and tertiary canal systems and in ground water in acidic soils exceed the maximum allowable limits applied for domestic supplies and agriculture or aquaculture uses (TCVN 5942-1995) (Trinh, 1997). In the Long Xuyen Quadrangle, the impact of acid sulphate soils on soil and water acidification is still going on although the land have been reclaimed for agricultural production since the late 1980s.



► Figure 6: pH values in canal water sampled during May-Jul in different acid sulphate soils in the Long Xuyen Quadrangle and the alluvial soil. Mean with standard error. Key: ASS (acid sulphate soils) (Source: Reproduced from Nhe, 2006).



► Figure 7: Values of pH (a) and concentrations of As (b), Cd (c) and Zn (d) in canal and table water sampled during May-Jul in the Long Xuyen Quadrangle. Mean with standard error (Source: Reproduced from Nhe, 2006).

Acid sulphate soil reclamation brings about potential risks to human health and aquatic ecosystems. Aluminium is considered the most important toxic element in acid sulphate soil zones. At the start of the rainy season, aluminium concentrations in the leachate or canal water can exceed the normal tolerance of local fish or plant roots, and causes the mass mortality of fish (NEDECO, 1993; Tin and Wilander, 1995; Minh *et al*, 1997). The rainfall and discharge from the Mekong River is not adequate to dilute the toxic substances to an acceptable level, and an extremely large amount of water is needed to dilute the leachate in order to prevent negative impacts to the environment (Minh *et al*, 1997).

Consequently, surface water in a large acid sulphate soil zone is heavily polluted with acidity and metals. The pollution from the soil leaching is most severe in mid-June due to a combination of the highest total amount of aluminium released to the canals and low river discharges (Nien, 1995; Minh *et al*, 1997). Recently, studying on water quality in acid sulphate soils in the Long Xuyen Quadrangle during May-July, Hoa *et al* (2006) and Nhe (2006) found high concentrations of arsenic, cadmium, copper, manganese, nickel and zinc in shallow ground water (**Figure 7b, c & d**). The concentrations of these metals in canal water in acid sulphate soils are from 4 to 54 times higher than in other soils. Although the metal concentrations in the water sources are still lower than the maximum limits for domestic water supplies, aquaculture and the environment (TCVN 5942-1995) (Trinh, 1997), one should be aware of the potential risk of human health and the environment by water heavily polluted with heavy metals.

Acid sulphate soil reclamation causes economic loss for agriculture and aquaculture downstream. Rice yields are low, particularly in the wet season crop, mainly due to low pH, high metal-toxicity and phosphorus-deficiency (Minh, 1996). During 2000-2005, average rice yields in the wet season crop were lower in low-lying severely acidic soil areas in Long An, An Giang and Kien Giang provinces than in neighbouring provinces (provincial statistics in 2006). Coastal shrimp farming in Bac Lieu province (Dong Hai, Gia Rai, Phuoc Long and Hong Dan districts) suffers from water discharges from agricultural acid sulphate soil areas in their upstream parts.

The extent and severity of water acidification and pollution depend on land use and the arrangement of irrigation or drainage canal systems. On the one hand, the farming practice of raised beds for upland crop production commonly applied in acid sulphate soil areas, discharges significantly larger amounts of acidic substances and metals than do rice fields (Minh *et al*, 1997). Under rice cropping, fields are submerged and pH increases, resulting in aluminium precipitation. In the raised beds, in contrast, soils are mostly in an oxidized condition, allowing more dissolved aluminium to

raised-beds release higher quantities of acidity and metals than the low raised-bed practice (Minh *et al*, 1997). In addition, the release of aluminium tends to decrease with land usage (Minh *et al*, 2002). On the other hand, if canal systems are long and complex, such as in the Plain of Reeds, the discharge and the dilution of acidic water is far from the acid source area to the sea. In contrast, canal systems which are short and simple, such as the Long Xuyen Quadrangle, the acid discharge and dilution is rapid. The acid discharge seems to have a small impact on the main rivers of the Mekong and the Bassac, as the discharge is rapidly diluted by a large volume of freshwater (Hashimoto, 2001).

3.2.3 Possible solutions

Particularly, acid sulphate soils reclamation for agricultural development aims at food security, at both household and national levels, as the first priority at the expense of water conflicts among water users, including resource-poor households depending on open-access aquatic resources. The challenge is how to improve soil quality and further enhance crop productivity while minimising the flushing of toxic substances from the field to surrounding and downstream areas. Water acidification and metal pollution is expected to decrease gradually once the Plain of Reeds, the Long Xuyen Quadrangle and the Camau Peninsula are mostly reclaimed for agriculture. In the past, acid sulphate soil reclamation was subsistence-oriented, thus farmers and authorities were willing to endure the problems. From now onwards, however, the use of the soils is commercially-oriented, improving economic growth and farmer's welfare. Human health and environmental protection therefore need to be given special attention.

In acid sulphate soils, deep oxidation and its associated acidification and solubilisation of metals can be minimized through appropriate management of water in fields and in drainage canals and improved farming practices. Based on the literature, the following possible solutions are identified. For rice farming:

- **Pyrite and the sulphuric horizons** should be submerged in order to prevent further formation of acidity, which was generated by oxidation of the sulphuric horizons when the water table is further lowered;

- **Strong reduction of the topsoil** in fields, however, should be avoided in order to further improve rice yields. This can be achieved by improving the drainage or removing surface water from the field for a number of days at mid-season or at the reproductive stage of the rice plant while maintaining the water table at the desired depths (Hanhart *et al*, 1997). Practically, this water management is quite difficult at a large scale, because of the high spatial variability of sulphidic horizons of acid sulphate soils and natural water table levels of surrounding canals, which complicate be removed by leaching. In raised-bed farming practice, the traditional and high management of the system (Tuong *et al*, 1998; Husson *et al*, 2000a);

- In addition, **improved farming practices** are also important solutions (Hanhart and Ni, 1993). Farmers have to establish their winter-spring crop as early as possible to avoid strong oxidation at the end of the crop season; thereby the need for irrigation could be reduced; and

- **Rice varieties** with a short-growth duration and tolerance to aluminium need to be selected and utilised.

For upland crop farming:

- **Land preparation**, such as ploughing and harrowing, which leads to rapid development of a plough-pan, and careful maintenance of field dikes and drainage ditches would be advisable;

- **Water table control** and the **minimization of the upward movement** of toxic substances in the soil are recommended. Some aluminium might move upward to the topsoil by capillary forces which could take place during the dry season or dry days between the rains. However, it is essential to control the water table levels such that it will not reach the topsoil layers at the beginning of the rainy season (Hanhart and Ni, 1993; Minh *et al*, 1998);

- **Mulching and surface tillage** help reduce evaporation and therefore are effective means of reducing aluminium accumulation (Minh *et al*, 1998); and,

- **Enhancing bypass flow** is an effective way of improving soil quality of acid sulphate soils by improved leaching efficiency of rain water, but this intervention has a negative environmental impact (Minh *et al*, 2002).

For extensive or semi-intensive coastal shrimp farming practices, farmers usually dig surrounding trenches to make shelters for shrimps, and dry out the field between the rice and shrimp crops in the beginning of the dry season. Therefore, the trenches should not be dug deeper than pyrite layers in acid sulphate soils. In addition, an appropriate water table level needs to be maintained during drying out of the field so that sulphidic horizons can not be oxidized. However, appropriate interventions have not been fully devised to minimise possible negative effects of the use of acid sulphate soils for coastal shrimp farming practices.

Proper management of embankments and drainage canals and promotion of recycling of field effluents in acid sulphate soils are also crucial. Embankments of newly dug canals and road construction are important sources of pollution (Tuong *et al*, 1998). Soil compaction may help reduce the bypass flow in these structures and minimise environmental hazards (Minh *et al*, 2002). Appropriately high water levels in drainage canals need be maintained in the dry season to maintain field water table and to save

precious irrigation water. Field effluent water can be re-used or purified with plants tolerant to acidity and aluminium such as *Melalueca* spp. or *Eleocharis* spp., instead of directly discharged to surrounding canals. This option looks promising, but in reality a vast area of *Melalueca* forests in the Mekong delta is being converted into rice or brackish water shrimp farming for economic reasons, resulting in a more intense water competition. For long-run sustainability, integrated solutions, including incentive policies, monitoring, assessment and prediction of temporal variations of soils and water quality are of great importance (Minh *et al.*, 1997). Sustainable management of land and water in the acid sulphate soils zone also means benefitting ecosystems and other water users in coastal areas.

3.3 Water conflicts in coastal zones

3.3.1 Multiple values of water and its associated livelihoods

In coastal zones of the Mekong Delta, water conflicts are more complex compared to those in the upper delta and acid sulphate soil zones. Freshwater is a scarce resource in the coastal zone of the delta, yet there are multiple values and associated livelihoods dependent on this resource, as well as brackish and saline water. The coastal zones seem to favour aquaculture over agriculture development, due to salinity intrusion. The zone is under-developed in socio-economic terms, compared to the other areas in the delta because of its poor physical and social services, and infrastructure (Hossain *et al.*, 2006; Sam, 2003; Truong and Anh, 2002). People's livelihoods rely mainly on agriculture, aquaculture, wild fisheries and forestry. Poor households, small-land holders or landless families, live on natural resource exploitation or waged labour (Hossain *et al.*, 2006; Sam, 2003).

Rice farming is the main agricultural activity. Farmers can earn an additional income by exploiting natural aquatic resources. Rice farmers in the coastal zone earn a lower income than those on alluvial soil and irrigated areas of the delta, due to water and land constraints. In salinity areas, traditional rice is practised with one crop per year and rice yields are low (Gowing *et al.*, 2006; Sam, 2003; Trung, 2006). Upland crop production is an economically promising activity but its marketing is constrained (Sam, 2003; Trung *et al.*, 2006). In salinity-controlled areas, on the contrary, high-yielding rice is grown with double or triple crops a year. This rice intensification has been commonly observed in national water resources development project areas such as the Camau Peninsula (Quan Lo Phung Hiep), Tra Vinh (South Mang Thit), Soc Trang (Tiep Nhat) and Tien Giang (Go Cong) provinces (Miller, 2003).

Shrimp production continues to expand though it is considered economically risky. Rice farming area in the coastal zone decreased from 970,000 ha in 2000 to 800,000 ha in 2002, whereas shrimp area increased from 230,000 ha to 390,000 ha in the same period (cited in Gowing *et al.*, 2006). However, shrimp culture needs high inputs and is

economically risky (Koopmanschap *et al*, 2002; Sam, 2003; Kempen, 2004). Shrimp farming income is not stable and varies greatly among farmers and locations, due to the poor quality of shrimp seed, the limited technological knowledge of farmers, and the poor quality of intake water (Be *et al*, 2003; Minh *et al*, 2003; Trung, 2006). About half of shrimp farming households become poorer and/or indebted, due to failures in shrimp farming (Sam, 2003).

For resource-poor households, income largely depends on wild fishery capture, and thus fishing equipment and access to resources are important. Poor households without adequate fishing equipment usually exploit inland natural resources and earn low incomes, due to the decline of natural aquatic resources. Consequently, the livelihoods of most of the poor fishing households are mainly reliant on waged labour (Hossain *et al*, 2006; Sam, 2003).

In the coastal region, mangrove forests are usually managed as state-run farms. The mangrove forest includes two zones: the core and the buffer zones. The core zone is fully protected yet in the buffer zone, the state-run farms make contracts with local farmers to manage and harvest the forest. The local people are allowed to use 30% of the forestland under the contract for shrimp culture (Koopmanschap *et al*, 2002; Sam, 2003). In addition, there is a small proportion of people living on illegal exploitation of the forest and natural aquatic products (Hossain *et al*, 2006). According to Sam (2003), approximately 28,740 households in the Mekong Delta coastal areas live on forest exploitation.

3.3.2 Local and regional water conflicts

Before 2000, the state and local governments put a lot of effort into rice development and related programmes. Salinity-control infrastructure was constructed and consequently, salinity in canal water was reduced and high-yielding rice farming was expanded in the salinity-free areas (Hossain, 2006). This intervention benefits rice farming households but impedes those who rely on aquaculture and inland fisheries (Tuong *et al*, 2003). In addition, this intervention has negative impacts on the livelihoods of the poor, who depend mainly on inland natural aquatic resource exploitation. In marginal land areas, farmers lack technological knowledge and capital to adopt the new technologies of high-yielding rice farming (Hoanh *et al*, 2003; Hossain *et al*, 2006). In the western part of Quan Lo Phung Hiep, socio-economic problems have arisen due to the creation of a weakly brackish zone at the front of the expanding irrigation area; here, the salinity levels are too low for shrimp aquaculture, yet too high for rice, undermining the livelihoods of many former shrimp farmers (Hashimoto, 2001).

Since 2000, a large number of rice farmers shifted to shrimp culture. This shift brings about conflicts between shrimp and rice farming within the community or between those upstream (rice area) and those downstream (shrimp area) (Gowing *et al*, 2006).

This is because rice and shrimp farming practices use the same irrigation or drainage systems. As a result, if more saline water is intentionally taken in for shrimp in the dry season, neighbouring or upstream rice fields are affected by saline water. For example, combined with shrimp farming expansion, the high tide from the western coast results in further salinity intrusion into the Ca Mau Peninsula, damaging about 6,550 ha of the dry season rice crops in Bac Lieu province (Hong Dan district, unpublished data). On the contrary, if more freshwater is supplied to the rice farming areas, the salinity in the shrimp farming areas is diluted. In addition, farmers heavily apply agro-chemicals in their intensive rice culture. Thus, effluent discharges from rice fields result in negative impacts on shrimp culture (Trung *et al*, 2006).

Conflicts also occur within the shrimp farming area. The effluent discharge from a shrimp farm might become the water intake of another. Therefore, the periodic discharge from shrimp farms brings about the potential of adverse effects on the receiving waters (Hoanh *et al*, 2001; Tuong *et al*, 2003). The shrimp farm effluents contain a high concentration of suspended solids, nutrients and bio-active chemicals, particularly in semi- and intensive shrimp farming systems.

Development of rice and recently of shrimp culture both result in losses of coastal mangrove forests. In the eastern coastal zone, the mangrove area significantly decreased, from 190,812 ha in 1953 to 29,534 ha in 1995, (Minh *et al*, 1999; Minh *et al*, 2001). In the Ca Mau Peninsula, the largest area of mangroves in Vietnam, a vast area of mangroves was deforested for rice and shrimp farming. Between 1983-1995, about 66,253 ha of mangrove forest were converted into shrimp farms in Ca Mau and Bac Lieu provinces (Cuong and Vuong, 1996). Using aerial photographs in Cai Nuoc district of Ca Mau province between 1968 and 2003, Binh *et al* (2005) calculated that about 40% of the loss of the mangrove could be attributed to shrimp farming, while the remaining 60% was attributed to needs for agricultural land. Presently, shrimp farming is the major source of mangrove loss in the district. They also estimated that in 1968 saline water covered about 220 km², in 1992, 1998 and 2003 about 92, 135 and 835 km², respectively. These figures could confirm the rice expansion in the 1990s and the fast growth of shrimp culture since 2000. This reduction of coastal mangrove forests leads to deterioration of water quality and fish populations. Consequently the productivity of shrimp farms and the livelihoods of the poor who strongly depend on the wild fish catch are threatened (Hirsch and Cheong, 1996).

3.3.3 Possible solutions

The current conflicts of water uses among agriculture, aquaculture, fisheries and environment in the coastal zone have prompted a rethinking of the government policy

with implications for water and land-use management in the coastal region, where water values are recognized as multiple rather than for rice or shrimp production only. Local authorities are challenged to turn around a conflicting situation of incompatible land and water use to achieve a workable compromise that can accommodate the needs of both the shrimp and rice farmers as well as minimize adverse effects on the poor and the environment (Tuong *et al*, 2003). The following are possible solutions:

- **Multiple values of land and water** uses need to be identified. An integrated approach to land and water management is required, encompassing much broader perspectives and including conflict resolution as an integral strategy (White, 2002). Geographical Information Systems and hydraulic models could be appropriate tools to support this integrated approach (Tuong *et al*, 2003).

- **Appropriate farming systems** should be promoted to minimize water conflicts among the water users and to further improve shrimp productivity. Integrated farming systems such as rice-shrimp and mangrove-shrimp farming can help reduce the economic risks of shrimp farming and stimulate environmental sustainability (Preston and Clayton, 2003). Integrated mangrove-shrimp farming systems can bring higher incomes than systems without mangroves (Gowing *et al*, 2006).

- **Technical solutions** for shrimp culture are of importance. Possible options include reducing water exchanges of shrimp farms and improving the quality of hatchery-reared post-larvae. Reducing the release of acidity from acid sulphate soils would be advisable (Gowing *et al*, 2006; see discussion in section 3.2.3).

- **Participatory approaches** are of importance to solve the conflicts. The participation of local farmers and other stakeholders (i.e. decision makers, extension workers, researchers and service providers) in land use planning and management allows not only decision makers and land use planners to understand the real needs, but also stimulates farmers' awareness of the possible conflicts and their consequences. Hence, the potential conflict can be minimized (Trung, 2006).

- **Institutional improvements** are an important option for the reduction of water conflicts. The institutional improvement includes better co-ordination and participation among stakeholders, from planning, implementing and monitoring to evaluation. Within this option, the concept of integrated coastal management needs to be considered. Conflict resolution should be shifted to the design and building of institutions, where they are absent, or the strengthening of those that already exist (Brugere, 2006).

3.4 Constraints to water access and sharing

The above sections have highlighted important areas of competition within the delta that limit easy access to water in adequate quantity and quality. There are also important social and micro level factors that influence access. Major factors influencing the water access and sharing include a number of bio-physical and socio-economic and institutional aspects, at household and community levels (**Table 2**). During the dry season, tertiary canal networks are usually shallow and their flow rates are low, due to poor maintenance and sedimentation. Consequently, within a community, upstream households can access to water better than those downstream, in terms of water availability, quality and timing. This constraint also limits possible options for people to deal with risks. Fields with low elevation levels can access to water better than those with a high elevation, or that are distant from canals. On the other hand, better-off people or people with good social connections can access water better than those who are worse-off. The combined constraints of bio-physical and socio-economic factors might cause severe effects on poor people's livelihoods. For example, poorer households with poor access to water have little choice but to rely on un-safe water sources. This makes them more susceptible to crop loss and illness, hastening economic decline (Miller, 2003).

Cooperation amongst neighbours plays an important role in water access at household level while coordination and participation of all local stakeholders, including authorities, are crucial at the community level. Livelihoods of farmers and local communities crucially depend on availability and quality of water resources. Thus, they understand how to adapt to scarce water resources. In many areas, farmers contribute about 40%-60% of their total budget for annual maintenance of tertiary canals, dikes or sluice gates (Nhan, unpublished data). Appropriate cooperation mechanisms can help alleviate inequities apparent in water access. Communication between farmers and local authorities plays a role in individual decision-making on production within the context of collective constraints, as it is difficult for gates to be operated to balance the needs of people pursuing different local interests and needs. In reality, a top-down approach or one lacking communication is still common in some areas (Miller, 2003). Good planning, coordination and regulation of local authorities is necessary, and helps contribute to greater equities in water access of a community (Hedelin, 2007). An appropriate combination of structural and non-structural measures is advisable when governmental budgets for water resource development and management are still limited.

► Table 2: Main factors affecting water assess and sharing at individual and community levels.

Levels	Factors		
	Physical	Socio-economic	Institutional
Household	- Rainfall - Water flow and tide from estuaries - Distance of field/house from canal - Micro-elevation levels - Water management infrastructure and sedimentation	- Household head's social position - Labour availability - Farming or livelihood options - Farming inputs and outputs - Household income - Pumping and water supply investments	- Cooperation with neighbours - Farm locations among owners and water sources - Private water assess fee - Seasonal calendars
Community	- Agro-ecosystems - Water flow and tide from estuaries - Distance of community from main canals/river - Macro- elevation levels - Water management infrastructure and sedimentation	- Farming or livelihood options - Farming inputs and outputs - Household income	- System maintenance and operation (canals, dikes, sluice gates, pumping stations) - Local coordination, cooperation and participation - Water management rules and norms by local authorities - Planning of land and water use

(Source: Adapted from Miller, 2003, and personal observations)

4 Conclusions on the major issues to be addressed

4.1. Upstream-downstream water competition

Policies and infrastructure investments of the government have encouraged intensification of rice and aquaculture in the upper and mid-delta, resulting in impacts on water use downstream. Intensive rice farming with two or three crops a year, mainly relying on water availability and other inputs, consumes much water during the dry season. The rice farming in the upstream and mid-stream delta might abstract about one-half of flow rates of the Mekong within Vietnam from December to May. This implies more tension between further expansion or intensification of dry-season rice farming upstream and freshwater availability and salinity intrusion downstream. Thus, possible solutions to improvement to water use efficiency in rice culture needs to be considered and impacts of water abstraction in rice farming in upstream delta needs to be monitored.

The salinity intrusion in the downstream Mekong delta is complex, depending on not only water abstraction and storage upstream but also environmental factors and land uses downstream. The development of canal systems and the expansion and intensification of the rice culture, which reduces the flood-plain water storage and river flows, could increase the extent and the severity of the salinity intrusion in the downstream part. Recently, the salinity intrusion has become more complicated due to new construction of irrigation systems and salinity-control structures.

Freshwater aquaculture competes for water through the discharge of a large quantity of pond (cage) effluents to surface water bodies. This might have negative impacts on aquaculture itself, domestic water supplies and the aquatic environment downstream. The extent of the negative impacts increases with increasing intensification levels of the farming because of higher water exchange rates. Pond effluent discharges not only pollute surface water bodies but also reduce economical benefit to aquaculture farmers. While the government promotes freshwater aquaculture farming as a way to develop the rural economy, water pollution and its associated impacts needs special attention.

Further improvements in water use efficiency in rice and aquaculture farming practices in the upper delta are identified as an important task to alleviate upstream-downstream water competition. For rice farming, several technical options could help improve efficiency of irrigation water use at both crop and field level. The proposed options, however, still have limitations such as labour-or cost-intensity, yield reduction, nutrient losses and nitrate leaching into groundwater. In addition, options at crop and field level are not very practical with a small-scale production. Solutions at community level are still being sought after. For aquaculture, minimizing effluent discharges while maintaining high farming income is of great importance. “Ecological or sustainable aquaculture” development should be promoted. Recycling nutrient-rich outflows from ponds/cages is promising to produce an extra crop of fish, terrestrial or aquatic plants before discharge. Water pricing or polluter pay policies are possible options but are likely not to be practical with small-scale and resource-poor farmers.

4.2. Impacts of acid sulphate soil reclamation

Most acid sulphate soil areas have been converted into agricultural areas, particularly rice culture and aquaculture. This was encouraged by extensive development of canal systems and human settlement in combination with improved cropping practices. An important impact of reclamation of acid sulphate soil is the acidification of soils and canal water and hence increased mobility of potential metals. The extent and the severity of the problems depend on seasons, arrangement of irrigation or drainage canal systems, land use patterns, water management in the field and crop farming practices. The acidity and metals released from acid sulphate soils have adverse impacts on domestic water use, agriculture and aquaculture practices, and aquatic ecosystems in surrounding and downstream parts, and the impacts can last for many years. The impacts are more severe in the beginning of the rainy season, in tertiary canals or shallow ground water and in upland farming areas. After two decades of the reclamation, pH values of canal water in the Plain of Reeds and in the Long Xuyen Quadrangle are still exceeding the maximum allowable limits applied for both domestic supplies and agriculture or aquaculture uses. With common farming

practices, normal rainfall and discharge from the Mekong River is not sufficient to dilute the leachate to an environmentally acceptable level.

The challenge of acid sulphate soil reclamation is how to further improve crop productivity while minimizing environmental impacts in surrounding and downstream areas. This is not an easy task because of trade-off between these two objectives. There are possible technical options to solve this problem. The key principle is to prevent the oxidation of the pyrite layer and to minimize the concentration of toxic metals in the top soil through appropriate management of water in fields and in drainage canals and improved farming practices. Unfortunately, the options seem to be very promising at field scale but not at larger scales, due to high spatial variability of sulphidic horizons of acidic soils and natural water table levels of surrounding canals and small-scale farming production. In addition, proper management of embankments and promotion of recycling of field effluents by appropriate integrated farming systems are also crucial. Further disturbance of the soil could make the impacts more severe. Recognizing these impacts, further expansion of agriculture and aquaculture land in acid sulphate soil areas needs careful consideration because of the potential risk to human health and environment. Monitoring, assessment and prediction of temporal variations of soils and water characteristics are of great importance.

4.3. Water conflicts in coastal zones

Water conflicts in the coastal zone are brought about by not only interventions in the reaches but also changes made within the zone. In the inland coastal zone, the ecosystems have undergone rapid changes in recent decades; there has been a clear shift of natural mangrove forests and salt fields to rice and recently to shrimp culture. These changes have caused conflicts among three major water resource users: rice cultivation, shrimp culture and fishing. The government promoted intensive rice production in the past and shrimp farming in recent years. For rice farming, in the past many large water management projects have been carried out and saline water was replaced by freshwater. This led to larger areas of mangrove forest being turned into rice areas. Now, for shrimp farming, mangrove forest is also cut down. This causes significant loss of mangrove land, in turn resulting in a decline of natural aquatic resources. Shrimp farming is more profitable than rice but this farming practice needs higher input costs and is economically risky. The zone comprises a mosaic of rice, shrimp and natural forest lands, which use the same irrigation or drainage systems. It is difficult to meet all needs of water use because of the different water requirements and some of them are not compatible. Rice farming impedes downstream people who rely on shrimp culture and inland fisheries, due to salinity dilution and effluents discharged from rice areas. In contrast, shrimp culture adversely affects rice farming due to soil and water salinisation. Water conflicts occur within the shrimp farming community from pollution of water courses.

The current conflicts have prompted a rethinking of the government policy and the planning of land and water use in the coastal region. Further promoting integrated farming systems, improving farming technology packages, enhancing participation of local people and improving institutions in land and water use planning and management are possible solutions. Furthermore, the concept of integrated coastal management needs to be vigorously promoted.

4.4. Constraints to water access and sharing

Increasing scarcity for water is associated with both quantity and quality. Major factors influencing the water access and sharing are associated with a wide range of physical settings, and socio-economic setting or coordination and cooperation, at both household and community levels. The combined constraints of driving factors might cause severe effects of poor water access on people's livelihoods, especially the poor. Individual cooperation and participation of all local stakeholders are crucial, at both farm and community level, representing and responding to local interests and needs. On top of that, good planning, coordination and regulation of local authorities are necessary.

5 Contested issues

This review paper describes the current stage of rice cultivation and aquaculture and its associated impacts on water conflicts in the major agro-ecological zones in Mekong delta. Possible options are also suggested to alleviate the conflicts while maintaining high productivity and income from rice and aquaculture farming. In general, however, available information on water conflicts in the delta is still patchy and current information is inadequate. The following are contested issues:

- Strong evidence of the impacts of rice farming and aquaculture practices in upper delta is still limited.
- Patterns of the salinity intrusion in the delta are not yet fully understood. To what extent the water abstraction by rice crops in the dry season causes salinity intrusion downstream, and how recent changes in salinity-control structure and canal development influence salinity intrusion, are still not clear.
- Water-saving techniques have not yet been tested in rice farming and aquaculture practices in the delta. Thus, how these techniques can be applied successfully is unclear.
- That to what extent the impacts of acid sulphate soils reclamation still continue is not yet known.
- Water has multiple values and water saving needs to be considered at larger scales. In the long-run to further sustainability, solutions balancing interests among water uses or regions are not yet well-known.

- Together with technical options, non-structural solutions are considered important to reduce water conflicts and to strengthen people's awareness of risks. The non-structural options are still rarely applied to real situations.

- Water conflict and its causal effects are dynamic. Thus, proposed solutions need to be long-term and adaptable to constant changes of physical and socio-economic circumstances within the delta, as well as in the whole Mekong River Basin.

6 Research priorities

6.1. Crop and field levels

Further improvements in water productivity in agriculture, mainly rice cultivation, and aquaculture at a field level and maximizing water value at larger scales is the key to alleviating water tension between the upper delta and the downstream, the impacts of acid sulphate soils and conflicts in the coastal zones. Water productivity here means less water input but maintaining high incomes. There seem to be trade-offs existing between economics and water use efficiency or the environment in rice farming (Bouman and Tuong, 2001) and aquaculture (Nhan *et al*, 2007b). Moreover, adoption of water saving practices is influenced by a range of technical, physical and socio-economic aspects (see section 3.1.4). Unfortunately, this knowledge and insight are still limited in Vietnam, particularly in the Mekong delta. The following are gaps of knowledge that need urgent investigation:

- What is the water productivity of rice production in different agro-ecological zones of the delta?
- How can water productivity in rice farming and aquaculture systems be improved while remaining high income production systems and still safeguarding the environment?
- Under what conditions could high-water-productivity practices be applied?
- How can flood water at maximum volume be stored to irrigate crops during the dry season in acid sulphate soil areas?
- How can leachate from fields in acid sulphate soils be re-used or purified before being released to drainage canals?

6.2. Zone and regional levels

Increased water productivity at the field level does not always translate into those at larger scales (Molden *et al*, 2003). The effectiveness of the water use is also of great importance. For example, in rice production, most water-saving technologies increase water productivity through irrigation and save water through a reduction in seepage and percolation flows, which can be re-used downstream (Tuong *et al*, 2005). At the larger scales, moreover, water has multiple uses: crop production, aquaculture,

livestock production, domestic use, industries, fisheries, environment, etc. (Barker *et al*, 2003; Mushtaq *et al*, 2006). Barker *et al* (2003) laid down some of the concepts and complexities in economic analysis related to increasing water productivity and show that increases in water productivity in one sector might reduce the water productivity elsewhere – that is, in economic terms, there are significant externalities. Moreover, institutional matters dealing with the distribution of deriving benefits from different water use options among different water users are the crucial challenge. Information on this matter is still little known in the Mekong delta. The following questions need to be answered at zone or regional level:

- Will impacts of acid sulphate soils reclamation still continue in the future? If so, how can they be anticipated and what are the determinants?
- What are spatial and temporal patterns of salinity intrusion, what are the determinants, and what will the patterns be with the possible development of water resources in upstream countries in the future?
- What are linkages between poverty and depletion of natural resources, particularly water?
- What are risk strategies to increasing scarcity of water, when special attention to the poor is given?
- What are the total gains in upper delta and the total losses downstream, and who will gain and lose in each option?
- How can the economic value of water be maximized with less environmental impacts, increased livelihoods of the poor and ensuring national food security? And how are proposed interventions adapted to possible changes of physical and socio-economic circumstances?
- What are incentives to apply water-saving practices in agriculture and aquaculture by farmers?
- What are appropriate mechanisms for better local cooperation, participation and coordination, especially the role the local community plays, in better arrangement of water access?
- What are mechanisms for secure and equitable water sharing at local and delta scales? What are the social contexts and ways in which conflict over water can be anticipated, reduced and eventually resolved at the community, project, agro-ecological zone and delta wide scale?

7 Conclusion: Policy linkages

The current stage of rice farming and aquaculture practices and their impacts and conflicts give some implications for policies on sustainable agriculture and aquaculture development for the Mekong delta. Policies on, and investments for, rice and aquaculture development resulted in water conflicts between the upper delta and downstream, adverse impacts in acid sulphate soil areas and conflicts in coastal zones.

These interactions are complex and more evidence of causal relationships are still needed to provide policy makers clear trade-offs between different water users and necessary guidelines of optimal water resources management. In the delta, subsistence-orientated production shifted to market-orientated production with improved welfare of people. The state and local governments need to balance immediate food production and economic growth with sustainable resource-base management. To do this, laws or decrees related to environment and water resources protection need to be taken into account when strategies of agricultural, aquacultural and socio-economic development are designed. The Mekong delta is highly susceptible to the negative impacts of upstream development interventions, which contribute to changes in the flood regime, reduction in total and dry season flows, an increase in water pollution, and changes in sediment and nutrition loads (Miller, 2003).

The current water conflicts can be solved through a combination of a range of technical, bio-physical, socio-economic and institutional aspects at community and regional levels.

First, rice and aquaculture development in upper delta have impacts on water uses in downstream areas. Land and water use planning needs to be considered at the regional scale (i.e. upstream vs. downstream) rather than locally. For any intervention projects, gain and loss trade-offs between upstream and downstream should be assessed and valued.

Second, acid sulphate soils reclamation for rice farming development contributes to national food security at the expense of the environment and human health risks. These negative impacts should be considered when the expansion of acid sulphate soils reclamation for aquaculture development is still going on in the coastal zone.

Third, the coastal ecosystem is very sensitive and water conflicts among water users are complicated. Land and water use policies and planning therefore should take a more holistic approach, taking into account interests of all resource users not only within the zone but also with the upper delta, especially the poor and their related resource base, instead of focusing on a single sector. Multi-objective decision-making and predictive tools need to be developed at different spatial scales to provide adequate options for policy making and planning.

Fourth, the equity of water access and sharing is determined by a combination of physical and socio-economic settings. Participatory approaches are required to support well-informed planning, policy options, intervention developments, implementation, evaluation and feedbacks of local needs to policies (Roetter *et al*, 2007). The concept of integrated resources basin management should be given priority, due to increasing water competition leading to increased efforts in

management. This shifts to a greater concern for water management institutions and mechanisms for cooperation and coordination (Miller, 2003).

Fifth, water-saving practices in agriculture and aquaculture need to be considered at different spatial scales. The water-saving practices should be realized as one of the basic policies for sustainable agriculture development in the region. Incentives that encourage farmers to apply water-saving practices are necessary. This measure is successfully applied in China (Li, 2001; Hoanh *et al*, 2003; Gowing *et al*, 2006).

Sixth, further research should focus on both micro- (i.e. crop and field) and macro-scale (zone and region), and consider both technical and socio-economic solutions. Continuous monitoring of the environmental and socio-economic conditions following intervention is essential for a timely supply of adequate data for resource planning and management that would enhance the positive outcomes and minimize the negative impacts.

Seventh, collaboration among countries in the Mekong Basin is of great importance for better management of the same water resources, for greater gains in the whole but least impacts downstream. More equitable approaches to water rights are necessary, encapsulating principles such as riparian rights and equitable utilization, benefiting both upstream and downstream countries (Nickum, 1999).

References

- Barker, R., Dawe, D., Inocencio, A. (2003) Economics of Water Productivity in Managing Water for Agriculture. In: Kijne, J.W., Barker, R., Molden, D. (Eds), *Water Productivity in Agriculture: Limits and Opportunities for Improvement*.
- Be, T.T., Clayton, H., Brennan, D. (2003) Socioeconomic characteristics of rice-shrimp farms in the study region. In: Preston, N. and Clayton, H. *Rice-shrimp farming in the Mekong Delta: Biophysical and socioeconomic issues*. ACIAR Technical Reports 52e: 15-26.
- Belder, P., Bouman, B.A.M., Cabangon, R., Guoan, L., Quilang, E.J.P., Yuanhua, L., Spiertz, J.H.J., Tuong, T.P., (2004) Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia. *Agricultural Water Management* 65: 193-210.
- Berg, H. (2002) Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam - economic and ecological and considerations. *Ecological Economics* 41: 95-107.
- Beveridge, M.C., Philips, M.J., Macintosh, D.J., (1997) Aquaculture and the environment: the supply of and demand for environmental goods and services by Asian aquaculture and the implications for sustainability. *Aquaculture Research* 28: 797-807.
- Binh, T.N.K.D., Vromant, N., Hung, N.T., Hen, L., Boon, E.K., (2005) Land cover changes between 1968 and 2003 in Cai Nuoc, Ca Mau Peninsula, Vietnam. *Environment, Development and Sustainability* 7: 519-536.
- Bouman, B.A.M. (2007) A conceptual framework for the improvement of crop water productivity. *Agricultural systems* 43: 43-60.
- Bouman, B.A.M., Tuong, T.P., (2001) Field water management to save water and increase its productivity in irrigated lowland rice. *Agricultural Water Management* 49: 11-30.
- Boyd, C.E., Gross, A. (2000) *Water use and conservation for inland aquaculture ponds*. *Fisheries Management and Ecology* 7: 55-63.
- Brugere, C., (2006) Can Integrated Coastal Management Solve Agriculture-Fisheries-Aquaculture Conflicts at the Land-Water Interface? A Perspective from New Institutional Economics. In: Hoanh, C.T., T.P. Tuong, J.W. Gowing, B.Hardy (Ed.), *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Aquaculture-Fishery Conflicts*. CABI.
- Cantrell, R.P. (2004) Challenges and opportunities for rice-based farming in the International Year of Rice and beyond. *Paddy Water Environment* 2: 1-4.
- Between Mangrove Forest Rehabilitation and Coastal Aquaculture, Vietnam., Hue, October 31st - November 3rd 1996*. (in Vietnamese). pp. 36-42.
- Delinc?, G. (1992) *The ecology of the fish pond ecosystem - with special reference to Africa*. Kluwer Academic Publisher.

- Dittert, K., Shan, L., Kreye, C., Zheng, X.H., Xu, Y.C., Lu, X.J., Shen, Q.R., Fan, B.A.M., Hengsdijk, H., Hardy, B., Bindraban, P.S., Tuong, T.P., Ladha, J.K. (eds.) *Water-wise rice production*. International Rice Research Institute, Los Baños (Philippines), pp. 197-206.
- Edwards, P. (1993) Environmental issues in integrated agriculture-aquaculture and wastewater-fed fish culture systems. In: Pullin, R.S.V., Rosenthal, H., MacClean, J.L. (eds.) *Environment and aquaculture in developing countries*. ICLARM conf Proc. 31, pp. 139-170.
- FAO/NACA (1995) *Regional Study and Workshop on the Environmental Assessment and Management of Aquaculture Development (TCP/RAS/2253)*. NACA environment and Aquaculture Development Series No. 1. Network of Aquaculture Centre in Asia-Pacific, Bangkok.
- Frankic, A. and Hershner, C. (2003) Sustainable aquaculture: developing the promise of aquaculture. *Aquaculture International* 11: 517-530.
- Fujimoto, N., Tomosho, T. (2003) A viewpoint to apply water pricing to the Asian humid tropics. *Paddy Water Environment* 1: 75-83.
- Gowing, J.W., Tuong, T.P., Hoanh, C.T. (2006) Land and Water Management in Coastal Zones: Dealing with Agriculture-Aquaculture-Fishery Conflicts. In: Hoanh, C.T., T.P. Tuong, J.W. Gowing, B.Hardy (eds), *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Aquaculture-Fishery Conflicts*. CABI.
- Gowing, J.W., Tuong, T.P., Hoanh, C.T., Khiem, N.T. (2006) Social and Environmental Impact of Rapid Change in the Coastal Zone of Vietnam: an Assessment of Sustainability Issues. In: Hoanh, C.T., Tuong, T.P., Gowing, J.W., Hardy, B. (eds) *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Aquaculture-Fishery Conflicts*. CABI.
- GSO [General Statistical Office] (2003) *Results of the 2001 Rural, Agricultural and Fishery Census*. Statistical Publishing House, Hanoi.
- GSO [General Statistical Office] (2005) *Statistical Yearbook*. Statistical Publishing House, Hanoi.
- Guerra, L.C., Bhuiyan, S.I., Tuong, T.P., Barker, R. (1998) *Producing More Rice with Less Water from Irrigated Systems*. SWIM Paper 5. IWMI/IRRI, Colombo, Sri Lanka.
- Hanhart, K., Ni, D.V. (1993) Water management on rice field at Hoa An in the Mekong delta. In: Dent, D.L., Van Mensvoort, M.E.F. (eds) *Selected Papers of the Ho Chi Minh City Symposium on Acid Sulphate Soils*, 53: 161-176. ILRI Publisher, Wageningen
- Hao, N.V. (2006) Status of catfish farming in the delta. *Catch and Culture* 12: 13-14.
- Hashimoto, T.R. (2001) *Environmental Issues and Recent Infrastructure Development in the Mekong Delta: review, analysis and recommendations with particular reference to large-scale water control projects and the development of coastal areas*. Working Paper No. 4. Australian Mekong Resource Centre, University of Sydney.

- Hirsch, P. and Cheong, P. (1996) *Natural Resource Management in the Mekong River Basin: Perspectives for Australian Development Cooperation. Final overview report to AusAID.*
- Hoa, N. M., Cuong, H.T., Tinh, T.K. (2006) *Pollution of some toxic metal (Al, As, Cd, Fe, Mn, Ni, Pb, Zn) in canal water leached out from Acid Sulphate Soils in the Mekong Delta- Vietnam in relation to available concentration of these metals in soil. Technical report submitted to The Vietnamese Ministry of Education and Training* (in Vietnamese with English abstract).
- Hoanh, C.T. (1987) *Analysis of Data Prior to 1984 Relating to Salinity Intrusion Studies in the Mekong Delta No. 3.* In Proceedings of the Seminar on Phase II of Salinity Intrusion Studies in the Mekong Delta. Mar 1987, Ho Chi Minh City. Interim Committee for Coordination of Investigations of the Lower Mekong Basin.
- Hoanh, C.T., Tuong, T.P., Gallop, K.M., Gowing, J.W., Kam, S.P., Khiem, N.T., Phong, N.D. (2003) Livelihood impacts of water policy changes: evidence from a coastal area of the Mekong river delta. *Water Policy* 5: 475-488.
- Hoanh, C.T., Tuong, T.P., Kam, S.P., Phong, N.D., Ngoc, N.V., Lehmann, E. (2001) Using GIS-linked hydraulic model for managing water quality conflict for shrimp and rice production in the Mekong River Delta, Vietnam. In: Ghassemi, F., Post, D., Sivapalan, M., Vertessy, R. (eds) *Proc MODSIM 2001, Int Congr on Modelling and Simulation, 10-13 Dec*, Canberra, Australia, pp. 221-226.
- Hedelin, B. (2007) Criteria for the assessment of sustainable water management. *Environmental Management* 39: 151-163.
- Hossain, M., Ut, T.T., Bose, M.L. (2006) Livelihood Systems and Dynamics of Poverty in a Coastal Province of Vietnam. In: Hoanh, C.T., T.P. Tuong, J.W. Gowing, B.Hardy (Ed.), *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Aquaculture-Fishery Conflicts*. CABI.
- Husson, O., Hanhart, K., Phung, M.T., Bouma, J. (2000a). Water management for rice cultivation on acid sulphate soils in the Plain of Reeds, Vietnam. *Agricultural Water Management* 46: 91-109.
- Husson, O., Phung, M.T., Van Mensvoort, M.E.F. (2000b) Soil and water indicators for optimal practices when reclaiming acid sulphate soils in the Plain of Reeds, Viet Nam. *Agricultural Water Management* 45: 127-143.
- Kempen, B. (2004) *Multi-criteria evaluation as a decision-making tool in land use planning on district level: integrating biophysical land evaluation with socio-economic and environmental assessments in a decision support system for land use planning: with applications for the coastal zone of Vinh Loi district, Mekong Delta, Vietnam.* Wageningen University and Research Center.

- Koopmanschap, E., Vullings, W., Mensvoort, M.E.F.v., Tri, L.Q., Tromp, M., (2002) Remote sensing as tool for identification of aquacultural systems and mangrove species in the coastal Mekong delta, Vietnam. In: Van Mensvoort, M.E.F., Tri, L.Q. (eds) *Selected Papers of the Workshop on Integrated Management of Coastal Resources in the Mekong Delta, Vietnam*. Office C.T. de Wit Graduate School for Production Ecology & Resource Conservation (PE&RC).
- Kristensen, J. (2001) *Food Security and Development in the Lower Mekong River Basin - A Challenge for the Mekong River Commission*. Paper presented at the Asia and Pacific Forum on Poverty: Reforming Policies and Institutions for Poverty Reduction, held at the Asian Development Bank, Manila, 5-9 February 2001.
- Lang, M.T. (2005) *Management of the Mekong River Basin: Contesting its sustainability from a Communication Perspective*. Research Center on Development and International Relations (DIR) Aalborg University, Denmark. Working Paper No. 130
- Li, Y.H. (2001) Research and practices of water-saving irrigation for rice crop in China. In: Barker, R., Loeve, R., Li, Y.H., Tuong, T.P. (eds.) *Water Saving Irrigation for Rice: Proceedings of an International Workshop*. Wuhan, China. International Water Management Institute, Colombo, Sri Lanka.
- McMurtry, M.R., Sanders, D.C., Cure, J.D., Hodson, R.G., Haning, B.C., Amand, P.C.S. (1997) Efficiency of water use of an integrated fish/vegetable co-culture system. *Journal of the World Aquaculture Society* 28: 420-428.
- Miller, F. (2003) *Society-Water Relations in the Mekong Delta: A Political Ecology of Risk*. PhD thesis, University of Sydney, Australia.
- Minh, L.Q. (1996) *Integrated soil and water management in acid sulphate soils: balance agricultural production and environmental requirements in the Mekong Delta, Vietnam*. Thesis, Wageningen University, the Netherlands.
- Minh, L.Q., Tuong, T.P., van Mensvoort, M.E.F., Bouma, J. (1997) Contamination of surface water as affected by land use in acid sulphate soils in the Mekong Delta, Vietnam. *Agriculture, Ecosystems & Environment* 61: 19-27.
- Minh, L.Q., Tuong, T.P., van Mensvoort, M.E.F., Bouma, J. (2002) Aluminum-contaminant transport by surface runoff and bypass flow from an acid sulphate soil. *Agriculture, Ecosystems & Environment* 56: 179-191.
- Minh, L.Q., Tuong, T.P., van Mensvoort, M.E.F., Bouma, J. (1998) Soil and water table management effects on aluminum dynamics in an acid sulphate soil in Vietnam. *Agriculture, Ecosystems and Environment* 68: 255-262.
- Minh, T.H., A.Yakupitiyage, Macintosh, D.J. (2001) *Management of the Integrated Mangrove-Aquaculture Farming Systems in the Mekong Delta of Vietnam*. ITCZM Monograph No. 1.

- Minh, V.Q., Anh, V., Trom, M., Hoa, P.P., Diep, N., D.V.Tho (1999) *Mekong delta mangrove forest changes over the last five years by means of remote sensing*. Proceeding of an International Workshop on the rehabilitation of degraded coastal systems., Phuket Marine Biological Center, Department of Fisheries, Thailand, 19-24 January 1998., pp. 73-81.
- Molle, F. (2005) *Irrigation and water policies in the Mekong region: Current discourses and practices*. IWMI, Colombo, Sri Lanka.
- Muirhead, W.A., Blackwell, J.B., Humphreys, E., White, R.J.G. (1989) The growth and nitrogen economy of rice under sprinkler and flood irrigation in south-east Australia. I. Crop response and N uptake. *Irrigation Science* 10: 183-199.
- Mushtaq, S., Dawe, D., Lin, H., Moya, P. (2006) An assessment of the role of ponds in the adoption of water-saving irrigation practices in the Zhanghe Irrigation System, China. *Agricultural Water Management* 83: 100-110.
- Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H., Troell, M. (2000) Effect of aquaculture on world fish supplies. *Nature* 405: 1017-1024.
- NEDECO (1993) *Mekong Delta Master Plan, Thematic Study on Environmental Impacts, Volume 3: Existing ecological conditions and present status of environmental protection and guidelines for environmental protection and monitoring*.
- Nickum, J.E., 1999. Some Factors that Influence Water Security, and Some that Don't. Paper presented in the "Water and Conflict Seminar," held on September 17th, 1999 at the Asia-Pacific Center for Security Studies, Honolulu, Hawaii.
- Nhan, D.K., Be, T.T. (2005) *Water use in freshwater aquaculture systems in the Mekong delta, Vietnam: An implication for environmental sustainability*. Paper presented in a consultative workshop on "Sustainable Water Uses in the Mekong Delta", held on April 21 2005 at Can Tho city, Vietnam (in Vietnamese).
- Nhan, D.K., Duong, L.T., Sanh, N.V., Verdegem, M.C. (2004) Development of VAC Integrated Farming Systems in the Mekong Delta - A View of a System and Participatory Approach. In: Yamada, R. (ed.) *The Development of Agriculture and Sustainable Farming Systems in the Mekong Delta*. Tre Publishing House, pp. 101-125.
- Nhan, D.K., Milstein, A., Verdegem, M.C.J., Verreth, J.A.V. (2006) Food inputs, water quality and nutrient accumulation in integrated pond systems: a multivariate approach. *Aquaculture* 261: 160-173.
- Nhan, D.K., Phong, L.T., Verdegem, M.J.C., Duong, L.T., Bosma, R.H., Little, D.C. (2007a) Integrated freshwater aquaculture, crop and animal production in the Mekong Delta, Vietnam: determinants and the role of the pond. *Agricultural Systems* 94: 445-458.

- Nhan, D.K., Verdegem, C.J.M., Binh, N.T., Duong, L.T., Milstein, A., Verreth, J.A.V. (2007b) Economic and nutrient discharge tradeoffs excreta-fed aquaculture in the Mekong Delta, Vietnam. *Agriculture, Ecosystems and Environment* (in press).
- Nhe T.T. (2006) *The potential of the release of heavy metals from acid sulphate soils to water sources in the Long Xuyen Quadrangle*. Msc Thesis, Can Tho University, Vietnam (In Vietnamese with English abstract).
- Nien, N.A. (1995) *Possible use of flood water for reclamation of acid sulphate soils in the Plain of Reeds of the Mekong Delta*. Paper presented at the Workshop on Management of Acid Sulphate Soils, Ho Chi Minh City, 18-20 October 1995, Mekong River Commission, Bangkok.
- Ohlsson, L. (1995) *Hydropolitics - Conflicts over Water as a Development Constraint*. London, Zed Books Limited.
- Perez, R. T., Feir, R. B., Carandang, E., and Gonzalez, E. B. (1996) Potential Impacts of Sea Level Rise on the Coastal Resources of Manila Bay: A Preliminary Vulnerability Assessment, *Water, Air and Soil Pollution* 92: 137-147.
- Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E., Nandagopal, S. (2004) Water resources: agricultural and environmental issues. *Bioscience* 54: 909-918.
- Preston, N. and Clayton, H. (2003) *Rice-shrimp farming in the Mekong Delta: Biophysical and socioeconomic issues*. ACIAR Technical Reports 52e.
- Rigg, J., Salamanca, A. (2004) *Urban development, land policy and the future of peri-urban aquatic food production systems in Southeast Asia*. Paper presented during the PAPUSSA special session at the 7th Asian Fisheries Forum held on November 31st - December 3rd, 2004 in Penang, Malaysia.
- Rijsberman, F.R. (2006) Water scarcity: fact or fiction? *Agricultural Water Management* 80: 5-22.
- Roetter, R., van Keulen, H., Hengsdijk, H., van den Berg, M., van Laar, G. (2007) Sustainable resource management and policy options for rice ecosystems. *Agricultural Systems* (in press)
- Sam, L. (1997) *Agricultural irrigation in the Mekong delta*. Agricultural Publishing House (in Vietnamese).
- Sam, L. (2003) *Saline Intrusion in the Mekong Delta*. Agricultural Publication House, Vietnam (in Vietnamese).
- Sam, L. (2006) Results of study on salinity intrusion for socio-economic development in the Mekong Delta. In: Sam, L., Hoi, T.N., Nien, N.A., Tho, N.V., Huan, H.V., Hung, L.M., Thang, T.D. (Eds.), *Results of Science and Technology 2005*. Agriculture Press, pp. 104-112.
- Singh, G., Singh, Y., Singh, V.P., Singh, R.K., Singh, P., Mortimer, M., Johnson, D.E., Orr, A. (2003) *Direct seeding as an alternative to transplanting rice for the rice-wheat systems of the Indo-Gangetic Plains: sustainability issues related to weed management*. British Crop Science Congress.

- Smith, P. J., Gross, C. H. (1999) *Water and Conflict in Asia?* Paper presented in the “Water and Conflict Seminar,” held on September 17th, 1999 at the Asia-Pacific Center for Security Studies, Honolulu, Hawaii.
- Son, V.N., Yi, Y., Phuong, N.T. (2005) River pen culture of giant freshwater prawn *Macrobrachium rosenbergii* (De Man) in southern Vietnam. *Aquaculture Research* 36: 284-291.
- Tabbal, D.F., Bouman, B.A.M., Bhuiyan, S.I., Sibayan, E.B., Sattar, M.A. (2002) On-farm strategies for reducing water input in irrigated rice: case studies in the Philippines. *Agricultural Water Management* 56: 93-112.
- Tin, N.T., Ghassemi, F. (1999) *Availability and quality of surface water resources. Report for the ACIAR Project: An evaluation of the sustainability of farming systems in the brackish water region of the Mekong Delta*. Centre for Water Quality and Environment, Sub-Institute for Water Resources Planning and Management (SIWRPM) and Centre for Resource and Environmental Studies, the Australian National University, Ho Chi Minh City, Vietnam.
- Tin, N.T., Wilander, A. (1995) Chemical conditions in acidic water in the Plain of Reeds, Vietnam. *Water Research* 29: 1401-1408.
- Trinh, L. (1997) *Monitoring and controlling water pollution*. Scientific and Technical Publishing House, Hanoi, Vietnam.
- Trung, N.H. (2006) Comparing land use planning approaches in the coastal Mekong Delta, Vietnam. Wageningen University, the Netherlands.
- Trung, N.H., L.Q.Tri, Mensvoort, M.E.F.v., Bregt, A. (2006) Comparing Land-Use Planning Approaches in the Coastal Mekong Delta of Vietnam. In: Hoanh, C.T., Tuong, T.P., Gowing, J.W., Hardy, B. (Eds.), *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts*. CABI Publishing, UK.
- Truong, T.V. (1999) *Research on salinity intrusion forecasting in the Mekong delta and proposed solutions to overcome*. SIWRP, Vietnam.
- Truong T.V, N.N. Anh (2002) *Water resources development for socio-economic stability and development strategy in the Mekong Delta*. National workshop on “Water, Food and Environment”, Hanoi, Vietnam.
- Tuong, N. T. (2001) *Sea Level Measurement and Sea Level Rise in Vietnam, PSMSL Report for Vietnam*, Proudman Oceanographic Laboratory, Birkenhead, U.K.
- Tuong, T.P., Bouman, B.A.M., Mortimer, M. (2005) More rice, less water-integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. *Plant Production Sciences* 8: 229-239.
- Tuong, T.P., Kam, S.P., Hoanh, C.T., Dung, L.C., Khiem, N.T., Barr, J., Ben, D.C. (2003) Impact of seawater intrusion control on the environment, land use and household incomes in a coastal area. *Paddy Water Environment* 1: 65-73.

- Tuong, T.P., Minh, L.Q., Ni, D.V., van Mensvoort, M.E.F. (1998) Reducing acid pollution from reclaimed acid sulphate soils: experiences from the Mekong delta, Vietnam. In: Pereira, L.S., Gowing, J.W. (Eds.), *Water and the Environment: Innovative Issues in Irrigation and Drainage*. E&FN Spon, Routledge, London, UK pp. 75-83.
- Wassmann, R., Hien, N.X., Hoanh, C.T., Tuong, T.P. (2004) Sea level rise affecting the Vietnamese Mekong delta: Water elevation in the flood season and implications for rice production. *Climatic Change* 66: 89-107.
- White, I. (2002) *Water Management in the Mekong Delta: Changes, Conflicts and Opportunities. Technical Documents in Hydrology No. 61*, IHP-VI, UNESCO, Paris, France.
- Wolanski, E., Nguyen, H.N., Spagnol, S. (1998) Sediment dynamics during low flow conditions in the Mekong River estuary, Vietnam. *Journal of Coastal Research* 14: 472-482.
- Yi, Y., Lin, C.K., Diana, J.S. (2003) Hybrid catfish (*Clarias macrocephalus* x *C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) culture in an integrated pen-cum-pond system: growth performance and nutrient budgets. *Aquaculture* 217: 395-408.

*Sustainability Challenges to
Address in the Mekong Delta*



This report has examined the current state of knowledge on flooding and salinity management, livelihoods and resource use strategies, fisheries policy and competition for water use in the Mekong Delta. It has done so as part of the Sumernet programme in order to understand the issues that crucially affect the chances of achieving a transition to sustainable development in this vulnerable yet nationally and internationally pivotal region of south-east Asia. Some of the issues are relatively well documented and well understood. Others have turned out to need considerable further research before their full importance and influence may be drawn together so that a full appreciation of the range of policies required to give the transition a chance of success are formulated and implemented.

Key Findings

The chapters included in this report have brought to light a number of key findings which are summarized below.

- Coping capacity and resilience of local communities depend on the changing flood regimes will be shaped by global climate change.
- The institutionalisation of the integration principle requires the establishment of a mechanism promoting institutional and social learning as well as sharing experiences on how best to manage water resources across provinces and sectors in the Mekong Delta and across Vietnam and Cambodia.
- Floods and saline intrusion cause damage but may also bring some benefits.
- Changes in livelihoods of the local people are associated with a complex interplay between physical conditions, resettlement, water resource infrastructure development and socio-economic situations as well as government policies.
- Three key policies relating to economic changes include: (i) rice intensification through to livelihood diversification, (ii) effective use of land, and (iii) land and water use conflicts.
- Multiple resource interests need to be addressed in natural resources management to avoid resource conflicts.
- Both technical and socio-economic issues need to be addressed through institutional support.
- The full range of stakeholders' participation is required in the development of major infrastructure improvement.
- Transboundary issues of fisheries include regional fisheries ecology (habitat, migration) and fish trade.
- Fisheries production, from habitat to market, involves a series of scaled networks-formal and informal regulations, norms, and rules.
- Domestic fisheries policy challenges need better regulations.
- Quality improvements within the fisheries' supply chain need continuing support from the government.

- The implementation of environmental regulations for the protection of aquatic resources needs to be enforced.
- Competition (or conflicts) in water use occur at different levels:
 - (i) transboundary effects on countries sharing the Mekong River;
 - (ii) among provinces within the Mekong Delta of Vietnam and
 - (iii) between sectoral users (urban versus rural, industrial versus agricultural, production and domestic consumption of clean water).
- There is a need to introduce integrated water resource management in the Mekong Delta to address the issue of conflicts over the use of water. This integration principle requires changes in policy-making procedures supporting the decentralisation of the administration to a lower level, strengthening the role of local communities in planning and managing resources (most important. .
- There is a need to verify and clarify land use for agricultural and fishery production in the Mekong region, by the use of land use certificates and land accumulation procedures.

Priority Research Needs

The chapters in this report have highlighted priorities for further research. These include:

Floods and Salinity Management

- Impact assessment of *hydropower dams* upstream, considering cumulative and synergistic impacts, on the downstream hydrology, ecology and livelihoods.
- Environmental impact assessments of *full-flood protection dykes* upstream and downstream within the Mekong Delta.
- Effects of *global warming* scenarios on water and land resources, and human activities in the Mekong Delta.
- Production of flooding and salinity *hazard maps*.
- *Instituting multi-purpose* water management.
- Impact assessment of *over-exploitation of ground water resources* on land depression in the coastal areas or arsenic contamination in the Mekong Delta.
- Conservation of *wetland ecosystems* in the Mekong Delta.
- There is a research gap on *transboundary water cooperation on environmental problems*, rather than only technical problems.

Livelihood and Resource Use Strategies

- *Adopt community-based approaches* to natural resources management and livelihood improvement of the local poor.

- Adopt strategies to strengthen the *asset base* of the rural poor aiming at poverty alleviation and sustainable development

Fisheries

The report has revealed gaps in research, with respect to regional transboundary management challenges, supply chain management for regional and global trade, and further development of domestic policies related to transboundary issues, prioritising the following two:

- Measures for a better *regional policy integration* of fisheries ecology, transboundary sources of aquaculture feed, and for the improvement of transboundary trade of aquatic products in the Delta region;
- Fisheries sustainable development by appropriate *chain policy, supply chain quality management, and value chain analysis*.

Water Use and Competition

- Improvement of *water productivity* in rice farming and aquaculture for sustaining high income from production systems and safeguarding the environment.
- Determine spatial and temporal *patterns of salinity intrusion* and determinants in the context of water resource developments in upstream countries.
- Maximising the *economic value of water* in reducing environmental impacts, moving to improved livelihoods of the poor and ensuring national food security.
- Putting in place *incentives for farmers* to save water in agriculture and aquaculture.
- *Developing mechanisms* (cooperation, participation, coordination) for secure and equitable water access and use at local and delta scales.

Overall Research Priorities for Sumernet

The Sumernet programme will in all likelihood begin to address many of these problems with priorities including studies of changes in the *flood situation* in the upper Mekong Delta (Cambodia and Vietnam) and their *impacts on livelihoods*; exploring the role and effectiveness of *community organisations* in coping and responding to environmental changes and other risks and *promoting sustainable fisheries development* potentially through value chain analysis of the Mekong Delta with an emphasis on regional linkages.

Authors



Dr. Bach Tan Sinh

Dr Sinh is a Acting Director at the Department of Science Policy Studies, National Institute for Science and Technology Policy and Strategy Studies (NISTPASS), Ministry of Science and Technology (MOST).

After completing a Bachelor of Science degree in Precision Mechanical Engineering at Ilmenau University, Germany, and a Master of Science in Science and Technology Policy at Lund University, Sweden, in 1998 Dr. Sinh obtained his PhD. in Environmental Social Science at Aalborg University, Denmark. Over the course of his career he has also had many visiting appointments at various universities in Europe, North America, Hong Kong and Australia.

Dr. Sinh has more than fifteen years experience in policy analysis in the field of sustainable development, environmental protection and innovation in Vietnam, including a good understanding and experience in analysing institutional frameworks and capacity building in regard to sustainable development, environmental management and community resource management. He has been a national consultant in a number of development and environment projects in Vietnam and, most recently, Dr. Sinh has been carrying out research on civil society in general and on NGOs in particular in Vietnam.

He has been involved during the period 1996-1998 as the coordinator of the Sustainable Development Planning Network of the Ministry of Planning and Investment, established in the framework of the UNDP supported project 'Strengthening National Capabilities to Integrate the Environment into Investment Decisions'. 'Throughout the implementation of the project, he has managed the Programme on Sustainable Development Planning- the MPI's informal network which provides platforms for informal discussion on institutional aspects of sustainable development planning in Vietnam. This network has successfully played an instrumental role in overcoming the formal administrative barriers among different stakeholders and actors involved in development planning in Vietnam, and also led a number of studies on institutional barriers to sustainable development planning in Vietnam.



Dr. Chu Thai Hoanh,

Dr. Chu Thai Hoanh is a Senior Water Resources Specialist having joined the International Water Management Institute (IWMI) in 2003. He holds a Ph.D. in Agricultural and Environmental Sciences from the International Institute for Aerospace and Earth Sciences (ITC) and Wageningen University in the Netherlands. He has 35 years of experience in research and management with wide and varied subjects in GIS and modelling for agriculture and water management, including hydraulic modelling, crop modelling, optimization, supply-demand analysis, climate change scenarios. He joined the International Rice Research Institute (IRRI) in 1997 for research for rice and shrimp production in the coastal area, regional and national balancing of rice supply and demand, and developing optimization model for land use planning with many case studies in India, Malaysia, Philippines, Thailand and Vietnam. In 2001, he was awarded a medal by the Ministry of Agriculture and Rural Development of Vietnam in recognition of his contribution to agriculture and rural development. At present he is the consulting specialist on climate change for the Mekong River Commission (MRC), and the research coordinator of Sumernet, the Sustainable Mekong Research Network funded by Sida.



Dr. Dang Kieu Nhan

Dr. Dang Kieu Nhan's current position is Researcher at the Mekong Delta Development Research Institute, at Can Tho University, Vietnam, where his major themes include water quality management and agricultural systems.

After studying for a Bachelor of Science in Agronomy at Can Tho University, a Master of Science in Water Resources Engineering at K.U. Leuven and V.U. Brussels, Belgium, Dr. Nhan obtained his Doctorate degree in Aquaculture Production and Environment from Wageningen University, the Netherlands.

Most recently Dr. Nhan has participated in research with Wageningen University during 2000-2006 on 'Improving resource use efficiency in Asian integrated pond-dike systems'; and, during 2007 on 'Sustainable management of water resources' and 'Sustainable agriculture development in Mekong delta' in collaboration with Sumernet and WISDOM.



Mr. Le Anh Tuan

Mr. Le Anh Tuan has been working at Can Tho University since 1982 and currently holds the position of Senior Lecturer at Department of Environmental and Water Resources Engineering, College of Technology, Can Tho University, Vietnam.

He completed his Bachelor and Master degrees in Engineering, specialised in Water Resources Development and Management and Soil Reclamation and since 2004 up to now he is a Ph.D. candidate in Applied Biological Sciences and Engineering with a major in Environmental Hydrology and a minor in Constructed Wetland at Catholic University of Leuven, Belgium.

His extensive publications are in both English and Vietnamese languages; the most recent ones include ‘Water environmental conservation for improved livelihood in the Mekong River Delta, Vietnam’ and ‘Economic differentiation of rice and shrimp farming systems and riskiness: a case of Bac Lieu, Mekong Delta, Vietnam’.

Mr. Tuan’s teaching subjects at Can Tho University include Water Resources Planning, Meteorology - Hydrology, Disaster prevention and preparation, Waste Water Treatment Works and Rural Development Project Formulation and Analysis.



Dr. Le Than Duong

Dr. Le Than Duong has held the position of Senior Lecturer and Deputy Director of the Training and Communication Centre at Can Tho University’s Mekong Delta Development Research Institute.

After completing his Bachelor and Master degrees in Agronomy, in 2005 Dr. Duong obtained his Doctorate degree at the Tokyo University of Agriculture and Technology, Japan. His past research participation has focused on integrated farming systems, particularly in the Mekong Delta, and has examined topics such as rice-fish, rice-shrimp, deepwater rice, and sustainable farming systems.

Dr. Duong is published extensively in both English and Vietnamese languages; his most recent publications in 2007 include work on ‘Nutrient accumulation and water use efficiency of ponds in integrated agriculture-aquaculture farming systems in the Mekong Delta’ and ‘On-farm integration of freshwater agriculture and aquaculture in the Mekong Delta of Vietnam: The role of the pond and its effects on livelihoods of resource-poor farmers’. Dr. Duong also has extensive managerial experience during his career at Can Tho University, and in his work with many national and international organisations on research and development projects.



Dr. Fiona Miller

Dr. Fiona Miller has considerable experience conducting research on the social dimensions of environmental change in South and Southeast Asia, notably Vietnam and Australia. She has applied and theoretically-informed knowledge of development issues and natural resources management specialising in vulnerability, water resources management, sustainable livelihoods and community participation.

Fiona is currently a Future Generation Fellow in the School of Resource Management (Geography) at The University of Melbourne. Prior to taking up this appointment Fiona was a Research Fellow in the Risk, Livelihoods and Vulnerability Programme of the Stockholm Environment Institute from 2004-2007. During her time at SEI she was Programme Manager for the Sida-funded programme “Sustainable Recovery and Resilience Building in the Tsunami-Affected Region” and also led a number of projects within the “Poverty and Vulnerability Programme” and participated in the Sumernet programme.

Fiona has a PhD in Human Geography from the University of Sydney for her research on the political ecology of risk and society - water relations in the Mekong Delta, Vietnam. She also holds a B.A. (Hons) in geography and government. She has close to 15 years professional experience conducting research in the Asia Pacific region, and prior to joining SEI taught human geography at Macquarie University and worked with the Australian Mekong Resource Centre, Division of Geography, the University of Sydney.

Her research interests include social vulnerability, resilience, political ecology, water resources management, sustainable livelihoods and community participation. She is currently pursuing research on “Social Vulnerability to Urban Water Stresses in the Asia Pacific: Social-ecological and Political Dimensions”



Dr. Le Xuan Sinh

Dr. Le Xuan Sinh is currently Vice Head of the Department of Fisheries Economics & Management at Can Tho University, Vietnam, where he has worked since 1987.

After obtaining a Bachelor of Science in Agricultural Economics from Can Tho University and a Master of Science in Rural and Regional Development from the Asian Institute of Technology, Thailand, in 2005 Dr. Sinh obtained his Doctorate degree in Agricultural & Natural Resources Economics from the University of Sydney, Australia.

Having participated in many different research projects throughout his career, Dr. Sinh has ample experience in the management and exploitation of natural aquatic resources. During 2007 he participated as Team Leader in several research projects, including in a marketing study supporting the development of hard clam in Tra Vinh province; the Mekong Wetlands Biodiversity Project (MWBP); and, in an assessment of the social impacts of fish losses in the Omon-Xano subproject area.

Other projects Dr. Sinh has contributed to over the course of his career relate to aquaculture, household economics, market research, and rural development and planning, especially in the Mekong River Delta of Vietnam. He also has considerable skills in the organisation and implementation of field surveys, and data analysis, reporting and modelling.



Dr. Nguyen Duy Can

Dr. Nguyen Duy Can currently works at Can Tho University, Vietnam, as Lecturer and Researcher, and Deputy Director of the Mekong Delta Development Research Institute.

After completing his Bachelor of Science equivalent (Engineer of Agriculture) at Can Tho University, and his Masters of Science in Agriculture Systems at the Asian Institute of Technology in Thailand, in 1999 Dr. Can obtained his Doctorate in Agronomy from Kyushu University, Japan. He has also participated in field-work training on agricultural development and systems in the Philippines and the Netherlands. Most recently, Dr. Can worked during 2001 to 2005 as Project Coordinator of the Mekong Delta Agricultural Extension Project, supported by VVOB (Belgium); and, in 2002 as Team Leader on a Study Needs Assessment for Low-cost Post Harvest Methods in the Mekong River Delta.

Dr. Can recently co-authored with Nico Vromant two books on Participatory Technology Development and Participatory Rural Appraisal, which were published in Vietnamese in 2006.



Dr. Nguyen Hieu Trung

Dr. Nguyen Hieu Trung's current position is Vice Dean, College of Technology, Cantho University, Vietnam.

He has a Bachelor degree on Engineering (Hydraulic Construction) from Can Tho University, Masters on Geographical Information System (GIS) for Rural Development from Wageningen Agricultural University, the Netherlands, and Doctorate on Land Use Planning.

His research participation has focused on land use planning using GIS, especially in the Mekong Delta area. His most recent publications include Participatory Land Use Planning in the Mekong Delta, Vietnam, and Comparing land use planning approaches in the Mekong Delta, Vietnam.

Dr. Trung's teaching subjects at Cantho University include Technical Drawing, Hydraulic Construction and Mapping and GIS for Water and Environmental Management.



Dr. Nguyen Van Be

Dr. Nguyen Van Be's current position is Deputy Head of Research and Graduate Program, Department of Environment and Natural Resources Management, College of Agriculture, Can Tho University (CTU), Vietnam, where his major responsible courses at CTU include natural resources management and environmental impact assessment.

After completing his Bachelor from CTU, with a focus on Chemical Education, and a Master's majoring in aquaculture from Asian Institute of Technology, Thailand, he obtained a Doctorate degree, majoring in Forest Resources Management and minors in Social Forestry and Environmental Science from College of Forestry and Natural Resources, University of the Philippines Los Banos, the Philippines.

Dr. Be has extensive work experience in different countries. Currently, besides his lecturer position at CTU, he is the National Project Coordinator of the Project on 'CTU and University of Aarhus Link in Environmental Science (CAULES Project)' and Environmental Specialist, Member of Project Management Unit (PMU) of the project on 'Building a model for community based environmental management and protection in 4th ward, Vi Thanh town, Hau Giang province'.



Dr. Nguyen Van Sanh

Dr. Nguyen Van Sanh currently holds the position of Senior lecturer and Deputy Director of the Mekong Delta Research Development Institute at Can Tho University, Vietnam.

After completing a Bachelor degree majoring in crop sciences at Can Tho University, Vietnam, and a Master of Science in Agricultural Systems from the Asian Institute of Technology, Thailand, in 2003 Dr. Sanh obtained his Doctorate degree in Policy in Rural and Agricultural Economic Development from Arkansas University, USA, with his thesis 'Community Capacity Building for Poverty Reduction in Mekong Delta'.

Dr. Sanh's research background has revolved around themes such as community based natural resource management, community capacity building, and poverty reduction, particularly in the Mekong region. His most current research has involved participating in 2005 in 'Livestock-based farming systems' with the Department for Research Cooperation (SAREC), and contributing as main author on 'Tra vinh Improvement Livelihoods' with the Canadian International Development Agency (CIDA).

Over his career Dr. Sanh has authored and co-authored literature relating to areas such as flood control mitigation, poverty reduction, and community development for forest resource management; and to date has been published in four books relating to various development issues.



Dr. Simon Bush

Dr. Bush is currently Assistant Professor of the Environmental Policy Group at Wageningen University, the Netherlands, where he has worked since 2005. Prior to this position, Dr. Bush worked for five years in the Mekong River Basin countries as a freelance fisheries social scientist, and in 2000 at the Australian Mekong Resource Centre in Sydney, Australia.

In 2005 Dr. Bush obtained his Doctorate from the School of Geosciences at the University of Sydney, Australia, with his thesis on 'A political ecology of living aquatic resources in Lao PDR'.

Currently, Dr. Bush is participating in research on 'Governance and policy for rebuilding resilience of coastal populations and aquatic resources: habitats, biodiversity and sustainable use options (RESCOPAR)' in Vietnam and Indonesia; plus facilitating the Environmental Research Network in Asia (ERNASIA); and, is also Research Coordinator for the Environmental Policy Group at Wageningen University.

Previous projects Dr. Bush has contributed to include 'Living aquatic resources trade and marketing' for the Xe Kong River Basin Management Project for the World Wide Fund for Nature in Lao PDR; 'Market access and value added production for small-scale fishers in the Lower Mekong Basin', for Oxfam America in Cambodia; and, in 'Fish Marketing Review of the Lower Mekong Basin - Lao PDR, Cambodia, Vietnam, Thailand -Assessment of Mekong Fisheries ComponentI' for the Mekong River Commission in Lao PDR.



Dr. Tran Thanh Be

Director, Mekong Delta Development Research Institute (Mekong Delta)

Dr. Tran Thanh Be was born in 1955 in a rural family in Soc Trang, a coastal province of the Mekong Delta (Mekong Delta), Vietnam. He started his career, junior tutor and researcher at Faculty of Agriculture, Can Tho University (CTU) in 1978 - on his graduation of BSc in Agronomy at the university. Dr. Be was a research fellow, 1986-88, at the Cuban Agriculture University in the Soviet Union and then a trainee of a short Training and Technology Transfer Course (T3C) at the International Rice Research Institute (IRRI) in 1990. His MSc degree in Systems Agriculture, studying the sustainability of integrated rice-shrimp farming systems in the Mekong Delta, was awarded in 1994 by the University of Western Sydney - Hawkesbury (Australia). Mr Be has been promoted Deputy Director of the Mekong Delta Farming Systems Research and Development Institute (Mekong DeltaFSI) since 1996 and became a senior lecturer of CTU in 2001. Dr Tran Thanh Be was re-appointed as Director of the Mekong Delta Development Research Institute (Mekong DeltaI, former Mekong DeltaFSI) at CTU in March 2007 for the second 5-year term. He was promoted to this position in 2002 after his completion of Doctorate program under the Department of Agricultural Economics at the University of Sydney with the thesis entitled *"Agricultural Extension in Vietnam: Alternative Institutional Arrangements"*.

Dr Be has been involved in research and lecturing on Rice Sciences and Production, Farming Systems, Extension, and Rural Development. He has supervised several BSc, MSc and PhD students, including international. He has given lectures in short training courses on Training Skills, Participatory Rural Appraisal (PRA), Extension Methodology, Plant Variety Policy.... to local staff and farmers. A lot of his time has been offered to the rural people, in particular the poor, in the Mekong Delta through research and/or development projects. Currently Dr Be is the principal researcher of studies on *"Impacts of changes in farming systems on livelihoods of the local people in the Mekong Delta"*, *"Bio-fertiliser for rice production"*, *"Khmer people in the Mekong Delta: customs and development"*, and advisor for the Mekong Delta Agricultural Extension project (VVOB funded) and Community-based Biodiversity Development and Conservation (CBDC) project (SEARICE funded), those are being implemented by Mekong DeltaI teams in collaboration with local people and organizations.

Dr Be has been involved in scientific councils of CTU and a couple of provinces in the Mekong Delta. He has been invited to chair several sessions of international conferences, workshops. Some of his research papers have been published in

international journals, books, including “*Economic characteristics of extensive shrimp farms in the Mekong Delta*”, “*An optimising budget model for resource allocation in a provincial extension system in Vietnam*”, “*Economic issues in promoting sustainable shrimp farming: A case study of the rice-shrimp system in the Mekong Delta*”, “*Extension services and market integration of small farmers: Case studies of INVE and VN-Dutch Lady in Vietnam*”.



Dr. Vo Thi Thanh Loc

Dr. Vo Thi Thanh Loc currently works at the Mekong Delta Development Research Institute at Can Tho University, Vietnam.

After completing her Bachelor degree in Agricultural Economics at Cantho University, and a Master degree from the Asian Institute of Technology, Thailand, in 2006 Dr. Loc obtained her Doctorate in ‘Management and Organization - Fisheries Quality Management’ in the Netherlands.

Most recently Dr. Loc has participated in research on ‘Quality management implementation framework in shrimp supply chain in the Mekong Delta’ and ‘Research on transboundary challenges for fisheries policy in the Mekong Delta, Vietnam: implications for economic growth and food security’.

Over her career Dr. Loc has contributed to much research on marketing and agricultural supply chains. This research relates to themes such as fish and shrimp production and markets, rural credit agriculture, rice cost and farm-household income, sample evaluation of past compensation and resettlement of irrigation projects, and industrial products.

Dr. Loc also has much experience in writing project proposals regarding many economic, agricultural and aquacultural aspects; project implementation and supervision; designing questionnaires; collecting, processing, analysing and integrating research data; and, has over ten years experience of International Relations activities for Can Tho University.

Sumernet Partners



Centre for Biodiversity and Indigenous Knowledge (CBIK)

CBIK is a non-profit membership organization based in Kunming, Yunnan province of P.R. China. It has more than 100 members from different institutions including research professionals, development practitioners and resource managers. CBIK focuses on biodiversity conservation and community development through projects in social, economic and environmental development with emphasis on the relevance of indigenous knowledge to resource management at community and watershed levels. It regards ethnic minorities as socio-cultural assets in the development process as these are knowledgeable conservationists of both biological diversity, as well as the nurturing of diverse landscapes. The future of these ethnic minorities depends on the sustainable development of their livelihood, cultures and biodiversity. Thus CBIK seeks to enable local groups to strengthen their evolving cultural traditions as well as generate innovative ways to improve their livelihoods and enhance biodiversity through interdisciplinary research, capacity building and participatory approaches that nurture intercultural dialogue among people of varying local and scientific cultures, languages and knowledge systems in Southwest China.

www.cbik.org or www.cbik.ac.cn



The Environmental Research Institute (ERI)

ERI is a department within the Science Technology and Environment Agency (STEA) in Lao PDR, which started to work as a separate entity in 2000. Its research program is intended to lead to long term protection and development of the nation's natural resources, and thereby contribute to sustainable development and a higher quality of life for the Lao people. The institute has four centres and one division, and has four main functions: to conduct research on sustainable use of natural resources (specifically water and biological resources), on implementation of environmental policy and regulations and on the technology of pollution prevention and control; to undertake environmental quality monitoring at the national level as well as being the third-party monitoring body; to compile environmental data, formulating the State of Environment Report of Lao PDR and publishing environmental indicators; to build capacity of Lao staff in the environmental field through short-term courses. ERI also carries out environmental quality inspections and provides testing facilities and services such as GIS and water quality testing. Furthermore, the institute is the focal point of the Stockholm Convention on Persistent Organic Pollutants and East Asia Acid deposition.

www.stea.gov.la



National Agriculture and Forestry Research Institute (NAFRI)

NAFRI is based in Vientiane, Laos, and operates under the supervision of the Ministry of Agriculture and Forestry (MAF). NAFRI undertakes integrated agriculture, forestry and fisheries adaptive research in order to provide technical information, technical norms and results for agriculture, forestry, and fisheries development strategy formulation in accordance with the Lao government policy. NAFRI's mandate also include the implementation of natural resources assessments and socio-economic studies within agriculture, forestry, livestock, and fisheries in order to support land-use master plans and development of agriculture, forestry, and fisheries production, in accordance with the potential of agro-ecological zone. In addition, NAFRI manages the production and provision of information on agriculture, forestry, livestock and fisheries production techniques and technologies for implementation of government priority programs of line department. The institute also undertakes adaptive research on local feed resources, forages and fodder trees, use of feed from local available resources and manufactured feed to improve small holders' livestock and fisheries production and processing of livestock and fisheries products for domestic consumption and future export. Furthermore, NAFRI contributes to the development of norms and regulations, and extension policies with the organization involved.

www.nafri.org.la



Institute for Science and Technology Policy and Strategy Studies (NISTPASS)

NISTPASS is a Vietnamese government research institute based in Hanoi under the Ministry of Science and Technology. NISTPASS' major functions are to conduct research on various issues regarding Science and Technology (S&T) policy and strategy, in order to assist the government in formulating S&T development strategies. The Institute's main tasks include conducting research on theoretical and practical issues of S&T based on sustainable development in Vietnam and implement forecasts and foresights on development trends in S&T; carry out studies on the role of R&D, technology innovation and promotion in socioeconomic development; research the environmental and social impacts of economic development and S&T development projects; and research theoretical and practical issues related to the legal framework of S&T activities. In addition, NISTPASS provides post graduate programs in S&T poli, cooperates with research and training organisation, businesses, S&T associations and individuals in order to provide S&T consultancy and advisory services and also publish outreach material.

www.nistpass.gov.vn



Can Tho University (CTU)

CTU is among the leading universities in Vietnam. Over the years CTU has built a broad network of international cooperation and established linkages with many major international organizations, as well as training and research institutes worldwide. CTU has an excellent reputation among international academic institutions for its realistic approach to training, scientific research, and technology transfer activities. The international cooperation at CTU comprises many facets: cooperation with international organizations and governments; twinning programs with universities and research institutes; and the sharing knowledge with other institutions. CTU has agreements of collaboration with many universities, research institutions such as IRRI, ICRISAT, etc.; and UN organizations, namely FAO, UNDP, etc.; and many NGOs. Through these collaboration projects, CTU has secured much of the needed equipment for its instruction and research, more international expertise, and more scholarships for its staff to do their graduate studies. CTU shares its expertise with neighbouring countries. For instance, CTU is helping Laos to improve food production in The South of Laos. CTU is also innovative in developing new concepts in training as well as new approaches in doing research and is always striving to achieve quality in all of its academic programs. The university offers training programs leading to Bachelor, Master and Ph.D. degrees in various fields. Presently, there are more than 15,500 students at Can Tho University with an additional 14, 500 studying at satellite training centres in the provinces.

www.ctu.edu.vn



Chulalongkorn University (CU)

CU is the first institution of higher learning in Thailand; it has eighteen faculties and a number of schools, institutes and projects, which are engaging in teaching and other related activities. At the Faculty of Economics at Chulalongkorn University, the principal objective is to undertake activities that promote the economic and social development of Thailand. The faculty has established links with many organisations to bridge the gap between academic knowledge and the everyday world. It has also promoted intellectual endeavour, exchange programmes, training and inter-disciplinary studies that have strengthened the Faculty's overall capacity to produce professional Economists with various and practical approaches. The Centre for Ecological Economics (CEE) was established in the Faculty of Economics in 1995 to encourage academic research work both at the theoretical and empirical levels. The focus of the research is two-fold; methodological and policy relevance. It is also the aim of the Centre to contribute to the on-going discussion on global environmental issues; such as, climate change, biodiversity conservation and the use of economic instruments.

www.chula.ac.th



The United Nations Environment Programme (UNEP)

UNEP aims to provide leadership and encourage partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations. In the Asia-Pacific Region, UNEP's Division of Early Warning and Assessment (DEWA) is implemented through the facility of UNEP Regional Resource Centre for Asia and Pacific (RRC.AP), which is situated within the Asian Institute of Technology (AIT) in Bangkok, Thailand. AIT is an international graduate institution of higher learning with a mission to develop highly qualified and committed professionals that will play a leading role in the sustainable development of the region and its integration into the global economy. RRC.AP envisions being the key agency to service the needs on environment data and information in the region. Towards this goal, RRC.AP's three necessary elements for implementation include: the establishment of a collaborative assessment network; technical backstopping on information technology for the network and data archiving dissemination; and assistance with State of the Environment reports (SoE's) at national, sub-regional, regional and global levels, as well as the establishment of knowledge base as emerging issues of concern. At present, RRC.AP is focusing on four early warning issues including glacial lake outbursts and flooding (GLOF), water, land cover and air. In addition RRC.AP produces assessment reports and develops Early Warning Systems.

www.rrcap.unep.org



Fishery Actions Coalition Network (FACT)

FACT is a coalition of NGOs working on fisheries and environmental issues around the Tonle Sap Lake. The main focus of FACT activities is to build the capacity of independent community leaders and strengthen grassroots organizations in order for them to advocate to the government and donors on issues that affect their livelihoods. FACT continues to help local people liaise with the government through providing a forum where local people can meet government, donors and media. At the same time, FACT involves in gathering information on fisheries issues, collecting facts and information, analyzing it and distributing it to government, line agencies and donors in supports of community efforts in order to influence decision makers and policy makers. FACT also advocates government and donors to explore alternatives for fishing communities in order to improve their livelihoods. FACT is guided by a vision, which is based on the value and importance of fisheries for the food security of rural people. FACT seeks to participate in further building up and developing good governance in fisheries management where people can access to fisheries resources to have enough food for their day to day living; where local fishing communities voices are integrated into decision-making and policy

formulation; which fisheries resources are used and managed in a sustainable way for the benefit of present and future generations; where local people have equal access to fisheries resources and are supported to attain their social, political and economic rights and enhance their quality of lives; where fisheries resources are not for just economic benefit but also for local people. FACT also involved in the research and documentation on the fisheries and environmental issues that affect the fishing communities and the environment of Tonle Sap Lake.

www.fact.org.kh



World Conservation Union (IUCN)

IUCN was founded in 1948 and is today the world's oldest and largest global conservation body, as well as a multi-cultural and multilingual organisation. IUCN has a global network of experts, and 1000 staff located in 62 different countries with headquarters in Switzerland. The organisation has helped over 75 countries to prepare and implement national conservation and biodiversity strategies and action plans, and develop and adopt legal and institutional policies related to environment management. The IUCN Asia Region was established in 1999 and covers 23 countries. The secretariat of IUCN in Asia comprises several programme and management components that play an integrated role in working towards the IUCN's goals in Asia. These include the following:

- Ecosystems, habitats and species are conserved and rehabilitated, as a basic need for the present population and as a basic right for future generations.
- Natural resources are used and managed on an equitable and sustainable basis within and among nations, communities and gender groups, contributing to increased solidarity, poverty alleviation and improved human well-being.

The Asia Regional Office (ARO) corporate services and core central functions, provides a co-ordinating, integrating, and support structure for the region. ARO, in close collaboration with the Membership Unit at HQ, also coordinates Membership and constituency related matters, many of which are directly handled at the country level. A number of regional level initiatives in emerging thematic areas are developed and co-ordinated in ARO by the Emerging and Emergency Programmes (EEP) or a focal point person at regional or country level.

www.iucn.org/places/asia



The Mekong River Commission (MRC)

MRC was established in 1995 by the Agreement on The Cooperation for The Sustainable Development of The Mekong River Basin. The MRC member countries are Cambodia, Lao PDR, Thailand and Vietnam. In addition, MRC maintains regular dialogue with the two upper states of the Mekong River Basin, China and Myanmar. MRC seeks to promote and co-ordinate sustainable management and development of water and related resources for its member countries' mutual benefit and their people's well-being by implementing strategic programmes and activities and providing scientific information and policy advice. The MRC member countries agree to co-operate in all fields of sustainable development, utilisation, management and conservation of the water and related resources of the Mekong River Basin, such as navigation, flood control, fisheries, agriculture, hydropower and environmental protection. The MRC consists of three permanent bodies: the Council, the Joint Committee (JC), and the Secretariat and the National Mekong Committees (NMCs). The Council makes policy decisions and provides other necessary guidance, whereas the Joint Committee is responsible for the implementation of the policies and decisions of the Council and supervises the activities of the Mekong River Commission Secretariat. The MRC Secretariat is the operational arm of the MRC that provides technical and administrative services to the Council and the Joint Committee. The National Mekong Committees represent the main points of contact between the MRC and the governments of its member states. In each country, the NMCs are the main coordinating bodies of MRC programmes and policies at the national level.

www.mrcmekong.org



International of Water Management Institute (IWMI)

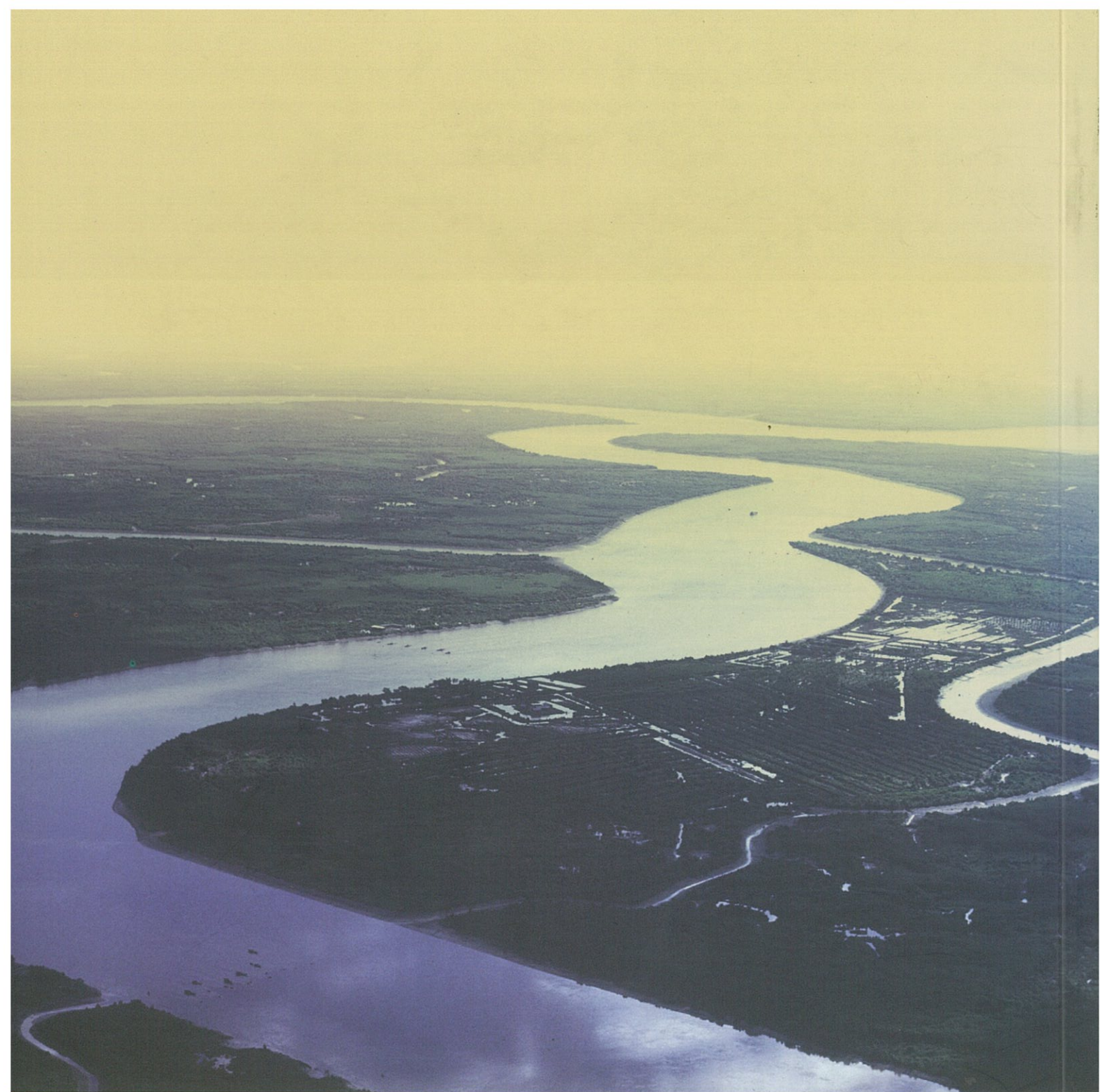
IWMI is a non-profit scientific organization funded by the Consultative Group on International Agricultural Research (CGIAR). The Institute concentrates on water and related land management challenges faced by poor rural communities. The challenges are those that affect their nutrition, livelihoods and health, as well as the integrity of environmental services on which these depend. IWMI works through collaborative research with partners in the North and South, to develop tools and practices to help developing countries eradicate poverty and better manage their water and land resources. The immediate target groups of IWMI's research include the scientific community, policy makers, project implementers and individual farmers.

www.iwmi.cgiar.org



Stockholm Environment Institute (SEI)

SEI is an independent, international research institute specializing in sustainable development issues at local, national, regional and global policy levels. SEI's mission is to support decision-making and induce change towards sustainable development around the world by providing integrative knowledge that bridges science and policy in the field of environment and development and contributing to the capacities of different societies. The Institute was established in 1989 following an initiative by the Swedish Government to develop an international environment/development research organisation. Since then SEI has established a global reputation as an honest broker in its handling of complex environmental and social issues, as a research institution committed to rigorous and objective scientific analyses in support of improved public policies, and as an agent of creative change in seeking global transitions to a more sustainable world. Running through SEI programmes and efforts is an uncompromising commitment to high ethical standards for the conduct of research and the provision of policy advice. The SEI approach is highly collaborative and participatory; involving partners in the regions of research both to incorporate local knowledge and values in the analysis and to build the capacities of regional institutions and researchers. SEI's work includes new assessment practices, tools, and departures from existing policies and approaches. SEI has centres in Sweden, the United Kingdom, Estonia the United States, and most recently an Asia Centre in Thailand (SEI-A); the initial presence in Bangkok was established in 2000 to assist ADB in decision making in its regional economic co-operation programme for the region. The decision of the SEI Board to establish SEI's fifth research centre in Bangkok envisages the development of the Sustainable Mekong Programme.



The Sustainable Mekong Research Network (Sumernet)

The Sumernet Secretariat

15th Floor, Witthyakit Building, 254, Chulalongkorn University

Chulalongkorn Soi 64, Phyathai Road

Pathumwan, Bangkok 10330 Thailand

Tel: +66 (0)2 2514415-8 Fax: +66 (0)2 2514419 www.sumernet.org

