ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF RICE-SHRIMP FARMING: COMPANION MODELLING CASE STUDY IN BAC LIEU PROVINCE, MEKONG DELTA, VIETNAM

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นาย ลี ชาน ดุง : ผลกระทบด้านสิ่งแวดล้อมและด้านเศรษฐกิจ-สังคมของการทำนาข้าว-นากุ้งแบบบูรณาการ: กรณีศึกษาแบบจำลองเพื่อนคู่คิดในจังหวัดบาคลิว สันดอนแม่น้ำโขง ประเทศเวียตนาม
(ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF INTEGRATED RICE-SHRIMP FARMING: COMPANION MODELLING CASE STUDY IN BAC LIEU PROVINCE, MEKONG DELTA, VIETNAM) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ,
อ.ที่ปรึกษาวิทยานิพนธ์ร่วม : จู ไท ฮวน, Ph.D.; คริสตอฟ เลอ พาจ, Ph.D, 158หน้า

ในปัจจุบันได้มีข้อวิกฤตความขัดแย้ง 3 ประการ อาทิเช่นความต้องการน้ำ ศักยภาพสำหรับความยากจนสูงสุดที่สามารถปรับได้ตามความแตกต่างทางเศรษฐกิจ และศักยภาพผลกระทบของการเกิดดินเค็มที่มีต่อการผลิตข้าวในระบบนาข้าว-นากุ้ง วิทยานิพนธ์นี้จึงมีวัตถุประสงค์เพื่อเข้าใจความขัดแย้งการใช้ที่ดินและคุณภาพน้ำระหว่างนาข้าวกับนากุ้งได้ดีขึ้น
การตอบสนองส่วนบุคคลที่
ปรับตัวต่อสภาพทางกายภาพ-ชีวภาพ และสังคมและความแตกต่างทางเศรษฐกิจในจังหวัดบาคลิว สันดอนแม่น้ำโขง ประเทศเวียตนาม โดยใช้หลักการแบบจำลองเพื่อนคู่คิด (ComMod) ซึ่งประกอบด้วยการเล่นเกมบทบาทสมมุติ (RPG) และแบบจำลองภาคี (ABM) ในการศึกษานี้การเล่นเกมบทบาทสมมุติสองครั้งและการสร้างแบบจำลองภาคีชื่อ RiceShrimpMD ABM ได้ดำเนินการร่วมกันระหว่างนักวิจัยและผู้มีส่วนร่วมในช่วงปี ค.ศ. 2006-2009
บทเรียนที่ได้รับจากการเล่นเกมบทบาทสมมุติและผลลัพธ์จากการจำลองสถานการณ์ 5 ปีด้วยแบบจำลอง RiceShrimpMD ABM แสดงว่าความขัดแย้งของความต้องการน้ำต่อการทำนาข้าวและนากุ้งเกิดขึ้นเมื่อทั้งการทำนาข้าวและนากุ้งเกิดขึ้นในเวลาและในพื้นที่เดียวกันหลังจากเดือนกันยายนซึ่งเป็นเวลาที่เริ่มปลูกข้าว
ในบริเวณปลายน้ำของจังหวัดนี้พบความขัดแย้งมากกว่าเมื่อสถานการณ์ในช่วงเวลาเริ่มแรกมีความเค็มของน้ำมากกว่า 5 ppt เกิดขึ้นในเดือนธันวาคมและไม่มีกระบวนการเตรียมสภาพแวดล้อมที่เหมาะสมต่อการทำนาข้าว ในประเด็นความยากจนสูงสุดบ่งชี้ว่าต้นทุนครัวเรือนสะสมและความแตกต่างทางเศรษฐกิจเกิดขึ้นเมื่อชาวบ้านเพิกเฉยต่อการทำนาข้าวหรือนากุ้งเพียงชนิดเดียวโดยไม่สนใจต่อวิธีการทำโดยเฉพาะอย่างยิ่งบริเวณปลายน้ำ
เช่นนาข้าวจะได้รับผลผลิตต่ำกว่าที่ควรเมื่อเทียบผลผลิตในปีน้ำที่ไม่ขาดน้ำ
แต่อย่างไรก็ตามผลกระทบสิ่งแวดล้อมที่เกิดขึ้นไม่รุนแรงต่อผลผลิตข้าวที่เกิดขึ้นทุกปี

สาขาวิชา เทคโนโลยีการเกษตร

ลายมือชื่ออ.

ปีการศึกษา 2551 ลายมือชื่ออ.

ทีปรึกษาร่วม……………………………………...

ลายมือชื่ออ.

4873891723 : MAJOR AGRICULTURAL TECHNOLOGY
KEYWORDS: CONFLICT / ECONOMIC DIFFERENTIATION / EXTREME POVERTY / SALINIZATION / COMPANION MODELLING

LE CANH DUNG : ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF INTEGRATED RICE-SHRIMP FARMING: COMPANION MODELLING CASE STUDY IN BAC LIEU PROVINCE, MEKONG DELTA, VIETNAM. ADVISOR: ASSC. PROF. NANTANA GAJASENI, Ph.D., CO-ADVISOR : CHU THAI HOANH, Ph.D. CHRISTOPHE LE PAGE, Ph.D., 158 pp.

Currently, there are three critical issues of conflict over water demand, the potential for extreme poverty coupled with economic differentiation, and the potential effect of soil salinization on rice production in rice-shrimp farming systems. The thesis aims to better understand conflicts on land use and water quality between rice and shrimp culture, individual's responses coping with bio-physical and social conditions, and economic differentiation in Bac Lieu province, Mekong Delta, Vietnam by using Companion Modelling (ComMod) approach including role playing game (RPG) and agent-based model (ABM). In the study, two successive RPG sessions and a RiceShrimpMD ABM were co-constructed between researchers and local involved stakeholders over the period 2006-2009. Lessons learned from the RPGs and five-year simulation results of the RiceShrimpMD ABM show that conflict over water demand for rice and shrimp crop occurs when both rice and shrimp crops coexist in the same period within a plot after September, which is the proposed time to start rice crops. In downstream locations of the province, more conflicts occurred in the scenario where earlier salinity over 5ppt was provided in December and without any application for serving appropriate environmental conditions on rice crop. In case of extreme poverty, it also indicates that accumulated household capital and economic differentiation occurred whenever people had less concern to practice rice in rice-shrimp farming system , especially in the downstream location; rice yield reduced a bit due to the effects of salinization, compared to normal yield in the drought-free year. However, this environmental impact can be avoided as rice crops are annually practiced. Income obtained from rice crop is an essential compensation to reduce extreme poverty in a household.

Therefore, sustainable agricultural development in Bac Lieu province is likely a dynamic process that is challenged by a wide range of biophysical and socio-economic factors at both the macro level of policy makers and water management schemes to the micro level of household decision making. Extreme poverty coupled with economic differentiation is also challenging for future sustainability. This study is confident that the companion modeling approach is an appropriate methodology for opening opportunity to all relevant stakeholders to share their knowledge of and a dialogue on water demand, enhancing better understanding of and collaboration on water management issues for sustainable development.

Field of Study: Agricultural Technology Student's signature...

Advisor's signature...

Academic Year 2008 Co-Advisor's signature......................................

Co-Advisor's signature......................................

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LIST OF ABBREVIATIONS

ABM	Agent-Based Model
ASS	Acid Sulfate Soils
AVG	Average
BL	Bac Lieu province
BMP	Best Management Practices
BPC	Bac Lieu People Committee
CIRAD	French Agricultural Research Centre for International Development
ComMod	Companion Modeling
CORMAS	Common-pool Resources and Multi-Agent Systems
CPWF	Challenge Program on Water and Food
C_p	Potential Conflict Index
CTU	Can Tho University
DAI	Distributed Artificial Intelligence
DFID	UK Department for International Development
FAO	Food and Agriculture Organization of the United Nations
G	Gini index
GDP	Gross Domestic Product
GIS	Geography Information System
GNI	Gross National Income
GR	Gia Rai district
GREEN	Management of renewable resources and environment
GSO	General Statistical Office (of Viet Nam)
HD	Hong Dan district
HH	Household
IBM	Individual-Based Model
IRMC	Integrated Resource Mapping Center
IRRI	International Rice Research Institute
KIP	Key Informant Panel
MAS	Multi-Agent Systems

MD	Mekong Delta
MDI	Mekong Delta Development Research Institute
ODD	Overview-Design Concepts-Details
PN	Project Number
ppt	Part Per Thousand
PT	Phong Thanh village
RF	Weekly probability of shrimp disease-free
RI	Increment risk probability
RPG	Role Playing Game
RT	Tabulation of accumulative probability of shrimp disease
RW	Weekly risk probability
RiceShrimpMD	Agent-Based Model of Integrated Rice-Shrimp farming in the MD
S	Scenario
SE	South East
UML	Unified Modeling Language
USD	United State Dollar
USDA	United States Department of Agriculture
WB	World Bank
WCED	World Commission on Environment and Development
VL	Vinh Loc village
VND	Vietnamese Dong (Vietnamese currency unit)

CHAPTER 1

INTRODUCTION

1.1 RESEARCH CONTEXT

Vietnam has experienced a great reform in economic development, particularly in the agriculture sector since reformations in 1986. The de-collectivization of agriculture and the liberalization of agricultural markets (Phuc, 2006) were the key contributors to agricultural growth and in turn national economic development. The enactment of land law in 1988, and its revision in 1993 in the de-collectivization process, has allowed for the privatization of long-term land use ownership, which allows individual agricultural households to autonomously decide on land use patterns, investment and intensity degrees (Boothroyd et al., 2000; Toan et al., 2003).

Inadequacies sometimes exist as a result of the privatization of land use ownership and its existence alongside short or medium-term land use planning strategies that are set by various state level bodies. Individual households make their preferred land use decisions in accordance with the privatization process, regardless of common land use planning for a certain region. Conflicts over the use of common resources that serve agricultural/aquacultural production have emerged as a consequence of the different preferences between private individuals and the majority who follow common land use planning strategies. Following Ribot (2004), decentralization has not been a stand-alone panacea for natural resource management, especially in the coastal region of the Mekong Delta (MD), Vietnam. Here the land use is diverse, quickly shifting and strongly contrasting both in resources used and in economic profitability and environmental sustainability (Trung et al., 2006).

In connection to land use dynamics in the Mekong Delta as driven by economic forces, contrasting trends of rice and aquacultural land development over the last decade have been observed. Cultivated rice land developed up to the coastal region, reaching a peak of 3.985 million hectares in 1999 (GSO, 2006). Rice cultivation dropped after policy objectives shifted from the production of rice at any cost to relative competition of land use efficiency in the early 2000s. Aquacultural land recently scaled up to 0.63 million hectares, accounting for 20% of total agricultural land in the MD (GSO, 2006; White, 2002); in particular, shrimp land— mostly in the coastal region— increased greatly up to 330,000 ha in 2005.

After nearly a decade of competing objectives for land use and natural resource exploitation in Bac Lieu coastal province in the MD, different farming systems have been practiced in different corresponding land use zones in accordance with research since 2002 (Gallop et al., 2003; Hoanh et al., 2003; Hossain et al., 2006; Khiem et al., 2007; Tuong et al., 2002). Integrated rice-shrimp farming systems in downstream communities have tended to shift into shrimp monoculture systems due to economic profitability. Issues of unsustainable development have emerged as a result of this tendency to practice shrimp monoculture pattern in the province.

The increasing of shrimp farming area in the coastal region, and in particular the encroachment of shrimp monoculture on rice land, has led to conflict over water demands for rice and shrimp production, especially in mixed farming areas. Water conflicts occur between rice and shrimp farmers within the same community or between upstream and downstream communities, especially when both are using a common infrastructure of water supply. Water conflicts can escalate and become a social conflict if no proper mechanism to manage the situation is in place; this can be seen as an element of unsustainability.

In addition, shrimp monoculture itself can be a highly vulnerable production system due to bearing high risk and causing environmental impact. The high risk might cause shrimp producers to extreme poverty while saline water inundation for shrimp culture without proper farming techniques might cause soil salinization. The combination of water conflict between rice and shrimp farmers, potential extreme poverty and soil salinization in shrimp monoculture are three important elements that highlight the unsustainable farming practices in the province.

Water conflicts can be minimized by increasing the farmers' and other relevant institutional authorities' knowledge of sustainable development and management of natural resources in the province, a crucial mean in lessening the seriousness of the problems. The participatory companion modeling approach (Bousquet et al., 2005a), which has been recently applied for all relevant stakeholders reaching a better understanding and collecting learning on natural resource management, was considered a good approach for minimizing water conflicts and was thus selected to deal with unsustainable development in Bac Lieu province over the 2005-2008 period. This research is a case study under the framework of a research project entitled: "Companion modelling for resilient water management: Stakeholders' perceptions of water dynamics and collective learning at the catchment scale" coding CPWF PN#25.

1.2 RESEARCH QUESTION

With the awareness that environmental, social and economic components are three crucial constitutive dimensions of sustainability, the research question is "Do conflict, potential extreme poverty and soil salinization threaten sustainable agricultural development of the coastal area in Bac Lieu province?"

1.3 RESEARCH PROBLEMS

Sustainable development, as defined by the World Commission on Environment and Development (WCED), is composed of three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. However, the three components as defined by the WCED are in shortage in Bac Lieu province's agriculture. This research is therefore an attempt to study three problems that are challenging sustainable agricultural development in the province: (i) conflict over water demanded by rice and shrimp farmers; (ii) risk leading to potential extreme poverty of farmers who cultivate shrimp monoculture; (iii) potential effect of soil salinization on rice production in rice-shrimp farming systems.

1.4 RESEARCH OBJECTIVE

The general objective of this research is to attempt an innovative methodology of Companion Modelling (ComMod) on land and water resource management through which it provides farmers and local institutional authorities a better understanding and knowledge of sustainable development that would lead them to manage and practice sustainable farming in the coastal area of Bac Lieu province. To reach this general objective, three specific objectives as follow should be met.

(1) To better understand conflicts arising from the water demanded by rice and shrimp farmers within the community and between upstream and down-stream communities who are using a common irrigation system. To reach this objective, the innovative ComMod is used to provide a platform for sharing opinion, dialogue on water demand between rice and shrimp farmers within village and between villages

(2) To investigate factors leading to extreme poverty and economic differentiation among household in a community of upstream and downstream villages where different levels of integrated rice-shrimp farming practiced.

(3) To build a shared representation of potential salinization effects on rice yields using local knowledge.

. As long as these three specific objectives are reached, farmers and local institutional authorities would have a better knowledge and perception of the potential damage caused by shrimp monoculture system if practiced over the long term. A better knowledge and perception would significantly contribute to changes in behavior and action, encouraging local people to consider seeking sustainable agricultural development.

1.5 CONCEPTUAL FRAMEWORK

The problem of agriculture development in Bac Lieu province is the increase of unsustainable land use pattern of shrimp monoculture in a large area, which has been scientifically allocated for the practice of integrated rice-shrimp farming. Three apparent corollaries of the problem have been determined. The first is the emergence of conflicts over water demanded by rice and shrimp farmers within the community or from upstream and downstream communities. The potential for social conflict is real, unless there is better collaboration and coordination among farmers and various relevant stakeholders in regards to land use and water supply. The second is the emergence of potential extreme poverty, as well as economic differentiation as a result of the risk associated with large scale practice of shrimp monoculture. The third is potential soil salinization arising from the fields being inundated with saline water when shrimp monoculture is practiced year-round.

A better coordination of land use and water supply and collaboration among farmers and relevant stakeholders is a sound approach to minimize the conflict. In this case, understanding the water demands of each party within the production systems can be reached; it would facilitate a dialogue, as well as negotiation, among those seeking an equitable water supply scheme founded on compromise. On the other hand, the conflict would be eliminated if only one farming system was practiced and the other disappeared. In light of sustainable development both in ecological and economic terms, the practice of integrated rice-shrimp farming system is encouraged, while the shrimp monoculture should be banned due to its potential vulnerability.

There is no way to convince farmers to reject the practice of shrimp monoculture pattern farming unless they are equipped with the knowledge of how vulnerable shrimp monoculture pattern farming can be if practiced in the long term. Farmers should think about the trade off between high levels of income that come with the high risks associated with shrimp monoculture, and moderate income levels that can be attained with low risk integrated rice-shrimp farming. The knowledge to equip farmers would stem not only from observations of interactions among different participants in the common platform of role playing games (RPGs) but also more importantly from the consequences that are the result of individual farming decisions made in an RPG. Through an RPG, knowledge is acquired through the principles of 'learning by doing' and the exploration of cause-effect relationships by the farmers themselves.

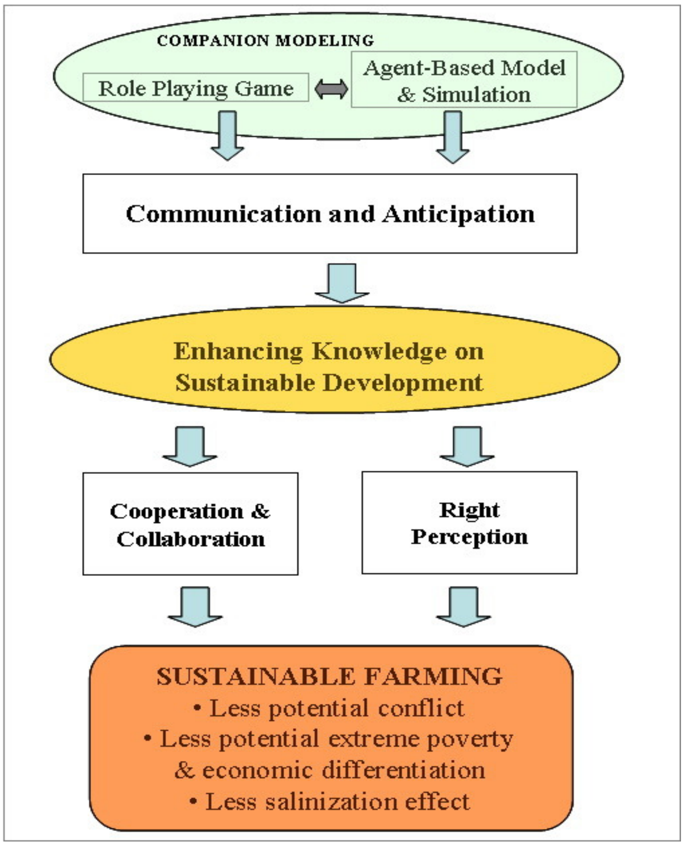


Figure 1.1 Research Conceptual Framework

RPGs can equip the farmers and relevant stakeholders with knowledge of the potential vulnerability of shrimp monoculture pattern farming in the short term (one year), which would be equivalent to one gaming session. What would be the consequence of shrimp monoculture five or ten years in the future, based on the farmers decisions made in the present time? This would be answered through agent-based model (ABM) simulation, in which simulation outputs are based on examining individual farmer agents' farming decision making and their interaction with the biophysical and ecological environmental conditions in Bac Lieu province. Farmers will be completely convinced to practice a more sustainable farming system once they have the chance to consider the trade off between the economic returns of two different farming systems upon the simulation. So, the ABM simulation would contribute an anticipation function of natural resource-based production systems. The conceptual framework of this research is defined and illustrated in figure 1.1.

RPGs and ABM simulations, two key tools in the Companion Modeling (ComMod) approach, are proposed for application in this case study. Besides the two primary charters of understanding complexity of a certain system and facilitating a better management of natural resource use in that system, the ComMod in this case study would strengthen the understanding of the system through the anticipation function of an ABM simulation.

1.6 OUTLINE OF THESIS

The body of this dissertation is composed of eight chapters. Titles and brief content of the chapters are introduced as follows:

Chapter 1: Introduction. This chapter introduces the research context, research problems, objectives, conceptual framework, methodology and thesis outline.

Chapter 2: Literature Review. This chapter presents condensed knowledge on a number of topics relevant to the research, including participatory modeling, the Companion Modeling approach, characteristics of Vietnam and Mekong Delta agricultural development, conflict issues, economic differentiation and salinization.

Chapter 3: Methodology. This chapter presents the research process of ComMod and other supportive tools applied in the research.

Chapter 4: Facilitating Dialogue between Aquaculture and Agriculture: Lessons from Role-Playing Games with Farmers in the Mekong Delta, Vietnam. This chapter is a published article in the journal namely Water Policy, which introduces results and lessons learnt from the first participatory gaming workshop organized in selected locations in Bac Lieu province.

Chapter 5: Role Playing Games for Social Learning on Rice-Shrimp Farming in Bac Lieu Province, Mekong Delta, Viet Nam. This chapter presents lessons in social learning obtained from the second gaming workshop.

Chapter 6: The RiceShrimpMD Agent-Based Model. This chapter describes a basic Agent-Based Model of rice and shrimp farming that is co-constructed with local farmers and institutional authorities. Structure, association among entities and parameters used in the model are presented.

Chapter 7: Simulation of Environmental and Socio-economic Impacts of Integrated Rice-shrimp Farming in Bac Lieu Province, Mekong Delta, Vietnam. Scenarios of different water management schemes and various values of parameters are input into the RiceShrimpMD Agent-Based Model for simulation. Simulated results are analyzed and discussed.

Chapter 8: Conclusions and Recommendations. This chapter summarizes the analytical results of the research through which optimal solutions on water management and sustainable farming practices are proposed to local farmers and institutional authorities.

CHAPTER 2

LITERATURE REVIEW

2.1 AGRICULTURAL LAND USED IN THE MEKONG DELTA

2.1.1 Natural characteristics of the Mekong Delta

Vietnam is a country located in Southeast Asia, which borders China in the north, Laos and Cambodia in the west and the China Sea in the south and the east. Vietnam has a total land area of 331,211.6 km^2 and a coastline of 3,260 km. Over 70 percent of Vietnam's land area consists of mountainous or hilly terrain while less than 30 percent of the total area is utilized for agriculture. With a population of 85,154,900, Vietnam is quite densely populated: 257 people per km^2 (GSO, 2008).

The country is categorized by the World Bank as a lower middle-income country with Gross National Income (GNI) equaling 790 USD (< 1,887 USD) in 2007 (WB, 2008). Presently, agriculture is still an important sector in the national economy. Agriculture, forestry & fisheries make up a 20.3 percent of GDP and 72.56 percent of the total population live in rural areas (GSO, 2008), where their livelihoods still primarily rely on agriculture and natural resource exploitation.

Mekong Delta in the Southern tip of Vietnam is located at latitude $8^o33'$ to $10^o55'$N and longitude $104^o30'$ to $106^o50'$E. The Mekong Delta extends from the border of Cambodia to the Gulf of Thailand and the East Sea. The delta occupies 39,000 km^2 accounting for 12 percent of national land, of which more than 31,200 ha are used for agriculture (Figure 2.1). This is a flat plain with an average elevation of 0.5 to 1.5 m above the mean sea level. The Mekong Delta includes one city and 12 provinces, namely: Long An, Tien Giang, Dong Thap, Ben Tre, Vinh Long, Tra Vinh, Soc Trang, Can Tho city, Hau Giang, An Giang, Kien Giang, Bac Lieu and Ca Mau.

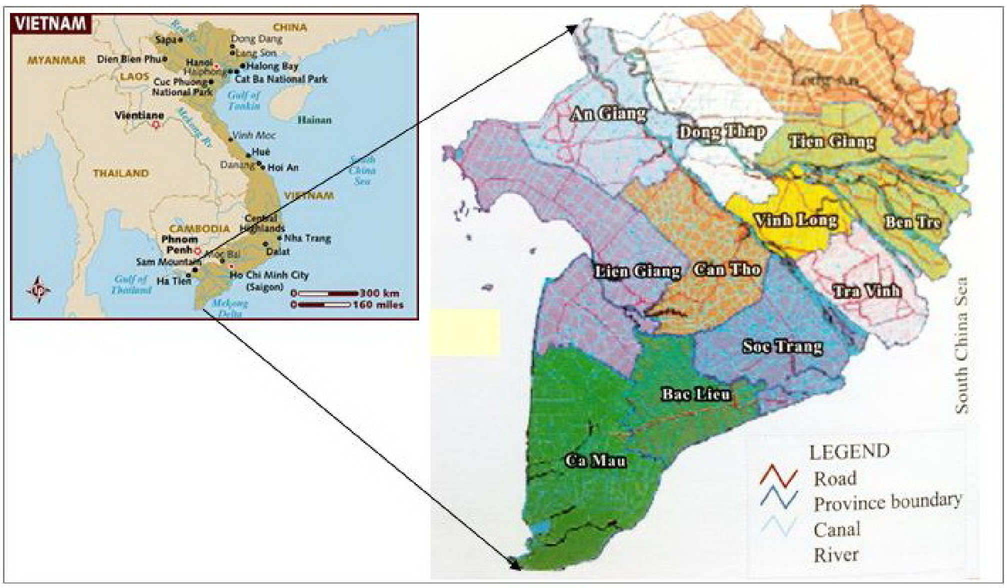


Figure 2.1 Location of the Mekong Delta in the Southern Viet Nam

2.1.2 Socio-economic characteristics of the Mekong Delta

The Mekong Delta is well known as the most favorable region for agriculture and aquaculture development in the country. It plays a very important role in the socio-economic development strategy of Viet Nam, as well as being a main key for food security and export. It produces more than 50 percent of rice, 60 percent of fish, and 80 percent of fruit products in Vietnam. More than 80 percent of exported rice comes from the delta and the delta shared 27 percent of Vietnam's total GDP (Be et al., 2007). The Delta's population is almost 17 million: 22 percent of the national population (Be et al., 2007; Ni et al., 2002).

Acid sulphate soil—the dominant type of soil in the Mekong Delta— accounted for 1.6 million hectares, followed by alluvium soil (1.1 million ha) and saline soil (0.8 million ha). Annual rainfall in the delta is around 1,700 mm. Soil and hydrology are the major physical criteria used to determine the six agro-ecological zones in the delta, of which the fresh water alluvial zone occupies the largest area with 900,000 ha. It is followed by Ca Mau peninsula with 800,000 ha and the coastal zone of 600,000 ha (Xuan et al., 1998).

There has been a great change in the Mekong Delta's economic structure towards increasing the size of the industrial and service sectors; however, agriculture has still played an important role in local people's livelihoods. Agriculture still makes up a large proportion of total GDP in the delta even though it reduced dramatically from 60.8% in 1995 to 47.81% in 2004 (Be et al., 2007).

As for land use change in the delta, rice land reached a peak in 2000 and declined soon after; this was a consequence of policy shifting from one of rice production at any cost in the 1990s to relative competition of land used efficiency in early 2000s. Presently land devoted to rice production equals 1.85 million ha, a dominant 57.6 percent of total agricultural land. However, more of the rice production land is being used for the purposes of aquaculture and urbanization.

2.1.3 Land used dynamics in the Mekong Delta

Perceiving the potential of aquaculture in the delta (GSO, 2006; White, 2002), the Vietnamese government has promoted diversification in agriculture since 1999, aiming to increase the contribution of aquaculture to its economic growth. Therefore, aquaculture has increased significantly for economic reasons and becomes the second largest proportion of land use in the delta, occupying 0.63 million hectares and 20 percent of total agricultural land. Among the types of species being raised in aquaculture, shrimp is a key economic species in aquaculture practice. It was promoted by the five-year aquaculture plan of the Vietnamese Government with a targeted expansion from production areas of 226,407 ha in 1999 to 330,000 ha in 2005 (Wilder et al., 2002). The aquaculture area increased rapidly up to 717,500 ha in 2007 (GSO, 2008), with most expansion taking place in the coastal provinces of Ca Mau, Bac Lieu, Kien Giang and Tra Vinh. Consequently, rice and aquaculture production, especially brackish water shrimp, are two predominant products in the Mekong Delta.

With the expansion of rice land and increase in aquacultural land areas, conflicts have emerged relating to the various land use and water quality demands made by different resource users in the delta. Conflict in this context can be considered as interest incompatibility or livelihood loss among various resource users, which has existed among communities or regions. Currently, tension has risen in the coastal zone due to the demand for differing water quality made by rice and shrimp producers. Changes in water quality and resource exploitation together have created a serious problem for people who have primarily relied on natural resources in the coastal area for their livelihoods, and a loss of such livelihoods has been observed.

Shrimp monoculture is risky in an economic sense; it is affected by environmental conditions and economic differentiation, which are both constraints of sustainable agriculture in the coastal zone (de Haan and van Ittersum, 1999; Hoanh and Roetter, 1998) as cited in Trung (2004). Naturally, the coastal zone has a distinguished habitat like mangrove forests, which are also highly vulnerable in the agro-ecosystem. Even the water has dynamic conditions with multiple uses and values for crop and shrimp production, as well as fishing. On the one hand, crop farming needs freshwater for farming activity, while shrimp aquaculture needs brackish water for its farming activity. But the wetland ecosystem in the delta requires different land and water resources, making water resource management more complex (Gowing et al., 2006a).

Along with flooding, salinity intrusion is the second major natural phenomena that annually occur in different areas of the delta. While flooding does not cause much constraint to agriculture development in coastal region, salinity has significantly affected production and local people's livelihood in this region. About 2.1 million hectares of coastal zone are affected by salinity intrusion during the dry season (from December to May) (Tuan et al., 2007). The cost of the damage caused by saline intrusion is difficult to quantify. Soil salinization 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 gm per liter. Vegetable and other crops are scarce in the affected area during the period of saline intrusion.

Salinity, however, has a positive effect for reducing acidity in potential acid sulphate soil land according to Tinh (1999) cited in Tuan (2007). Moreover, saline and brackish water is considered by coastal shrimp producers to be a positive occurrence for their livelihood (Miller, 2003) whereas it is considered damaging by crop producers in the coastal zone. To restrict saline water intrusion, a number of measures were studied and invested. Estuary dike systems, canal embankment systems, pumping stations and sluices have been built over time, especially in the 1990s when the policy of promoting rice production remained. The systems were built not only to protect the area against saline water intrusion but also to preserve fresh water for production and domestic use. Therefore, opposing demands for the type of water needed have arisen among fresh water based farming producers and saline water based farming producers. Bac Lieu province in the coastal zone is a typical case of this kind of conflict (Hoanh et al., 2003; Kam et al., 2001; Tuong et al., 2002) .

2.2 LAND USE IN BAC LIEU PROVINCE

2.2.1 Natural characteristics of Bac Lieu province

Bac Lieu is a coastal province located on the Ca Mau peninsula of the Mekong Delta. Its natural land size is 2,582.46 km^2 and consists of six administrative units including five districts (Hoa Binh, Vinh Loi, Hong Dan, Gia Rai, Dong Hai) and one town (Bac Lieu). The province's population is 819,000 people; 75% of the people live in rural areas and are engaged in agricultural, aquacultural and fishing activities (2007). The province has a tropical monsoon climate with distinct dry (mid-November to April) and rainy (May to mid-November) seasons. It is predominantly a floodplain and generally flat, with micro-topographical differences occurring between river and canal levees and pockets of inland swamps. The soils are generally young and of alluvial origin, and heavy textured. About 60% of the province area is covered by acid sulfate soils (ASS), mostly occupying low-lying areas in the western parts of the area, of which about 40% is shallow ASS, having the sulphuric layer within a 50-cm depth as found by Breemen and Pons (1978). Soils in the eastern parts are predominantly alluvial and saline types according to Ve (1988) and IRMC (2000), as cited in Tuong (2002). Annual rainfall in the province ranges from 2,000 to 2,300 mm and the average temperature is 26^{o}C with 2,500 to 2,600 sunny hours annually. The province is also affected by drought that influences rice production in late period of rainy season. Drought in this case means that during late wet season (from October to December) the rainy season is terminated earlier than usually through which rice production can be damaged due to deficiency of water supply. The frequency of drought—as recorded by two major research sites/stations in Gia Rai and Hong Dan districts—is presented in Table 2.1.

Normally, the province does not directly suffer from floods, but it is strongly affected by daily and bi-daily saline tidal activity from the West and East Seas, respectively.

The province has dense canal systems serving agriculture and aquaculture production; there are a number of big canals, namely Quan Lo – Phung Hiep, Canh Den, Pho Sinh and Gia Rai. Land in the province is primarily devoted to aquaculture and salt production, occupying 120,714 ha and accounting for 47 percent of total land, followed by 98,309 ha of rice land, which accounts for 38 percent of total land (BPC, 2008).

Table 2.1 Frequency of drought/early ended rain occurrences (1997-2007)

Period	In Gia Rai station (%)	In Ngan Dua station (%)	Accumulative frequency of drought occurrence in Gia Rai station (%)
Before 20 October	7.3	19.2	7.3
21 to 30 October	32.3	7.7	39.6
01 – 10 November	28.2	34.6	**67.8**
11 – 20 November	19.8	23.1	87.6
21 – 30 November	0	11.5	87.6
01 – 10 December	0	3.8	87.6
After 10 December	12.4	0	100
Total	100	100	

Source: Bac Lieu Province Meteorological Center

2.2.2 Land use dynamics in Bac Lieu province

There have been great changes in land use over the last decade following changes in rice and aquacultural production policy. In the mid 1990s, under a policy promoting rice production, rice land in the province increased up to a peak of more than 131 thousand hectares. However, the land devoted for rice production reduced when global rice demand declined. Rice land was then replaced for the purposes of aquacultural production, especially the production of black tiger shrimp (*Penaeus monodon*) after the year 2000 thanks to a policy of value export and technological innovations in shrimp culture (Figure 2.2). The disparity between high value earnings from shrimp exports over rice earnings (Figure 2.3) was critical in the change of provincial policy, as well as the change in local producers' perceptions of land use in the province.

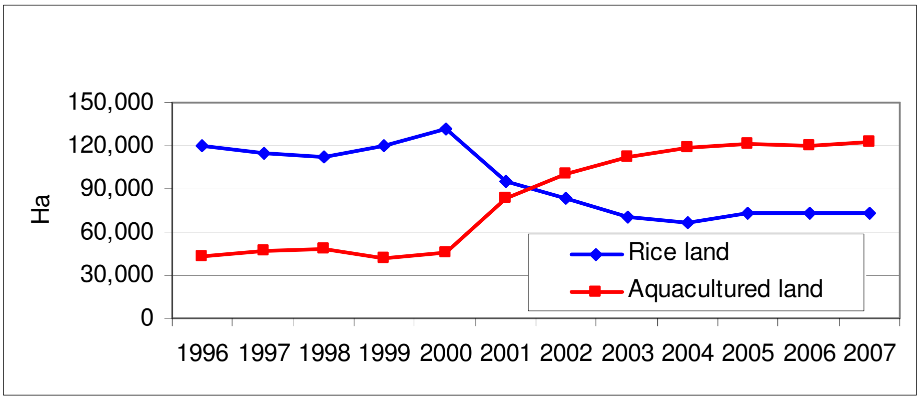
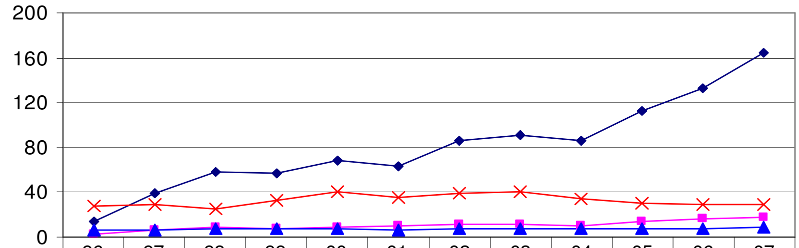


Figure 2.2 Rice and shrimp production land use trends in Bac Lieu province

Source: General Information of Bac Lieu Province

To promote the policy of rice production during the period 1994-2000, the government made a huge effort to install sluice systems to prevent seawater intrusion into the Ca Mau Peninsula. After completion, two rice crops per year have been able to grow in irrigated areas behind the sluices as a result of the decrease of salinity ingress into the area behind the floodgates and an increase in the flow of freshwater from the Bassac River during the dry season. However, not all the stakeholders in the saline water protected area have benefited from this intervention; rice farmers have experienced low rice productivity in unfavorable acid sulphate soil land and other environmental problems.



	96	97	98	99	00	01	02	03	04	05	06	07
Ex. shrimp ($US Mil.)	15	39	58	57	68	64	86	91	87	112	133	165
Ex. shrimp (1,000 Ton)	2	6	8	8	9	10	12	11	11	14	16	18
Price of shrimp ($ US.kg-1)	6	7	7	7	8	6	7	8	8	8	8	9
Price of shrimp/ milled rice (time)	28	29	25	33	40	35	39	41	34	30	29	29

Figure 2.3 Comparative figures of rice and shrimp exports in Bac Lieu province

Source: General Information of Bac Lieu Province

2.2.3 Revision of production policy and land use zoning

As stated by Kam (2001), Tuong (2003) within the DFID-R7467c project, implementation of policy for the promotion of rice production has come with the heavy costs of environmental degradation and livelihood deterioration for many poor people. These poor people's livelihoods have relied primarily on shrimp culture and fishing through river and canal systems in areas now lacking saline water, a consequence of rice production policy that has prevented salinity intrusion (Hossain et al., 2006). Conflicts among stakeholders, including rice farmers, shrimp farmers and fishermen have occurred for economic reasons. The conflict reached a peak in February 2001 when farmers destroyed a major dam at Lang Tram to get salt water flow in the region for better shrimp production.

With an awareness of how sustainability can be threatened by poor management of economic factors and social conflict, provincial authorities have adjusted land use plans since 2002 by moving away from monoculture rice production to shrimp and rice-shrimp culture (Hoanh et al., 2003). Using the same hardware of sluice and dike systems built previously for saline water prevention, the water management has been changed accordingly to satisfy both fresh water and saline water based farming. A new land use zoning and accompanying flexible water management schemes were scientifically developed in the collaborative CPWF PN#10 research project (Jackson, 2004).

Consequently, at present there are six distinct zones with different land use patterns recommended that have been adopted by local people. (Figures 2.4 & 2.5). By using a temporary dam as seen in figure 4, zones 4, 5 and 6—which are mainly characterized by alluvial soil in the eastern part—are absolutely prevented from saline water intrusion. Rice and upland crop patterns are practiced using fresh water provided by the Mekong River through the Quan Lo Phung Hiep canal. Zones 1, 2 and 3 in the western part—predominantly containing acid sulphate soil—have been adopted for seasonal rotation of rice and shrimp farming. A flexible water management scheme which carries fresh water in wet seasons and saline water in dry seasons has been set up and controlled by local government to satisfy both rice and shrimp farmers. In the western part, however, there is a big gap between recommended land use patterns and actual farming practice. A number of issues have arisen: conflicts over water demanded between upstream (zone 1) and down stream (zone 3) villagers using the same canal system; the high risks associated with shrimp monoculture; and economic differentiation among the zones. These problems threaten sustainable development in the province. An in-depth study of the above issues is needed.

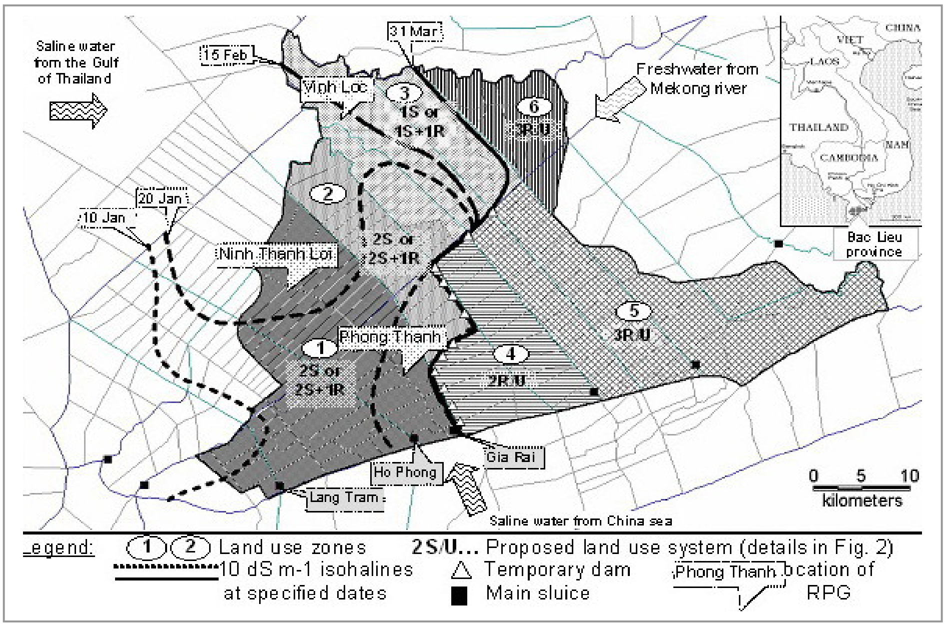


Figure 2.4 Six different land-use zones after 2002 in Bac Lieu province

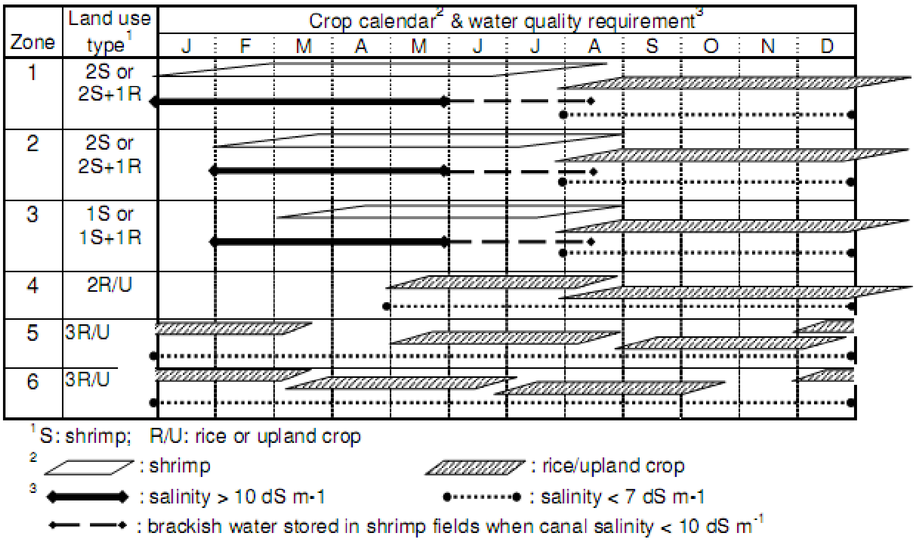


Figure 2.5 Proposed farming systems corresponding to six land-use zones

2.2.4 Water management schemes before and after production policy revision

Saline water is a key factor directly affecting rice and shrimp production in the province. Since 1994, there have been three saline water supply schemes corresponding to three provincial production policies. Before 1998, a scheme for the natural intrusion of saline water without any intervention was drawn up, whereby sea water could intrude some ten kilometers up into the main canal and to upstream areas in dry season. Shrimp culture and catching could be practiced in swamp lands. Rice could be cultivated in wet seasons in highly elevated areas. The second intervention period from 1998 to 2002 fully prevented saline water intrusion with a dyke system and limited intrusion inland. Whole areas beyond the dyke system remained in fresh water conditions, enabling rice production that served state policies for food security and rice export. This intervention caused changes that negatively impacted upon local livelihoods; accordingly, policy revisions were promptly made in 2002. Policy revision promoted the co-production of rice and shrimp in the province, and the water supply scheme has since been controlled by a sluice system. Saline water is provided in dry seasons for shrimp cultivation. In the wet season, farmers in the area can produce rice using rainfall and fresh water from Mekong River. Characteristics of the three saline water supply schemes since 1994 are presented in figure 2.6.

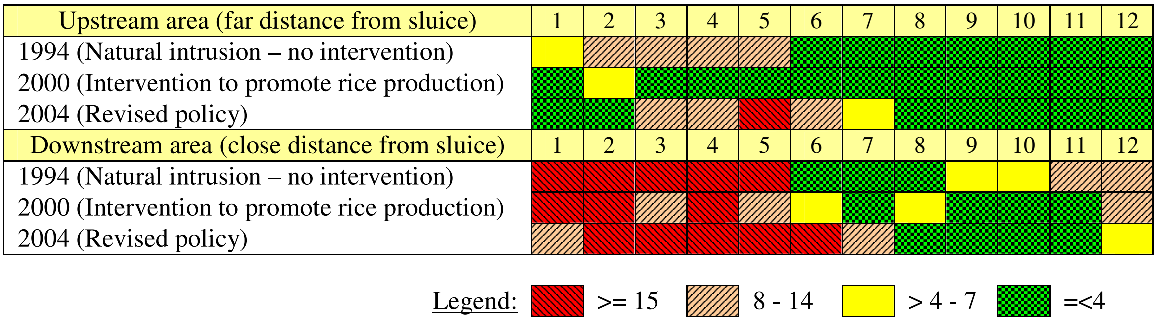


Figure 2.6 Salinity strata of water schemes provided by three production policies

In downstream area, recent water salinity is provided lately as compared with that in the past, usually from late December to early January in order to ensure shrimp crop can be cultured but salinity is not damaged rice crop if rice is practiced in this area. In the other hand, duration of salinity less than 4 ppt in downstream area is long enough, from August to the end of November, for rice crop if it practiced. For the upstream area, recently, after 2004, the saline water higher than 8 ppt is prolonged at least for 4 months that can permit one crop of shrimp to be cultured. This salinity is come lately in March, so it is good for rice crop in this area to fully harvest without damaged from salinity.

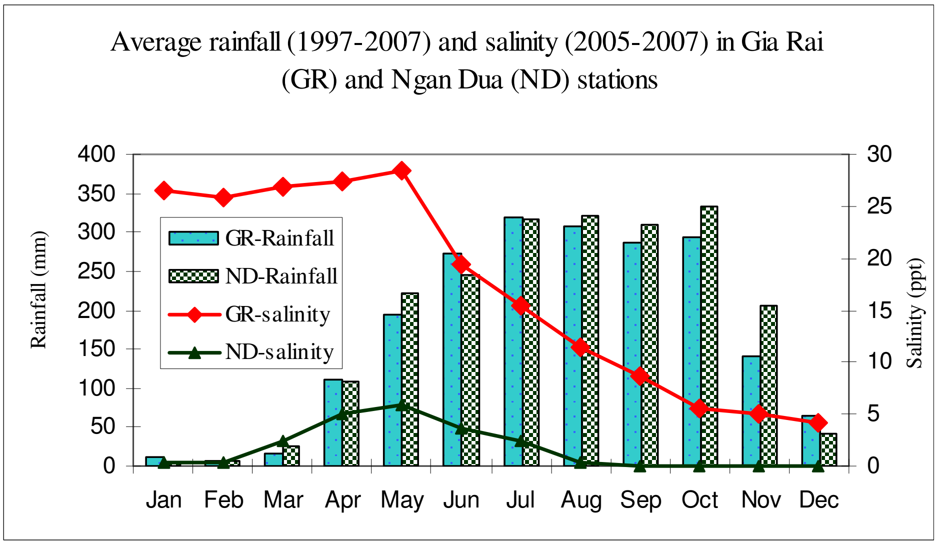


Figure 2.7 Rainfall and salinity in recent years in two key stations in Bac Lieu province

The figure 2.7 is presenting average salinity pattern over last three years (2005-2007) and average rainfall over last ten years (1997-2007) for both upstream (Hong Dan district) and downstream area (Gia Rai district) in the study site. These salinity and rainfall patterns would be favorable for shrimp and rice crop successively cultivated in dry and wet season in

2.3 LOCAL KNOWLEDGE INTEGRATION

2.3.1 Conflicts

2.3.1.1 Conflict definition

Conflict is a phenomenon that commonly occurs among parties involved in natural resource management, especially in the management of common resources. In general conflict is defined as a disagreement through which the parties involved perceive a threat to their needs, interests or concerns (Webne-Behrman, 1998). Conflicts can occur when a party perceives that there is a threat to their needs, interests or concerns as a consequence of a disagreement with the other parties in a context. The conflicts over the use of a common resource are situations of competition and potential disagreement between two or more stakeholder groups who are exploiting scarce resource. In this dimension, there are four categories of conflicts and trade-offs between stakeholders at macro-macro, macro-micro, micro-macro and micro-micro levels (Grimble et al., 1996).

2.3.1.2 Conflicts over land and water resource use in Bac Lieu province

Water is the most crucial natural resource for life. Inequitable access to water is a major cause of conflicts in many communities, regions and even nations who are mainly reliant on a common supply of water resource for living and agriculture. When such conflicts are not addressed appropriately, it may lead to a breakdown in social institutions or even threaten society and sustainable development.

In the Mekong Delta of Vietnam where land and water resource are crucial for the agricultural sector, water management conflict is largely a consequence of different and competing land uses that all require the shared use of a common water resource.

Uncertainty about future land use objectives, land resources and exploitation technologies also cause conflicts (Trung et al., 2004). In this sense, conflicts over land use between agriculture and aquaculture farmers are typical in the coastal region of the Mekong Delta. For instance, farmers have perceived that the salinity prevention measures have caused a decline in the abundance of natural fishery products in rivers and canals, which are the major sources of income for the landless. In stark contrast, those same measures are good for land owning stakeholders who can develop rice and other fresh water based farming. As more sluices became operational—a measure to protect against saline intrusion—the change in hydrological conditions in the coastal region has progressively impacted local people's livelihoods and consequently conflicts over the operations of sluices have arisen (Tuong et al., 2002; White, 2002).

In Bac Lieu coastal province, conflicts over agriculture and aquaculture development have typically occurred between those who seek short-term financial gain and practice the potentially lucrative but vulnerable shrimp farming and those who practice integrated rice and shrimp farming systems for long term sustainable development; between people whose livelihood is based on an intensification of agriculture/aquaculture and environmental impacts (Gowing et al., 2006b). In other coastal regions in Bangladesh and Thailand, similar conflicts have occurred between producers of low-salinity shrimp—which has caused soil salinization, water pollution and increased competition—and agriculture and fresh aquaculture producers (Chowdhury, 2007; Szuster, 2006). The conflicts in such coastal regions arise when economic considerations often favor the more lucrative aquaculture enterprise at the expense of rice (Primavera,1994) as cited in Kam (2001).

2.3.1.3 Resolutions for minimizing conflict

Recently, the creative Integrated Natural Resources Management (INRM) approach developed by the Consultative Group on International Agricultural Research (CGIAR) (2000) has been largely used for agricultural development that minimizes potential conflicts.

It is hard to eliminate conflicts completely since there are so many interactions between many dynamic factors in natural resource management; ideally then, conflicts need to be resolved or managed (Caldwell, 2000). A good way to resolve or manage conflicts is by increasing the understanding and negotiating competencies of individuals and organizations involved in natural resource uses. Conflict resolution incorporates three dimensions: substantive, procedural, and psychological, all of which must be considered in the negotiation process (Webne-Behrman, 1998). Creative problem-solving strategies are essential in creating positive approaches to conflict management. In land use planning, creating a dialogue amongst all participants to reach decisions based on consensus (Amler et al., 1999; Kibi, 2003) is a core element in resolving conflicts. Moreover, a perception of sustainability in land use planning is to be taken into account to minimize conflict, at which both socially and environmentally compatible desired by the society and technically viability to be included. Conflict is hard to annul, making it difficult to manage complex resource and satisfy each and every stakeholder's and people desires in the context. Yet, conflict can be the impetus for positive change (Caldwell, 2000).

2.3.2 Economic Differentiation

2.3.2.1 Economic differentiation as inequity component

Sustainable development—as defined by the World Commission on Environment and Development (WCED)—is composed of three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. In many indicators for measuring the three dimensions of sustainability, the Gini coefficient is an important indicator for measuring inequity of income distribution of a society, an important feature reflecting economic sustainability. The Gini indicator was developed by the Italian Statistician Corrado Gini (1912). This coefficient has been applied to topics other than income and wealth, but mostly within economics (Buchan, 2002).

2.3.2.2 Gini coefficient for measuring economic differentiation

The Gini coefficients have a value ranging from 0 for perfectly equal to 1 for perfectly unequal income distribution in a given population. This indicator is particularly relevant to the equity component of sustainable development. Income or resource distribution has direct consequences on the poverty rate of a country or region. Broadly speaking, average material welfare can be defined by the per capita Gross Domestic Product (GDP). A country can, for example, have a high per capita GDP figure, but its income distribution so skewed that the majority of people are poor. This indicator is useful both to measure changes in income inequality over time and for international comparisons.

In Vietnam, there are three methods to compute the gap between rich and poor, in which Gini is popularly used. According to the Ministry of Finance, income inequity increased during 1994 and 2004, as reflected by the increase in the Gini indicator from 0.35 to 0.423 over the period. From 1995 to 1999, 31 out of 62 provinces in Vietnam experienced increases in the inequity of income distribution by an average rate of 10% annually (Lam, 2002). Based on family consumption, the Gini indicator in Vietnam also increased from 0.34 in 1993 to 0.37 in 2004, which proved the increasing economic differentiation in the country.

The Gini indicator is one indicator used to measure inequality; it is independent of any considerations of the absolute living standards of the population under study. Therefore in using Gini to measure inequity, more is needed to understand the economic welfare of a society.

2.3.2.3 Income divergence in different land use patterns

Vietnamese rural income in general or that in the Mekong Delta in particular, is mainly reliant on agricultural activities, which are largely divergent among regions due to different resource endowment and human intervention. In the delta's Bac Lieu coastal province, rural household income has changed overtime and differs from area to area due to different land use patterns and water supply sources. In fresh water based farming system areas, average household income ranges from 1,960 to 3,362 USD per year and is mostly obtained from rice production. In the saline water areas, where shrimp culture is the dominant farming system, the income ranges between 1,610 to 3,375 USD per year. It is likely that the household income in saline water areas is more differentiated than that in the fresh water areas. A study on land use and income dynamics in the province has also recognized that household income in saline water affected areas dominated by shrimp culture is more largely divergent overtime. Risks of shrimp disease and negative environmental impacts are the main reasons of income variation in this area. On the contrary, household income in rice-based farming area was more stable over the same 2000 to 2006 period (Khiem et al., 2007).

2.3.3 Soil salinization

2.3.3.1 Soil salinization definition

Salinization is the process by which water-soluble salts accumulate in the soil. Salinization on the soil surface occurs when the following conditions occur together: the presence of soluble salts including sulfates of sodium, calcium, and magnesium; high water table; high rate of evaporation and low annual rainfall (USDA, 1998). High levels of salt in the soil have a similar effect as drought conditions by making water less available for uptake by plant roots.

There are two main salt accumulations, namely natural and anthropogenic cycles. Natural cycle means the sea water directly or indirectly influences soils and ground water, making the soil and ground water saline with salt concentrations ranging from 25 to $100 g.l^{-1}$. Anthropogenic cycle of salinization, or sodication, has numerous reasons. Mismanagement of irrigation can be a major reason, which includes a wide range of features like insufficient water application, irrigation at low efficiency, seepage from canals and water losses on the farm, and irrigation with saline water or marginal quality water without proper soils and water management and agronomic practices.

2.3.3.2 Soil salinization in selected Asian countries and in Vietnam

There are approximately 45 million hectares of salt-affected irrigated land, accounting for 19.5 percent of global irrigated land. In Asia, many countries have salt-affected land like Bangladesh (0.83 million ha), the Philippines (around 0.6 million ha), China (38.5 million ha), Thailand (3.4 million ha), Vietnam (2 million ha) and some other countries including Indonesia and Pakistan.(FAO, 2000).

Salt-affected soils in Thailand are caused both by natural phenomenon and anthropogenic soil salinization. A typical salinization caused by anthropogenic process is in the Bangpakong basin where low salinity shrimp farming has been practiced for many years (Szuster et al., 2002). The authors estimated that 9,050 m^3 of saline water is used for one ha of shrimp crop in low saline water shrimp farming. During the grow-out period of shrimp crop, the seepage of saline water in this kind of shrimp field represented 38% (11.5 tones.crop^{-1}) of salt losses, pond discharge 33% (9.7 tones.crop^{-1}), and accumulation of salt in pond sediment 6% (1.8 tones.crop^{-1}). Much of the salt in pond sediment was also exported to the canal system through tidal flushing of the ponds.

In Viet Nam the salt-affected areas that contain saline and acid sulphate soils total 4 million ha. Coastal saline soils—excluding acid sulphate soils (2.0 million ha)—occupy about 2 million ha along the coastal regions with seawater intrusion through river estuaries and creeks as the main causes of salinization. Salt-affected soils are concentrated in the two large deltas of the Red River and Mekong River. Seawater intrusion and its effects reach only 15 km in-land in the Red River delta, but can reach 40-50 km in the Mekong River delta.

Saline water intrusion in the Mekong Delta in dry seasons limits crop production, especially rice crops in coastal regions. Saline water can cause damage to rice yield when rice fields are suddenly flooded by saline water. The research on this type of effect shows that high yield rice varieties are affected by salinity in the water field such that the yield starts to reduce when salinity is higher than 2 ppt, and the yield loss 100% when salinity is at 4 ppt. For traditional rice varieties, the yield reduction displays a similar trend: 100% yield loss at 5 ppt (Hoanh, 1996). Another experiment on the effects of saline water used for irrigation showed a 100% mortality rate of rice plants occurred at 10 ppt salinity during the fourth week of saline water inundation; rice yield is reduced when the salinity is higher than 5 ppt; however, rice yield has no significant difference when irrigating it by brackish water between 2 ppt to 5 ppt (Cardenas, 1994). However, soil salinization is a gradual process that can affect crop production for 10 to 30 years (Guganesharajah et al., 2007).

2.3.3.3 The impact of soil salinization in Bac Lieu province

The western part of Bac Lieu province in the coastal region of the Mekong Delta has been delineated as a year-round rotating rice and shrimp farming system after revision of policy that sought to balance rice and shrimp production (Hoanh et al., 2003). In this rotational farming system, rice crops are planted in wet seasons after a long period of using saline water to inundate fields for shrimp production in the dry season. So far, no research into the effects of saline water inundation of fields in the dry season on rice crop yields in the wet season can be found.

However, local knowledge could bring about an understanding that by using fresh rain water and water from the Mekong River in the main rainy season to flush out salinity in the field carefully before growing rice, rice could grow well and a normal yield achieved in the year without the occurrence of drought during the growing period. Drought can seriously damage rice yield, especially when the rice crop is in the reproductive period for about ten days, usually two months after the sowing date. One of the reasons for reduced yields is that the panicle does not fully emerge from the leaf sheath (Barclay, 2005). Key informant panel (KIP) interviews indicated that rice planted in rice-shrimp fields can be damaged due to salinization in the year when two conditions occur simultaneously: (i) drought or early rain ending when rice is still standing in the field, and (ii) rice crops have never been planted in the shrimp field before (Table 2.2 and Figure 2.8). Based on provincial meteorological data (Sa, 2008), the possibility of early rain ending (drought occurrence) in downstream locations before 10th November, which is identical with rice reproductive stage (about 70 days after sowing date), is up to 67.8% (Table 2.1). The level of rice yield lost due to this kind of drought varies according to the number of years shrimp monoculture has been practiced without cultivation of rice crop. Long periods of shrimp monoculture in the shrimp field results in a higher level of rice lost due to drought, and vice versa. Therefore, cultivation of rice crops in previous years becomes an environmental remedy for rice production in the current year; it can then improve shrimp production in the following years.

In our case study, the effect of salininization/drought is therefore just significant happened in downstream location of Phong Thanh village because rice crops are not always practiced in the shrimp field implied that most households in downstream village frequently practiced shrimp monoculture. In upstream locations of Vinh Loc village— where rice crops are always practiced annually— farmers have paid enough attention to flush out salinity in the field before growing rice; therefore their rice yields are not affected by salinization/drought anymore. With the assumption that a normal yield in a year free from drought is equal to 3.5 $ton.ha^{-1}$, the function to express the rice production lost due to drought occurrence in Phong Thanh village is as follows:

$Y_d = 2.787 – 0.207X$ ($R^2 = 0.829$, $P=0.032$)

Where: Y_d: rice yield as drought occurred ($ton.ha^{-1}$)

X: years of shrimp monoculture (without prior rice crop in the field); $X > 0$

Table 2.2 Tabulation of the effects of drought associated with salinization on rice yield using local knowledge

Years of shrimp monoculture within plot	Percentage of rice yield when drought happened (Rice yield without drought happened = 100)	Corresponding rice yield Y_d (ton/ha)
0	100.00	3.50
1	70.00	2.45
5	30.00	1.05
10	10.00	0.35
15	5.00	0.18

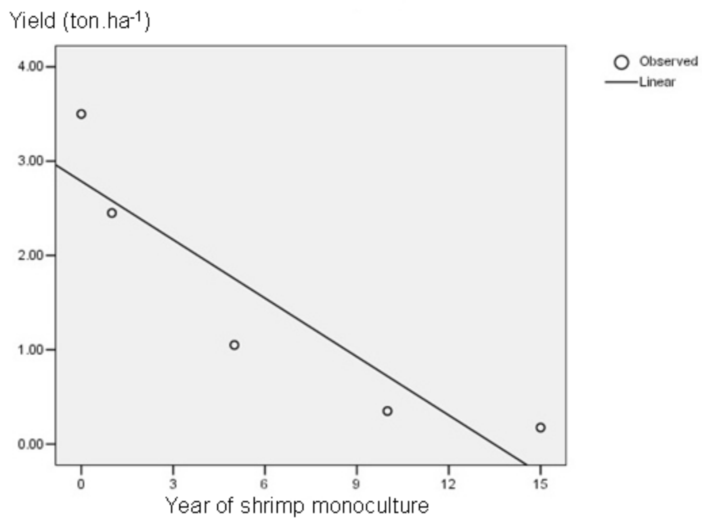


Figure 2.8 Rice yield lost as a result of drought associated with salinization

2.4 PARTICIPATORY MODELING

Nowadays, many forms of modeling like mediated modeling, conceptual modeling or participatory modeling have been used to help stakeholders improve their thinking at a social level thanks to being able to visualize the wider social and bio-physical processes that they cannot see without modeling. As a kind of participatory modeling approach, Companion Modeling is a methodology which makes use of multi-agent systems in a participatory way in fields such as sustainable resource management. The objective of companion modeling is to apply simulation tools when dealing with these complex systems in order to understand the institutions and norms that drive the interactions among actors, and consequently between actors and their environment.

2.4.1 Origin and posture of Companion Modeling (ComMod)

Management of renewable natural resource is complicated since it involves a complex interaction between biophysical and social economic factors. It is more difficult to manage the resources under common property and open access since there are numerous actors involved and complex interactions. Finding the best approach for the management of general and common property renewable natural resources in particular has been increasingly demanded. During the 1990s, a new approach entitled Companion Modeling (ComMod) dedicated to examining natural resource management issues was created by the GREEN (management of renewable resources and environment) research unit at CIRAD, France in 1993 (Trebuil, 2008). ComMod was operated based on a simulation platform called Common-pool Resources and Multi-Agent Systems (CORMAS, http://cormas.cirad.fr), which principally relies on the use of multi-agent systems (MAS) (Bousquet et al., 2005a).

No precise definition of the ComMod can be identified; rather it is a scientific posture. ComMod is a participatory modeling approach which can tackle a number of issues related to decision making processes, common property, and co-ordination among actors in the exploitation and management of renewable natural resource (Barreteau, 2003b). Two specific objectives of the ComMod are (i) understanding complex environments and (ii) supporting collective decision-making processes in that complex environment (Barreteau, 2003a; Trebuil, 2008). The approach is one of interdisciplinary action-oriented research that aims to strengthen adaptive management capacity of local communities (Bousquet et al., 2005b).

2.4.2 Key tools of Companion Modeling

The active participation of involved stakeholders in resource management is a prerequisite condition for tackling the problem in resource management. ComMod is a participatory approach that is able to create a common platform for the stakeholders to share different points of view, dialogue and negotiate problems in context. Agent-Based Models (ABM) and Role-Playing Games (RPG) are two principal tools that enable the ComMod approach to function effectively (Barreteau, 2003b; Bousquet et al., 2005a). These tools are built based on a concept of multi-agent systems (MAS), which are considered as short-lived participatory simulation tools (Bousquet et al., 2004).

MAS are computer systems composed of autonomous entities or agents (Berger, 2001). MAS come from the field of computer science—distributed artificial intelligence (DAI) to be exact—rely on the technology of cellular automata, and are based on the principles of distribution, interaction, and control (Trebuil et al., 2003). The principles of MAS are principles of collective decision-making of societies of agents that have different representations (Bousquet et al., 2004). Decision-making process of agents and interactions with social organizations in which the agents are embedded is emphasized in MAS. Regarding its usefulness, MAS has recently been used to study interactions between society and environment (Gilbert et al., 1999). As for MAS being applied to ecology, there are three major types of interactions: interactions by communication among agents, physical interactions (grow, push, eat), and interactions mediated by the environment.

MAS are also called Agent-Based Modeling (ABM) (Bousquet et al., 2004). The ABM is operated in the common platform of CORMAS. It is defined as one of the second school of study of social behavior. In the past decade, ABM has been popular applied in economics, sociology and some other social sciences (Gilbert, 2008), and largely applied in the field of natural resource management where heterogeneous populations of agents exist (Janssen, 2005). ABM is also elaborated based on participatory principles throughout the process, from the co-construction of the model to simulation and validation of its outputs. To build MAS models, the Unified Modeling Language (UML) has been used (Le Page et al., 2005; Wuyts, 2005). The UML is a formal language to describe systems using the object-oriented paradigm. It is a descriptive language: specifically, a graphic-based representation language of models. UML therefore can be seen as a dialogue tool facilitating communication among scientists, modelers and stakeholders.

RPG is a type of game in which the participants assume the roles of characters and collaboratively create stories. RPGs have their origin in a 1974 publication of ‘Dungeons & Dragons on Tactical Studies Rules’ (Arneson, 1974). There are three objectives for using the RPG as follows: training, observation and negotiation support. Participants of an RPG session are not only players, but also observers (Barreteau et al., 2001). With its negotiation supportive purpose, RPGs have been used for research in natural resource management since 1996 (D'Aquino et al., 2002). One can use an RPG to present a MAS model, or it can be built itself with the players (Bousquet et al., 2004). RPGs have a number of limitations including a cumbersome set up, a slow development of practical action and a difficult analysis of its results (D'Aquino et al., 2002). Computer modeling that combines an RPG and a MAS running on CORMAS is seen as the best way to mitigate an RPG’s limitations; such modeling can simplify the task of simulating and provides a heuristic modeling support (Bousquet, 1998).

MAS’s and RPGs have been developed separately; however, they display potential for their joint use in the field of renewable resource management. These two tools can be used together to aid in the organization of RPG sessions with little difficulty (Barreteau et al., 2001). In addition to the three major objectives mentioned, the RPG can firstly be used to validate the MAS as well as simulation outcomes. The debriefing stage in the RPG session allows participants to provide feedback about the game and this key element is a requirement for validation, enabling researchers to validate and improve their model, as well as the agent-based simulation (Guyot et al., 2006). Therefore a combined use of a MAS and an RPG is considered as an effective discussion support tool in natural resource management.

2.4.3 ComMod process

There are five phases in ComMod methodology (Trebuil, 2008) as follows: initialization of a ComMod process; co-construction & conceptualization of models with stakeholders; implementation and validation of ComMod models; scenario identification, exploration and assessment; and monitoring & evaluation of ComMod effects and impact. RPGs and MAS simulation models are flexibly associated and combined with key tools such as Geography Information System (GIS), surveys and interviews. Due to the complex and dynamic nature of the processes under study in the ComMod approach, permanent and iterative confrontation between theories and field circumstances is required. This means that there is an endless cycle of field work, modeling and field work in the application of the ComMod approach (Barnaud et al., 2008; Barreteau, 2003a). The back and forth iterative process between simulation in laboratory and field activities can generate a succession of evolving loops in a long term research process (Figure 2.9).

2.4.4 ComMod applications in natural resource management

The ComMod approach was introduced in South East (SE) Asia in 2002 (http://www.commod.org/; http://www.ecole-commod.sc.chula.ac.th). Since then a number of case studies applying this approach have been carried out or are part of on-going research in the region. All the case studies involve natural resource management, in which separate applications of either an RPG, a MAS or a complete ComMod approach have been applied in different circumstances. The diverse and flexible application of ComMod tools have been summarized (Bousquet et al., 2005a; Hoanh et al., 2008), including five case studies in the region (Mekong delta, Northeast and upper Northern Thailand (two sites), and in West-Central Bhutan) that have applied the ComMod approach in an interactive process for knowledge generation and exchange and supporting collective decision-making. ABM tool in the ComMod is a powerful tool, and it can be used as part of explanatory or descriptive approaches for understanding the complexity and changes in systems under various internal and external factors. SAMBA model (Castella et al., 2005a; 2005b) is a typical case study that was undertaken in Bac Can province, North Vietnam to understand changes in land use under policy changes and many other dynamic social economic conditions in a period of agricultural transition in Vietnam during last two decades.

Hence, through the exploration of different scientific documents and local knowledge at the study site and a literature review, all necessary subjects relevant to the research topic have been overviewed. General pictures of land use dynamics and their relevant policies at regional and provincial have been summarized. A series of references on socio-economic and environmental impacts have been deeply analyzed, which have been very useful for the purposes of this case study. More importantly, the approach—as well as the research process— of Companion Modeling, a member in participatory modeling family, has been carefully systematized.

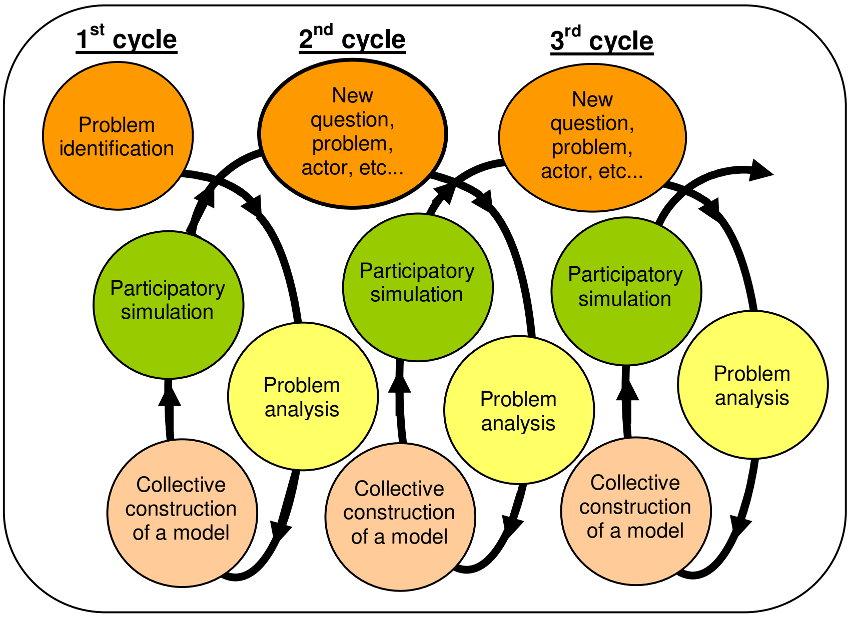


Figure 2.9 Evolving loops of ComMod Modeling in long-term research

Source: Trebuil G, 2008.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH SITE DESCRIPTION

The research area is the two districts of Gia Rai and Hong Dan in the western part of Bac Lieu province. After a long period (1998-2002) of implementing rice production strategies, the western part of Bac Lieu province was delineated as an area for both rice and shrimp production based on scientific research (DFID-R7467C, 2000-2002). However, due to the high profitability of shrimp, people in some communities, particularly in downstream areas in Gia Rai district, have tried to produce only shrimp crops, neglecting the rice component in the proposed farming system. A number of problems among different rice and shrimp farmers—as well as between downstream and upstream communities—have emerged due to the increase of shrimp monoculture in downstream areas.

Therefore I have selected three representative villages, namely Vinh Loc, Ninh Thanh Loi and Phong Thanh, which are scattered along a main canal connecting upstream and downstream areas, for the research (Figure 3.1).

In demographical terms, the number of household members and percentage of people involved in agriculture at the research sites are almost similar to that of the rural areas of the Mekong Delta. Average household size is around 5.3 members per family, and 72% of the total population in the three villages is engaged in on-farm activities. 65% of the total population is of working age.

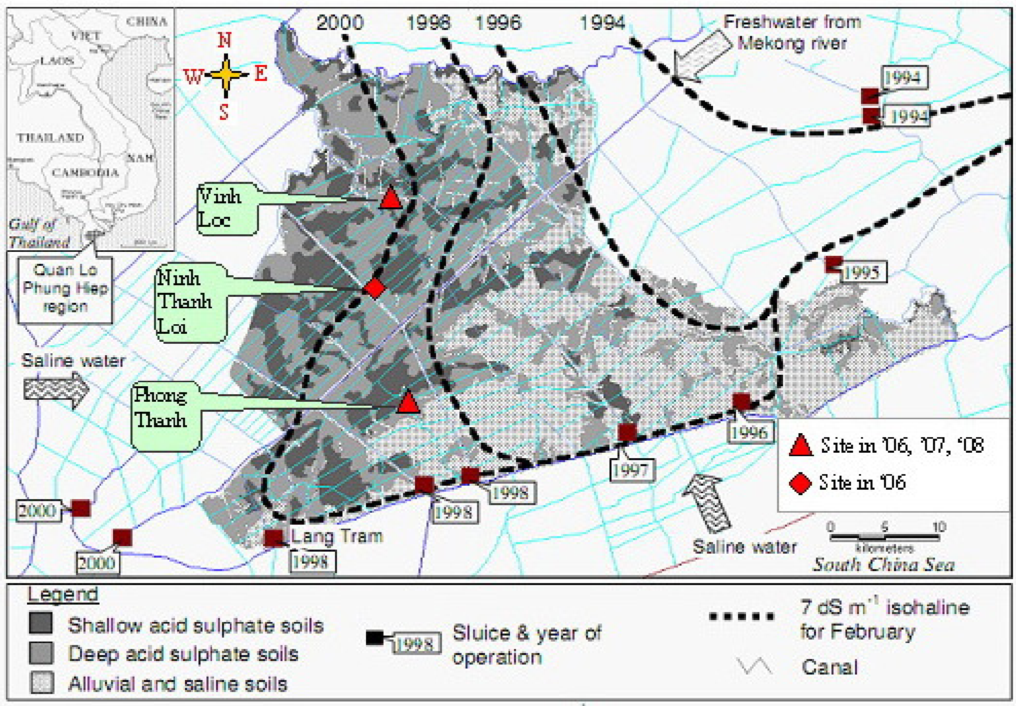


Figure 3.1 Study sites in the western area of Bac Lieu Province

The two villages of Phong Thanh and Vinh Loc are located in two extreme locations along the main canal and each has a land size of 3,000 ha. However, there is a big difference in the cropping patterns of the two villages. Most areas in Phong Thanh practice shrimp monoculture with an average yield of 140 $kg.ha^{-1}.year^{-1}$. Only 82 households in Phong Thanh practice rice farming in their shrimp fields. Rice can yield 3,000 $kg.ha^{-1}.year^{-1}$ (2007).

In the other extreme village of Vinh Loc, where there are 1,768 households, the systematic rotation of rice and shrimp production is fully practiced. Shrimp yields average 80 to 90 $kg.ha^{-1}$. Detailed characteristics of the selected villages for this research are summarized in Table 3.1.

Table 3.1 Major characteristics of the three research sites in Bac Lieu province

Characteristics	**Phong Thanh village (Hamlet: No. # 19)**	**Ninh Thanh Loi village (Hamlet: Chu Chot)**	**Vinh Loc village (Hamlet: Vinh Thanh)**
Relative location	Downstream (Gia Rai district)	Middle way (Hong Dan district)	Upstream (Hong Dan district)
Soil type	Shallow acid soil	Shallow acid soil	Deep acid soil
Average farm-size (ha)	1.2	3.0	2.2
Land owning status	83.43% total households own land, and 16.57% total households are without land. Among the landowners, 63% of households have 1 plot, 24% of households have 2 plots, and 13% of households have 3 plots.		
Proposed farming system (2002 upward) (Hoanh et al., 2003)	Rice-shrimp rotation (shrimp: Jan.-Aug; rice: Sep-Dec/Jan.)	Rice-shrimp rotation (shrimp: Feb.-Aug; rice: Sep-Dec/Jan.)	Rice-shrimp rotation (shrimp: Mar.-Aug; rice: Sep-Dec/Jan.)
Actual farming system (2003)	60% shrimp monoculture; 25% rice-shrimp; 15% rice monoculture	40% shrimp monoculture; 60% rice-shrimp	15% shrimp monoculture; 60% rice-shrimp; 25% rice monoculture
Rice yield (ton/ha) (in 2003)	1^{st} crop: 1.7; 2^{nd} crop: 3.5	1^{st} crop: 0.5	1^{st} crop: 2.8; 2^{nd} crop: 3.3; 3^{rd} crop: 3.2
Shrimp yield (kg/ha/yr)	200 (in 2003); 140 (in 2007)	280 (in 2003)	90 (in 2003); 80-90 (in 2007)
Income (in 2003) (USD/household/year)	1,250	3,439	938

Note: exchange rate: 1 USD = 15,995 VND (01/01/2003).

3.2 RESEARCH PROCESS

As indicated in the introductory chapter, the Companion Modeling (ComMod) approach is applied for this research. The research process has several stages (Figure 3.2), which are respectively described as follows:

3.2.1 Problem identification

The problem has been identified based on a combination of expert and local knowledge domains based on literature review, key informant panel interview and household survey. Crucial problems to study are identified: (i) conflict over the water demands of rice and shrimp farmers within a village or between up-stream and down stream villages; (ii) vulnerability of shrimp monoculture system, including the potential for extreme poverty and impact of salinization on rice yield.

3.2.2 Model construction

Based on available knowledge, a Multi Agent System (MAS) model is developed with the participation of researchers and local institutional authorities. Unified Modeling Language (UML) is employed to build the model. Stakeholders and objects in the production system are translated into entities in the model. The model functions to represent entities, attributes, operation methods and their relationship in the production system.

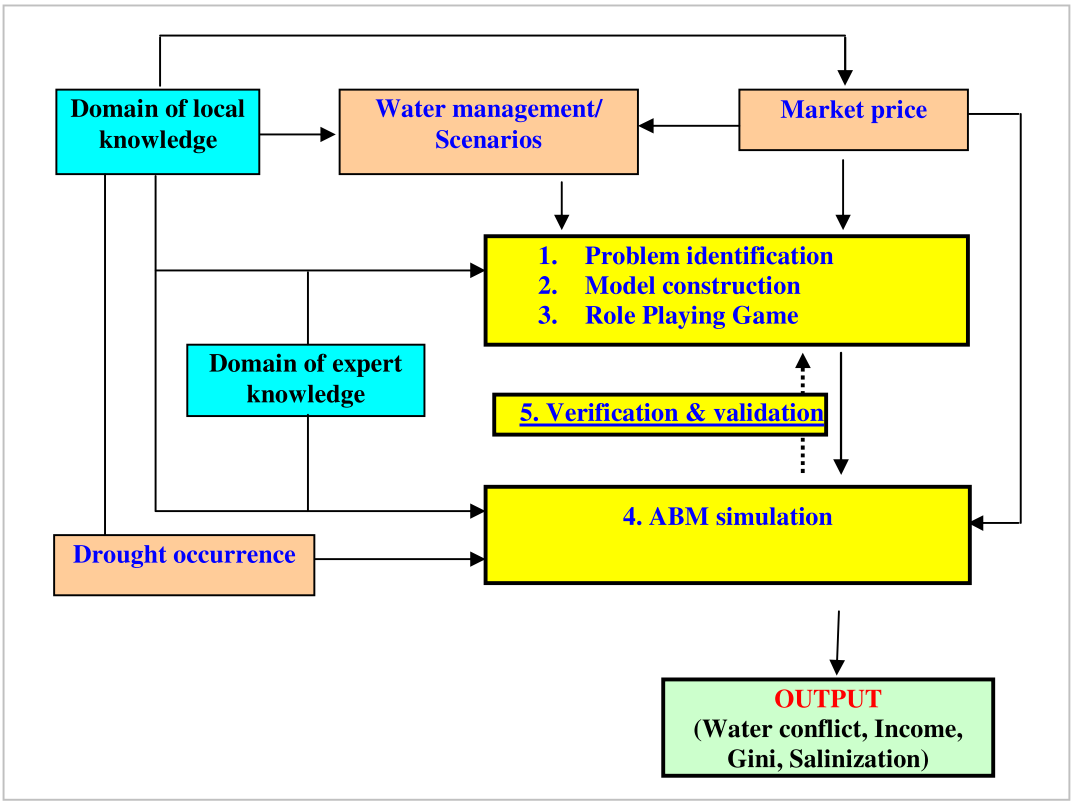


Figure 3.2 Research methodology process

3.2.3 Role Playing Game (RPG)

Two RPG sessions were conducted in the province to test the MAS model and explore knowledge of the production system. The first RPG session in 2006 was carried out separately in three selected villages respectively located along the canal system from downstream to middle and upstream location namely Phong Thanh, Ninh Thanh Loi and Vinh Loc. This first game was to test the MAS model and understand the farmers' production strategies, as well as understanding how they coped with two scenarios simulating early and late saline water supply. Due to limited purpose and scope of the game session in 2006, only two stakeholders representing farmers and village authorities were invited to participate. Details of RPG session in 2006 are described in chapter 4.

The second RPG session was carried out in the same place in 2007; selected farmers from two extreme villages located upstream and downstream of the canal namely Phong Thanh and Vinh Loc, and local institutional authorities from village to provincial levels were invited to participate. The purposes of this game session were twofold: (i) to explore interaction among stakeholders in the game to better understand conflict over water demands upstream and downstream and to find a water supply scheme based on compromise to lessen conflict among rice and shrimp farmers and the two extreme villages; (ii) to enrich knowledge of the vulnerability of shrimp monoculture production systems, which is seen as a kind of social learning. It was believed that these two major purposes would facilitate better collaboration and coordination among stakeholders that would provide comprehensive solutions for problems at the research site. Details of RPG session in 2007 are described in chapter 5.

3.2.4 Agent-Based Model and Simulation

This is a participatory stage where both researchers with their expert knowledge of computer programming, and local stakeholders with their feedback on simulation outputs, contribute. The MAS model and knowledge obtained from the two previous RPG sessions are used to build the ABM. Stakeholders and objects in MAS are translated into the Agent-Based Model (ABM). The ABM is built based on a computer platform namely CORMAS (Common Pool Resource and Multi Agent System) (http://cormas.cirad.fr/indexeng.htm). Smalltalk syntax is used to implement the action and interaction among agents in the ABM. The purpose for the building and simulation of an ABM is to understand the long term output of a MAS model and RPG which are still based on the principles of the agents' decision making. In the ABM simulation we can do many experiments of the MAS model by inputting many different scenarios, involving expected biophysical and social economic parameters. Therefore, the ABM simulations are tools that can help us to anticipate the long term outcomes of potential vulnerabilities based on the present decision making of the agents in the production system. The description of the ABM and its simulation analysis are respectively presented in chapter 6 and chapter 7.

3.2.5 Verification and validation

A prerequisite condition in the ComMod approach is that all involved stakeholders, especially local people, must understand the output of the ABM simulation. Verification and validation are therefore the compulsory stages in the ComMod process. The verification and validation are done by presenting the simulation process, outputs and getting comment/feed back from all stakeholder representatives involved in the model. Moreover, since the ABM can be adjusted, other parameters could be inputted for deeper experiments. In order that the local stakeholders can keep track with how the model progresses, the representation of simulation output can be conducted several times over the process of simulation.

3.3 Research Analysis

The general objective of this research is to provide farmers and local institutional authorities with a better understanding and knowledge of sustainable development that would lead them to manage and practice sustainable farming in the coastal area of Bac Lieu province. In this research, three critical indicators to measure the socio-economic and environmental impacts of current rice-shrimp farming systems are proposed for analysis.

3.3.1 Social impact

By using techniques to store saline water in the field, farmers can extend shrimp culture duration by at least one month after the period when salinity is above 8 ppt. The shrimp crop can thus be prolonged until the end of August or even early September. This extension of shrimp duration means shortening the duration of the period of salinity less than 4 ppt, which is conventionally devoted for rice crop production in the wet season. In August, farmers therefore have to make a decision on whether to grow rice when the salinity in the canal is favorable for the production of rice crop or continue to grow shrimp. They have to trade off the benefits of shrimp and rice production. It is supposed that different farmers have different choices, which implies that farming systems practiced by different households in a community are not unified, particularly in the downstream village of Phong Thanh. Potential conflicts can occur if and when shrimp crops are practiced in the period from September December, a period when rice crops are grown in the community. Potential conflict index is a multiplication between percentage of rice plots (after September) and percentage of shrimp crop (from September to December) in a village. It is potential conflict because rice and shrimp crop need different degree of salinity for growth. Rice crop can tolerate up to a maximum salinity of 4 ppt while shrimp crop can be survived at a minimum salinity of 5 ppt. The potential conflict index coding as "C_p", ranges in values from 0 to 1 corresponding to the lowest to highest degrees of conflict. Formula to compute potential conflict index is as follow:

C_p = Percentage of rice area after September over total area* Percentage of shrimp area after September over total area

The C_p is used to measure potential conflict for both downstream and upstream villages in this case study after 5 years of simulation of the Agent-Base Model of rice-shrimp farming. The higher value of C_p is the higher potential conflict would be theoretically happened. However, besides the value of C_p theoretically calculated through the result of simulation, the potential conflict should be considered with real situation based on both actual salinity in the common canal and individual farm management. Farm management is an important factor to reduce potential conflict because getting in or out of salinity into the field for prolonging shrimp crop into wet season can be totally done by farm manager according to individual production strategy.

3.3.2 Economic impacts

There are two economic indicators that reflect the degree of sustainability at household and community scales. The first economic indicator is on-farm net income. This is to measure household income status and whether it is increasing in a stable or unstable manner from year to year under the current conditions of the rice-shrimp farming sector. This is also to understand the potential for the household income status of those who only cultivate a shrimp monoculture pattern to fall to levels of extreme poverty. Below are formulas of yearly on-farm net income and capital at the household level.

- Household on-farm net income = Net income of all on-farm activities

  Where: net income of activity = output * price – production cost
- Household capital = household on-farm net income – household living cost

The second economic indicator is Gini index (G) to measure equity degree of income distribution among households in a community. Value of Gini index ranges from 0 to 1 correspondingly with completely equity to completely inequity of income distribution.

- Gini index is computed using the formula below and its configuration is presented in figure 3.3.

$$G = 1.0 - \sum_{i=1}^{n} f_i \,(p_i + p_{i-1})$$

Where:

G: Gini index

f_i: proportion of households in interval i

p_i: the proportion of total household capital received by households in interval i and all lower intervals

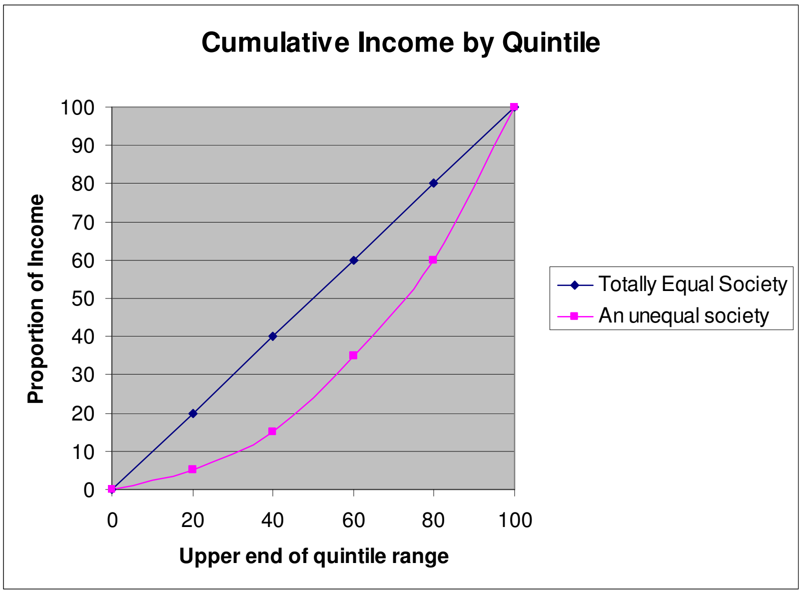


Figure 3.3 Configuration of Gini measuring inequity of income distribution

Two above economic indicators are used to measure and compare value of household capital and polarization degree of household capital among households in two villages at the initial year and the end of 5th year of simulation of the Agent-Based Model of rice-shrimp farming system. The extreme poverty is defined as the accumulative household capital after 5 years simulation is lower than current poverty line in the province or it is become negative. Gini index is also used to compare its values between initial year and that after 5 years of simulation. These two economic indicators are computed among scenarios of water salinity provisions and with and without application of environmental condition on rice crop.

3.3.3 Environmental impact

Environmental impact in this research refers to the effect of drought and salinization on rice production. As it has been analyzed in chapter 2, the effect only occurs when both salinization and drought occur at the same time. Rice yield lost due to this effect is considered as the environmental impact. Reduction in rice yield due to environmental impacts is a subtraction the normal rice yield to rice yield in the year when drought has occurred.

Rice yield in downstream village after 5 years of simulation of the Agent-Based Model of rice-shrimp farming is to compute and compare that with the normal rice yield. The simulated rice yield in this village is to compare among scenarios or between two groups of with and without application of environmental condition on rice crop. This environmental impact will be deeper discussed in chapter 7 when results of model simulation are obtained.

The environmental condition is strongly effect shrimp production both for upstream and downstream villages. However, environmental impact on shrimp production is not analyzed separately since it has been imposed into the value of risk of shrimp disease. Value of risk probability is varied according to duration of shrimp grown in the plot. The longer duration of shrimp growing in the plot the higher value of risk is to be occurred. It is calibrated and discussed more detailed in chapter 7 before simulation the model.

CHAPTER 4

FACILITATING DIALOGUE BETWEEN AQUACULTURE AND AGRICULTURE: LESSONS FROM ROLE-PLAYING GAMES WITH FARMERS IN THE MEKONG DELTA, VIETNAM

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ABSTRACT

During the last few years, conflicts between agriculture and aquaculture have been an important issue in the Bac Lieu province, Mekong Delta, Vietnam. A large area of rice production has been converted to shrimp or shrimp–rice based production systems that require the intake of saline water into fresh water zones that have been used for agriculture. To manage this conflict, the provincial authorities have reviewed land use plans and identified a buffer zone with a mixed land use system of shrimp–rice (rice in the rainy season and shrimp in the dry season when sluices are opened). Under the CPWF (Challenge Program on Water and Food) Project No. 25, role playing games (RPGs) were applied for analyzing the land and water management strategy of farmers in the buffer zone. The RPGs organized in three villages (Phong Thanh, Ninh Thanh Loi and Vinh Loc) indicate that due to much higher revenue earned from shrimp compared with rice, farmers are attempting numerous techniques to prolong the duration of saline water in their fields for shrimp cultivation. This strategy makes the growing of a subsequent rice

crop impossible even in the rainy season, thus requiring harmonization of water management at different levels (farm and canal systems). The results from these RPGs also indicate the need for further research on cultivation techniques for the shrimp–rice systems and on participatory methods to achieve better understanding of farmers' decisions.

Key words: Land use change; rice and shrimp production; water management; role playing games.

4.1. INTRODUCTION

Rapid land use changes have been observed in the coastal zones of many countries in recent times. The expansion of shrimp farming, partially driven by growing demand and advances in technology, is a major feature in South and South-East Asia. For example, a large number of rice farmers in central Thailand converted irrigated paddy fields into shrimp ponds during the latter half of the 1990s (Szuster et al., 2003); in Bangladesh the area under shrimp has expanded from 51,812 ha in 1983 to 137,996 ha in 1994, and to 141,353 ha in 2002 (DoF, 1995; 2003); and in the Mekong Delta of Vietnam, the shrimp area increased from 230,000 ha to 390,000 ha over the same period (MONRE, 2002).

The expansion of shrimp farming in the coastal zone of Mekong Delta of Vietnam is primarily responsible for the decrease in the area of rice cultivation from 970,000 ha in 2000 to 800,000 ha in 2002. Several studies have contributed to improving the understanding of the environmental and socio-economic impacts of land-use changes, and identified land use and water controls required to optimize shrimp, fishery and rice production (Gowing et al., 2006b; Hoanh et al., 2009). In 2006, the provincial authorities requested assistance on how to manage conflicts arising from land use and water control measures at different management levels, such as amongst rice farmers, shrimp growers, fishermen, landless labourers, the water management company, the commune and district authorities. The ComMod (Companion Modeling) approach, composed of Role Playing Game (RPG) and Multi Agent Systems (MAS) modeling (Bousquet et al., 2005a) was selected to enhance stakeholder participation by harnessing the rich amount of information available to build a communication platform among stakeholders (Gurung et al., 2006). This platform was expected to assist in clarifying the existing complex interactions between various stakeholders, and to harmonize their demands on and use of water resources in this coastal region. This paper presents the lessons from a series of RPGs organized in August 2006 in three villages in Bac Lieu province.

4.2. THE STUDY CONTEXT

4.2.1 Overview of the study area

The Mekong Delta is the "rice bowl" of Vietnam. Land use in the delta has long been agriculture-oriented with rice as the main crop, although diversification is required to increase farmers' income. Two main constraints for agricultural production in the Mekong Delta are flooding in the rainy season (May to November) and salt water intrusion in the dry season (December to April). To increase rice production, several water control systems (sluices, dikes and irrigation canals) were built to expand the area of rice cultivation into the coastal zones.

Located in the southern part of the Ca Mau peninsula (Figure 4.1), about 61% of Bac Lieu province lies inland from a series of sluices constructed with the original intention of excluding saline water to increase rice cultivation. Over a seven-year period of phased construction of sluices (1994–2000), various developments occurred that diminished the prospects and promise of development of the rural economy entirely through rice intensification (Tuong et al., 2003). The recent expansion of brackish-water pond culture in the western part of the province (where acid sulphate soils pose constraints to rice cultivation) has made shrimp *(Penaeus monodon)* production a much more lucrative venture (albeit more risky due to shrimp disease) than rice production in the eastern part.

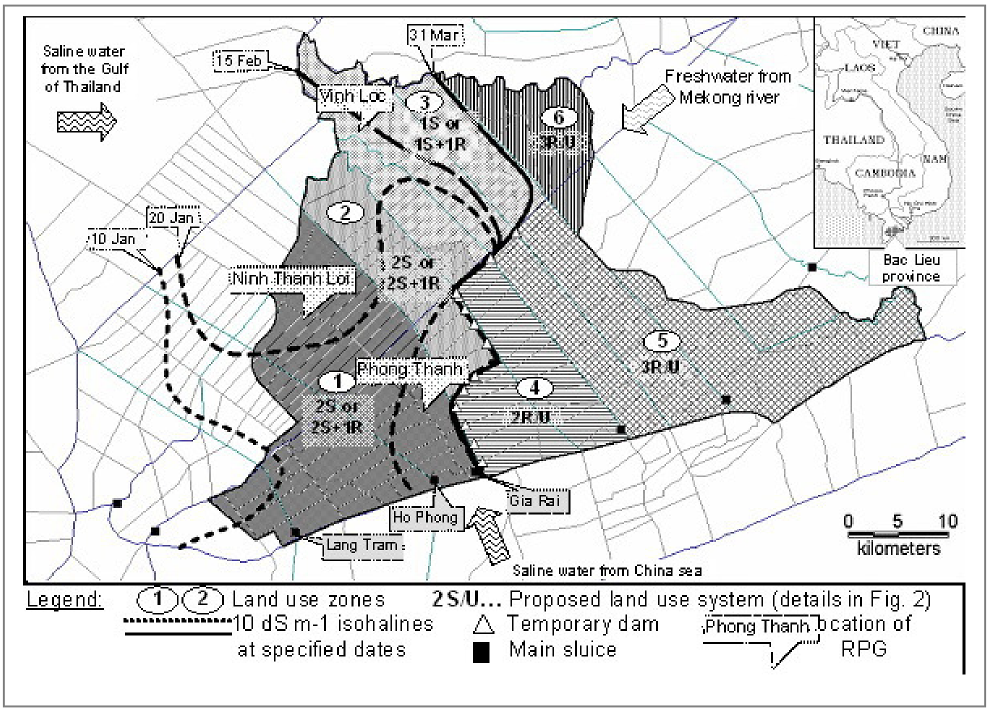

Figure 4.1 Land use zones, isohalines under a salinity control scenario and RPG locations

4.2.2 Shrimp farming

Shrimp-farming methods are classified according to the level of technology adopted, stocking density and yield. In general, the following cultivation levels are distinguished (Gowing et al., 2006a):

i. Extensive: Traditional methods rely on natural recruitment of shrimp post-larvae from wild sources, and natural productivity of the ecosystem; built-in intertidal areas with water exchange by tidal action; trap and hold wild shrimp or low stocking density of 1–3 shrimps per m^2; yield typically less than 200 kg $ha^{-1}year^{-1}$.

ii. Semi-intensive: The first stage of development usually involves some stocking of shrimp post-larvae from a hatchery; natural productivity may be enhanced by fertilizers and occasionally some use of feeds; water exchange usually provided mainly by tidal action, supplemented by low-lift axial-flow pumps; and stocking density of 3–10 shrimps per m^2 with yields typically 1000–2500 kg $ha^{-1}year^{-1}$.

iii. Intensive: Progression to advanced production systems relies on artificial stocking at high density (>10 shrimps per m^2) in small ponds (1–2 ha) with heavy feeding rates; mechanical aeration of ponds; occasional incorporation of water recirculation and/or treatment; generally above the high-tide level to allow drainage and drying of the pond bottom between crops; and yields of between 5000 - 7500 kg $ha^{-1}year^{-1}$ with possible multiple cropping.

Extensive shrimp farming has been practiced for a very long time in some countries as part of a traditional livelihood system. The recent rapid expansion and intensification, generally unplanned, has provoked conflicts among the three dominant resource-dependent livelihoods in the inland coastal zone, namely agriculture, shrimp farming and fishing. A major portion of the conflicts arising from the expansion of shrimp farming are the environmental and social degradation that is not included in the costs of shrimp production (Barraclough et al., 1996). For example, in Thailand, the most obvious impact of shrimp farming on local people arises from the seepage of brackish water out of culture ponds into surrounding rice fields, irrigation canals and groundwater supplies (Vandergeest et al., 1999). Unfortunately, the underlying conditions of low incomes for rice farming households, indebtedness, limited off-farm employment opportunities, and the high profit potential associated with shrimp farming, intensify the pressure to choose short-term exploitation benefiting relatively few people over long-term resource stewardship (Flaherty et al., 1999). However, these remarks may arise from a perceived bias in the literature, which tends to see all rural people as ‘victimised’ and ‘losers’, all producers as ruthlessly exploitative ‘winners’, and governments as willing accomplices to producers, and this tendency to polarization only leads to conflict iland (Neiland et al., 2001). Farmers are beginning to take measures to increase their ponds’ lifetimes independently of regulations by reducing stock density, water exchange and chemical inputs (Huitric et al., 2002). Béné (2005) indicated that there are two main discourses in the literature on shrimp farming. The Political Ecology (PE) discourse argues that shrimp farming, as it is currently operated in most developing countries, is not ecologically and socially sustainable, and that some major political changes will have to be made if the activity is to benefit the rural poor and have a reduced impact on the environment. In contrast, the Best Management Practices (BMP) discourse argues that while there have been some problems with the development of shrimp aquaculture in the past, these will be solved in the near future, essentially through technical improvements and the wider adoption of better management practices.

4.2.3 Emerging conflicts

The threat of conflict in the use of land and water resources loomed by the end of 2000 as rice farmers and shrimp growers made demands on the freshwater and brackish-water supply, respectively (Kam et al., 2006). The conflict reached a peak in February 2001 when shrimp growers broke a major dam at the Lang Tram sluice (location in Figure 4.1) to allow saline water from the China Sea to flow into the protected area. Resolving such a conflict required a rethinking of land/water-use policy and the management implications arising. After that event, a revised land use zoning was carried out by the provincial authorities, their local representatives and national planners. Six zones were delineated (Figure 4.1), and their corresponding land uses and cropping calendars determined (Figure 4.2), taking into account farmers' preferences, soil characteristics and "expected" water quality (Hoanh et al., 2003) which is dependent on the distance to fresh and saline water sources and the operation of sluice systems. The proposed land uses vary from 2 or 3 rice/upland crops in the eastern part, near the freshwater source (zones 4, 5 and 6), to 2 shrimp crops, or 1-2 shrimp crops in rotation with 1 rice crop, in the western part close to the main saline water source from the China Sea (zones 1, 2 and 3). The zones with shrimp–rice rotation are considered a buffer zone between agriculture and brackish water aquaculture areas.

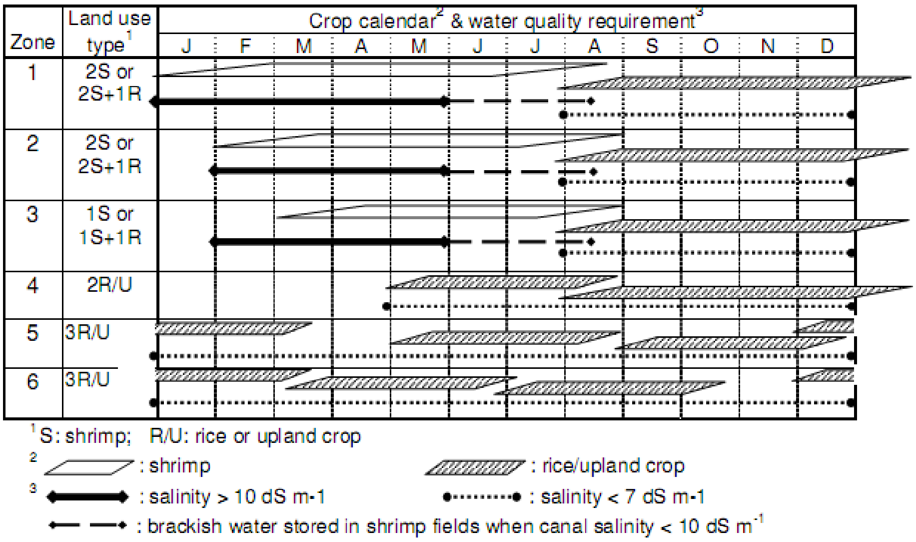

Figure 4.2 Land use, cropping calendar and salinity requirements for the different zones (See figure 4.1 for location of zones).

The main sluices in the province, Gia Rai, Ho Phong and Lang Tram, were operated to control the salinity for both rice and shrimp production, as shown by the isohalines of one water control scenario in figure 4.1. In addition, a series of temporary dams and small sluices were built at the beginning of the dry season for salinity control but opened in the rainy season for drainage purpose. These salinity control measures have been adopted by the provincial authorities since 2001, after studies by a DfID funded project (2000-2003), (IRRI, 2004) on accelerating poverty elimination through sustainable resource management in coastal lands protected from salinity intrusion[1] in the province and the follow-up project CPWF (Challenge Program on Water and Food) No.10 (2004-2007), (IRRI, 2004) on managing water and land resources for sustainable livelihoods at the interface between fresh and saline water environments.[2]

[1] http://www.research4development.info/projectsAndProgrammes.asp?ProjectID=2429
[2] http://cpwf-theme1.irri.org/PN10.htm

4.3. METHODOLOGY

4.3.1 Overview of Role Playing Games

A Role Playing Game (RPG) is a type of game in which the participants assume the roles of characters and collaboratively create stories (Waskul et al., 2004). Participants determine the actions of their characters based on their characterization, and the actions succeed or fail according to a formal system of rules and guidelines. All the components of a "game", such as rules, temporal structures, conflict and goals can be identified easily from RPGs. A role-playing game rarely has winners or losers, but it is typically more collaborative and social than competitive. The conflict in a game can be internal or external, i.e. character-based or group-based as opposed to world-based, and it can be used as a starting point, motivator or dynamic element in the game. Role-playing games are usually divided into three categories (Heliö, 2004): (i) tabletop (or pen and paper) RPGs, which are usually played around the table where players perform their characters in a more or less immersed manner; (ii) live-action RPGs where players dress up as their characters and act them out in surroundings simulating the game world; (iii) computer and video role-playing games where the medium is the digital game. In the iterative and evolving ComMod process of this study a co-construction of the tabletop RPGs and computer RPGs (MAS model) of the game occurs, each one facilitating the analysis and improvement of the other (Bousquet et al., 2006).

The objectives of the series of RPGs organized in Bac Lieu province in August 2006 were to understand the decision-making process at the farm level at various sites under different salinity conditions, created by the decision of salinity control at provincial level. The study focused on zones 1, 2 and 3 where extensive shrimp farms have expanded into rice land during recent years. We did not include the semi-intensive and intensive shrimp farms in these RPGs because they require high investment for shrimp monoculture, and hence there are no trade-offs in selecting annual land use systems.

4.3.2 Sites of RPGs and players

Three villages with different characteristics were selected for this RPG series (Table 4.1). People in the Mekong Delta usually use the village name to distinguish their place of origin and to identify their specific characters, for example, their experience in rice cultivation or fishing, therefore we used the village name in discussions. In each village we invited both the husband and wife of eight randomly selected farm households to participate in the RPG organized at the village office. However, due to different reasons (heavy rain, unexpected business…), four couples and four single players at each of Phong Thanh and Vinh Loc villages, and five single players at Ninh Thanh Loi village participated in the RPGs (Appendix A).

Table 4.1 Selected RPG sites and their characteristics

Hamlet	Village	Soil	Water	Main crops in 2006
Hamlet 19	Phong Thanh	Shallow acid sulphate soil	Short distance to saline water source	Shrimp combined with fish/crab,
Chu Chot	Ninh Thanh Loi	Shallow acid sulphate soil	Medium distance to saline water source	Shrimp combined with fish/crab,
Vinh Thanh	Vinh Loc	Deep acid sulphate soil	Long distance to saline water source	Integrated shrimp and rice farming

4.3.3 Designing and organizing the RPGs

The RPGs chosen were the tabletop type, i.e. players played the game on a table with a board (Figure 4.3) showing the relative location of their farms upstream or downstream of a canal, with the assumption that farm sizes were the real size that they were managing. Flow direction in the canal was indicated so that the players could take the effects of upstream water pollution and risk of shrimp disease into consideration. The players placed stickers for monitoring their activities and outcomes (production inputs and outputs, and revenues from farming) on a monthly basis on the board.

In addition to the players, 14 staff of the Can Tho University in Vietnam participated as RPG assistants (Appendix A). They assisted the players (one for each household) in recording all decisions, activities, inputs (seeds, fertilizer, petroleum, etc.) and outputs (shrimp, rice, fish, crab production) in each month. Others were assigned positions as game master, banker, input supplier, a middleman for buying outputs, a camera and video operator and a reporter to input data into the computer. Some local administrative and agricultural officers participated in the RPGs and provided valuable inputs in the discussions of gaming outcomes and their implications

Figure 4.3 The board represents the locations of players' farms in the RPG.

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At the beginning of the game (which represented the beginning of a growing season) each player was provided by the banker with initial capital in (fake) money bills. The amount was either the household's own capital in proportion to their farm size (2 million Vietnam Dong (VND) per ha; the exchange rate in September 2006 was 1 US$ = 16,000 VND) or a bank loan with a monthly interest rate of 1%. During the RPGs, prices of products such as shrimp, rice, fish and crab were negotiated between the producers and trader (middleman). The prices varied from player to player and from village to village depending on the supply (quality and quantity of produce) and the demand. At the end of the game, a farm budget was carried out to assess the gross and net benefits that each producer achieved.

Relationships between shrimp seed, disease and corresponding yield are generally unknown. To capture how farmers deal with shrimp seed quality issues in real-life situations, a risk value of 0.5 was applied (representing the probability of 50% infected and 50% uninfected) for all shrimp seeds in three villages. In the RPG, the quality of purchased shrimp seeds for each player was determined by a randomly picked ball from a basket that contained equal numbers of infected and uninfected balls (Figure 4.4). Shrimp yield differs from village to village and farmer to farmer because water, environmental factors and the management skill of players (such as pre-stocking treatment) are different.

Corresponding yield probabilities were derived for the three villages (see Table 4.2) from participatory meetings and key informant panel (KIP) interviews before the RPG (CBDC, 2001). In the RPG, depending on the risk of infection determined when shrimp seeds were purchased, and on the decision to apply pre-stocking treatment, players picked a ball in another basket that contained a number of good/bad harvest balls corresponding to the percentages of average yield shown in figure 4.4.

To capture the influence of water control at a provincial level on decisions made at the farm level, two scenarios of saline water supply imposed by operating the main sluices at Gia Rai, Ho Phong and Lang Tram were played during the RPG: scenario A, early operation (from February), providing sufficient saline water supply; and scenario B, late operation (from March), providing insufficient saline water supply. Obviously, the further the distance to the sluices (as in the case of Vinh Loc village) and the later the saline water supply, the shorter duration and lower salinity at the location.

Table 4.2 Relationship between risk of shrimp seed disease and corresponding yield.

Risk by stage of production	**Phong Thanh village**		**Ninh Thanh Loi and Vinh Loc villages**			
Shrimp seed health (1)	Uninfected (2)	Infected (3)	Uninfected (4)		Infected (5)	
Pre-stocking treatment* (decided by players)	Not applied		Yes	No	Yes	No
Probability good/bad harvest **	70%/30%	50%/50%	80%/20%	50%/50%	20%/80%	All shrimp died

Source: Synthesis from participatory meetings and KIP interview.

* Pre-stocking treatment is the technique to stock post-larva shrimp in the nursery with high quality water for domesticating with local environment before putting into large field.

** Two numbers of percentage in each box in this row are presenting probability of disease before harvesting shrimp, which is depending on both conditions of seed health (see 1st row in this table) and with and without application of pre-socking treatment (2nd row in this table).

Each RPG lasted one and a half days, including half a day for each saline water supply scenario of one production year. The remaining half day was devoted to synthesis and discussions amongst players, and interviewing individual players.

Figure 4.4 A couple picking a “risk” ball when harvesting shrimp in the RPG.

4.4. RESULTS AND DISCUSSIONS

4.4.1 Players’ trade-offs and associated outcomes from RPGs

The players’ average farm size in Phong Thanh, Ninh Thanh Loi anh Vinh Loc were 1.64, 1.96 and 1.74 ha, respectively. Farms of this size, larger than the average farm size of 1.10 ha in the Mekong Delta (Minot et al., 2000), are usually found in the newly reclaimed area for aquaculture where production systems have not been stabilized.

Shrimp cultivation was the preferred production system in all 3 villages. For example, in Vinh Loc village, players only grew rice if they could not raise shrimp due to the lack of saline water over a long period. If they could not grow rice, they raised crab and some fish species such as elongated goby, seabass and tilapia in order to derive additional income. These efforts are reflected by the composition of net revenues in Ninh Thanh Loi and Vinh Loc, with lower revenue from shrimp than in Phong Thanh (Figure 4.5). This graph also shows that revenue from shrimp under scenario B was lower than that of scenario A, although players were trying to adjust the stocking and harvesting schedule, and the above mentioned risk of shrimp seed disease and yield losses were randomly incorporated into RPGs. The further the distance from saline water sources, the larger difference in revenue from shrimp between the two scenarios. Revenue from rice crops in Vinh Loc village is almost the same under the two different scenarios.

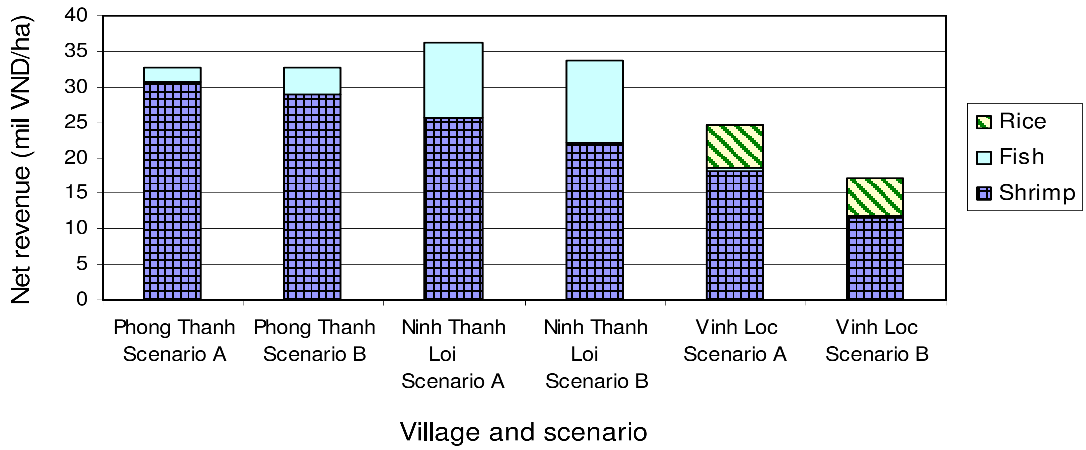

Figure 4.5 Net revenue from production in the three villages, by scenario.

In all the villages, players stocked the shrimp seeds under scenario B one month later than under scenario A. However, one player in Phong Thanh decided to stock in February, as in scenario A, although saline water was only available in the canal from mid-March, by keeping a saline water layer at the bottom of his field during the rainy season and carefully testing the saline suitability before stocking large numbers of shrimp. The other players confirmed that they were trying to stock shrimp as early as possible because using saline water early in the dry season has a lower risk of shrimp disease. This remark reflected a trend to prolong for as long as possible the duration of saline water in the fields by all players because revenue from shrimp is much higher (5 to 10 times) than from rice. Therefore players were applying multiple stocking and harvesting methods that differed to traditional practice in this province in which the cultivation period was split into two crops with a few days interruption for drying the field. During the stocking period, players stocked from 3 to 7 times to maintain the shrimp density in the field; they correspondingly also harvested several times, even monthly, by selecting only big shrimp with a high commercial value. Players explained that with this multiple stocking method they can reduce the cost for land preparation, and also reduce the risk of shrimp disease by changing water in the middle of the cultivation season.

The highest cost in extensive shrimp cultivation is for post-larvae seeds, about 60-70% of the total cost. However, most players mentioned that at present there is no relationship between the risk of infection and the price of shrimp seeds. Therefore they selected the shrimp seeds based on their simple observations and their belief about the fortune (low risk) of the seed supplier, rather than based on price. This remark reflects the insufficiency of seed quality control systems. There was a general trend for players to reduce the number of shrimp seeds (6% and 17% in Phong Thanh and Ninh Thanh Loi villages, respectively) under scenario B compared to that in scenario A, except in Vinh Loc village where players increased the number of shrimp seeds by 19% in scenario B to compensate for losses due to a shorter duration of shrimp crop.

Players also made a trade-off in selecting the raising period for crab in shrimp fields. If they start in January, the price of post-larva crab in that month is low (1,000 VND/each) compared with that in June (1,500 VND/each), but the price at harvest of January stock in July is also low (about 80,000 VND/kg) compared with higher prices at harvest of June stock in December (200,000 VND/kg).

4.4.2 Players comments on the RPG

All players expressed the view that they found the RPG useful and enjoyed playing it. The main reasons were (i) the RPG provided conditions similar to reality for reviewing the logic in decision-making processes, but playing a game was more fun and less difficult than making a decision in the real world; (ii) the RPG provided an opportunity for exchange of knowledge and learning new methods of farm management and cultivation techniques, in particular during the synthesis and discussions among players after the RPG, and therefore they recognized the need of cooperation at the community level for production; (iii) the RPG also provided a forum where they could, to some extent, express their concerns and comments on policy and management activities, in particular water control for both shrimp and rice production in the province.

Players highly appreciated that banking and trading of inputs/outputs were included in the RPG, so that they could be faced with conditions similar to reality.

However, they mentioned that in the real world, getting a loan from the bank was much more difficult with a large amount of bureaucracy within the banking system (Lin et al., 2007). They also suggested increasing the number of middlemen and seed suppliers to provide a competitive market as in reality, and including the sluice manager and local leaders in the RPG.

The most difficult item for players was to estimate and decide the shrimp yield that they could harvest, because in reality the factors that determine the risk of losses due to disease are still unknown. There is a risk of infection from neighboring fields as designed in the RPG, but also when water is pumped into the field during the cultivation period. Some players commented that the risk in the RPG was still low compared with reality. This risk is the reason why these players have not converted their farms into semi-intensive or intensive shrimp cultivation.

4.4.3 New insights for irrigation managers

As in the revised land use plan recently approved by the Government, establishment of a buffer zone for shrimp–rice rotations in between the monoculture shrimp area and agriculture area in the province is a good approach for managing the conflicting water quality demand for agriculture and aquaculture. However, the RPGs confirmed the trend of prolonging the duration of saline water in fields as long as possible (although some players recognized that changing back and forth between the brackish and fresh water environment could reduce the risk of shrimp disease). Consequently, a short period in the rainy season is not enough to leach salinity from deep in the soil profile, and hence rice grows well during the seedling stage but dies when roots intrude into the saline layer. At present the buffer zone is narrow due to the expansion of shrimp monoculture but could be expanded if the revenue from shrimp is lower and the risk higher.

Date and duration of saline water supply is a critical factor for shrimp cultivation. It is important for shrimp growers to know the schedule of sluice operation to prepare their water management plan at farm level. Prediction of water conditions, in particular salinity, at different locations in the province under the selected schedule is an essential activity in water management. Hydraulic and salinity modeling is a useful tool for this purpose, but monitoring for adjustment in time is also necessary because it is not possible to predict farm water management accurately. On the other hand, it is also important to keep the operation schedule as was informed to the public, because shrimp growers cannot take saline water into their fields if the period of opening sluices is too short (less than 3 days). Shrimp growers also understood that if the sluices are opened too long, saline water may intrude into the agriculture area in zones 4, 5 and 6, and even into the upstream province. Using infrastructure in the dry season to completely separate the fresh water zone for agriculture and brackish water zone for shrimp is an ideal option to avoid conflicts, but requires more investment and the design of flexible structures for easy adjustment when production systems are changed.

Quality control of shrimp seeds is critical, but the current quality control system is not sufficient. Moreover, the existing canal system was designed and operated for agriculture and navigation; it is not suitable for aquaculture, in particular when a disease outbreak occurs in shrimp farms. Therefore the risk of losses in raising shrimp is still very high. An immediate action that players proposed in the RPGs is to establish an aquaculture cooperative for sharing knowledge and updating the situations of shrimp farms to limit the spreading of shrimp disease.

4.4.4 Lessons learned by researchers from the Bac Lieu RPGs

The RPGs identified several requirements for research of new technologies, such as how to prolong the duration of saline water for shrimp but not create salt residue in the soil that affects the rice crop in the rainy season; how to adjust and operate the existing canal and sluice system for both aquaculture and agriculture; and how to minimize the risk of losses due to shrimp disease when taking saline water in the canal into shrimp fields.

RPGs are considered a participatory approach for natural resource management (Castella, 2007). Some remarks were made at the Bac Lieu RPGs that required further studies in participatory methodologies:

- do players in the RPGs react to changes of water conditions or land use policies in the same manner as they do in reality? This question came from a special case during the RPG in Phong Thanh village. One player applied the traditional shrimp cultivation system with two separate crops and only stocked twice at the beginning of crop seasons. The reason, as he said during the general discussion after the game, was that he did not want to show that he was doing differently to the instructions given by extension officers. This reason leads to a common question arising from the participatory approach or stakeholder consultation for understanding decision rules: is the presence of government officers or other players influencing the reaction or response of a participant? To minimize such influence, individual interviews were carried out after the game to get additional information to clarify players' reactions. RPGs with only farmers and without officers can be organized, but whether such alternative would remove their influence is unclear.

- a "smart" player may make use of the RPG to gather knowledge from other players or researchers (i.e. from university staff present in the RPG) to support his hypotheses in technology development. This issue came from the case of a player in Phong Thanh village who introduced several techniques to prolong the duration of the shrimp raising period. It is similar to the case of creative ideas suggested at the participatory meetings for evaluation by participants. By analyzing the answers from individual interviews after the RPG we could verify that some techniques were just new ideas of the player that have not been practiced, but further survey at the sites would be needed to clarify the conclusion.
- one of the main advantages of RPGs compared to other participatory simulation methods is that it has been developed with game technology and game design principles. Even if its primary purpose is obviously other than pure entertainment, it includes elements that create a playful atmosphere. The rising concept of a "serious game", mainly applied to education, suggests that more and more scientists are convinced that when exposed to this kind of contextualization, participants are more open-minded and thus more responsive to solicitations for expressing their views.
- participants have learned by looking at how the other participants did when faced with the same situation and constraints. Adaptation and learning are two distinct but related processes. The purpose of the game was not to detect which farm management would be revealed as the most appropriate, but rather to give the opportunity to all participants to become aware of the diversity of farm management methods and to

discuss the rationales related to each of them during the collective debriefing where they were all compared. With all the participants facing the same simulated conditions, they shared the same simplified representation of the system. Generally, participating farmers reproduced similar behavioral patterns during the game to those exhibited in real life. However, when this was not the case, it came out during the debriefing and fuelled very interesting discussions about the reasons why they behaved differently during the game. Additionally, when presumed irreversible environmental processes are at work, "learning by simulating" has fewer side effects than the usual "learning by doing".

- a limitation of the RPGs is the short time for playing (half a day for one scenario), so that players could only play a one-year game for each scenario, and therefore could not learn from their own mistakes and adjust their strategies in the following year. This is reflected by the faster game, with better management, that players showed when playing the second scenario. Therefore it would be better if players could play iteratively and learn to improve their management strategies after each game. To respond to this requirement, a MAS computer model has been developed to allow players to play interactively over a number of years during a shorter time. The model supporting the RPG is a simplified but shared representation of the system.

4.5. CONCLUSIONS AND IMPLICATIONS

The RPGs in Bac Lieu province provided better understanding of the conflicts between brackish water aquaculture and fresh water agriculture in the same area for all people concerned, including farmers, managers and researchers. The RPGs confirmed that due to high revenues from shrimp culture, farmers are trying to prolong the duration of saline water as long as possible into the rainy season, and this causes restrictions on the following rice crop. The intended buffer zone between brackish water aquaculture and agriculture, where shrimp-rice crops are applied, has become narrower under the current conditions of cultivation technologies and market prices. This remark leads to a question to managers as to how water management at regional and farm levels can be harmonized, for example, through improvement of information exchange between the regional water manager who supplies water and farmers at different locations who need water with different salinity levels during certain periods. These RPGs also presented several issues concerning cultivation technologies, in particular for combined production systems as shrimp-rice, and in participatory and consultation methodologies as to how to minimize the influence of managers and other participants, or how to distinguish rules and hypotheses in the decision-making process during the games or participatory meetings. Some of these issues will be included in future RPGs in Bac Lieu province with the help of MAS modeling that have been developed under CPWF Project No. 25, but other issues related to technologies will require the efforts of aquaculture and water researchers.

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Note: Table 4.2. The relationship between risk of shrimp seed disease and corresponding yield. (Source: Synthesis from participatory meetings and KIP interview). As an example, using this Table in the RPGs: if a player in Ninh Thanh Loi village picked a “risk” ball that indicated that shrimp seeds were uninfected when purchased, his/her harvest is shown in column (4); if the player decided to implement the pre-stocking treatment that required labour and some costs, he/she would have picked another ball in a basket with 80% good and 20% bad harvest balls; if the player decided not to implement pre-stocking treatment, he/she would pick a ball from a basket containing 50% good and 50% bad harvest balls, i.e. with a higher risk of getting a lower yield.

CHAPTER 5

ROLE PLAYING GAMES TO PROMOTE COLECTIVE LEARNING ON RICE-SHRIMP FARMING IN BAC LIEU PROVINCE, MEKONG DELTA, VIETNAM(3)

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ABSTRACT

Besides being economically profitable to a large population, shrimp aquaculture in coastal inland regions in the Mekong Delta, Vietnam is potentially pregnant with problems that challenge sustainable development in the region. Among the problems defined include conflict over the water quality demanded by existing rice producers and new inland shrimp producers and the associated vulnerability of shrimp aquaculture itself, specifically the potential for extreme poverty and detrimental environmental impacts. Poor communication leading to less collaboration and coordination among stakeholders and their lack of knowledge of sustainable development are major constraints causing the problems. In order to achieve an adaptive management approach towards sustainable development in the province, a novel participatory mediation approach has been investigated for the research. The approach investigated is called

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Companion Modeling (ComMod), which is composed of two key tools: Role Playing Games (RPGs) and Agent Based Model (ABM) simulation. In the first stage of the ComMod process, a series of RPGs were carried out in selected locations of the province to better understand the complex situation as well as achieving collective learning outcomes among relevant stakeholders in the complex system. This paper presents the design, process and lessons learnt of a RPG conducted in 2007 in the province following a first one done in 2006.

Keywords: Mekong Delta, role playing game, collective learning, adaptive management, sustainable development

5.1 INTRODUCTION

Inland shrimp aquaculture has developed rapidly in Asia-Pacific coastal areas because of its potential profitability, which makes up roughly 84% of the global shrimp market (FAO, 2004). As in other countries in Southeast Asia, Vietnam has recently experienced a similar trend of inland shrimp farming expansion. Particularly in the Mekong Delta of Vietnam, traditional rice farming areas in coastal zones decreased from 757,300 ha in 1995 to 363,400 ha in 2006. Rice areas have been replaced by shrimp farming areas, increasing from 289,400 ha to 699,200 ha in the same period (GSO, 2006). Rapid development of shrimp aquaculture has caused a number of problems which have challenged the government to implement a policy based on sustainable development that covers at least three dimensions, namely conflict over water demand between rice and shrimp producers, potential for extreme poverty arising from social economic inequity and environmental impact.

Bac Lieu coastal province in the Mekong Delta has currently been experiencing a complex situation of conflict over water demands for rice and shrimp farming as well as the self-vulnerability of shrimp monoculture development. The province is hence selected as a case study for researching the situation and seeking adaptive measures for natural resource management. The conflict over water demand that has emerged in the province is a typical conflict between short-term, potentially financially rewarding shrimp monoculture farming and long-term sustainable integrated rice and shrimp farming systems (Kam et al., 2001). Downstream areas located close to saline water sources have preferred to develop shrimp monoculture while upstream people have practiced a balance of rice and shrimp integration.

The long-term practice of shrimp monoculture can potentially cause extreme poverty brought about by economic differentiation and environmental problems: namely, the high risk of shrimp disease and soil salinization respectively in the Bac Lieu province (Gowing et al., 2006b). Similar risks and environmental effects have also occurred in coastal Thailand (Szuster, 2006) and Bangladesh (Chowdhury, 2007) where low salinity shrimp farming has encroached on agricultural land.

Conflicts can not be resolved absolutely but can be minimized by applying specific methodology in negotiation processes to increase understanding of involved actors in the context (Caldwell, 2000). Webne-Behrman (1998) proposed a consideration of all three dimensions of substantiality, procedure and psychology when resolving conflicts. In the search for better adaptive management of natural resources, as well as attaining sustainable development in Bac Lieu province, it is necessary to find a comprehensive resolution to minimize the conflicts between upstream and downstream people over water demanded, risk and environmental effects of less integrated rice-shrimp production itself. Understanding socio-economic and environmental impacts that would serve in the better adaptive management of existing production systems and natural resource use in the coastal area of the province requires an active participation of many research disciplines and involved stakeholders in the context (Dougill et al., 2006). Therefore, a participatory approach supporting collaboration to find a better coordination among farmers and other involved stakeholders in the use and management of water resources, as well as enhancing their knowledge of sustainable development, is proposed (Kibi, 2003).

Among participatory methods, Companion Modeling (ComMod) (Bousquet et al., 2001) has been increasingly used for resolving problems in natural resource management, and is selected for this research in Bac Lieu province. Advantages of the ComMod approach is that it can enable people to understand complex systems and support collective decision making in a complex situation (Barreteau, 2003a; Trebuil, 2008) and hence strengthen the adaptive management capacity of local communities (Bousquet et al., 2005b). Aside from Agent Based Model (ABM) simulation (Barreteau, 2003a; Bousquet et al., 2005a), the Role Playing Game (RPG) in ComMod is a key tool that is able to create a common platform for interaction among relevant stakeholders and help them to understand the complex system and make collective decisions regarding adaptive management. RPGs have often been used in natural resource management matters since 1996 (D'Aquino et al., 2002). RPGs can be seen as a social experiment (D'Aquino et al., 2002), in which different scenarios of natural resource management can be investigated. This paper presents the application of an RPG conducted in 2007 as an evolutionary stage in the ComMod process after the first RPG workshop was carried out in 2006 in Bac Lieu province.

5.2 METHODOLOGY

During the implementation of ComMod methodology, the RPG was selected as a first stage in the ComMod process. A series of RPG workshops were conducted in the study area and stakeholders were also interviewed after playing games. In the Bac Lieu case study, including Phong Thanh located in a down stream area and Vinh Loc village located in an upstream area, two RPG workshops were conducted in 2006 and 2007 respectively. Theoretically, one of two crucial purposes of the RPG is to enrich knowledge in the context of study and explore the interaction of stakeholders playing in the game. In order to meet those purposes, two RPG workshops, comprising several series of sessions running through a time step of one year, were conducted for the purposes of this study.

5.2.1 First RPG workshop

The first RPG was conducted in 2006 in three villages located in downstream, middle and upstream areas along the main canal supplying saline and fresh water seasonally for shrimp and rice production respectively. The 2006 RPG sessions were done separately for each village where key participants were comprised of selected farmers in the role as players and selected village officers as observers, and some outsiders with supportive roles. Two scenarios simulating early and late saline water supplies, ranging from January to March, were played out in the game. Land use strategies and water demand for rice and shrimp farming in each location of the game session were explored through observation and analysis of individual farmer's responses corresponding to the two water supply scenarios as well as to various bio-physical and economic conditions. A number of lessons both in technical and social learning have been useful for farmers and local authorities as well as outside researchers who participated in the game. Conflict over the water quality demanded by rice and shrimp farmers within the village could be better understood. After the completion of the 2006 RPG, gaps regarding conflict management and sustainable development on a larger scale appeared. Consequently, it was necessary to conduct a further participatory platform to strengthen our knowledge above and beyond what was learned in the 2006 RPG sessions.

5.2.2 Second RPG workshop

The second RPG was conducted in 2007. For a more streamlined process, the number of participants and locations involved in the 2007 RPG were reduced compared with the 2006 RPG. Selected farmers came from only two villages in two extreme locations along the canal; the location in the middle of the region included in the RPG 2006 session was dropped. The first of the villages selected was Phong Thanh, located in a downstream area. It is characterized by its acid sulphate soil, close location to a saline water source; the land is mainly used for shrimp monoculture. The other location, Vinh Loc village, is located in an upstream area, which is categorized by its alluvial soil, its distance from the coastal zone and saline water sources; the land is mainly used for integrated rice and shrimp farming systems (Figure 5.1).

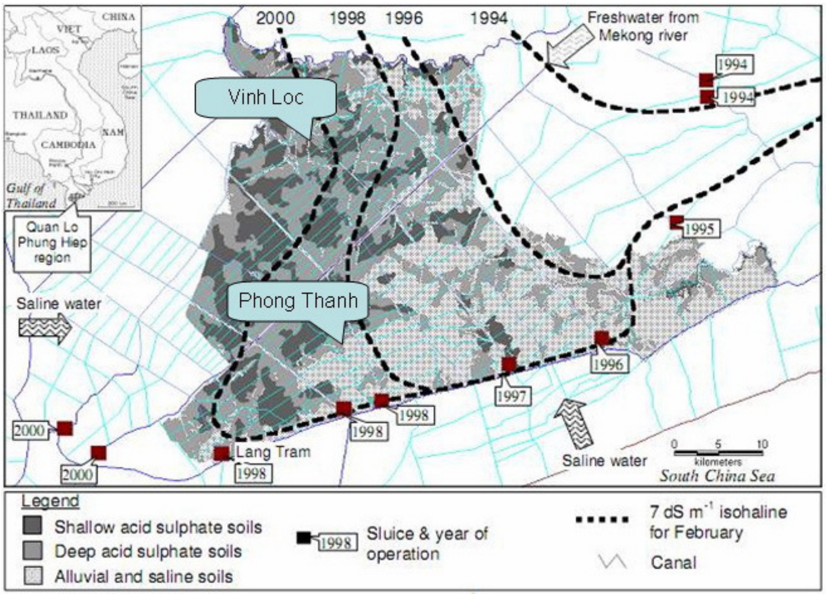

Figure 5.1 Location of Phong Thanh and Vinh Loc villages in Bac Lieu

Three simulated scenarios for the water quality supplied were used in the game. The first scenario followed the actual water salinity provided by the water management agency in 2005. The second and third scenarios of water were those respectively provided by upstream and downstream villagers. Roles and rules were similar to the 2006 RPG. Monthly water quality information and other social economic conditions were provided to the players; they were then requested to present the decisions they made for utilizing their land. One game session was equivalent to one year in reality, which meant that the players had to make their monthly decisions from January to December. At the end of each game session, a collective group discussion and a review of the gaming results were conducted under close observation. After the third scenario was completed, a final collective session for reviewing the differences among the gaming results from the three scenarios, as well as the facilitation of dialogues regarding water management issues among the stakeholders was also conducted.

5.3 DESCRIPTION OF SECOND RPG WORKSHOP

5.3.1 Participants and their roles

Participants of a RPG workshop include not only players, but also observers (Barreteau et al., 2001). For interaction and collective learning purposes, not only were farmer stakeholders key players in the workshop, but supportive staff and many other observers, ranging from village officers to local institutional authorities (Appendix A), were invited to participate (Figure 5.2).

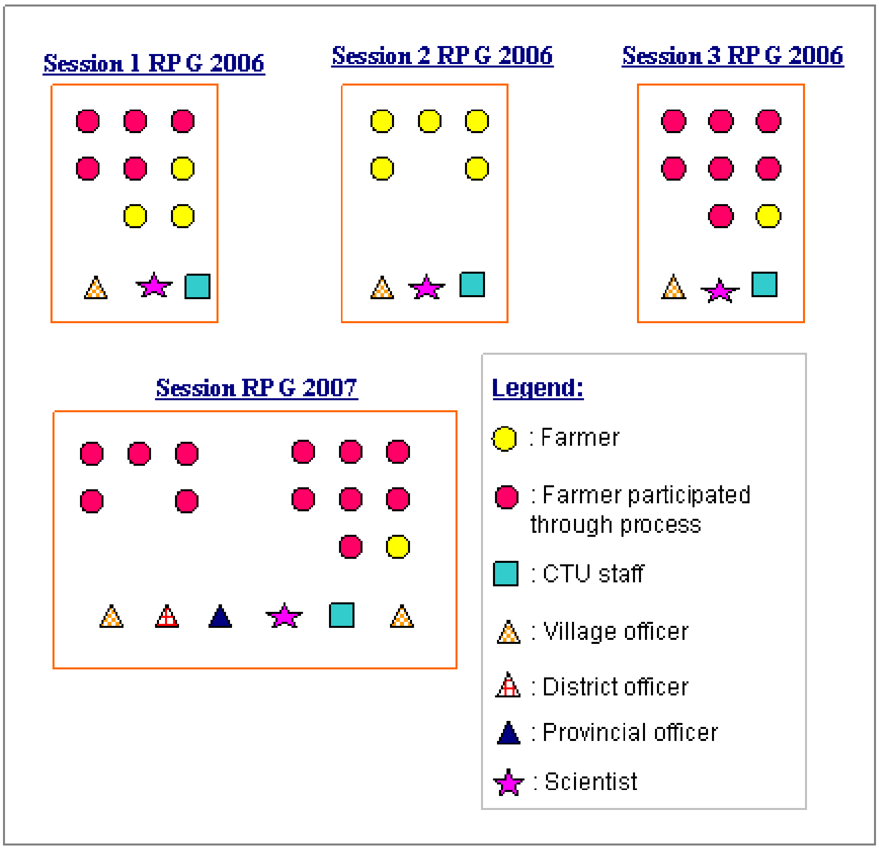

Figure 5.2 Different stakeholders participated in RPG 2006, RPG 2007

In the 2007 RPG workshop, key players included thirteen farmers: five farmers from downstream Phong Thanh village and eight farmers from upstream Vinh Loc village. Based on monthly water quality information announced by the sluice operator, key players were requested to present their decisions on what kind of on-farm activity they were performing, such as rice, shrimp, fish and crab farming. They also imitated other tasks that typically support their on-farm activities like getting loans and buying seed among others.

To assist the key players perform their key activities and the researchers to capture all relevant information pertaining to each of the key player's decision making during the game session, thirteen assistants from Can Tho University were assigned to accompany the thirteen key players (Appendix A). These assistants helped key players record their own decision making on and then glue them onto the correct place in a game board later on without any intervention by the key players. At the end of each game session, key players were asked to calculate individual on-farm income with their individual research assistants. They had to discuss collectively with neighbors in their village, or collectively negotiate with farmers in the other extreme village, to obtain agreements over aspects of water a quality management scheme.

Supportive players included the sluice operator, seed provider, middle man and government banker. These supportive roles were played by researchers from Can Tho University. The most important supportive player was the sluice operator, whose function was to announce monthly water salinity to everyone; based on this information, the key players could decide what kind of farming to do and how much to produce in their field plots. The seed provider was assigned to sell shrimp seed and other input materials like rice seed and fertilizer to farmers. The government banker provided loans at a conventional interest rate to the farmer who wanted to borrow to make farming investments. The last supportive player was the middle man, who was responsible for buying production output sold by farmers at current market prices.

The first group of observers represented institutional authorities at village, district and provincial levels. While all of them were not from management or policy making domains, they were working in agricultural/aquacultural/administrative sectors. They therefore were able to offer valuable suggestions in collective sessions in the games, which later on significantly contributed to the collective learning session. Another group of observers were the scientists, who specialize in water management, game design and ecological economics. They certainly contributed their observations and substantive comments on issues, especially when water salinity was provided and controlled by villagers in the second and third scenarios, as well as raising questions during collective discussion sessions. Their comments could be used for verifying a given idea, which in turn contributed significantly to the collective learning process.

5.3.2 Game board

Intelligence stemming from the interaction among players and individual decisions made by key stakeholders within the game context needed to be represented and analyzed to serve the collective learning session. We used a common board where each upstream and downstream village participant's decision making information was placed during the game session. RPGs are not only a common platform for the interaction of interdependent stakeholders in a context for a given purpose, but they can also present the outputs of what participants have decided over the game session. Through the presentation output, the players are able to review their decisions, be exposed to the experiences of the other participants via their decision making and outputs, and compare each participant's output against their own. The board is presented in figure 5.3.

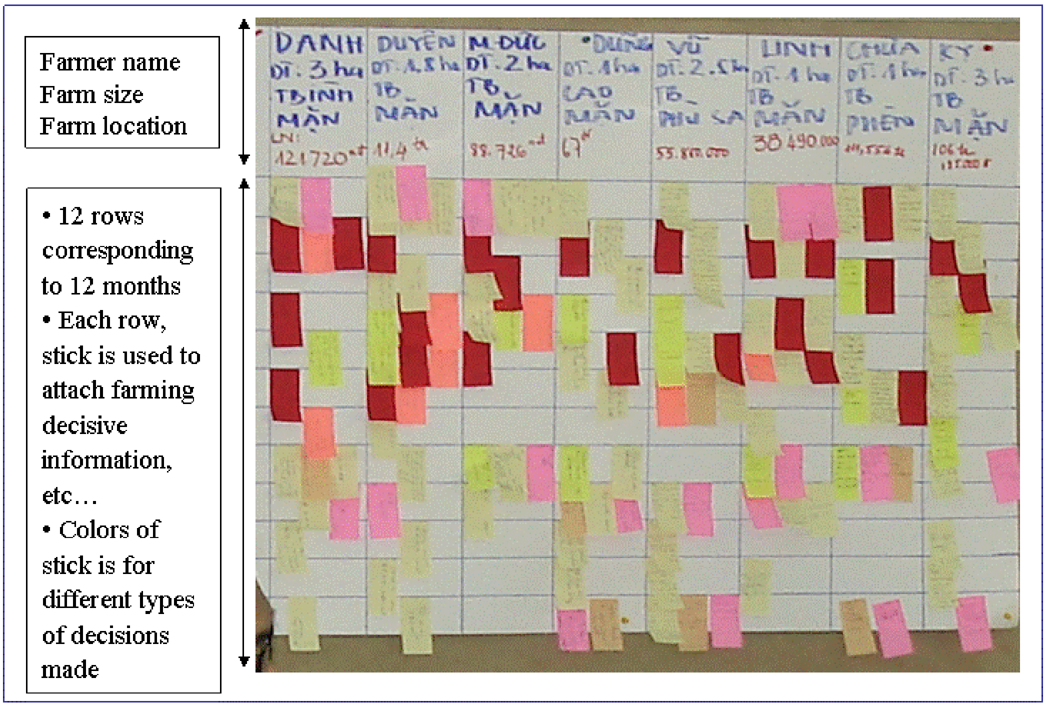

Figure 5.3 Two-dimension board used in game sessions

The board's horizontal dimension was used to locate random farmer field plots along the canal; five columns represented five farmers in Phong Thanh village on the first board and eight columns for eight farmers in Vinh Loc village on the second board. The board's vertical dimension was split into twelve rows equivalent to twelve months (January to December) for every farmer to stick up their monthly decision making information during the game sessions. The name, farm size and soil type of each field plot were written on the top of each column of the board. For better visual purpose, stickers with different colors were used to record the information for the decisions made and stuck on the appropriate position on the board.

5.3.3 Setting scenarios

Water provision is a crucial factor affecting agricultural and aquacultural production. Conflict among farmers within a village who practice different rice and shrimp patterns and between upstream-downstream villages in the Bac Lieu province plagues water resources. Thus, water provision as determined by different operators was used to set up different scenarios for game sessions. Three scenarios corresponding to three sluice operators were used. The first scenario had a government officer operating the sluice. Sluice operation in the second and the third scenarios was managed collectively by Phong Thanh and Vinh Loc villagers. It was expected that these two extreme scenarios would be a very good to explore the conflicts that would occur between the two villages, thus fulfilling the major objective of this case study.

The water provided in the first scenario was based on the reality of the province's water situation in 2005. Water salinity information from that year's water scheme was reused, with the players informed on a simulated monthly basis research staff from Can Tho University playing the role of sluice operator for reasons of simplicity. In the second and third scenarios, the downstream and upstream villagers collectively controlled the sluice in a similar manner. At the beginning of every month, the villagers in each village collectively discussed their opinions, attempting to reach a common agreement on water salinity levels so as to provide the sluice operator with the information to announce. Three game sessions were conducted for the three scenarios, in which each scenario was equivalent to one simulated year.

5.3.4 Gaming sequence

Farmers were the primary players in the game and their roles centered on realistic on-farm activities. The gaming sequence therefore mostly simulated farming and supportive farming activities. The activities were carried out from January to December in order to finish a yearly farming calendar. The sequence of those activities follows.

The first step was water provision. At the beginning of January, or in the following month in another year, the sluice operator announced water salinity information to everyone in the game session. The second step required the farmers to check their economic status to know whether or not they had sufficient funds to buy input materials for their farming investments. The third step allowed farmers to loan money from the government banker. Loan amounts were based on the size of the farmer's land while the interest rate was uniquely set up at one percent per month. The fourth step was when farmers invested into their farm plots. In this step, farmers bought shrimp seed and other input materials for their farming. The amount of shrimp seed and input material was decided by the farmers themselves.

In the fifth step farmers had to deal with the risks associated with shrimp seed. The risk of shrimp seed disease is an important factor that affects shrimp growth; therefore, after each purchase of shrimp seed, farmers had to draw a ball representing the risk of purchasing shrimp seed of poor health. The risk of drawing diseased shrimp seed varied according to the prices of seed that the farmer decided to buy (Table 5.1). In the sixth step, farmers stocked shrimp seed into the fields if their shrimp seed were healthy; otherwise they would have to redo the fourth step. In the seventh step, farmers performed other farming activities like stocking additional fish or crab in the fields.

Table 5.1 Risk possibility at shrimp seed stage used in RPG 2007

Price of shrimp seed (VND/seed)	Risk possibility (%)
45	50
70	30

After a certain period of growth, farmers harvested their output products in the eighth step. The risk of shrimp becoming diseased during the growing period is a factor affecting on-farm income. Therefore before harvesting, the ninth step required farmers to draw a risk ball simulating shrimp disease (Table 5.2).

If shrimp did not die as a result of disease, farmers could harvest shrimp; otherwise, there would be no need to harvest. As part of this step, farmers also harvested any fish and crab that they had stocked. In the tenth step, farmers sold their output products to the middle man at current market prices, which were negotiable between sellers and buyers. Yields of fish and crab were estimated based on farmer experience. Yield of shrimp was estimated based on a specific computation based on biophysical growth and survival rates (Table 5.3).

Table 5.2 Risk possibility at harvesting stage used in RPG 2007

Shrimp growing (month)	Risk possibility (%)
2	30
3	40
4	50
5	80

As long as the gaming sequence went to the rainy season, usually from the middle of May to November, farmers considered whether or not to grow rice in their fields. The eleventh step required farmers to grow rice if they so wanted. Two rice varieties of short and long duration were used. Rice is usually harvested during December or early January. Rice yield can vary based on the variety that the farmers have chosen to grow but not fail due to risks associated with weather conditions. Rice yield ranged from 3.5 to 4.0 ton per hectare in Phong Thanh village, and from 4.0 to 4.5 ton per hectare in Vinh Loc village. Farmers harvested their rice and sold it to the middle man in the twelfth step. The thirteenth step required the farmers to calculate their on-farm income generated from rice, shrimp, fish and crab production. Finally, the farmers had to update their household on-farm income at the end of the year.

Table 5.3 Tabulation of shrimp yield in partial harvesting method used in RPG 2007

Month after stocking	0	2.0	2.5	3.0	3.5	4.0	4.5
Initial population	**20,000**						
Survival rate	1	0.8	0.75	0.72	0.7	0.68	0.65
Population remained-1	20,000	16,000	15,000	14,400	14,000	13,600	13,000
Population harvested		345	3,856	1,590	1,976	2,168	3,406
Population remained-2	20,000	15,655	14,331	9,901	8,036	5,831	3,406
Avg. size of individual (kg)		0.0095	0.016	0.018	0.021	0.025	0.03
Probability of risk (disease)	0	0.3	0.35	0.4	0.45	0.5	0.7
Yield (kg, completely harvested)		152	240	259	294	340	**390**
Yield (kg, 1st partial harvest)		8					
Yield (kg, 2nd partial harvest)			85				
Yield (kg, 3rd partial harvest)				55			
Yield (kg, 4th partial harvest)					69		
Yield (kg, 5th partial harvest)						75	
Yield (kg, 6th partial harvest)							102
Accumulative yield (kg)							**393**
Shrimp grade proportion	Grade 1 (0.067 kg/shrimp)	0	0	0	0	0	**0.12**
	Grade 2 (0.040 kg/shrimp)	0	0	**0.15**	**0.22**	**0.25**	**0.22**
	Grade 3 (0.029 kg/shrimp)	0	**0.07**	**0.15**	**0.18**	**0.25**	**0.22**
	Grade 4 (0.022 kg/shrimp)	**0.05**	**0.37**	0.15	0.15	0.2	**0.22**
	Grade 5 (0.009 kg/shrimp)	0.95	0.56	0.55	0.45	0.3	**0.22**
	Total	1.00	1.00	1.00	1.00	1.00	1.00

Notes:

1) ***Initial population*** is the amount of post larvae (seed) stocked. It can be changed according to farmer's decision making on number of post lavas he/she wants to stock at beginning of crop
2) ***Population remained-1*** is the population resulted by multiplying initial population with survival rate in corresponding month
3) ***Population remained-2*** is population that equal population remained-1 minus population harvested in all previous partial harvests
4) ***Survival rate*** is supposed of 0.65 at 4.5 months after stocking. The figures between 1 and 0.65 for corresponding months are estimated by author
5) ***Population harvested*** is the amount of shrimps which are reached marketable size and harvested. It is calculated by multiplying Yield (at completely harvested) with proportion of shrimp grade to be harvested and then divided to grade size.
6) ***Yield (kg, completely harvested)*** = shrimp remained_1 * Average size of individual shrimp in corresponding month
7) ***Yield (kg, partial harvest)*** = Population harvested * Individual weight by shrimp grade at corresponding month
8) ***Accumulative yield*** = Sum of Yield from 1st to 6th partial harvests
9) ***Bold numbers in green cells are*** proportion of marketable shrimps to be partial harvested.

After updating household income, a session reviewing separate groups of farmers from each village was undertaken. Farmers in each village gathered around the common gaming boards where they had stuck their information on their decision making for on-farm activities for review. Information behind the individual decisions made during the gaming, as well as the output of the decisions made, was revealed. Information on every player within each of the villages could be observed, providing the participants with a fertile learning experience. The farmers learned not only from the cause-effect relationships of their own decisions, but of their neighbors too.

Another collective session was also carried out after completion of the third scenario. There were two parts to this session. In the first part, the consequences of individual decisions made for on-farm activities of each village were presented for every participant in the game to know. Based on these consequences, the second part of the collective session was conducted. The participants raised and explored many of the interlinked topics and issues of water supply and production; three areas in particular were robustly addressed: (i) a comparison of the differences among the three water supply scenarios to better understand conflict arising from water demanded by downstream and upstream villages or conflict over farmers' needs and the actual water scheme provided by the local water management agency; (ii) the negotiation process between farmers in two extreme villages and representatives from local and institutional authorities, as well as the scientists who participated in the game to enact a compromised water scheme that satisfied both villages; (iii) players and observers gave remarks, as well as lessons, on the usefulness of the RPG for tackling the problems of natural resource management that they had never experienced in reality.

5.4. COLLECTIVE LEARNING

Several lessons were absorbed in the RPG by key players—that is the farmers themselves—and other stakeholders who participated in the game. Lessons came from mutual learning between players, local authorities and researchers participating in the game. The lessons also came from the way farmers attempted to find adaptive management strategies for water demand, farmers' decision making in response to different water management schemes, risk and price of outputs, and especially from the economic consequences of on-farm activities resulting under different water management schemes.

5.4.1 RPGs as a useful platform for exploring and resolving conflict

Even local farmers using the water management scheme that is as a consequence resulted from revised production policy of the province, conflicts of different water demand for rice and shrimp production are obviously existed in the province. While the conflicts have long been a part of the reality in the region, they have not been formally recognized by local institutional authorities and farmers due to limitations of effective communication between them (Lee, 1999). RPGs provided a good platform for upstream and downstream farmers to represent their different water needs and since then conflicts over different water demands have been expressed. In the second and third sessions, farmers in downstream and upstream villages were respectively given a right to freely set up a water management scheme for their own demands. In this way farmers in one village had to adopt the water scheme set up by the other extreme village; conflicts over water demand that arose from such a situation could be explored deeply. Differences in the timing of the water supply and salinity intensity in the two water management schemes were found. A good point is that the conflicts over water demand were being observed and recognized by local institutional authorities participating in the game. While those people are not directly responsible for the management of water, they could significantly contribute their voices to future adjustments of water supply at the provincial level for better adaptive management.

A compromised water management scheme finally was agreed upon after participants arrived at a deeper understanding of the conflicts that arose as a result of the two water management schemes controlled by downstream and upstream villages. Once again the RPG created a good platform for all stakeholders to communicate, share knowledge and their perceptions, as well as their water demands, in order to seek a harmonized resolution for the conflict. The compromised scheme was considered as a collective output of all the stakeholders who had participated in the game. Water quality in the compromised scheme was however not similar to that of the actual water scheme provided by the local water management agency, which was used in scenario 1 in the RPG (Figure 5.4). In this compromised scheme, the timing of salinity available was almost one month earlier while salinity intensity was rather moderate compared to the first scenario. The water scheme in the first scenario was scientifically proposed as a blue-print scheme for the province after revised production policy in 2003. The essential lesson here would be that the blue-print water management policy needs to more flexible to cope with the dynamic demands of local people. As it stands now, there is no consensus on how to integrate scientific and local knowledge, and perception (Abelson et al., 2003). This lesson is consistent with Bouwen (2004) who have suggested that a blue-print planning-implementation approach is no longer sufficient to obtain viable and sustainable outcomes.

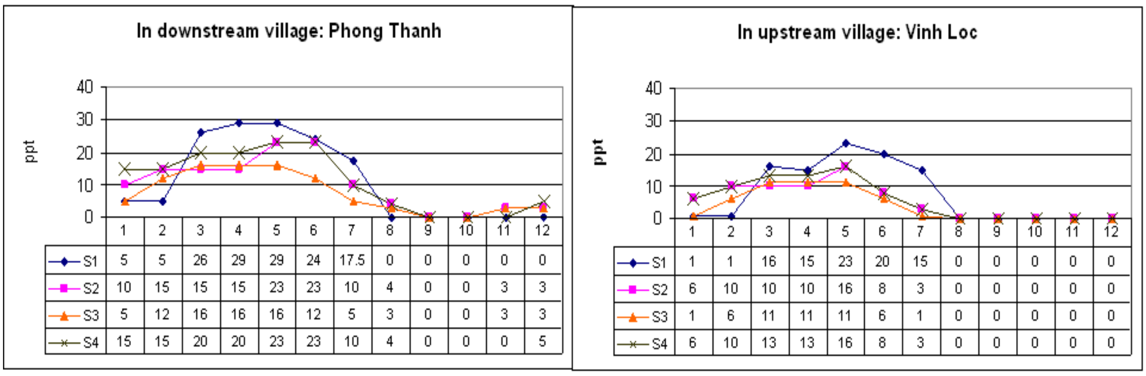

Figure 5.4 Scenarios of water salinity used in RPG session

5.4.2 Highly vulnerable land use tends to occur without state intervention

Integrated rice-shrimp farming systems are considered as a sustainable land use pattern in the coastal tidal areas in Bac Lieu province. However, the potentially high profitability of shrimp has led farmers to shift to a shrimp monoculture pattern. RPGs are a good social experiment that can help prove the important role of governmental intervention in pursuing sustainable development. By making a comparison of the cropping calendars for shrimp and rice among the different simulated scenarios of water management, we can see that there was a balance between shrimp and rice durations in dry and wet seasons in the first scenario when saline water was controlled and provided by the government agency. Longer shrimp durations were found in the second and the third scenarios when water provision was managed by either downstream or upstream villagers, respectively (Figure 5.5). Another indicator, like the number of farmers practicing rice in the wet season in downstream village, also proved that the collapse of integrated rice-shrimp farming was much more probable in the second scenario when water was controlled by downstream villagers themselves. A smaller proportion of farmers practiced rice in the wet season in the second scenario, compared with that in other scenarios, as can be seen in Table 5.4 below.

RPGs are a social experiment. In this case study, they were quite useful for performing a social experiment in which water management by different sluice operators was treated as an important factor. The role of government intervention in water management issues is once again strengthened in its pursuit of sustainable development in the coastal region. In other words, public involvement and participation in at least some stages of the problem solving and decision-making cycle have become major themes in the governance process (Huxham, 2000; Mostert, 2002; Pahl-Wostl, 2002; Tailieu, 2001; Wildemeersch, Janssen, Vandenabeele, & Jan, 1998) as cited in Bouwen (2004).

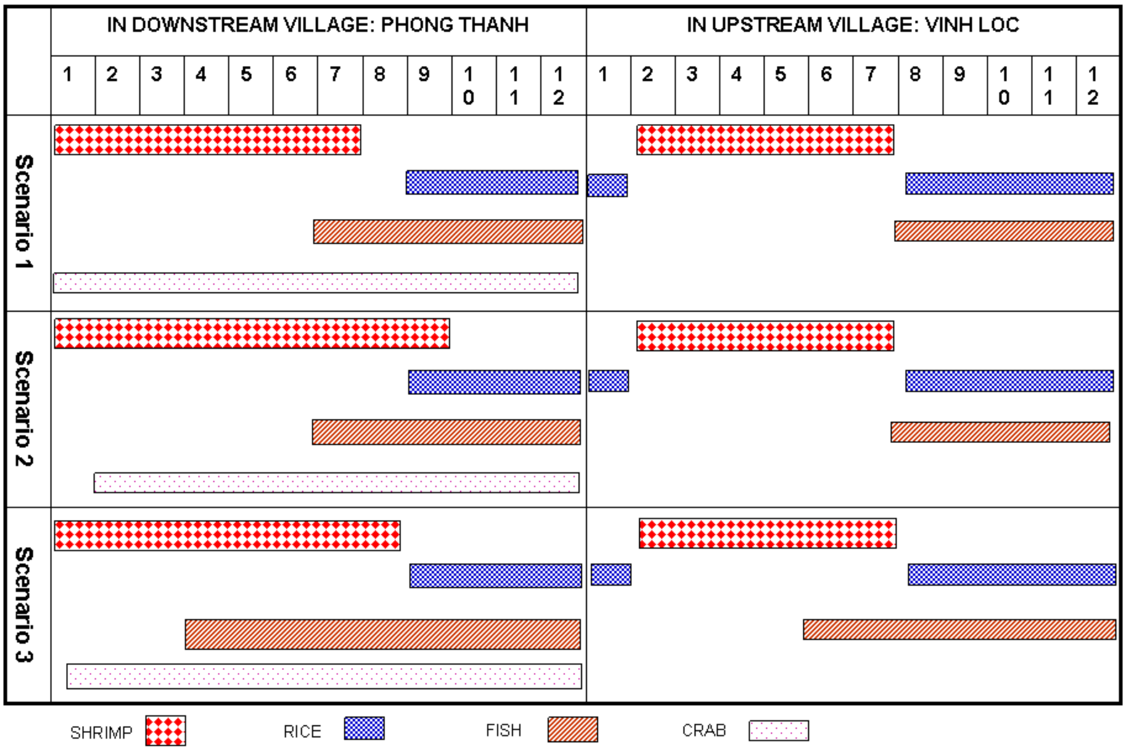

Figure 5.5 Cropping patterns by villages and scenarios in RPG

Table 5.4 Proportion (%) of players who cultivated rice and shrimp in the wet season

Scenario	Phong Thanh village		Vinh Loc village	
	Rice	Shrimp	Rice	Shrimp
1	60	40	100	50
2	40	80	100	62
3	60	80	100	50
Total	53	67	100	54

5.4.3 High risk and potential for extreme poverty in shrimp monoculture pattern

Shrimp monoculture has always been a risky enterprise for many reasons (Brennan, 2003), potentially resulting in extreme poverty and income inequity in the community. About 61.5% of total aquaculture households do not earn enough revenue to cover their annual living expenditures (Sinh et al., 2005). However, there is no evidence from other studies in this coastal region that show the relationship between the inherent risks in shrimp production and extreme poverty and income inequity. In our RPG we could observe that relationship by comparing the risk encountered in shrimp farming in the RPG's three simulated scenarios of water management, especially in the downstream village of Phong Thanh.

It was easier to find higher risk factors in both the stocking and harvesting stages of shrimp production in the first scenario compared to the other scenarios. In the first scenario, even though the saline water duration was shorter, the number of stocking times was much higher than that of the other two scenarios; as a result a higher risk was encountered in this scenario. When comparing upstream and down stream villages in the same scenario, we found higher risk encountered with shrimp farming of a monoculture pattern (Table 5.5). Risk is an essential factor leading to potential poverty and economic differentiation that threatens sustainability (Neiland et al., 2001).

In Table 5.6, we can see high income variations and income differentiation in the first scenario in the downstream village when farmers encountered high risks in their shrimp production.

Table 5.5 Risk occurrence (%) at seed and harvest stages by villages and scenarios

Scenario	Phong Thanh village			Vinh Loc village		
	Stocking (Time/yr)	Risk in stocking stage (%)	Risk in harvest stage (%)	Stocking (Time/yr)	Risk in stocking stage (%)	Risk in harvest stage (%)
1	6.20	41.50	76.00	3.00	10.42	43.75
2	4.80	24.67	35.00	2.75	14.17	25.00
3	5.20	20.67	48.67	3.00	18.75	29.17
Total	5.40	28.94	53.22	2.92	14.44	32.64

Table 5.6 Land and shrimp net income distribution by villages and scenarios

Village	Scenario	Land distribution (Gini)	Shrimp net income (USD/household/year)			Shrimp net income's distribution (Gini)
			Max	Min	Avg.	
Phong Thanh	1	0.25	760	-145	205	0.88
	2	0.25	5,322	768	2,597	0.39
	3	0.25	2,652	785	1,612	0.26
Vinh Loc	1	0.23	7,384	349	2,264	0.47
	2	0.23	4,369	481	2,169	0.38
	3	0.23	4,351	203	1,957	0.35

5.4.4 The merging of scientific and practitioner knowledge in RPG output

The attendance of the observers, who are multi-disciplinary experts especially in the domains of natural resource management, gaming, and ecological economics, proved very helpful in screening and providing analysis of the interactions of many stakeholders, as well as the outputs of farmer decision making during the game. Most helpful was their judgments on the compromised water management scheme agreed upon in the final collective discussion session. Without their knowledge, a too extreme water management scheme might have been created in a compromised resolution due to imbalances brought about by the dominance of one party involved in the negotiation process. Their attendance could also make farmers feel secure about their water demand claims during the game sessions, especially in the second and third scenarios when farmers were given rights to operate the sluice. Thus scientific and practitioner knowledge were merged in this RPG to produce a common output of a compromised scheme of water supply. It can be used as a lesson for actual natural resource management.

5.5. CONCLUSION AND PERSPECTIVES

The two RPG workshops in 2006 and 2007 have proven to be a potential and useful participatory simulation tool for understanding the way how the key stakeholders justified and made rational decisions in the midst of fluctuations and uncertainties of biophysical conditions and economic pressures. Throughout the game, robust dialogue among the relevant stakeholders was evident and facilitated a platform for sharing ideas as well as finding a better coordination dealing with land use and water management. As a result, the participants could improve their knowledge and explore the possibility of negotiation for appropriate land and water management driven by the tenets of sustainable development, which the researchers attempted to highlight during the games. However, the games did not comprehensively cover many issues and factors as desired; this was a result of streamlining the RPG. The RPGs are the first stage in the ComMod process and they should be followed by Agent Based Model (ABM) simulations for dealing with the dynamics of technical complexity and socio-economic domains.

ACKNOWLEDGEMENT

The authors would like to express our sincere thanks to the farmers in the two villages of Phong Thanh and Vinh Loc for their participation in the RPGs and the CPWF Project No. 25 (Companion modeling and water dynamics) for funding this study. Our appreciation and thanks also go to the staff at the Mekong Delta Development Research Institute, Can Tho University for their hard work, and the provincial, district and village authorities in Bac Lieu province for their valuable contributions to the success of the RPGs presented in this paper.

CHAPTER 6

THE RICESHRIMPMD AGENT-BASED MODEL

Agent-Based Models (ABM) are a form of computational tools used to explore, through simulation, representations of complex systems. . There is a direct correspondence between the actors of the reference system being modeled and the computer entities (the "agents") in the program (Gilbert, 2008). Agents are heterogeneous in their features and abilities (Janssen, 2005). ABMs are built based on the concept of multi-agent system (MAS), which is a short-lived paradigm to represent dynamic systems whose evolution is driven by the direct interactions between agents and by the interactions between agents and the resources hold by their environment. The principles of MAS and the generic building methodology of ABM are reviewed in chapter 2.

In this chapter, we present the agent-based model collaboratively developed and used with local farmers from two villages and institutional authorities from Bac Lieu Province in Mekong Delta. This model is called RiceShrimpMD as it is about rice and shrimp competition in the Mekong Delta. RiceShrimpMD was developed with the CORMAS (COmmon-pool Resources and Multi-Agent Systems)[4] platform, which allows Agent-Based Models to be designed and run. CORMAS was specifically developed to deal with renewable resource management. It uses the Smalltalk object-oriented language under the VISUALWORKS environment (Bousquet, 1998; CIRAD, 2003). CORMAS provides the developer with built-in facilities, including a set of pre-existing entities and agents control procedures and different types of interface to visualize the results.

Through a collaborative modelling process, the RiceShrimpMD model was co-constructed to achieve a representation of the reference domain shared by all the participants in the modelling process, including researchers. The sense of co-ownership of the RiceShrimpMD model therefore emerged as a result of such a model co-construction process.

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[4] CORMAS and the source code for RiceShrimpMD model are available at http://cormas.cirad.fr.

The ABM is elaborated based on participatory principles throughout the process, from co-construction of the model to simulation and validation of its outputs. The basic ABM version described in this chapter was introduced, validated and explored by farmers during a participatory workshop held in February 2009. During the workshop, some modifications were suggested by the participants, which are listed in the next chapter. Those suggestions led to the production of a second version of the ShrimpRice ABM that has been explored in the lab (see chapter 7).

Describing the implementation of any ABM is often cumbersome: its structure, characterized by intertwined interactions and rule-based algorithms, is difficult to unfold. Compared to traditional equation-based models, ABMs are undoubtedly more difficult to describe, communicate and analyze. Traditional equation-based models are easy to communicate because they are formulated in the unambiguous and universal language of mathematics. Unlike mathematical models, computer simulation models such as ABMs have no standard language or protocol for communication, so published descriptions of ABMs are often hard to read, incomplete, ambiguous (without clear indication of rules and schedules), and therefore less accessible (Grimm et al., 2005). Consequently, to reproduce an ABM from its published description remains problematic (Hales et al., 2003), which seriously questions the scientific status of such tools.

To help readers understand the structure of ABMs more easily, and enable them to re-implement such kinds of models, a protocol named "Overview-Design Concepts-Details (ODD)" developed by a group of modellers, has been proposed as a standard format for the description of both individual-based and agent-based models (Grimm et al., 2006). IBMs differ from ABMs in that they generally model non-human entities interacting within an ecological system (Grimm et al., 2005), while ABMs often model human actors making decisions (Gilbert et al., 1999). Even though the ODD was mainly developed by the IBM modelling community, its framework is suitable for describing any bottom-up simulation model including ABMs (Polhill et al., 2008). The description of the RiceShrimpMD ABM is, hence, based on the ODD protocol.

6.1. OVERVIEW

First, the purpose of the RiceShrimpMD model is explicitly stated to inform readers about what is to be done with the model. Then, the state variables of all entities (Table 6.1) and the spatial and temporal scales outline the structure of the model. As recommended by some ABM modellers (Le Page et al., 2005; Richiardi et al., 2006), a UML (Unified Modeling Language) class diagram showing the structure of the ABM completes the static representation (Figure 6.1). Finally, all the processes that occur in the model are listed and indications about how they are scheduled are given with a UML sequence diagram (Figure 6.4).

6.1.1 Purpose of RiceShrimpMD

The RiceShrimpMD is a communication tool used by scientists and local people including farmers and relevant local institutional authorities for knowledge-exchange and knowledge-integration regarding causality between land & water use and socio-economics and environmental impacts on coastal rice shrimp farming in Bac Lieu province in the Mekong Delta of Vietnam.

6.1.2 State variables and scales

The RiceShrimpMD is made of six key entities, namely Plot, Farm, Village, Canal, Household and Crop that are classified into spatial, production and social modules. These modules are inter-connected.

Table 6.1 List of parameters classified by entity, default values and their sources

Entity	Parameter	Default value	Unit	Source and main tool used
Plot	Minimum size	0.25	Ha	Author's survey
	Maximum size	1.00	Ha	
Farm	Minimum size	0.75	Ha	Author's survey
	Maximum size	3.00	Ha	
	Minimum number of plot	1	Plot	Author's survey
	Maximum number of plot	8	Plot	

Table 6.1 (continued)

Household	Minimum household size	4	Person	Author's survey
	Maximum household size	9	Person	
	Initial capital	5	10^6VND.ha^{-1}	KIP, RPG2007
	Living cost per person	0.2	10^6VNDmonth^{-1}	KIP
Shrimp	Minimum salinity to start shrimp crop	8	ppt	KIP, RPG2007
	Earliest month to start shrimp crop	1st	Month	KIP, RPG2007
	Density stocked	15,000	Seed. time^{-1}.ha^{-1}	KIP, RPG2007
	Weekly mortality rate	2.6	%	(Kungvankij et al., 1986), (Chanratcha-kook, 2005)
	Probability of shrimp disease (at 1st week)	4	%	KIP, RPG2007
	Probability of shrimp disease (in succeeding week)	0.2	%	
	Weight of marketable shrimp	0.03	Kg.shrimp^{-1}	KIP, RPG2007
	Price of marketable shrimp	0.1	10^6VND.kg^{-1}	KIP, RPG2007
	Price of shrimp seed	0.00006	10^6VND.seed^{-1}	KIP, RPG2007
	Initial shrimp production cost	1.0	10^6VND.ha^{-1}	Author's survey
	Minimum duration of shrimp crop	3	Month	KIP, RPG2007
	Maximum duration of shrimp crop	4	Month	
	Proportion of shrimp population to be harvested as disease occurred later than 3 months after stocking date	30	%	KIP
	Proportion of shrimp population to be harvested as disease occurred between 2 and 3 months after stocking date	10	%	KIP
Crab	Minimum salinity to start crab crop	2	ppt	FAO (2006-09)
	Earliest month to start crab crop	3rd	Month	KIP, RPG2007
	Density	600	Seed.time^{-1}.ha^{-1}	KIP, RPG2007
	Survival rate	65	%	KIP, RPG2007
	Maximum duration of crab crop	183	Day	KIP, RPG2007
	Minimum duration of crab crop	122	Day	KIP, RPG2007
	Adult weight	0.4	Kg.crab^{-1}	KIP, RPG2007

Table 6.1 (continued)

Crab	Seed market price	0.002	10^6VND.seed^{-1}	KIP, RPG2007
	Adult marketable price	0.06	10^6VND.kg^{-1}	KIP, RPG2007
Fish	Earliest month to start fish crop	5th	Month	KIP, RPG2007
	Production cost	0.5	10^6VND.ha^{-1}	KIP, RPG2007
	Maximum duration of fish crop	150	Day	KIP, RPG2007
	Minimum duration of fish crop	122	Day	KIP, RPG2007
	Yield	5,000	Kg.ha^{-1}	KIP, RPG2007
	Market price	0.005	10^6VND.kg^{-1}	KIP, RPG2007
Rice	Earliest month to start	9th	Month	KIP, RPG2007
	Maximum salinity to tolerate	4	ppt	Hoanh et al, 2003
	Maximum duration of long duration variety	135	Day	Author's survey
	Minimum duration of long duration variety	120	Day	Author's survey
	Production cost of long duration variety	5.25	10^6VND.ha^{-1}	KIP, RPG2007
	Yield of long duration variety	4,500	Kg.ha^{-1}	KIP, RPG2007
	Market price of long duration variety	0.0035	10^6VND.kg^{-1}	KIP, RPG2007
	Maximum duration of short duration variety	100	Day	Author's survey
	Minimum duration of short duration variety	90	Day	Author's survey
	Production cost of short duration variety	1.5	10^6VND.ha^{-1}	KIP, RPG2007
	Yield of short duration variety	3,500	Kg.ha^{-1}	KIP, RPG2007
	Market price of short duration variety	0.00225	10^6VND.kg^{-1}	KIP, RPG2007

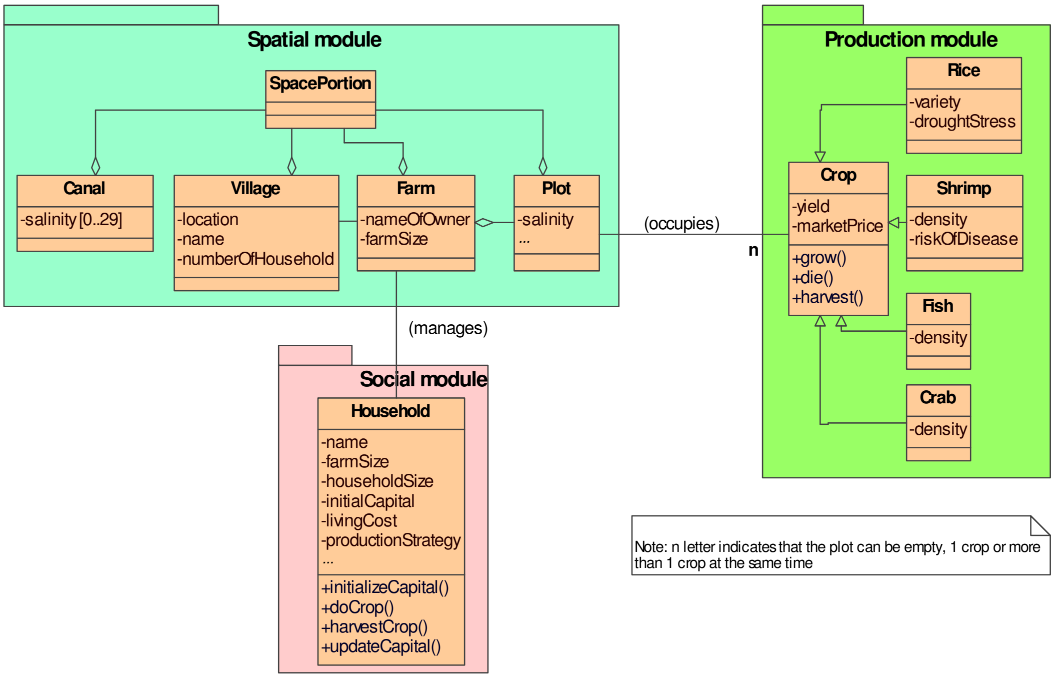


Figure 6.1 Model structure and components (with their associations) represented by a UML class diagram.

The household entity is a key decision-maker in the RiceShrimpMD model. All main farming activities are decided at this entity level by considering the crops already growing in the farm plots and the quality of water in accordance with the crop requirements. State variables embedded in this entity include name, farm-size, number of plots, household-size and initial capital.

The Crop entity is the abstract generalization of four specific production entities: rice, shrimp, crab and fish. The rice entity is diversified into two varieties (short duration in down stream village and long duration in upstream village). Key characteristics of these production entities are presented in Table 6.1. The Crop entity is a rule-based agent located in the farm plots, which subjectively generates economic income. The occupation of a crop is primarily based on plot occupation status (occupied/empty) with possibly different types of complementary crops growing at the same time in the same plot, salinity limitations and the suitability of the season in a year. Figure 6.2 illustrates the cropping calendar of four rule-based crop agents in RiceShrimpMD. .

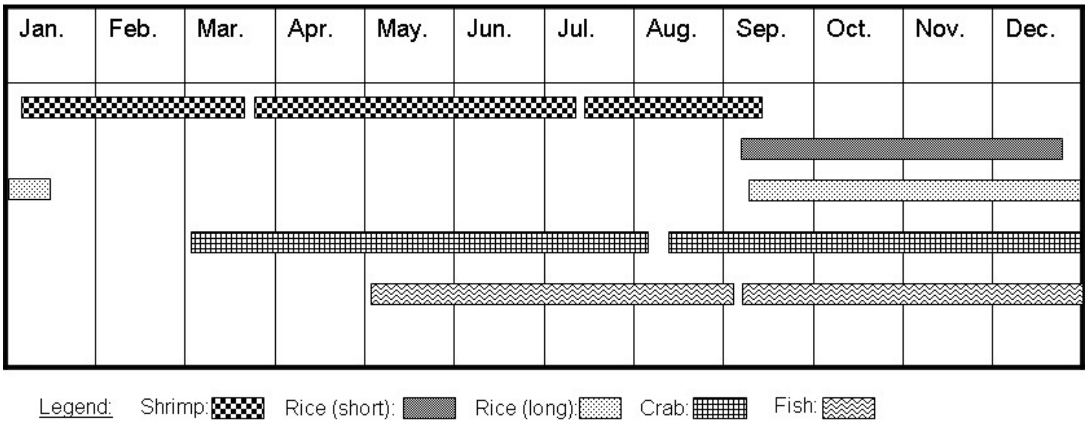


Figure 6.2 Cropping calendar of four rule-based agents in RiceShrimpMD

Canal, village, farm and plot are the four spatial entities of the RiceShrimpMD ABM. All are made of aggregated elementary space portions (cells). The spatial resolution was set to 0.25 ha that is represented by a cell (the smallest homogeneous spatial unit of the model). The size of Plot ranges from 0.25 to 0.5 ha. Each farm is made of a collection of plots, ranging from 0.75 to 3.0 ha in size. The overall spatial configuration of the RiceShrimpMD, made as a regular matrix of 13 lines by 408 columns of cells (total area is therefore 1,326 ha), is represented in figure 6.3.

The canal entity is made of cells representing the way saline water is carried from the sea to provide salinity to down stream and up stream villages at the two ends of the canal, namely Phong Thanh (PT) and Vinh Loc (VL) villages, respectively. The length of the canal is 20.4 km (408 columns * 50 m).

The village entity is an aggregation of farms. In the version of the model that was used with the farmers, we considered 5 and 8 farms respectively in the down stream and upstream villages. Figure 6.3 above illustrates the distribution of 13 households/farms in two villages with their first names displayed in the top left corner of the farm. One farm is composed of at least one plot to a maximum of ten plots. In this figure one can see the farm of Mr. Du located at the bottom left of village 2 (Vinh Loc). The farm is composed of 9 plots including 8 plots of 0.25 hectares (equal to a cell). The village is used as a unit to compare the average income between up and down stream communities, and income distribution among households.

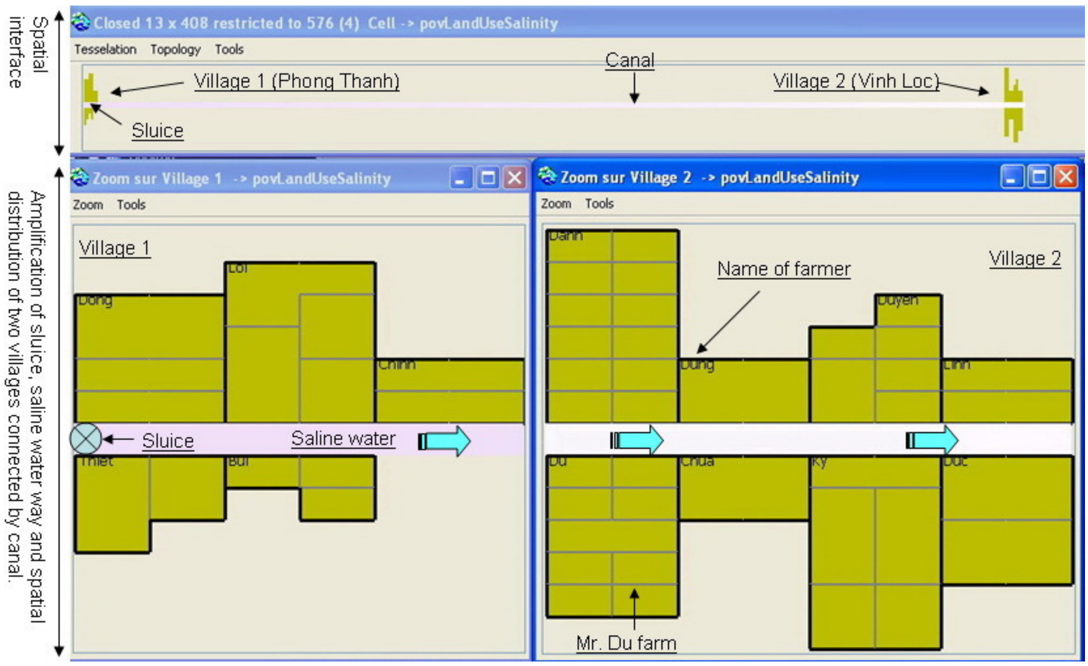


Figure 6.3 Spatial configuration of the RiceShrimpMD representing two end villages along the canal and their farms.

The RiceShrimpMD is a discrete time-step model. A weekly time-step was chosen because in reality, participating rice-shrimp farmers adjust their decisions to water tidal conditions on a weekly basis. However, to some extent this model is also event-driven since occurrences of shrimp disease may modify the cropping calendar of households. The time horizon was set to 5 years, equivalent to 260 weeks, in order to assess scenarios while limiting the impact of demographics and price of production output changes, which are not the focus of this model.

6.1.3 Process overview and scheduling

Crucial processes are the decision-making and operations of the agents. Figure 6.4 shows the sequence of farming activities throughout a crop year that was set to start on January 1st of the year.

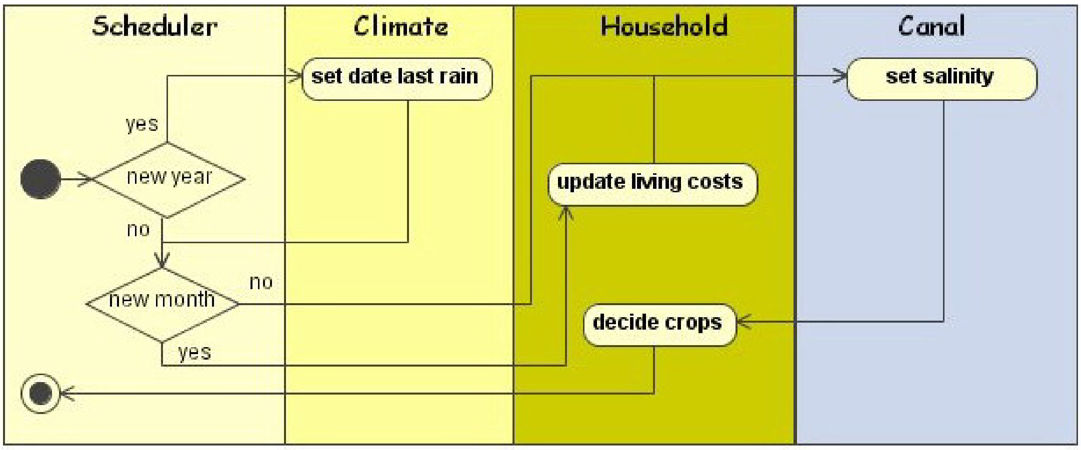


Figure 6.4 UML sequence diagram illustrating annual activities in the RiceShrimpMD

The sequence of activities is started by the scheduler, which activates to update the date of last rain to know drought occurrence in the year. This activity follows a principles that in the first week of each year, the date of the last rain is randomly picked; in the first week of each month, the household living costs are updated; and every week, each household checks its plots and salinity to decide on new crops and/or maintain or harvest existing ones.

6.2. DESIGN CONCEPT

The model is designed using both stochastic and deterministic concepts. Randomness refers to the duration of crops (between min and max); risk of shrimp disease; and date of last rain (drought). On the other hand, the model is deterministic regarding the critical constraints of salinity to allow the starting of crops. This combination of stochastic and deterministic factors is needed when the main objectives of the model are both to enhance knowledge and illustrate the causality between salinity patterns, crop selection and income generation.

6.3 DETAIL

The third part of ODD aims to describe key entities, process and scheduling in detail so that the model can be completely re-produced. The details include three elements: initialization, model input, and submodels.

6.3.1 Initialization

Thirteen households in two villages situated at the ends of the canal and their farms, as well as their plots, are represented in the model. Characteristics of each household have been chosen to represent the heterogeneity of the communities located in the two villages (Table 6.2). The initial water salinity scenario in the canal was set to the actual salinity scheme that was monitored in 2005 and was managed by local government officers. Figure 6.5 shows the initial configuration of the RiceShrimpMD.

Table 6.2 Characteristics of households pre-designed for initialization

Household (Name)	Farm size (Ha)	Household size (Member)	Initial capital(*) (10^6 VND)	Location (Village)
Nguyen Van Dong	2.00	5	10.00	PT
Nguyen Quang Bui	0.75	7	3.75	PT
Nguyen Van Thiet	1.25	7	6.25	PT
Tran Trung Chinh	1.00	9	5.00	PT
Nguyen Van Loi	2.50	6	12.50	PT
Mean	1.50	6.80	7.50	
Danh Duyen	1.75	4	8.75	VL
Nguyen Minh Duc	2.00	4	10.00	VL
Nguyen Van Dung	1.00	5	5.00	VL
Nguyen Cong Danh	3.00	4	15.00	VL
Ngyyen Van Du	2.50	4	12.50	VL
Son Minh Ky	3.00	6	15.00	VL
Son Chi Linh	1.00	5	5.00	VL
Son Thanh Chua	1.00	6	5.00	VL
Mean	1.91	4.75	9.53	

(*): Capital is set of 5 million VND per hectare of land

6.3.2 Input

Monthly salinity schemes, converted into weekly salinity data, are used in the model and influence the way the household agents make decisions on crop production. Possibility of drought occurrence in target period affecting rice production is at 0.70, which is a mean of statistical data gathered over ten years (1997-2007).

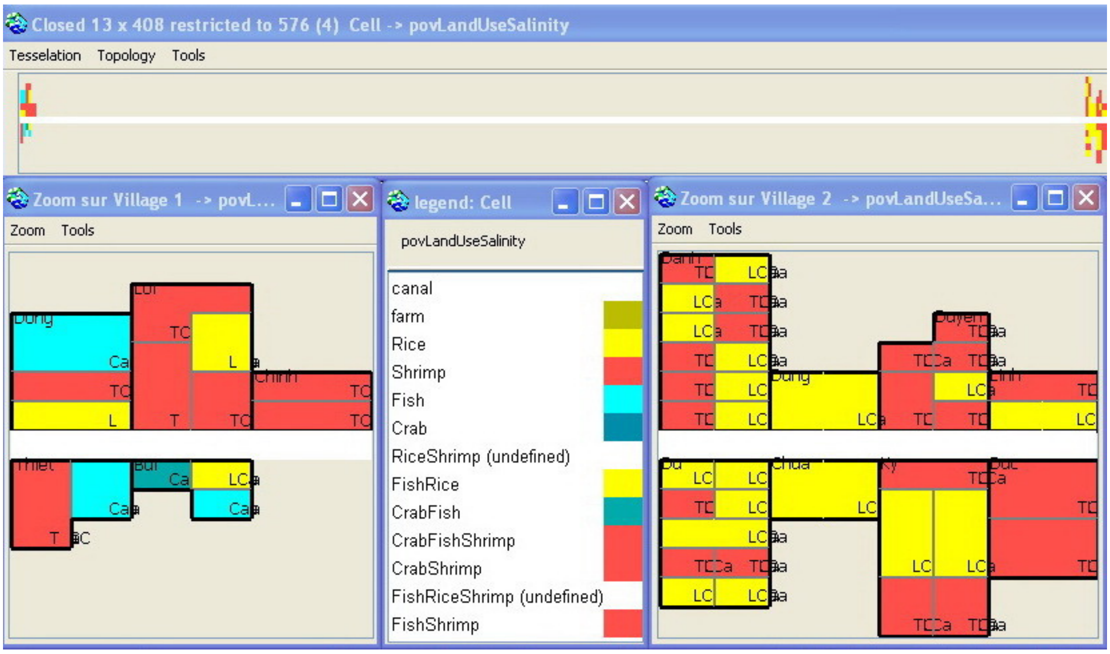


Figure 6.5 RiceShrimpMD simulation at initialization showing two villages and their farms with different crops.

6.3.3 Submodels

There are five submodels corresponding to one decision-making process (selection of crops to be grown in the plot based on plot status and salinity constraints) and four production activities related to each type of possible crops to be grown. (shrimp, rice, crab and fish).

6.3.3.1 Crop selection submodel

Crop selection is the key decision-making process of the RiceShrimpMD ABM. It is about selecting either shrimp, rice, crab, or fish crops, or an adequate combination of two/three single crops to be grown in a certain plot of a farm. Plot is the smallest unit of farm land to use for crop growing. The ultimate household objective is to generate income from all crops to be produced over a year. Hence, households always try to use their farm land in the most effective way they can based on the status and salinity of the plot.

The principle for a crop to start its cycle is that a new crop can be grown in a plot when that plot is empty. Otherwise the current crop being occupied in that plot continues to grow until it is naturally mature. On the other hand, each crop has specific salinity constraints according to its biophysical characteristics.

6.3.3.2 Shrimp submodel

Two requisite conditions for starting shrimp farming are salinity and household income. Salinity should be equal or higher than 8 ppt to match with shrimp biophysical characteristics. Household income should be equal to or higher than 2 million VND per hectare of land, which is sufficient enough for the initial investment of a shrimp pond at the beginning of the cropping year (Figure 6.6).

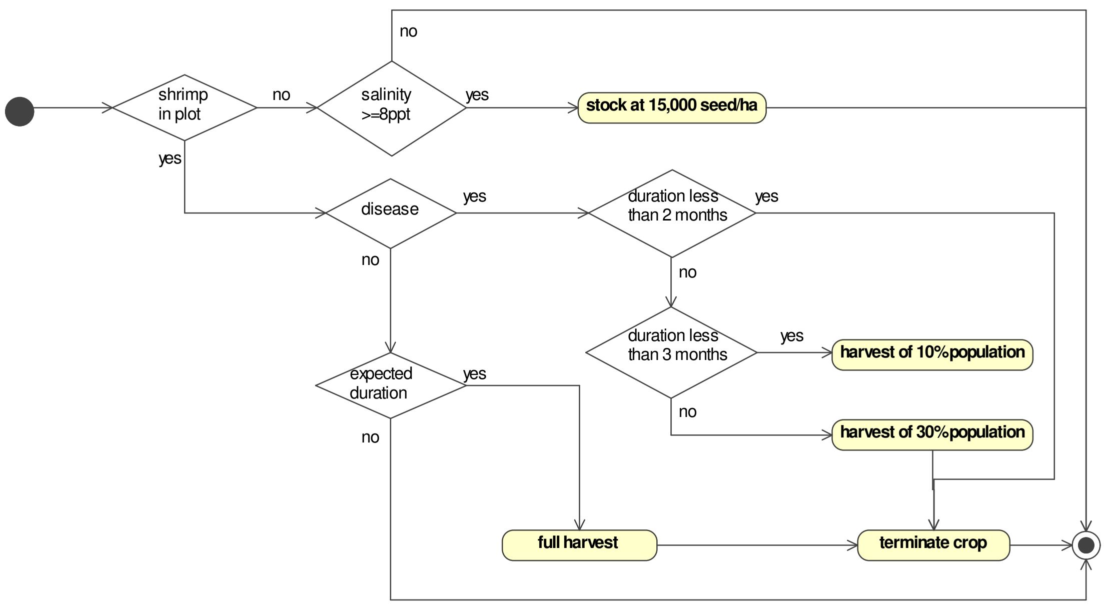


Figure 6.6 Activity diagram to present rule-based shrimp agent in RiceShrimpMD

The post-larvae of many Penaeid species, including black tiger shrimp *(Penaeus monodon)*, can tolerate wide salinity fluctuations which have little effect on their survival or growth. In pond conditions, black tiger shrimp can tolerate wide ranges of salinity from as low as 5 ppt to a high of 40 ppt (Kungvankij et al., 1986). In low salinity shrimp production areas, as in coastal Thailand, shrimp can tolerate a salinity ranging from 10 to 30 ppt, or even after acclimating, shrimp can be grown at a salinity ranging from 2 to 10 ppt in the growing out period (Mekhora et al., 2003). However, in Bac Lieu province, a minimum salinity ensuring good growth of shrimp is 8 ppt (KIP, RPG 2007).

The density of shrimp to be stocked is 15,000 seed per hectare. Referring to the survival rate of shrimp, ranging from 65% to 70% (Chanratchakook, 2005; Kungvankij et al., 1986) after 3 to 4 months of growing, we have linearly derived a weekly survival rate of 2.6%, and it is applied for our shrimp rule-based agent.

In addition, shrimp can die due to risk of disease at every time step during the simulation. Through local knowledge derived from KIP and applied in two RPG sessions in 2006 and 2007, accumulative risk probability of shrimp disease is tabulated as seen in table 3. In this tabulation, the initial risk probability of 4% is set as risk of seed disease. A weekly rate of shrimp disease at 0.2% in the growing out of shrimp in the field is computed such that an accumulative risk probability of 31%, 46%, 59% and 62% in week 8^{th}, 12^{th}, 16^{th} and 18^{th} is derived, respectively (Table 6.3). These risk probabilities have been calibrated to be consistent with what was applied in the RPGs of 2006 and 2007.

Shrimp product at maturing time without the risk of disease could be harvested as a normal yield, which equals a product between the initial population and survival rate and average individual weight. Shrimp is usually harvested when it reaches a marketable size of about 30 individuals per kilogram, mostly equivalent to a mean weight of 30g per individual. In the model, a minimum duration to reach a marketable size was set to 2 months. If the disease occurs before 2 months, all the production is lost. If it occurs between 2 and 3 months, the production harvested is estimated at 10% of what would be expected from a normal harvesting. If the disease outbreak happens after 3 months, the production is reduced to 30% of normal harvesting.

Table 6.3 Risk probability of shrimp disease in basic RiceShrimpMD

Week (n)	Risk probability of shrimp disease used in RPG 2007 (%)	Weekly increment risk probability in RiceShrimpMD (%) (RI)	Weekly risk probability in RiceShrimpMD (%) (RW)	Tabulation of accumulative probability of shrimp disease (%) (RT)	Tabulation of weekly probability of shrimp disease-free (RF)
1	20	4	4	4	96
2	21	0.2	4.2	8	92
3	23	0.2	4.4	12	88
4	24	0.2	4.6	16	84
5	26	0.2	4.8	20	80
6	27	0.2	5	24	76
7	29	0.2	5.2	28	72
8	30	0.2	5.4	31	68
9	33	0.2	5.6	35	64
10	35	0.2	5.8	39	60
11	38	0.2	6	43	57
12	40	0.2	6.2	46	53
13	43	0.2	6.4	50	50
14	45	0.2	6.6	53	47
15	48	0.2	6.8	56	43
16	50	0.2	7	59	40
17	60	0.2	7.2	62	38
18	70	0.2	7.4	65	35

Note: RW in week n = initial RW in the 1st week + (n-1)*RI
RF in week n = RF in last week *(1-RI in week n/100)
RT in week n = (1-RF in week n)*100

6.3.3.3 Rice submodel

Figure 6.7 below presents the rules that action the rice crop. Rice can be grown only in plots where salinity is equal to or less than 4 ppt, usually after September when a main rainy season arrives, associated with fresh water flowing from the Mekong River.

The varieties of rice grown are different based on the household production strategy. If the household production strategy is rice oriented, the long duration rice variety is used; otherwise, short duration rice variety is practiced. Moreover, the households following a shrimp-oriented strategy only practice rice when in the current year the number of shrimp crops that fail prior to September was more than twice. Under this situation, the household agent considers that the environmental conditions in that plot are very bad. Therefore it decides to practice rice, expecting that rice growing can "flush" the degraded environment that could be recovered in the following year. Rice yield in this situation is, however, largely affected by drought occurrence associated with salinity residue in the soil.

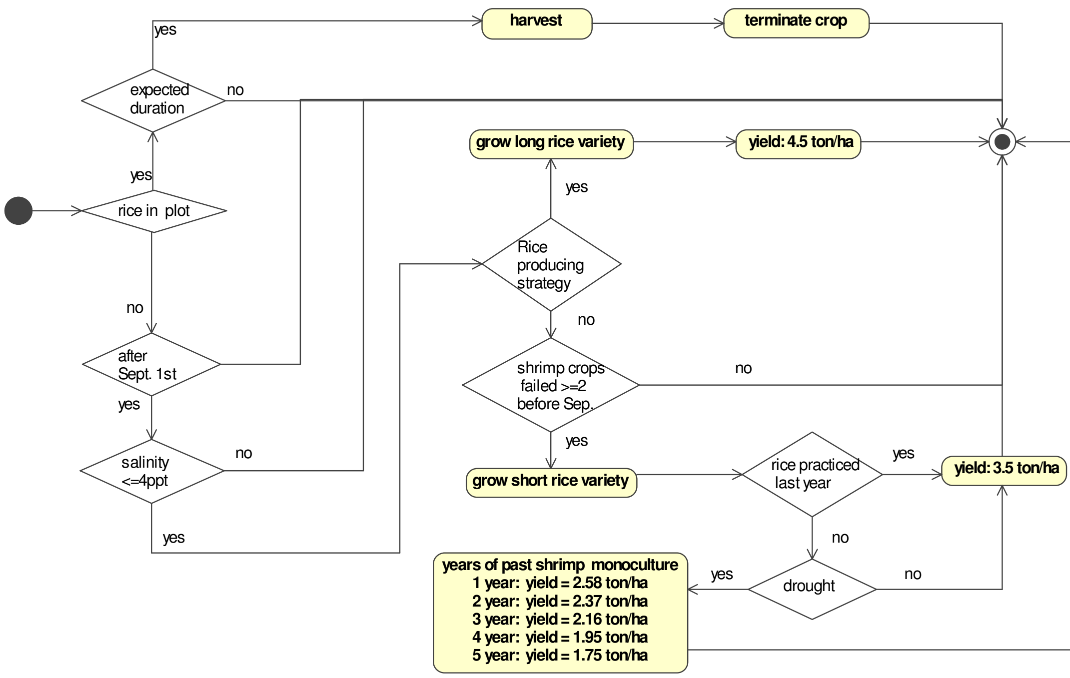


Figure 6.7 Activity diagram that presents rule-based rice agent in RiceShrimpMD

If in previous years rice was practiced in that plot, the drought does not affect rice yield in the current year anymore because the soil does not contain too much salt thanks to the long duration of fresh water inundation in the previous years. If in the previous years in that plot rice had not been practiced anymore (shrimp monoculture), rice yield in the current year would be greatly reduced when drought occurred. Local farming wisdom simplifies this basic fact: many years of shrimp monoculture means that less rice yield can be obtained.

6.3.3.4 Crab submodel

The crab here refers to mud crab *(Scylla serrata)*. Mud crabs are a species that are extremely tolerant to salinity and temperature variations. They can survive in a salinity range of 2 to 50 ppt and temperatures of 12 to 35^{o}C. In this research, only salinity is considered as a constraint for crab to grow. Crab can be practiced in plots when salinity there is equal to or higher than 2 ppt. On the other hand, crab can just be practiced in the plot where its owner's strategy is not rice-oriented (Figure 6.8). Hence, in the downstream village, namely Phong Thanh, all households practice crab farming in shrimp fields.

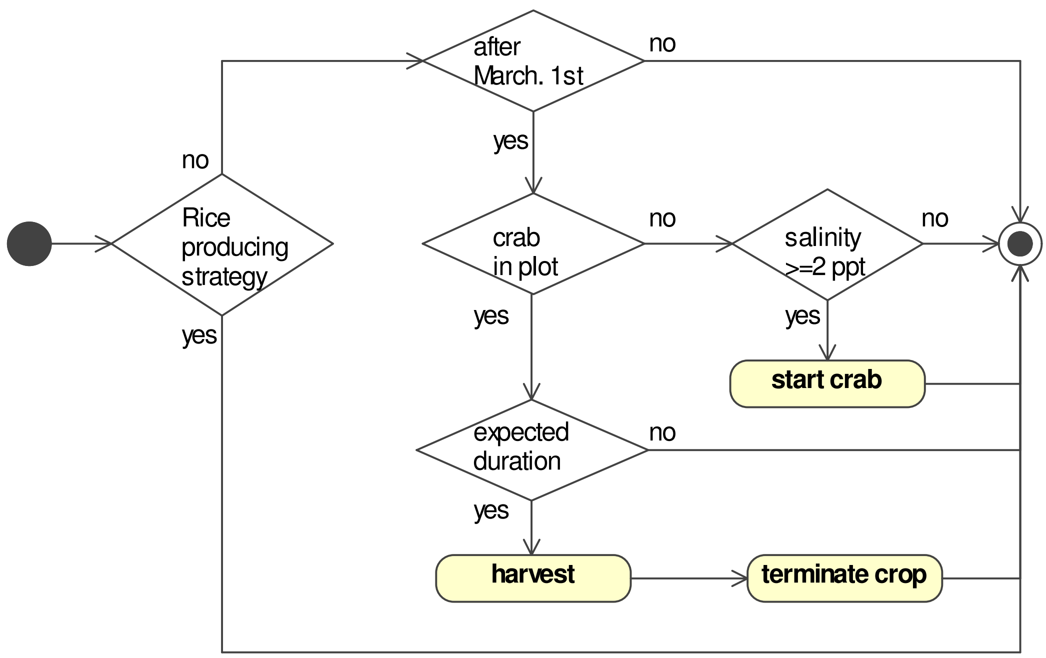


Figure 6.8 Activity diagram that presents rule-based crab agent in RiceShrimpMD

6.3.3.5 Fish submodel

The fish component is a generic term referring to many different fish species combined in the model to simplify the reality of coastal Bac Lieu province. Due to a wide range of combination of fish species, the fish component in this RiceShrimpMD can therefore be grown in the plot with a wide range of salinity, from zero to the highest salinity in the model. Therefore, for both villages in the model, household agents practice fish after May when salinity gradually declines in the rainy season (Figure 6.9).

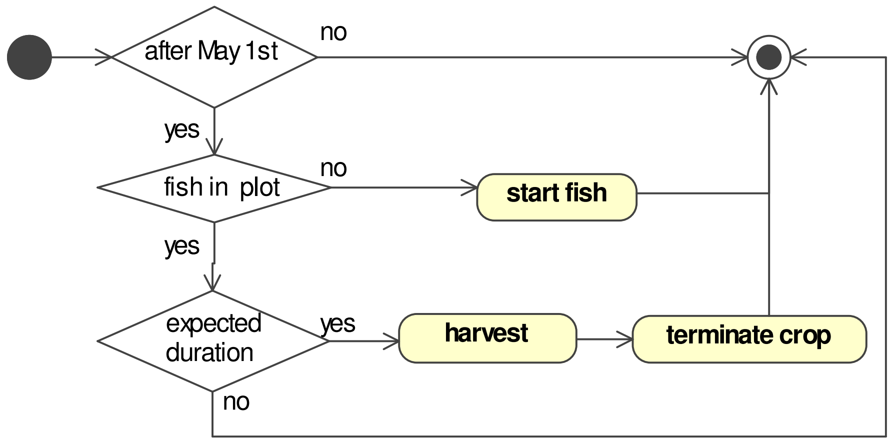


Figure 6.9 Activity diagram that presents the rule-based fish agent in RiceShrimpMD

6.4 MODEL VERIFICATION AND VALIDATION

Verification and validation of a model are fundamental steps to be performed before to start using the model to explore scenarios (Gilbert, 2008; 1999). We embedded local knowledge combined with empirical data, especially social economic data that was obtained from recent research in the province (Gallop et al., 2003; Hoanh et al., 2003)—to define the values of parameters in the model. By pursuing the verification principle of companion modelling, we presented RiceShrimpMD with all involved participants twice: one time when the model was under-construction, and in the final participatory workshop in February, 2009. The spatial interface of the model, including the location of farms in two villages, farm sizes, distance of the canal, as well as the appearance of a cropping calendar for each crop in the model, were collectively checked and adjusted with the participation of local farmers and researchers. The decision making process of household and crop rule-based agents embedded in the model was also collectively verified. Assessment on research objective, model coding and configuration perceiving by local participants in the simulation workshop held in February, 2009 in Can Tho University is presented in appendix B.

The purpose of validation is to assess whether the participants consider that the model is a fair representation of the reality (social validation). Classically, validating achieved through comparing the behaviour of the model with the "actual" system it is supposed to represent: when this comparison is satisfactory, the model is validated (Balci, 1998).

Alternatively, the companion modelling approach, intending to represent social processes as perceived by participating stakeholders, engages stakeholders in the validation process (Moss, 2008). During the participatory workshop held in February, 2009, the RiceShrimpMD ABM has been used to simulate several scenarios of water management schemes that had been used in previous RPGs sessions in 2006 and 2007, as well as new scenarios collectively created during the workshop. Primary economic results of every scenario simulated have been justified with what the local people and researchers expected by their own perceptions of the farming systems. All of them were satisfied with the results released from the simulation. Further analysis of economic and other social and environmental impacts exhibited by the RiceShrimpMD ABM is presented in the next chapter.

CHAPTER 7

SIMULATION OF SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF RICE-SHRIMP INTEGRATED FARMING SYSTEM IN BAC LIEU PROVINCE, MEKONG DELTA, VIETNAM

The principle of the ComMod approach and its ultimate objective is to develop simulation models for collective learning and assessment of scenarios (Bousquet et al., 2005a). In this sense, understanding process and their consequences in participatory modeling is important (Gilbert, 2008). The agent-based model simulation is a kind of experiment conducted in artificial worlds that can help us to embed empirical creative data that has emerged from participatory workshops with involved stakeholders in the ComMod process for calibration and validation of the findings (Boero et al., 2005). These experiments are also useful for assessing policy options (Berger, 2001); in this research a proper policy on water management is expected to be selected. This is the best way of improving the learning capabilities (Guyot et al., 2006) of the local farmers and institutional officers to attain the goal of sustainable development. In this chapter we present the results, analysis and discussion of the simulation of the RiceShrimpMD Agent-Based Model that has been investigated with local relevant stakeholders.

7.1 BASIC RICESHRIMPMD ABM EXPLORATION WITH STAKEHOLDERS

Running the basic model, the RiceShrimpMD, with indicators and their default values is an optimal way for verification as well as validation of the effects of model design and its consequences. Scenario exploration with local stakeholders is an important segment in the ComMod process (Trebuil, 2008). In the participatory simulation workshop conducted in Can Tho University, Viet Nam in February, 2009 with farmers and local institutional officers from Bac Lieu province, different scenarios of water management schemes associated with and without environmental concern in the rice-shrimp plot have been explored. Figures of household capital probing during simulation of the basic RiceShrimpMD ABM were showing by scenarios for all participants to do preliminary evaluation of causality between different scenarios and their consequences of household capital.

7.1.1 Exploring seven scenarios with local stakeholders

There are total seven scenarios have been explored with local participants in the simulation workshop. The scenarios are formed in principle of combination between water salinity patterns and environmental factor. The first three scenarios (1^{st}, 2^{nd}, and 3^{rd} scenario) are those have been used in the RPG sessions in 2007, at which water salinity patterns are respectively proposed by government officer, Phong Thanh and Vinh Loc villagers. The salinity pattern in fourth scenario is instantly collective proposed by all participants in simulation workshop including downstream, upstream villagers and water management officers who knew well about salinity dynamics in the province. In this fourth scenario, water salinity higher than 5 ppt is provided earlier than the first three scenarios, which is in December. The purpose of this fourth scenario is expecting that it can bring a higher household capital than that in the first three scenarios. The scenario 1^{st} to scenario 4^{th} are those have been combined between water salinity patterns while without concern of environmental factor. It means that in these first four scenarios, farmers only practiced rice crop whenever there are at least two failures of shrimp crop in a certain farm plot before September, which is the time for rice crop to start. In term of environmental factor, the scenario 5^{th}, 6^{th} and 7^{th} are those combined between water salinity patterns with concern of environmental factor. This implies that regardless shrimp crop status before September, every household are encouraged to practice rice crop in their plots in the wet season which can start at the 1^{st} September. In term of salinity pattern, the scenario 5^{th} is similar with that in the scenario 4^{th}. For the scenario 6^{th}, the water salinity pattern is similar with that in the scenarios 2^{nd}. The salinity pattern in scenario 2^{nd} is reused in scenario 6^{th} because through visualization of household capital during simulations, the scenario 2^{nd} produced a highest value of household capital as compared with that in the other scenarios. The scenario 7^{th} is also reused the salinity pattern of scenario 2^{nd}, however, salinity degree is set to be unique between upstream and downstream villages. This scenario is seemly unrealistic, however, it is collectively decided to test by all participants in the simulation workshop. Thus, in term of salinity, it has totally 5 different salinity patterns. The table 7.1 below summarizes a matrix forming of 5 different salinity patterns and environmental factor to get 7 scenarios that have been explored during the workshop with local people.

Table 7.1 Matrix of forming seven scenarios in simulation workshop in 2009

Scenarios	Salinity patterns	Environmental concern
1	Governmental officer control the gate	No
2	Phong Thanh villagers control the gate	No
3	Vinh Loc villagers control the gate	No
4	Collective created in workshop in 2009	No
5	Collective created in workshop in 2009	Yes
6	Phong Thanh villagers control the gate	Yes
7	Phong Thanh villagers control the gate but salinity degree is identical between two villages	Yes

Details of salinity pattern of seven scenarios are indicated in figure 7.1. In the simulation of this basic version of RiceShrimpMD ABM, minimum salinity level for a shrimp crop to start is set at 8 ppt, which is marked as yellow boxes as seen in figure 7.1.

Scenarios	Vil.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	PT	5	5	26	29	29	24	17.5	0	0	0	0	0
	VL	1	1	16	15	23	20	15	0	0	0	0	0
2	PT	10	15	15	15	23	23	10	4	0	0	3	3
	VL	6	10	10	10	16	8	3	0	0	0	0	0
3	PT	5	12	16	16	16	12	5	3	0	0	3	3
	VL	1	6	11	11	11	6	1	0	0	0	0	0
4	PT	5	10	25	30	25	15	8	0	0	0	0	5
	VL	0	2	10	15	20	15	6	0	0	0	0	0
5	PT	5	10	25	30	25	15	8	0	0	0	0	5
	VL	0	2	10	15	20	15	6	0	0	0	0	0
6	PT	10	15	15	15	23	23	10	4	0	0	3	3
	VL	6	10	10	10	16	8	3	0	0	0	0	0
7	VL	10	15	15	15	23	23	10	4	0	0	3	3
	VL	10	15	15	15	23	23	10	4	0	0	3	3

Legend: Marked of salinity equal or higher than 8 ppt

Figure 7.1 Seven scenarios explored in workshop 2009

7.1.2 Simulation of seven explored scenarios with local stakeholders

The RiceShrimpMD was built based on a combination of determined and stochastic concepts; therefore the simulation was replicated 10 times to eliminate randomness errors. Global results represented by average accumulative household capital (saving money: production income subtracted from production and living cost) in two upstream and downstream village and the average one after 5 years of simulation are presented in figure 7.2 to figure 7.8. A comparison of the accumulative household capital and ranking priority of water schemes are firstly presented in the table 7.2.

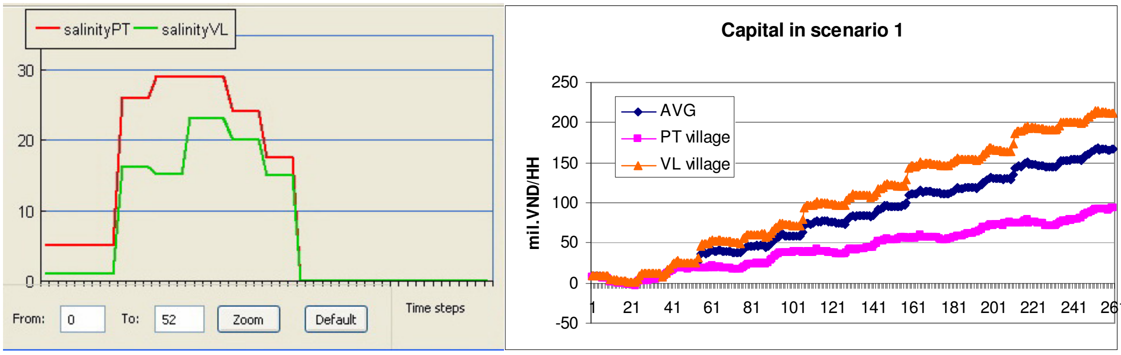


Figure 7.2 Average accumulative household capital in scenario 1

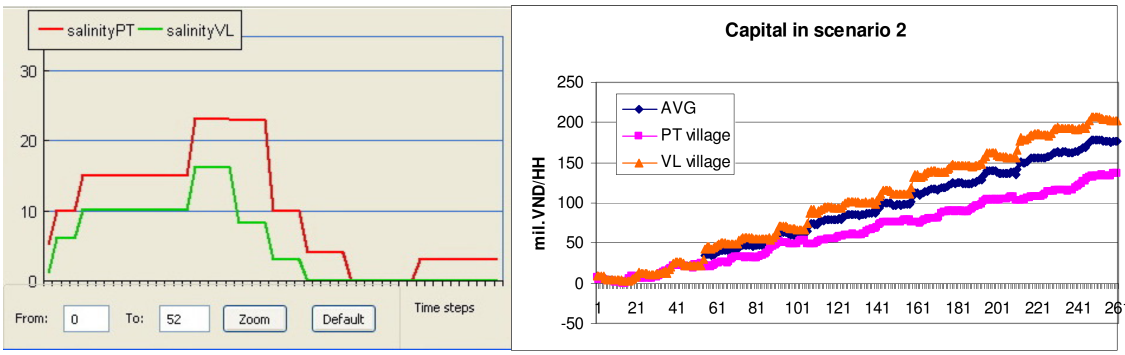


Figure 7.3 Average accumulative household capital in scenario 2

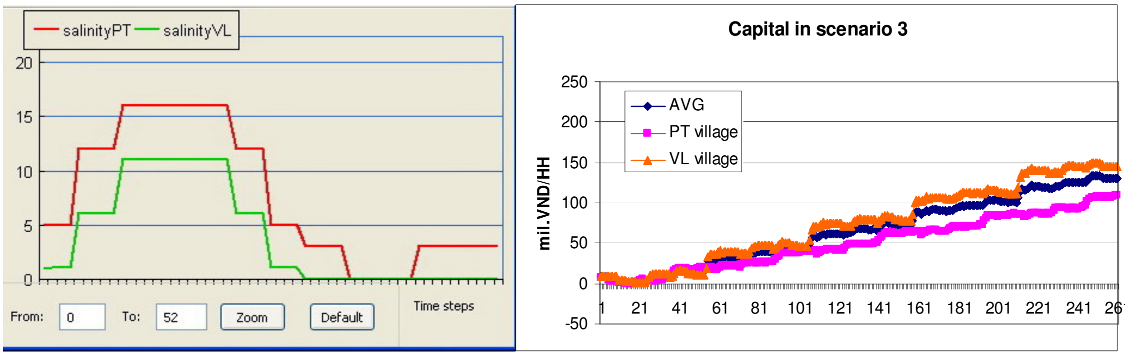


Figure 7.4 Average accumulative household capital in scenario 3

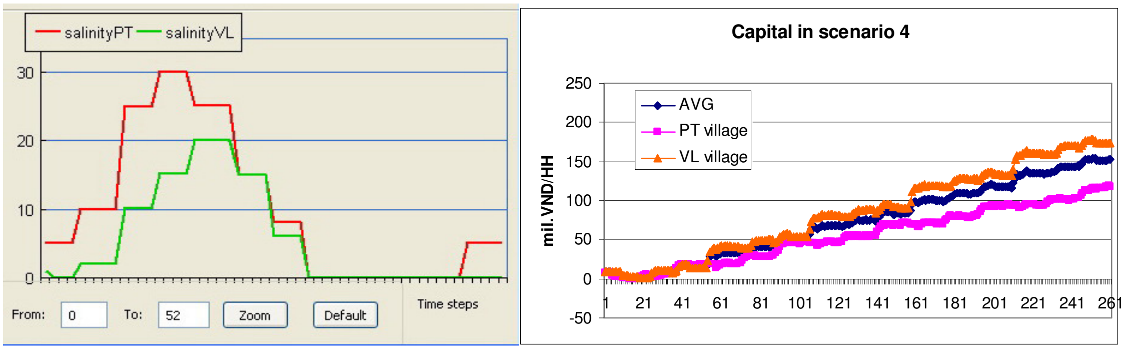


Figure 7.5 Average accumulative household capital in scenario 4

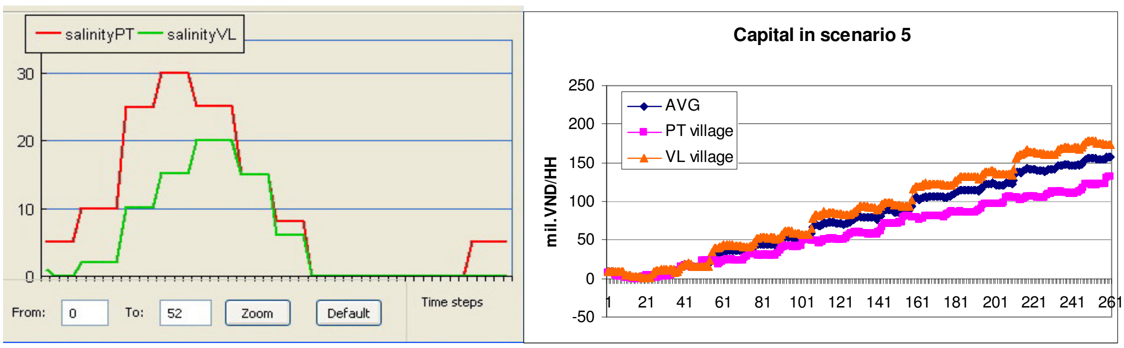


Figure 7.6 Average accumulative household capital in scenario 5

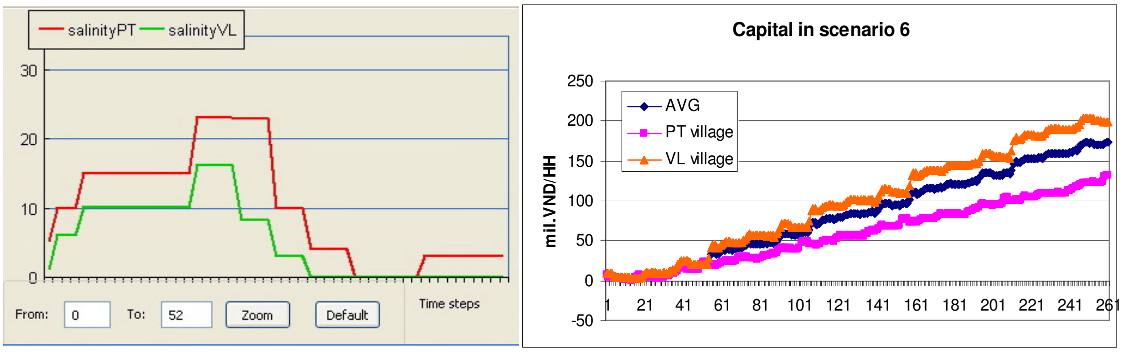


Figure 7.7 Average accumulative household capital in scenario 6

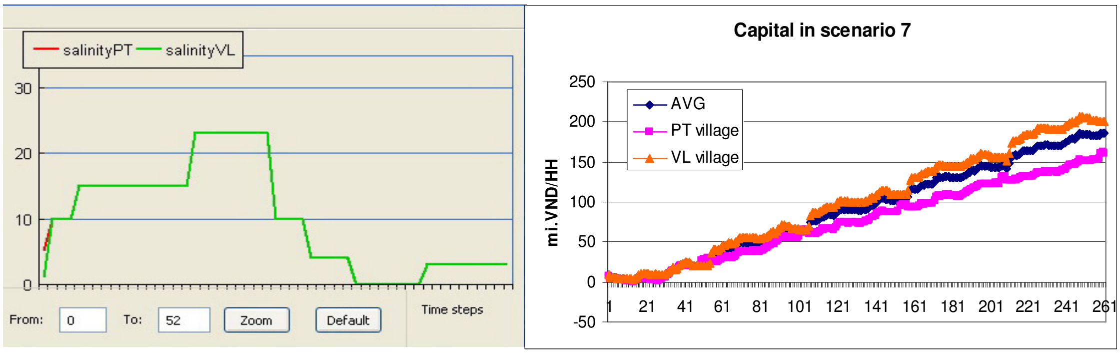


Figure 7.8 Average accumulative household capital in scenario 7

Table 7.2 presents average accumulative household capital resulted from simulation of seven scenarios using basic version of RiceShrimpMD ABM. Ranking priority of scenario is made to see which one brings higher household capital at the provincial level while less differentiation between the two villages. Each scenario produces a different rank of household capital in two villages. It implies that there is a conflict in water management to optimize the capital would be earned for every village. However, the highest household capital solution at provincial level would be a first priority for policy makers to consider regarding water management. In this aspect, scenario 7th seems to produce the highest average capital and less difference between the two villages; however, attaining the results of that scenario in reality is highly improbable because this scenario is using identical water salinity pattern between two villages, which is unrealistic. On the other hand, the scenario 2nd would be a good option when it can produce the 2nd average household capital and the 5th difference between the two villages.

Table 7.2 Average accumulative household capital (Million VND) after five years of simulation using basic version of RiceShrimpMD ABM

Scenarios	Average household capital in PT	Average household capital in VL	Weight average household capital between two village	Difference of average household capital	Rank priority (*)
1	94a	212c	166bcd	118	7
2	137bc	202c	177cd	65	2
3	109ab	144a	131a	35	4
4	118ab	173b	152ab	55	6
5	132abc	173b	157bc	42	3
6	132abc	199c	173bcd	67	5
7	161c	201c	186d	40	1
Mean	126	186	163	60	

Note: The numbers followed by same letters in a same column are not significantly different by Duncan test at 0.05.
(*) Ranking rules: higher average accumulative household capital and lesser difference

7.2. NEW VERSION OF RICESHRIMPMD ABM

The spatial configuration, the main algorithms and default parameters values, and finally the simulation results of 7 scenarios were presented and discussed with relevant stakeholders during the participatory workshop. Collective learning on the causality between water management schemes and economic results was achieved by using the basic version of the RiceShrimpMD ABM. However, the building of this basic version started in 2006, in which a number of input parameter values had to be updated in accordance with current biophysical and socio-economic conditions but also to cope with the evolution of the representations of the system by all stakeholders involved in the modeling process. Indeed, the companion modeling process being naturally reflexive, just by contributing to the design of a model representing a reference system he/she knows very well, any participant to that process is stimulated to modify his own representation. As a result, the successive modifications of the ABM simply reflect the iterative and reflective nature of the process that is driving the learning. When input values or rule-bases algorithms more satisfactorily reflect reality, participants trust the model more deeply and become more eager to explore more refined scenarios. Table 7.3 lists all the modifications that were suggested along the process (mainly during collective workshops) by participating stakeholders.

Black tiger shrimp presently tolerates lower salinity levels thanks owing to the ability of the shrimp to acclimatize. As in coastal Thailand, black tiger shrimp can be practiced in low salinity levels (Mekhora et al., 2003; Szuster et al., 2002). In the coastal Mekong Delta, shrimp is not exactly cultured in fairly low levels of salinity, but according to local knowledge the shrimp can start to grow at 5 ppt of salinity. Consequently, the value of salinity for household to start a shrimp crop was reduced from 8 ppt to 5 ppt in this new version of the RiceShrimpMD model.

Density of shrimp stocked in downstream village of Phong Thanh was also found to be higher than that in the upstream village of Vinh Loc. This was due to the higher salinity available in the downstream location, which could accommodate a higher shrimp density. So, in this version, shrimp density of 15,000 seed.ha^{-1} per batch was applied for Phong Thanh village while that in Vinh Loc it remained to only 7,500 seed.ha^{-1} per batch.

In the basic version of the RiceShrimpMD, low probability (4%) of risk in the shrimp seed stage was set. However, in reality, shrimp crops always encounter different probabilities of risk due to disease, depending on its growing stages. In this new version of the RiceShrimpMD, we imposed three different values of risk probability of shrimp disease. A higher risk probability (20%) of disease at seed stage was imposed. In the growing period, risk probability varied; this variation can be split into two stages. In the first 3 months of the growing period (week 2nd to 12th) when shrimp can reach a minimum marketable size, the weekly risk probability is 2.5%.

Table 7.3 Modification of parameter values in the new version of the RiceShrimpMD

Parameters	**Unit**	**Default value**	**New value**	**Source**
Minimum salinity to start shrimp crop	ppt	8	5	KIP
Density stocked in shrimp oriented strategy household	Seed. $time^{-1}.ha^{-1}$	15,000	15,000	Workshop
Density stocked in rice oriented strategy household	Seed. $time^{-1}.ha^{-1}$	15,000	7,500	Workshop
Probability of shrimp disease at 1st week of seed stage	%	4	20	Workshop
Duration for detecting shrimp died due to disease after stocked date	week	0	4	Workshop
Duration for stocking new shrimp crop from last shrimp crop failure or harvesting	week	0	2	KIP
Probability of shrimp disease from 2nd to 12th week (the minimum duration of shrimp crop)	%	0.2	2.5	Author tabulation
Probability of shrimp disease from 13th to 18th week (reaching to maximum duration of shrimp crop)	%	0.2	10	Author tabulation
Earliest time to start fish	month	5th	1st	Workshop
Production cost of long duration variety	$10^6 VND.ha^{-1}$	5.25	4.5	Workshop
Production cost of short duration variety	$10^6 VND.ha^{-1}$	1.5	3.5	Workshop
Market price of long duration variety	$10^6 VND.kg^{-1}$	0.0035	0.0045	Workshop
Market price of short duration variety	$10^6 VND.kg^{-1}$	0.00225	0.0035	Workshop
Living cost	$10^6 VND.person^{-1}.month^{-1}$	0.2	0.3	KIP

When shrimp crop is prolonged in the water body, farmers face a higher risk of shrimp disease due to environmental factors. Therefore, 10% of risk probability was imposed for shrimp crop after the 13th week and up to 18th week. The modified risk probability is tabulated as presented in table 7.4. To verify that the model can correctly simulate the risk of disease, the evolution of the global percentage of shrimp crop failure due to disease was tracked over a 5 years simulation (Figure 7.9).

Table 7.4 Risk probability of shrimp disease in the new version of the RiceShrimpMD

Week (n)	Risk probability of shrimp disease used in RPG 2007 (%)	Weekly increment risk probability in RiceShrimpMD (%) (RI)	Weekly risk probability in RiceShrimpMD (%) (RW)	Tabulation of accumulative probability of shrimp disease (%) (RT)	Tabulation of weekly probability of shrimp disease-free (%) (RF)
1	20	20	20	20	80
2	21	2.5	4	22	78
3	23	2.5	4.2	24	76
4	24	2.5	4.4	27	74
5	26	2.5	4.6	28	72
6	27	2.5	4.8	30	70
7	29	2.5	5	31	69
8	30	2.5	5.2	33	67
9	33	2.5	5.4	35	65
10	35	2.5	5.6	36	64
11	38	2.5	5.8	38	62
12	40	2.5	6	39	61
13	43	10	6.2	46	54
14	45	10	6.4	51	49
15	48	10	6.6	56	44
16	50	10	6.8	60	40
17	60	10	7	64	36
18	70	10	7.2	68	32

Note: RW in week n = initial RW in the 1^{st} week + (n-1)*RI
RF in week n = RF in last week *(1-RI in week n/100)
RT in week n = (1-RF in week n)*100

Shrimp seed that became diseased infected and died could be detected 4 weeks after the stocking date. This was owing to the fact that shrimp seed is too small for farmers to recognize disease immediately at its outset. Moreover, farmers need at least one week after shrimp crop failure as a result of disease to restart a new shrimp crop. The one week interval is for field preparation like water exchange and chemical treatment, among other activities.

As stated in chapter 6, fish raised at the research site is a combination of several fish species. The raising of fish is practiced the whole year round. The month for starting the fish farming was set for January, instead of May as in the last version. Numbers of new values regarding rice production cost and its market price were made based on local participants' comments, which centered on the current market situation. Living cost per capita was also increased from 0.2 to 0.3 million VND per month, which is equal to the new poverty line in rural Vietnam (2008).

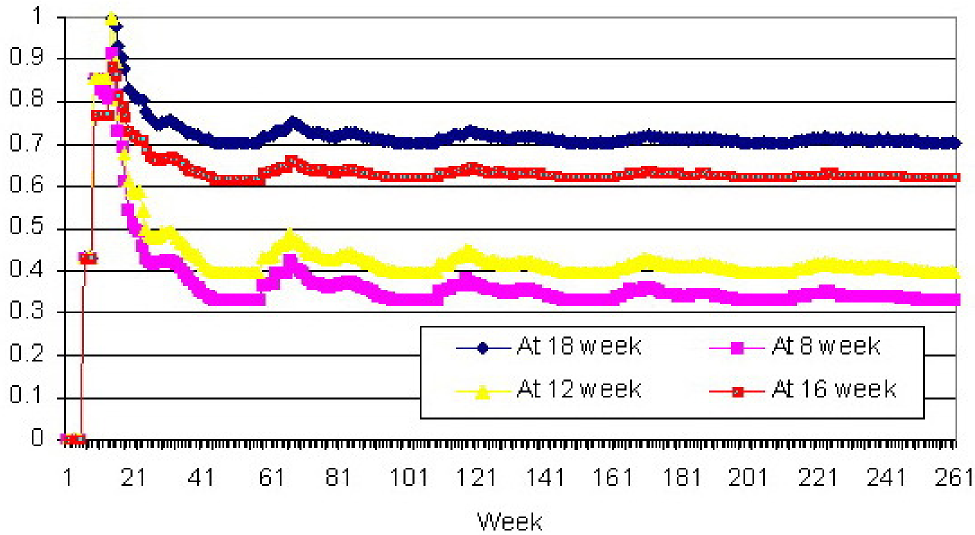


Figure 7.9 Proportions of shrimp failures due to disease at 4 different stages (cumulative average values calculated for each week of a 5 years simulation run)

7.3. SIMULATION OF NEW VERSION RICESHRIMPMD

The new version of the RiceShrimpMD ABM was produced with its old values of input parameters replaced by new ones, as described in the previous section. Simulation of this new version was a crucial objective of the research. Similarly to the exploration of the basic version, the simulation was replicated ten times for every scenario to account for stochastic processes. For new simulation and impact analysis, ten scenarios including five different salinity patterns (Figure 7.10) combining with and without application of environmental concern have been used. As with environmental concern, the RiceShrimpMD ABM is set such that every household are encouraged to practice rice crop in every plot in the wet season. As without environmental concern, the RiceShrimpMD ABM is set such that the household to practice rice crop whenever in a plot, there is at least two failed shrimp crops found prior 1st September. It is because in reality, farmers jut thought of environmental pollution of water body in the field which caused shrimp died in dry season. Practicing rice crop is then perceived as a recovery of the environmental pollution. However, rice crop planted in Phong Thanh downstream village is affected by salinization and drought. If drought happened, rice yield is reduced according to the previous years of shrimp monoculture in the plot (see figure 6.7 in chapter 6). Combination of five water salinity patterns and environmental concern to form 10 scenarios is summarized in table 7.5.

The new version of RiceShrimpMD ABM is simulated with 10 scenarios. Each scenario, the model is run for ten times of replication for eliminating radon error. Five years equivalent to 260 steps (260 weeks) is used for the simulation. Simulated outputs are automatically exported to excel files. Data from these excel files are computed and statistical analysis.

Table 7.5 Matrix of forming ten scenarios in experimental simulation

Scenarios	**Way of setting salinity patterns**	**Environmental concern**
1	Governmental officer control the gate	No
2	Phong Thanh villagers control the gate	No
3	Vinh Loc villagers control the gate	No
4	Collective created in workshop in 2009	No
5	As Phong Thanh villagers control the gate but salinity degree is identical between two villages	No
6	Governmental officer control the gate	Yes
7	Phong Thanh villagers control the gate	Yes
8	Vinh Loc villagers control the gate	Yes
9	Collective created in workshop in 2009 as the 4^{th}	Yes
10	As Phong Thanh villagers control the gate but salinity degree is identical between two villages	Yes

Salinity pattern	Vil.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	PT	5	5	26	29	29	24	17.5	0	0	0	0	0
	VL	1	1	16	15	23	20	15	0	0	0	0	0
2	PT	10	15	15	15	23	23	10	4	0	0	3	3
	VL	6	10	10	10	16	8	3	0	0	0	0	0
3	PT	5	12	16	16	16	12	5	3	0	0	3	3
	VL	1	6	11	11	11	6	1	0	0	0	0	0
4	PT	5	10	25	30	25	15	8	0	0	0	0	5
	VL	0	2	10	15	20	15	6	0	0	0	0	0
5	PT	10	15	15	15	23	23	10	4	0	0	3	3
	VL	10	15	15	15	23	23	10	4	0	0	3	3

Legend: [yellow box] Marked of salinity equal or higher than 5 ppt

Figure 7.10 Five water salinity patterns used for simulation of new version RiceShrimpMD ABM

7.4. IMPACTS ANALYSIS AND DISCUSSION

Sustainable development, as defined by the World Commission on Environment and Development (WCED), is composed of three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. This section analyzes three principal indicators reflecting the sustainability of rice-shrimp integrated farming system in Bac Lieu using the simulation results from the RiceShrimpMD ABM.

Through a thoughtful analysis of simulation results, farmers and local institutional authorities might have a better knowledge and perception of the potential damage caused by shrimp monoculture system if practiced over the long term. As a result, better knowledge and perception would encourage local people to consider seeking sustainable agricultural development through changes in their perceptions, behaviours and ultimately actions.

7.4.1 Social impact analysis

The first concern in this research is analysis of potential conflict over water demand for rice and shrimp crops among farmers within the village and between upstream and downstream villages who are using a common irrigation system. The potential conflict index is defined by the author as a multiplication of the rate of rice plots (after September) and rate of shrimp crop (from September to December) in a village. This is because rice crops require a maximum salinity of 4 ppt while shrimp crops survive at a minimum salinity of 5 ppt. The co-existence of these two different crops creates conflict due to contrary water salinity demand (Figure 7.11).

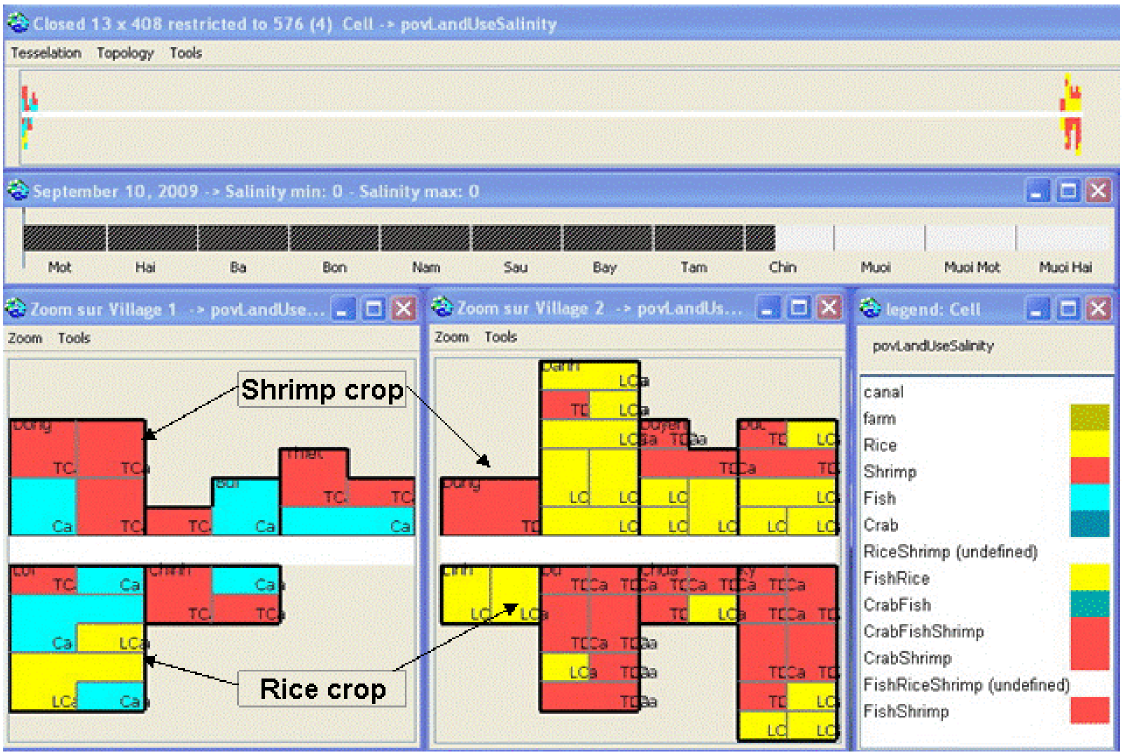


Figure 7.11 Co-existence of rice and shrimp crops after September in two villages

By measuring area of late shrimp crop (remained after 1st September) in Phong Thanh and Vinh Loc village, the percentage of late shrimp area over total village area for each village is derived. At the same time, percentage of rice area over total area of each village is also obtained through measuring the area of rice cultivated in each village. The way to compute conflict index as mentioned in chapter 3, is the multiplication between percentage of late shrimp area and percentage of rice area. Based on these computations, the average values of potential conflict index for Phong Thanh and Vinh Loc villages are 0.26 and 0.33 respectively (table 7.6). The values of the potential conflict index vary according to different scenarios of water patterns and status of environmental concern.

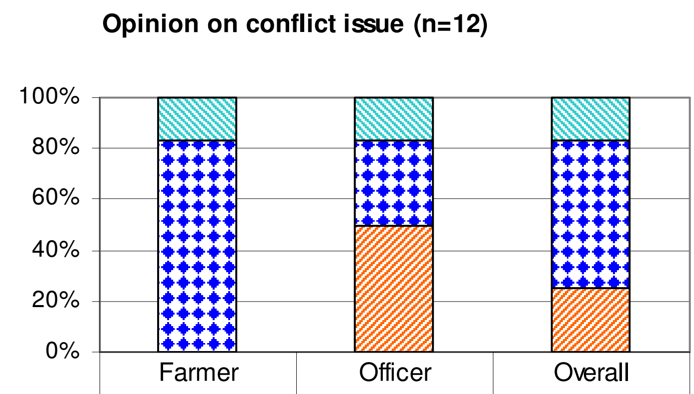
Table 7.6 Conflict index by villages and scenarios at the end of year 5th in simulation

Scenarios	Cultivated rice area over PT village area (%)	Late shrimp area over PT village area (%)	Conflict index in PT village	Cultivated rice area over VL village area (%)	Late shrimp area over VL village area (%)	Conflict index in VL village
1	24.00	39.67	0.10	100.00	51.48	0.51
2	44.67	30.33	0.14	100.00	4.43	0.04
3	28.00	39.00	0.11	100.00	32.95	0.33
4	33.00	35.33	0.12	100.00	47.05	0.47
5	44.67	30.00	0.13	100.00	25.41	0.25
6	100.00	51.00	0.51	100.00	48.20	0.48
7	100.00	36.00	0.36	100.00	4.26	0.04
8	100.00	37.33	0.37	100.00	41.48	0.41
9	100.00	35.33	0.35	100.00	46.89	0.47
10	100.00	41.00	0.41	100.00	31.64	0.32
Group A	34.87	34.87	0.12	100.00	32.26	0.32
Group B	100.00	40.13	0.40	100.00	34.49	0.34
Total	67.43	37.49	0.26	100.00	33.37	0.33

Group A includes scenarios from 1st to 5th; Group B includes scenarios from 6th to 10th

In Phong Thanh village, the conflict index is averaged of 0.12 for group A, which is not much serious. In fact, there is a bit variation of conflict index value among scenario 1st to scenario 5th in this group, however, not much different. In the other group B, from scenario 6th to 10th, the average conflict index value is of 0.40, which is quite higher than that in group A. Rate of late shrimp area in this group is seemly a bit higher than that in group A associating with the fact that rice crop is encouraged to practice in all plot. This causes to reach a higher potential conflict in this situation. Rate of late shrimp area is relating to not only duration of water salinity, but also the salinity degree at the end of dry season and rate of risk of shrimp disease. This statement is will be more clearly observed in following section of environmental impact in this chapter.

In Vinh Loc village, conflict index value is seemed highly in all scenarios excepting for scenario 2nd and scenario 7th when smaller rate of late shrimp area is found. This smaller rate of late shrimp area is strongly affected by shorted duration of water salinity provided in these two scenarios as comparing with that in the other scenarios. The average conflict index value is almost not different between two group A & B, because rice is always practiced in this village. However, the potential conflict in Vinh Loc village is highly theoretical computation for understanding the way of it rather than it actually happened. It is because salinity degree at the end of dry season in this village is rather small, which is easily diluted after one month from July under heavy rainfall season. Moreover, long rice variety in this village is photosensitive, which can be delayed its plating date or using seedling method in a small area in their plot before harvesting late shrimp crop.



	Farmer	Officer	Overall
not important	16.67	16.67	16.67
important	83.33	33.33	58.33
very important	0.00	50.00	25.00

Figure 7.12 Conflict issue perceived by local people in 2009

The direct individual interviews investigated during the participatory simulation workshop in 2009 it clearly confirmed that local people are highly concerned about the conflicts. Fifty percent of local institutional officers perceive the conflict issue as "very important" while the majority of local farmers perceive it as only "important". However, there still exists a certain percentage of local people (16.67%) who think that the issues of conflict are not important (Figure 7.12). The conflict depends on the co-existence of rice area and late shrimp area in the village, which nominally depends on water salinity pattern. However, the rates of these two different crops are also able flexibly managed by individual households who directly control sluices at farm scale for salinity provision.

7.4.2 Economic impact analysis

Extreme poverty and economic differentiation are two sides of the economic impact of rice-shrimp integrated farming systems. These are crucial issues of concern in this research. New version of the RiceShrimpMD is run ten times for each of ten scenarios to derive the economic data. There are 261 weekly time-step is simulated, which is equal to 5 years. Data used for analysis are those resulted from the simulation at the end of year 5th. Average annual household capital in year 5th and its distribution in the population measured by Gini index are analyzed in table 7.7.

Table 7.7 Household capital analysis by scenarios at end of year 5th

Scenario	Phong Thanh village				Vinh Loc village			
	Max	Min	Avg.	Gini	Max	Min	Avg.	Gini
1	37.80	-5.65	14.40a	0.69	76.62	8.66	41.41bcd	0.34
2	42.84	8.20	26.72c	0.30	70.37	8.26	38.08ab	0.35
3	35.48	-2.97	14.34a	0.58	65.88	8.98	37.11a	0.34
4	38.45	-2.56	16.50ab	0.53	76.20	8.47	38.13ab	0.36
5	48.16	1.87	23.09bc	0.43	70.32	17.02	42.45cd	0.27
6	59.33	-0.09	26.47c	0.51	73.92	11.68	39.04abc	0.33
7	55.61	11.46	31.10c	0.32	74.16	7.87	38.17ab	0.34
8	47.72	0.06	22.94bc	0.43	72.17	9.82	39.57abc	0.35
9	48.30	7.49	23.96bc	0.33	67.35	10.13	39.56abc	0.33
10	70.68	3.30	30.40c	0.44	84.22	15.56	45.22d	0.31
Group A	40.54	-0.22	19.01	0.50	71.87	10.27	39.43	0.33
Group B	56.32	4.44	26.97	0.40	74.364	11.01	40.31	0.33
Total	48.437	2.111	22.99	0.45	73.12	10.64	39.87	0.33

Group A includes scenarios from 1st to 5th; Group B includes scenarios from 6th to 10th

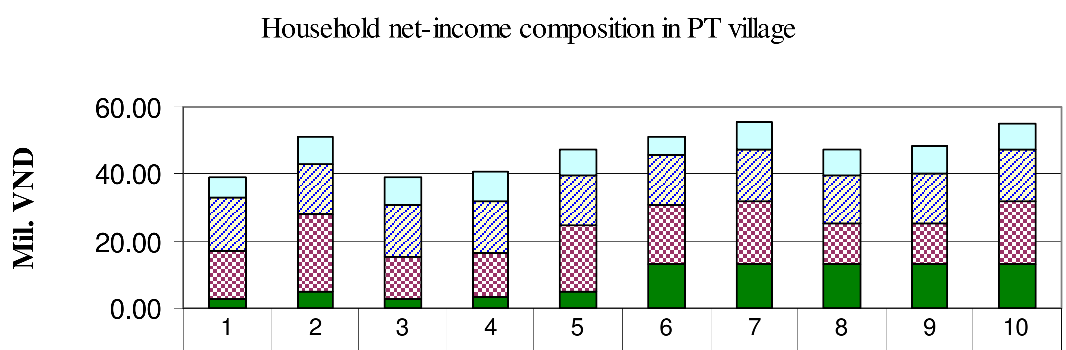
Note: The numbers followed by same letters in a same column are not significantly different by Duncan test at 0.05.

It is defaulted that in Phong Thanh village at initial stage before simulation, average household capital is of 5 Million VND per hectare of land (see table 6.2) , which is equivalent to 7.5 Million VND per household for 1.5 hectare of farm land. In Vinh Loc village this figure is 9.53 million VND per household for 1.91 hectare of farm land. Based on initial household capital distribution among them in the community, initial value of Gini index in Phong Thanh and Vinh Loc village is all equal 0.24.

Household capital in Phong Thanh village is get a highest value in scenario 7th and scenario 10th as the water salinity is long and rice crop is practiced in every household. The household capitals in these two scenarios are higher than that in two scenarios 2nd and 5th that have used the same water salinity patterns, respectively. However, in scenarios 7th and 10th rice component is contributed a larger share in total household income as they are illustrated in figure 7.13 below.

Higher household capital in group B (scenario 6th to 10th) is quite higher than that in group A (scenario 1st to 5th) since in group B, every household practiced rice crop in their field, and as a return, income from rice has increase the higher household capital while the income from other component like fish and crab is almost remained the same between two groups of scenarios. Extreme poverty is more frequent happened in scenarios that belong to group A. The extreme poverty occurrence is likely according to risk possibility of shrimp disease which is stochastic factor in shrimp production. However, extreme poverty is significantly reduced in scenarios 6th to 10th when rice component shares higher income proportion in the household income. This is implying that rice crop is considered as a intermediate component that contribute to reduce extreme poverty in the downstream Phong Thanh village. As comparing average household capital between two groups of scenarios, the group B is producing a higher capital than that in group A, almost 8 million VND.year^{-1} higher in the 5th year. Thanks to rice component fairly practiced in the rice-shrimp farming system, the less income differentiation in group B of scenario is found. Thus, rice component, once again, contributes to less income polarization in the community of downstream village.

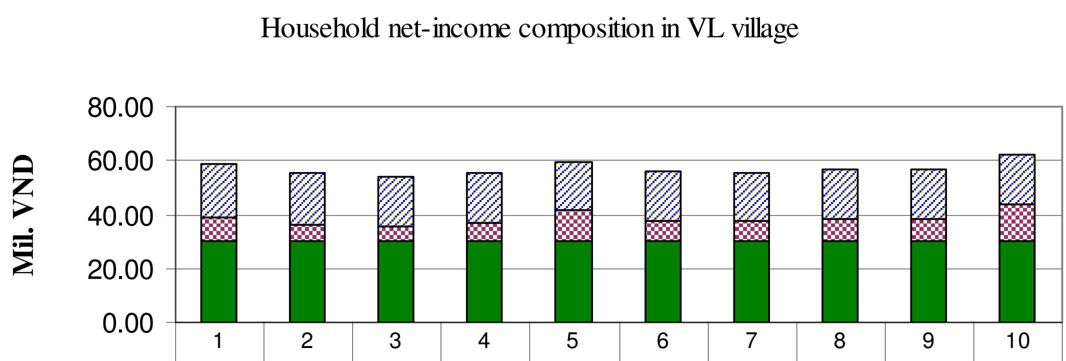
In Vinh Loc village, average household capital variation is mostly according to income gained from shrimp production due to no much change of income from other components like rice or fish. The longer duration of water salinity allowing a longer shrimp duration and in turn, higher household capital is obtained. This is truth in scenario 10th, 5th and 1st. More interesting is found in scenario 10th is that the highest household capital is reached as compared with other scenarios when the water salinity pattern is set similarly with that in Phong Thanh village.



	1	2	3	4	5	6	7	8	9	10
CRAB	5.89	8.35	8.19	9.27	7.82	5.11	8.24	7.79	8.32	7.80
FISH	15.77	14.96	15.21	15.01	15.22	15.10	15.19	14.53	14.73	14.98
SHRIMP	14.64	22.71	12.56	13.15	19.50	17.63	19.03	11.98	12.27	18.98
RICE	2.58	5.18	2.86	3.55	5.03	13.13	13.13	13.13	13.13	13.13

Scenario

Figure 7.13 Household net-income in Phong Thanh village in year 5th



	1	2	3	4	5	6	7	8	9	10
CRAB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH	19.30	18.82	18.55	18.47	18.09	18.84	17.84	18.33	18.63	18.73
SHRIMP	9.18	6.34	5.63	6.74	11.43	7.28	7.41	8.32	8.01	13.57
RICE	30.02	30.02	30.02	30.02	30.02	30.02	30.02	30.02	30.02	30.02

Scenario

Figure 7.14 Household net-income in Vinh Loc village in year 5th

In Vinh Loc village, no extreme poverty (negative capital) is found among scenarios. In the other hand, income distribution is more equal among the household in the community, which is reflected by lightly Gini index value for all scenarios. Even there is no different of Gini index value between two groups of scenarios in this village. It is interesting to see that in scenario 5th less Gini index value is found when higher income from shrimp crop obtained (Figure 7.14).

Extreme poverty and economic differentiation are important issues from the research point of view. This is also the vision of local participants: during direct individual interviews with local participants conducted in February 2009, most respondents believed those issues to be very important. More interestingly, there is a similar perception among farmers and local institutional officers (Figure 7.15). The issues however, as illustrated by our analysis of the simulation results, occurred more acutely in the downstream location of Phong Thanh village, where people working under a shrimp oriented strategy tended to cultivate monoculture of shrimp.

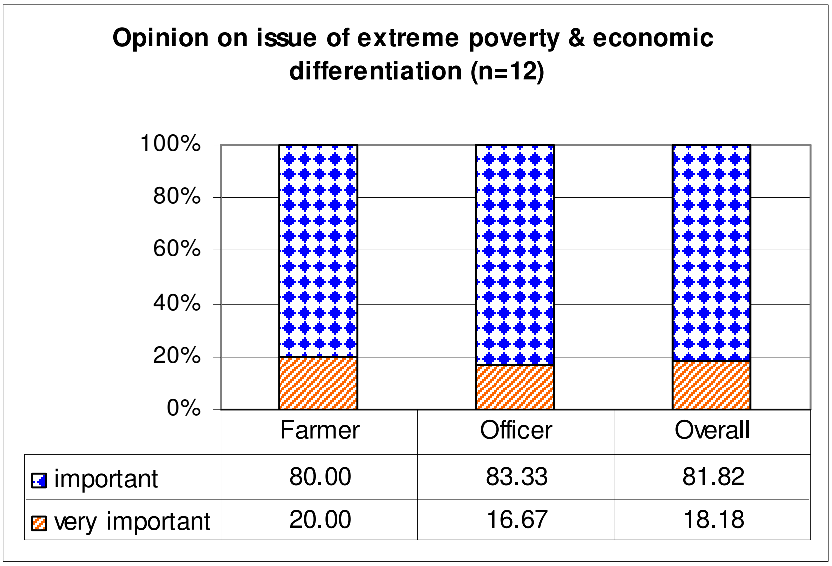


Figure 7.15 Extreme poverty and economic differentiation perceived by local people

7.4.3 Environmental impact analysis

Salinization is a process by which water-soluble salts accumulate in the soil. High levels of salt in the soil have a similar effect as drought conditions by making water less available for uptake by plant roots. Local knowledge could bring about an understanding that by using fresh rain water and water from the Mekong River in the main rainy season to flush out salinity in the field carefully before growing rice, rice could grow well and a normal yield could be achieved in the year even there is occurrence of drought during the growing period. This implies that with practicing integrated rice-shrimp system annually, rice yield in this system could reach a normal yield regardless drought occurrence thank to the techniques done by farmers for adequately eliminating residual salt. Consequently, rice could tolerate to water stress in the year with drought occurrence.

In case of rice is not practiced in previous year, level of rice yield lost due to drought in current year varies according to the number of years shrimp monoculture has been practiced without the cultivation of rice crops. Long periods of shrimp monoculture in the shrimp field results in a higher level of rice lost due to drought, and vice versa.

This section analyzes the rice yield lost due to salinization and drought occurrence in the RiceShrimpMD, especially in downstream Phong Thanh village. Table 7.8 shows average rice yield in Phong Thanh village for the first five scenarios as rice is not always practiced. In scenario 6th to 10th the model is set such that every household practice rice crop in wet season (after September), it is therefore, drought occurrence is not effected rice yield anymore. Hence, rice yield in these five late scenarios is not taken into account for analysis.

Average rice yield for all five scenarios is 3,128 kg.ha^{-1}, which is 371 kg.ha^{-1} lower than the normal rice yield (3,500 kg.ha-1) without salinization and drought occurrence. However, not much difference in rice yield among scenarios is found. More interesting point is that size of rice area has been practiced. Rice area varied among scenarios is seemly following a rule that the higher shrimp yield obtained due to longer water salinity duration provided in scenario 2nd and scenario 5th the larger size of rice area to be practiced. This is because higher shrimp yield implying the longer duration of shrimp in the field to be, which can cause the higher number of shrimp crop failed before

1st September and in turn the larger size of rice area to cultivate. It is consistent with the rule set by the model.

The other interesting point can be found is that all parameters like rice area effected by drought and rice yield are not significantly different among scenarios. In the other hand, size of rice area is significantly different among scenarios, especially in scenario 2nd and 5th as compared with the other remaining scenarios. The rice yield among scenarios is not significantly different probably due to the model is run for only 5 years while the salinization associating with drought effect is gradually effected for a long process. However, it is likely that rice yield is tending to reach a higher value when large size of rice area is practiced as we can see in the scenario 2nd and scenario 5th regardless the rate of rice area effected by drought.

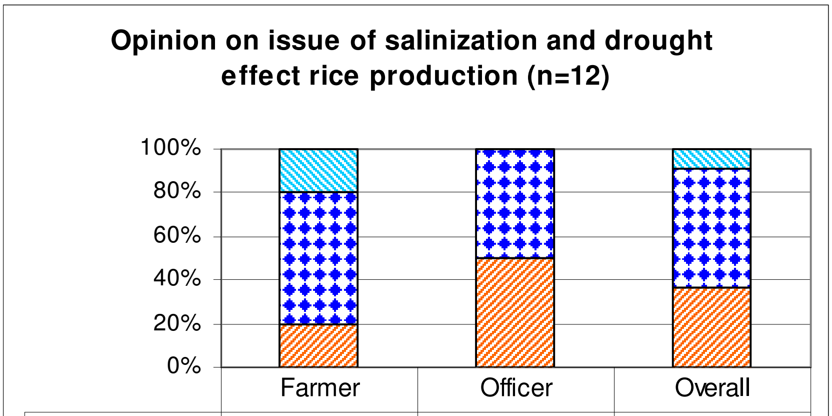
Once again, this environmental impact is also perceived by local people. Nevertheless, there remains a certain portion of local people who do not think about the ramifications of salinization and its effects on their field (Figure 7.16). Most probably they are confident with their management capacity and their ability to minimize such effects on their fields.

Table 7.8 Rice yield in first five scenarios from 1st to 5th in Phong Thanh village

Scenario	Rice area (ha. household$^{-1)}$	Rice area effected by drought (ha. household$^{-1)}$	Rate of rice area effected by drought (%)	Rice yield (kg.ha^{-1})	Rice yield reduction (kg.ha^{-1})	Shrimp yield (kg.ha^{-1})*
1	0.36a	0.13	36	3,106	394	126a
2	0.67b	0.16	24	3,240	260	237b
3	0.42a	0.14	33	3,043	457	110a
4	0.49a	0.15	31	3,053	447	119a
5	0.67b	0.26	39	3,200	300	201b
Total	0.52	0.16	32	3,128	371	159

(*) This column is for reference in relation with variation of rice area by scenarios

Note: The numbers followed by same letters in a same column are not significantly different by Duncan test at 0.05.



	Farmer	Officer	Overall
not important	20.00	0.00	9.09
important	60.00	50.00	54.55
very important	20.00	50.00	36.36

Figure 7.16 Salinization and drought effect on rice crop perceived by local people

7.5 CONCLUSION

The RiceShrimpMD Agent-Based Model was basically built and improved on with the participation of relevant local stakeholders using local knowledge and the expert knowledge of researchers. We simulated different scenarios of water salinity patterns and application of environmental concern on rice crops in the downstream location of Phong Thanh village. Simulation results were analyzed, giving us a very interesting look at the implications of the environmental and socio-economic impacts of the rice-shrimp farming system in the Bac Lieu province. Implications for the creation of water management policy, as well as decision making on agricultural production at household level, have been obtained. The environmental and socio-economic impacts are strongly happened in Phong Thanh downstream village rather than in Vinh Loc upstream village. Most impact analysis is emphasized to take into account for the downstream village in this chapter.

Conflict over water demand for rice and shrimp crop can occur whenever both rice and shrimp crop coexist at the same period of time within a plot. This possibility is dependent not only on the water scheme that is controlled at the upper levels of policy makers, but also depends on household decision making. Although saline water in the canal can be present right up until August, farmers could stop shrimp crops earlier in order to prepare their fields before September for rice crops if they wanted to reach stable household incomes.

Extreme poverty (negative household capital) in the year 5th is happened frequently in scenarios that rice is not always practiced in rotation with shrimp crop in the rice-shrimp farming system. Rice is considered as an intermediate component to increase household capital while reduce economic differentiation among households in the community.

Environmental impact, precisely salinization and drought occurrence, was examined. It was found that there is not much serious damage on rice production if farmers did not practice rice crop annually. Rice yield can be lesser a bit due to salinization effect, however, income from rice component still substantially reduce extreme poverty in a household

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Sustainable agricultural development is a goal for every dominated agricultural region such as the Bac Lieu province in the Mekong Delta, Vietnam. Dynamic land-use change and its environmental and socio-economic impacts, a result of its agricultural systems, are challenging sustainable development in the region. The implementation of optimal production policy driving water management in the areas of mixed rice and shrimp farming in the province is a very important influence on local people's farming behaviors and practices, and as a consequence, sustainable development. Enhancing the sustainable development knowledge of farmers and local institutional officers, who are both involved in water management and decision making, is crucial.

Up to the present, there has been a lack of suitable means for the study of causality between water management options and empirical farming consequences, as well as environmental and socio-economic impacts resulting from such farming systems in the province. In this sense, we have applied a novel, creative methodology for stimulating individual and collective awareness of the effects of water management schemes and their practical consequences at community and household levels in the province. In this thesis, three critical issues as stated in the problems identification in the chapter one have been studied: conflict over water demanded by rice and shrimp farmers; the potential for extreme poverty of farmers who cultivate shrimp monoculture; and the potential effect of soil salinization on rice production in rice-shrimp farming systems.

Participatory approaches have widely been applied in many aspects in natural resource management. The thesis has fully applied the Companion Modeling approach, a special participatory modeling approach that takes into account the link between natural and socioeconomic systems. This approach has proven to be suitable and useful for reaching the research objectives. Particularly, it allowed local farmers who, despite having received little formal education, have been able to actively interact with researchers in the process of formalizing their local knowledge and practices to collectively build a shared representation of the rice-shrimp farming system in Bac Lieu. The RPG sessions helped to lessen their bewilderment to address the high level of abstraction needed for formatting this information so that it may be entered into an agent-based model. Later on, they felt comfortable to follow computational simulations, suggesting modifications of the model and new scenarios to be tested. From a methodological point of view, this study is contributing to demonstrate that role-playing games sessions can efficiently pave the way to the involvement of local stakeholders in the use of computer models simulating the functioning of complex socio-ecosystems such as the farming systems of the Mekong Delta. I believe that through this co-learning process, both local stakeholders and researchers can acquire new knowledge and therefore gain understanding so that ultimately, it may positively impact the way they envision sustainable development.

The thesis started with in-depth reviews of socio-economic literature, local knowledge and integration of the companion modeling approach for systematization of the research issues and research methodology.

Results from the RPG sessions in 2006 and 2007 that took place during the research process have provided a number of lessons that are helpful for all stakeholders involved in the production systems and dealing with the three critical issues mentioned in the research. With the chance to earn higher revenues from shrimp compared with rice, farmers are attempting numerous techniques to prolong the duration of saline water in their fields for shrimp cultivation. Conflict has emerged as such a situation makes the growing of a subsequent rice crop impossible, even in the rainy season. Risk of shrimp disease in the seed stage and during the growing out period is also an important factor directly affecting household income. Risk is probably an essential factor leading to potential poverty and economic differentiation that threatens sustainability. The RPG sessions were a good platform for upstream and downstream farmers and other involved stakeholders to communicate, share knowledge and perceptions, as well as their water demands, in order to seek a harmonized resolution for the conflict. Compromised water schemes have been drawn up, a collective output of all the stakeholders who participated in the game. In the RPG sessions, highly vulnerable land-use of shrimp monoculture tends to happen unless there is intervention from the government. RPGs are therefore a good social experiment that proves the important role of governmental intervention in pursuing sustainable development.

An agent-based model has been later collaboratively developed and used with local farmers from selected villages and institutional authorities of the Bac Lieu Province. Exclusively entitled 'RiceShrimpMD', the model is specific to rice and shrimp production in the Mekong Delta. The RiceShrimpMD is elaborated based on participatory principles, from the co-construction of the model to simulation and the validation of its outputs. The RiceShrimpMD is made of six key entities, namely Plot, Farm, Village, Canal, Household and Crop that are classified into spatial, crop and social modules. The household entity is a key decision-maker in the RiceShrimpMD model. There are five complementary sub-models corresponding to five rule-based crop agents (crop, rice, shrimp, fish and crab) to do their production activities in the RiceShrimpMD. The RiceShrimpMD is a discrete time-step model, in which weekly time-step was chosen**.** The model employs both stochastic and deterministic concepts designed to cover the randomness of some parameters like the duration of crops (between min and max), risk of shrimp disease, date of last rain (drought) and deterministic parameters of critical constraints of salinity to allow the starting of crops.

The basic version of the RiceShrimpMD has been collectively verified and validated by simulating and analyzing the three scenarios that were previously defined and played with the same local participants during RPG sessions. Based on participants' feedbacks gathered during this final workshop, a new version of the RiceShrimpMD ABM has been created in the lab. This consolidated version has been used by the research team to conduct additional experiments and further analysis. All impacts from rice-shrimp farming system are mostly effective in downstream location of Phong Thanh village. The analysis is therefore more concentrative on downstream location.

Results from model simulation indicate that (i) potential conflict over water demand for rice and shrimp crops occur when both rice and shrimp crops coexist in the same period within a community after September, which is the critical time for starting rice crops. In the downstream location of Phong Thanh village, more potential conflict occurred in group B of scenarios 6th to 10th when all households concerned about environmental factors on their field, more rice areas are cultivated as compared with that in group A of first scenarios from 1st to 5th. Rice crop is however not the cause to create potential conflict but rather, late shrimp crop is the source of potential conflict. (ii) extreme poverty, in terms of household capital in the year 5th and economic differentiation, occurred in scenarios whenever people tried to practice monoculture shrimp and rice cropping was somewhat neglected, especially in the downstream location of Phong Thanh village. Simulation results showed that the risk of shrimp disease is a critical factor which strongly affects the economic returns of shrimp production; highest annual household capital can be obtained in the scenario that rice largely practice and shared a higher proportion in household income given stable income of fish and crab. Rice component in the rice-shrimp farming system is a best option selected to avoid extreme poverty occurrence while it can lessen economic differentiation among household in the community. (iii) environmental impact, precisely the effect of salinization and drought occurrence on rice production, is not so damaging as farmers practice rice cropping annually. Rice yield declines a little as a result of salinization; however, income from rice can be used a way to compensate against and reduce extreme poverty in a household. Hence, ignoring Vinh Loc village, due to its stability of household capital among scenarios, the 7th scenario is the most socially, economically and environmentally appropriate for Phong Thanh village.

In sum, sustainable agricultural development in Bac Lieu province is a dynamic process that is always challenged by a wide range of biophysical and socio-economic factors, from the macro level of policy makers and water management schemes to the micro level of household decision making processes. Among the three factors targeted in this research, the extreme poverty, coupled with economic differentiation, is threatening sustainability greatly. The risk of shrimp disease and individual decision making on whether to practice or not rice crops are the key components leading to extreme poverty and economic differentiation. The companion modeling approach in this study, with the use of RPGs and RiceShrimpMD ABM in combination, has proven to be a very good methodology for all relevant stakeholders to share knowledge, opinions on water demand; as a result, better understanding and collaborating on water management toward sustainable development have been obtained. In this research, RiceShrimpMD ABM has proven to be a good explanatory tool, allowing all concerned stakeholders to see the causality between scenarios and their consequences. Thus, the local participants' knowledge has been enhanced.

8.2 RECOMMENDATIONS

Water salinity degree and its fluctuation in time are critical factors that affect the degree of conflict between rice and shrimp crops, especially in the downstream location of Phong Thanh village. Water management that provides salinity over 5 ppt from January to the end of July, and from January to the end of June for Phong Thanh and Vinh Loc village respectively is the scheme that can be recommended. The risk of shrimp disease, especially at the seed stage is a very important factor that affects the economic outcomes of a household. Improvement of shrimp seed quality to reduce risk at this stage is the best solution for attaining better shrimp yields, and consequently, better household income.

Practicing the rice component, as well as other aquatic species other than shrimp, is a good combination in the farming system to sustain the stability of household on-farm income. In other words, diversified farming, rather than shrimp monoculture is a practice to be encouraged in the province.

Moreover, the rice component becomes a way of lessening the environmental impact on both shrimp yield and rice production as well. The frequent practice of rice cropping should be recommended to every household to relieve the negative impacts of shrimp monoculture.

The annual creation and facilitation of a platform for farmers and local institutional officers to gain a better understanding of water demand and to adjust the water management scheme to fit with upstream and downstream locations is most certainly a positive way of reaching for sustainable development

REFERENCES

Abelson J., Forest P.G., Eyles J., Smith P., Martin E., and Gauvin F.P. 2003. Deliberations about deliberative methods: Issues in the design and evaluation of public participation processes. Social Science and Medicine. 57:239-251.

Amler B., Betke D., Eger H., Ehrich C., Hoesle U., A. Kohler, Küsel C., Lossau A.v., Lutz W., Müller U., Schwedersky T., Seidemann S., Siebert M., Trux A., and Zimmermann W. 1999. Land Use Planning Methods, Strategies and Tools. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH P.O. Box 5180, 65726 Eschborn, Germany. 212 p.

Arneson D. 1974. Tactical Studies Rules, Lake Geneva US, *In* Ed D.D., (ed.) Beyond Role and Play – Tools, Toys and Theory for Harnessing the Imagination, Montola M. and Stenros J ed, Ropeconry, Helsinki.

Balci O. 1998. Verification, Validation and Testing. In: Banks J., ed. Handbook of Simulation. . John Wiley & Sons, Inc. Pp: 335-409.

Barclay A. 2005. Dream Beyond Drought [Online]. Available by IRRI - International Rice Research Institute. www.irri.org/publications/today/pdfs/4-2/14-21.pdf

Barnaud C., Guy T., Arie P.D., and Maria J. 2008. Area Study Prior to Companion Modelling to Integrate Multiple Interests in Upper Watershed Management of Northern Thailand. Southeast Asian Studies. 45 (4).

Barraclough S., and Finger-Stick A. 1996. Some ecological and social implications of commercial shrimp farming in Asia Discussion Paper No. 74. United Nations Research Institute for Social Development (UNRISD), Geneva.

Barreteau O. 2003a. The joint use of role-playing games and models regarding negotiation processes: characterization of associations Journal of Artificial Societies and Social Simulation 6 (2).

Barreteau O. 2003b. Our Companion Modelling Approach. Journal of Artificial Societies and Social Simulation. 6 (1).

Barreteau O., Bousquet F., and Attonaty J.-M. 2001. Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to Senegal River Valley irrigated systems Journal of Artificial Societies and Social Simulation 4 (2).

Be T.T., Sinh B.T., and Miller F. 2007. Challenge to Sustainable Development in the Mekong Delta: Regional and National Policy Issues and Research Needs. Sumernet. 208 p.

Béné C. 2005. The good, the bad and the ugly: discourse, policy controversies, and the role of science in the politics of shrimp farming development. Development Policy Review. 23 (5):585-614.

Berger T. 2001. Agent-based Spatial Models Applied to Agriculture: A Simulation Tool for Technology Diffusion, Resource Use Changes and Plicy Analysis. Agriucltural Economics. 25 (2-3):245.

Boero R., and Squazzoni F. 2005. Does Empirical Embeddedness Matter? Methodological Issues on Agent-Based Models for Analytical Social Science Journal of Artificial Societies and Social Simulation. 8 (4).

Boothroyd P., and Nam P.X. 2000. Socioeconomic Renovation in Viet Nam: The Origin, Evolution, and Impact of Doi Moi

International Development Research Centre, 30 Heng Mui Keng Terrace, Pasir Panjang, Singapore 119614

Bousquet F., and Le Page C. 2004. Multi-agent simualations and ecosystem management: a review. Ecological Modelling. 176 (3-4):313-332.

Bousquet F., and Trebuil G. 2005a. Introduction to companion modelling and multi-agent systems for integrated natural resource management in Asia. In: Bousquet F., Trebuil G. and Hardy B., eds. Companion Modeling and Multi-Agent Systems for Integrated Natural Resource Management in Asia. Los Banos, Philippines: IRRI (International Rice Research Institute). Pp: 1-20.

Bousquet F., Muller J.-P., Barnaud C., Suphanchaimart N., and Trebuil G. 2005b. Companion Modeling for resource management in Thai rice ecosystems. In: First Asia-Europe Workshop on Sustainable Resource Management and Policy Options for Rice Ecosystems (SUMAPOL 2005). 11-14 May 2005, Hangzhou, Zhejiang, Province, P.R. China.

Bousquet F., Trebuil G., Boissau S., Baron C., D'Aquino P., and Castella J.-C. 2001. Knowledge integration for participatory land management: The use of multi-agent smualations and a companion modeling approach. In: Participatory Technology Development and Local Knowledge for Sustainable Land Use in Southeast Asia. 6-7 June 2001, Chiang Mai, Thailand.

Bousquet F., Barnaud C., Barreteau O., Cernesson F., Dumrongrojwatthana P., Dung L.C., Ekasingh B., Gajaseni N., Hoanh C.T., Le Page C., Naininit W., Promburom P., Raj Gurung T., Ruankaew N., and Trebuil G. 2006. Companion modeling for resilient water management: Stakeholders' perceptions of water dynamics and collective learning at the catchment scale. In: In France and the Consultative Group on International Agricultural Research (CGIAR): Delivering scientific results for agriculture development. Washington D.C., USA.

Bousquet F., Bakam I., Proton H., and Le Page C. 1998. CORMAS: common-pool resources and multi-agent systems. In: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems. Benicasim (Spain). Berlin (Germany): Springer-Verlag. 826-837.

Bouwen R., and Taillieu T. 2004. Multi-party Collaboration as Social Learning for Interdependence: Developing Relational Knowing for Sustainable Natural Resource Management. Journal of Community & Applied Social Psychology. 14:137-153.

Brennan D. 2003. Factors affecting farm financial risk: observations from a bioeconomic model Rice–shrimp farming in the Mekong Delta: biophysical and socioeconomic issues. ACIAR Technical Reports No. 52e.

Buchan I. 2002. Calculating the Gini coefficient of inequality.

Caldwell W. 2000. Land-Use Issues and Conflict Resolution Rural Planning and Nutrient Management: Issues and Approaches.

Cardenas G.I.S. 1994. Impact of Inland Shrimp Culture on Soil Salinization and Rice Yield. Aquaculture and Aquatic Resource Management Msc Thesis. AIT, Bangkok, Thailand

Castella J.-C., Trung T.N., and Boissau S. 2005a. Participatory Simulation of Land-Use Changes in the Northern Mountains of Vietnam: the Combined Use of an Agent-Based Model, a Role-Playing Game, and a Geographic Information System Ecology and Society 10 (1).

Castella J.-C., Boissau S., Trung T.N., and Dang D.Q. 2005b. Agrarian transition and lowland-upland interactions in mountain areas in northern Vietnam: application of a multi-agent simulation model Agricultural Systems 86 (3):312-332.

Castella J.-C., Kam, S.P., Quang, D.D., Verburg, P.H. & Hoanh, C.T. 2007. Combining top-down and bottom-up modeling approaches of land use/cover change to support public policies: Application to sustainable management of natural resources in northern Vietnam. Land Use Policy. 24 (3):531–545.

CBDC. 2001. Study on the Plant Genetic Diversity and Seed Supply System of Vietnam. Community Biodiversity Development and Conservation (CBDC) Programme: Vietnam Project, Southeast Asia Regional Institute for Community Education, Quezon City, Philippines. Technical Report No. 19

Chanratchakook P. 2005. Collection and utilization of important data in shrimp farming Shrimp, *In* Wilkinson S., (ed.). Network of Aquaculture Centres in Asia-Pacific - Sustainable Aquaculture.

Chowdhury M.A. 2007. The sustainability assessment of shrimp farming: a case study of the present farming systems in Bangladesh. School of Environment, Resouces and Development AIT, Bangkok, Thailand.

CIRAD. 2003. CORMAS: Common-pool Resources and Multi-Agents Systems Tutorial 1. In. Green Research Unit, Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), Montpellier, France. Pp: 28.

D'Aquino P., Barreteau O., Etienne M., Boissau S., Bousquet F., Page C.L., Aubert S., and Daré W. 2002. " The role playing games in an ABM participatory modeling process: outcomes from five different experiments carried out in the last five years". . in: A.E. Rizzoli and A.J. Jakeman (eds), Integrated assessment and decision support. iEMSs. "1st biennial meeting of the International Environmental Modelling and Software Society", Lugano (Swizerland), June 24-27, pp. 275-280.

DoF. 1995. Central Shrimp Cell: Shrimp resources statistics. Department of Fisheries, Dhaka.

DoF. 2003. Fishery Statistical Yearbook of Bangladesh: 2002-2003. Department of Fisheries, Dhaka.

Dougill A.J., Fraser E.D.G., Holden J., Hubacek K., Prell C., Reed M.S., Stagl S., and Stringer L.C. 2006. Learning from Doing Participatory Rural Research: Lessons from the Peak District National Park. Journal of Agricultural Economics. 57 (2):259-275.

FAO. 2000. Extent and Causes of Salt-affected Soils in Participating Countries [Online]. Available by http://www.fao.org/ag/agl/agll/spush/topic2.htm.

FAO. 2004. Fisheries resources: trends in production, utilization and trade. World Review of Fisheries and Aquaculture.

Flaherty M., Vandergeest P., and Miller P. 1999. Rice paddy or shrimp pond: though decisions in rural Thailand. World Development. 27 (12):2045-2060.

Gallop K., Khiem N., Dung L., and Gowing J. 2003. Changes in farmer livelihoods and land-use strategies during the project period 2000 – 2003. DFID-CRF project: Accelerating poverty elimination through sustainable resource management in coastal lands protected from salinity intrusion: a case study in Vietnam. WP1-2. R7467C. 32 p.

Gilbert N. 2008. Agent-Based Models. Sara Miller McCune, SAGE Publications. 98 p.

Gilbert N., and Troitzsch G.K. 1999. Multi-Agent Models. In: Simulation for the Social Scientist. Philadelphia PA 19106 USA: Open University Press, Buckingham, Philadelphia. Pp: 288.

Gowing J.W., T.P. T., and C.T. H. 2006a. Land and water management in inland coastal zones: Lessons of experience and future challenges for researchers and policy makers. In: Hoanh C.T., Tuong T.P., Gowing J.W. & Hardy B, ed. Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts. Book No.2 of CA Series (Comprehensive Assessment of CGIAR). CABI Publishing, UK. Pp: 1-16.

Gowing J.W., T.P. T., C.T. H., and N.T K. 2006b. 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, ed. Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts. CABI Publishing, UK. : Book No.2 of CA Series (Comprehensive Assessment of CGIAR). Pp: 48-60.

Grimble R., and Wellard K. 1996. Stakeholder Methodologies in Natural Resource Management: a Review of Principles, Contexts, Experiences and Opportunities. Agricultural systems. 55 (2):173-193.

Grimm V., and Railsback S.F. 2005. Individual-based Modeling and Ecology. Princeton, NJ.: Princeton University Press. 480 p.

Grimm V., Uta Berger F.B., Sigrunn Eliassen, Vincent Ginot,, Jarl Giske J.G.-C., Tamara Grand, Simone K. Heinz, Geir Huse,, Andreas Huth J.U.J., Christian Jørgensen, Wolf M. Mooij, Birgit Mu¨ ller,, Guy Pe'er C.P., Steven F. Railsback, Andrew M. Robbins, Martha M. Robbins,, Eva Rossmanith N.R.g., Espen Strand, Sami Souissi, Richard A. Stillman,, and Rune Vabø U.V., Donald L. DeAngelis. 2006. A standard protocol for describing individual-based and agent-based models. Ecological Modelling. 198:115-126.

GSO. 2006. Annual Data. Statistical Publishing House, Ha Noi, Viet Nam.

GSO. 2008. Key economic indicators of Viet Nam. Statistical Publishing House, Ha Noi, Viet Nam.

Guganesharajah K., Pavey J.F., Wonderen J.v., Khasankhanova G.M., Lyons D.J., and Lloyd B.J. 2007. Simulation of Processes Involved in Soil Salinization to Guide Soil Remediation. Journal of Irrigation and Drainage Engineering. 133 (2):131-139

Gurung T.R., Bousquet F., and Trébuil G. 2006. Companion modeling, conflict resolution, and institution building: Sharing irrigation water in the Lingmuteychu Watershed, Bhutan. Ecology and Society 11 (2).

Guyot P., and Honiden S. 2006. Agent-Based Participatory Simulations: Merging Multi-Agent Systems and Role-Playing Games. Artificial Societies and Social Simulation. 9 (4).

Hales D., Rouchier J., and Edmonds B. 2003. Model-to-model analysis. Journal of Artificial Societies and Social Simulation (JASSS). 6:5.

Heliö S. 2004. Role-playing: A narrative experience and a mindset, *In* J. M.M.S., (ed.) Beyond role and play – Tools, toys and theory for harnessing the imagination. Ropeconry, Helsinki.

Hoanh C.T. 1996. Development of a Computerized Aid to Integrated Land Use Planning (CAILUP) at regional level in irrigated areas: A Case Study for the Quan Lo Phung Hiep Region in the Mekong Delta, Vietnam. P.O. Box 6. 7500 AA Enschede, The Netherlands: ITC. 297 p.

Hoanh C.T., Phong N.D., Gowing J.W., Tuong T.P., Ngoc N.V., and Hien N.X. 2009. Hydraulic and water quality modeling: a tool for managing land use conflicts in inland coastal zones. Water Policy. 11 (1).

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. Water Policy 5, 5:475-488.

Hoanh C.T., Page C.L., Barreteau O., Trébuil G., Bousquet F., Cernesson F., Barnaud C., Gurung T.R., Promburom P., Naivinit W., Dung L.C., Dumrongrojwatthana P., and Thongnoi M. 2008. Agent-based modeling to facilitate resilient water management in Southeast and South Asia. International Forum on Water and Food. 10-14 November, 2008. Addis Ababa, Ethiopia.

Hossain M., Tuong T.P., Cabrera E., Can N., and Ni D. 2006. Impact of land elevation on poverty elimination of shrimp-based farming in Bac Lieu, Vietnam. the 2nd Annual Meeting of Challenge Program on Water and Food (CPWF) Project 10. 30-31 March 2006. Los Baños, Laguna, Philippines.

Huitric M., Folke C., and Kautsky N. 2002. Development and government policies of the shrimp farming industry in Thailand in relation to mangrove ecosystems. Ecological Economics. 40 (3):441-455.

IRRI. 2004. Managing Water and Land Resources for Sustainable Livelihoods at the Interface Between Fresh and Saline Water Environments in Vietnam and Bangladesh (CP WF#10). International Rice Research Institute (IRRI), Los Banos, Laguna, Philippines.

Jackson M.T. 2004. Project CPWF PN10: Managing Water and Land Resource for Sustainable Livelihoods at the Interface between Fresh and Saline Water Environment in Vietnam and Bangladesh, *In* Jackson M.T., (ed.). IRRI.

Janssen M.A. 2005. Agent-Based Modelling. International Society for Ecological Economics.9.

Kam S.P., N.V. N., T.P. T., C.T. H., V.T. B.N., and A. M. 2006. Applying the Resources Management Domain (RMD) concept to land and water use and management in the coastal zone: Case study of Bac Lieu Province, Vietnam. In: Hoanh C.T., Tuong T.P., Gowing J.W. & Hardy B. , ed. Environment and livelihoods in tropical coastal zones: Managing agriculture-fishery-aquaculture conflicts. Book No.2 of CA Series (Comprehensive Assessment of CGIAR). CABI Publishing, UK. Pp: 193-205.

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., pp. 11.

Khiem N.T., and Hossain M. 2007. Dynamics of livelihoods and resource use strategies in different ecosystems of the coastal zones of Bac Lieu. Delta. 7-9 November, 2007. Bangsaen City, Thailand.

Kibi N. 2003. Resolving Water Conflicts Through Participatory Decision Making : A Case Study From The Nakanbé River Basin, Burkina Faso Project “GUCRE” CEDRES, University of Ouagadougou, Burkina Faso, 03 B.P. 7164, Ouagadougou 03, Burkina Faso

Kungvankij P., Chua T.E., Pudadera B.J.J., Corre K.G., and Borlongan E. 1986. Shrimp culture: Pond design, Operation and Management. Series title: FAO Training Series. 77 p.

Lam T.D.T. 2002. Gap grows between Vietnam's haves and have-nots [Online]. Available by http://www.atimes.com/index.html http://www.atimes.com/index.html (verified April 10, 2002).

Le Page C., and Bommel P. 2005. A methodology for building agent-based simulations of common-pool resources management: from a conceptual model designed with ULM to its implementation in CORMAS. In: Bousquet F., Trebuil G. and Hardy B., eds. Companion modeling and multi-agent systems for integrated natural resource management in Asia. Los Banos, Philippines: IRRI. Pp: 327-350.

Lee K.N. 1999. Appraising adaptive management. Conservation Ecology. 3:3.

Mekhora T., and McCann L.M.J. 2003. Rice versus shrimp production in Thailand: Is there really a conflict? Agricultural and Applied Economics.

Miller F. 2003. Society-Water Relations in the Mekong Delta: A Political Ecology of Risk. University of Sydney, Australia.

Minot N., and Goletti F. 2000. Rice market liberalization and poverty in Vietnam. Food Policy Research Institute (IFPRI). Report 114, Washington D.C., USA.

MONRE. 2002. Annual land use data of provinces in the Mekong Delta in Vietnam. Ministry of Natural Resources and Environment (Vietnamese).

Moss S. 2008. Alternative Approaches to the Empirical Validation of Agent-Based Models Journal of Artificial Societies and Social Simulation 11 (15).

Neiland A.E., Soley N., Varley J.B., and Whitmarsh D.J. 2001. Shrimp aquaculture: economic perspectives for policy development. Marine Policy. 25 (4):265-279.

Ni D.V., and Maltby E. 2002. Mekong River Delta. Report on the Modified Mega Delta Workshop. First Iteration. ANNEX A. Mega Delta Workshop.

Phuc N.T. 2006. Renovating the Party's political thinking in leading the cause of renewal Communist Review No.107.

Polhill G.I., Parker D., Brown D., and Grimm V. 2008. Using the ODD protocol for describing three agent-based social simulation models of land-use change. Journal of Artificial Societies and Social Simulation (JASSS). 11:30.

Ribot J.C. 2004. The Politics of Choice in Natural Resource Decentralization. WASHINGTON, DC: World Resources Institute. 154 p.

Richiardi M., Leombruni R., Saam N., and Sonnessa M. 2006. A common protocol for Agent-Based Social Simulation. Journal of Artificial Societies and Social Simulation (JASSS). 9:22.

Sa P.V. 2008. Major Climate Parameters in Bac Lieu Province Over Last Ten Years. Bac Lieu Meteorological and Hydrological Center

Sinh L.X., Chung D.M., Khuyen P.T.N., and Truyen T.T. 2005. Social impacts of coastal aquaculture in the Mekong Delta Can Tho University Scientific Journal.

Szuster B. 2006. Coastal Shrimp Farming in Thailand: Searching for Sustainability. In: C.T.Hoanh T.P.T., J.W. Gowing and B. Hardy, ed. Environment and Livelihood in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflict. Comprehensive Assessment of Water Management in Agriculture Series. Pp: 86-98.

Szuster B.W., and Flaherty M. 2002. Cumulative environmental effects of low salinity shrimp farming in Thailand. Impact Assessment and Project Appraisal. 20 (3):189–200.

Toan D.Q., and Iyer L. 2003. Land Rights and Economic Development: Evidence from Vietnam World Bank Policy Research Working Paper 3120. World Bank

Trebuil G. 2008. Companion Modelling for Resilient and Adaptive Social Agro-Ecological Systems in Asia. In: Agriculture for Community and Environment Ready to Handle Climate Change. 27-28 May 2008, Empress Hotel, Chiang Mai, Thailand. 90-104.

Trebuil G., Shinawatra-Ekasingh B., Bousquet F., and Thong-Ngam C. 2003. Multi-agent Systems Companion Modeling for Integrated Watershed Management: A Northern Thailand Experience. In Landscapes and Diversity: Indigenous and Knowledge, Sustainable Livelihoods and Resource Governance in Montan Mainland Southeast Asia. In: The 3rd Symposium on MMSEA. 25-28 August 2002, LIjiang, China. 349-358.

Trung N.H., Tri L.Q., van Mensvoort M.E.F., and Bregt A. 2004. GIS for Participatory Land Use Planning in the Mekong Delta, Vietnam. AFITA/WCCA Joint Congress on It in Agriculture.

Trung N.H., Tri L.Q., Mensvoort M.E.F.v., and Bregt A.K. 2006. Comparing Land-use Planning Approaches in the Coastal Mekong Delta of Vietnam. In: Environment and Livelihoods in Tropical Coastal Zones. CAB International. Pp: 177-192.

Tuan L.A., Hoanh C.T., Miller F., and Sinh B.T. 2007. Flood and salinity management in the Mekong Delta, Vietnam. In. The Sustainable Mekong Research Network. Pp: 15-68.

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 environment, land use strategies and household incomes in a coastal area. Paddy Water Environment. 1 (2):65–73.

Tuong T.P., Kam S.P., Hoanh C.T., Dung L.C., Khiem N.T., Barr J., Ben D.C., and 2002. Impact of salinity protection on the environment: farmers resource-use strategies and livelihood in a coastal area. Water Management Engineer, International Rice Research Institute, Los Baños, Philippines

USDA. 1998. Soil Quality Resource Concerns: Salinization [Online]. Available by USDA Natural Resources Conservation Service.

Vandergeest P., Flaherty M., and Miller P. 1999. A political ecology of shrimp aquaculture in Thailand. Rural Sociology. 64 (4):573-596.

Waskul D., and Lust M. 2004. Role-Playing and Playing Roles: The Person, Player, and Persona in Fantasy Role-Playing. Symbolic Interaction 27 (3):333–356.

WB. 2008. Gross national income per capita 2007, Atlas method and PPP. World Development Indicators database, World Bank.

Webne-Behrman H. 1998. The Practice of Facilitation: Managing Group Process and Solving Problems [Online]. Available by Quorum Books, Greenwood Publishing http://www.ohrd.wisc.edu/onlinetraining/resolution/index.asp.

White I. 2002. Water Management in the Mekong Delta: Changes, Conflicts and Opportunities. IHP-VI. Technical Documents in Hydrology. International Hydrological Programme. UNESCO, Paris, 2002. 75 p.

Wilder M., and Phuong N.T. 2002. The Status of Aquaculture in the Mekong Delta Region of Vietnam: Sustainable Production and Combined Farming Systems. In: 70th Anniversary of the Japanese Society of Fisheries Science. November 2002.

Wuyts R. 2005. UML:History and Overview. http://www.ulb.ac.be/di/rwuyts/INFO139_2004/.

Xuan V.T., and Matsui S. 1998. Development of farming systems in the Mekong Delta, Vietnam. Ho Chi Minh City Publishing House, Ho Chi Minh City.

APPENDICES

APPENDIX A PARTICIPANTS INVOLVED RESEARCH PROCESS

Table A1 Local participants in Phong Thanh village involved Companion Modelling process in 2006

No.	Full name	Gender	Title	Hamlet
In Group Meeting (12 July, 2006)				
1	Nguyen Van Tuan	Male	Farmer	19
2	Nguyen Van Dung	Male	Farmer	19
3	Nguyen Van Loi	Male	Farmer	19
4	Nguyen Van Hai	Male	Farmer	19
5	Nguyen Van Quang	Male	Farmer	19
6	Thi Van Van	Male	Farmer	19
7	Nguyen Van Diem	Male	Farmer	19
8	Tran Trung Chinh	Male	Farmer	19
9	Thi Chi Thien	Male	Farmer	19
\10	Tran Van Phong	Male	Farmer	19
11	Le Van Yen	Male	Farmer	19
12	Thi Van Nhan	Male	Farmer	19
13	Le Thi Chanh	Female	Farmer	19
14	Phạm Van Tam	Male	Farmer	19
15	Nguyen Van Hoang	Male	Farmer	19
16	Nguyen Van Thoi	Male	Farmer	19
17	Nguyen Van Som	Male	Farmer	19
18	Thi Van Luu	Male	Farmer	19
19	Nguyen Van Mong	Male	Farmer	19
20	Tran Van Son	Male	Farmer	19
21	Tran Van Hanh	Male	Farmer	19
22	Nguyen Quoc Tuan	Male	Hamlet officer	19
23	Nguyen Van Duc	Male	Hamlet officer	19
24	Dang Tan Hoai	Male	Village officer	
In Role Playing Game (14-15 August, 2006)				
1	Phan Van Tam	Male	Farmer	19
2	Nguyen Quoc Thong	Male	Farmer	19
3	Nguyen Van Loi	Male	Farmer	19
4	Nguyen Quang Bui	Male	Farmer	19
5	Nguyen Van Thiet	Male	Farmer	19
6	Thi Van Van	Male	Farmer	19
7	Tran Trung Chinh	Male	Farmer	19
8	Nguyen Van Dong	Male	Farmer	19
9	Nguyen Quoc Tuan	Male	Hamlet officer	19
10	Nguyen Van Duc	Male	Hamlet officer	19
11	Đo Thanh Phuong	Male	Hamlet officer	19
12	Lam Ut Em	Male	Village officer	

Table A2 Local participants in Ninh Thanh Loi village involved Companion Modelling process in 2006

No.	Full name	Gender	Title	Hamlet
In Group Meeting (13 July, 2006)				
1	Lam Van Tung	Male	Farmer	Chu Chot
2	Huynh Van Lung	Male	Farmer	Chu Chot
3	Tran Thanh Hien	Male	Farmer	Chu Chot
4	Nguyen Van Chinh	Male	Farmer	Chu Chot
5	Luong Van Chanh	Male	Farmer	Chu Chot
6	Le Hong Huan	Male	Farmer	Chu Chot
7	Đoan Trung Kien	Male	Farmer	Chu Chot
8	Nguyen Van Hai	Male	Farmer	Chu Chot
9	Vo Hong Phuoc	Male	Farmer	Chu Chot
10	Nguyen Thanh Quang	Male	Hamlet officer	Chu Chot
11	Nguyen Van Nam	Male	Hamlet officer	Chu Chot
In Role Playing Game (24-25 August, 2006)				
1	Nguyen Van Hoang	Male	Farmer	Chu Chot
2	Le Van Vung	Male	Farmer	Chu Chot
3	Nguyen Van Tham	Male	Farmer	Chu Chot
4	Luong Van Chanh	Male	Farmer	Chu Chot
5	Nguyen Van Lan	Male	Farmer	Chu Chot
6	Doan Trung Kien	Male	Farmer	Chu Chot
7	Le Hong Huan	Male	Farmer	Chu Chot
8	Nguyen Thanh Quang	Male	Hamlet officer	Chu Chot

Table A3 Local participants in Vinh Loc village involved Companion Modelling process in 2006

No.	Full name	Gender	Title	Hamlet
In Group Meeting (14 July, 2006)				
1	Nguyen Tan Phong	Male	Farmer	Vinh Thanh
2	Nguyen Van Kieu	Male	Farmer	Vinh Thanh
3	Nguyen Van Su	Male	Farmer	Vinh Thanh
4	Danh Sau	Male	Farmer	Vinh Thanh
5	Danh Be	Male	Farmer	Vinh Thanh
6	Danh Thang	Male	Farmer	Vinh Thanh
7	Vo Minh The	Male	Farmer	Vinh Thanh
8	Ngo Hoang Hung	Male	Farmer	Vinh Thanh
9	Son Thanh Quan	Male	Farmer	Vinh Thanh
10	Đong Minh Quan	Male	Village officer	
In Role Playing Game (26-27 August, 2006)				
1	Son Minh Ky	Male	Farmer	Vinh Thanh
2	Nguyen Hong Mai	Female	Farmer	Vinh Thanh
3	Nguyen Van Dung	Male	Farmer	Vinh Thanh
4	Nguyen Minh Duc	Male	Farmer	Vinh Thanh
5	Tran Quoc Khoi	Male	Farmer	Vinh Thanh
6	Son Thanh Chua	Male	Farmer	Vinh Thanh
7	Nguyen Cong Danh	Male	Farmer	Vinh Thanh
8	Son Chi Linh	Male	Farmer	Vinh Thanh
9	Nguyen Van Hung	Male	Hamlet officer	Vinh Thanh
10	Nguyen Hong Vu	Male	Village officer	

Table A4 Can Tho University staff and scientists involved Companion Modelling process in 2006

No.	Full Name	Gender	Title	Institution
1	Lam Huon	Male	Assistant	MDI-CTU(1)
2	Nguyen Thu An	Female	Assistant	MDI-CTU
3	Nguyen Cong Toan	Male	Assistant	MDI-CTU
4	Vo Thanh Dung	Male	Assistant	MDI-CTU
5	Pham Hai Buu	Male	Assistant	MDI-CTU
6	Nguyen Bao Quoc	Male	Assistant	MDI-CTU
7	Nguyen My Hang	Female	Assistant	MDI-CTU
8	Pham Thi Pari	Female	Assistant	MDI-CTU
9	Nguyen Thi Xuan Trang	Female	Assistant	MDI-CTU
10	Nguyen Ngoc Son	Male	Assistant	MDI-CTU
11	Huynh Cam Linh	Male	Assistant	MDI-CTU
12	Tran Duon Xuan Vinh	Male	Assistant	MDI-CTU
13	Hua Hong Hieu	Male	Assistant	MDI-CTU
14	Nguyen Thanh Binh	Male	Assistant	MDI-CTU
15	Le Canh Dung	Male	Game Master	MDI-CTU
16	Chu Thai Hoanh	Male	Scientist	IWMI(2)
17	Christophe Le Page	Male	Scientist	CU-CIRAD(3)

1:Mekong Delta Development Research Institute (MDI),Can Tho University, Vietnam (CTU).
2: International Water Management Institute, Regional Office for Southeast Asia (IWMI-SEA), Vientiane, Lao PDR
3: CU-CIRAD project. Faculty of Science, Chulalongkorn University, Bangkok, Thailand. CIRAD, UPR Green, Montpellier, France.

Table A5 Local participant involved Companion modeling process in workshop held at Can Tho University in 2007

No.	Full name	Gender	Title	Location/Institution
1	Nguyen Van Loi	Male	Farmer	Phong Thanh village
2	Tran Trung Chinh	Male	Farmer	Phong Thanh village
3	Nguyen Quang Bui	Male	Farmer	Phong Thanh village
4	Nguyen Van Thiet	Male	Farmer	Phong Thanh village
5	Nguyen Van Dong	Male	Farmer	Phong Thanh village
6	Nguyen Cong Danh	Male	Farmer	Vinh Loc village
7	Nguyen Minh Duc	Male	Farmer	Vinh Loc village
8	Nguyen Van Dung	Male	Farmer	Vinh Loc village
9	Son Minh Ky	Male	Farmer	Vinh Loc village
10	Son Chi Linh	Male	Farmer	Vinh Loc village
12	Danh Duyen	Male	Farmer	Vinh Loc village
13	Đong Minh Chien	Male	Village officers	Vinh Loc village
14	Nguyen Ngoc Thong	Male	Village officers	Phong Thanh village
15	Nguyen Van Tran	Male	District officer	Gia Rai District
16	Luong Trung Tinh	Male	District officer	Hong Dan District
17	Phan Hong Thai	Male	Province officer	Agricultural & Rural Development Department

Table A6 Can Tho University staff and scientists involved Companion modeling process in workshop held at Can Tho University in 2007

No.	Full Name	Gender	Title	Institution
1	Lam Huon	Male	Assistant	MDI-CTU(1)
2	Nguyen Thu An	Female	Assistant	MDI-CTU
3	Nguyen Cong Toan	Male	Assistant	MDI-CTU
4	Pham Cong Huu	Male	Assistant	MDI-CTU
5	Vo Thanh Dung	Male	Assistant	MDI-CTU
6	Pham Hai Buu	Male	Assistant	MDI-CTU
7	Nguyen Bao Quoc	Male	Assistant	MDI-CTU
8	Nguyen My Hang	Female	Assistant	MDI-CTU
9	Nguyen Thi Xuan Trang	Female	Assistant	MDI-CTU
10	Pham Thi Pari	Female	Assistant	MDI-CTU
11	Huynh Cam Linh	Male	Assistant	MDI-CTU
12	Huynh Thanh Chi	Male	Assistant	MDI-CTU
13	La Thi Dieu Hanh	Female	Assistant	MDI-CTU
14	Huynh Nhu Dien	Male	Assistant	MDI-CTU
15	Nguyen Van Nhieu Em	Male	Assistant	MDI-CTU
16	Vo Tuan	Male	Assistant	MDI-CTU
17	Pham Cong Huu	Male	Assistant	MDI-CTU
18	Le Canh Dung	Male	Game Master	MDI-CTU
19	Chu Thai Hoanh	Male	Scientist	IWMI(2)
20	Christophe Le Page	Male	Scientist	CU-CIRAD(3)
21	Nantana Gajaseni	Female	Scientist	CU(4)

1:Mekong Delta Development Research Institute,Can Tho University, Vietnam.
2:*International Water Management Institute, Regional Office for Southeast Asia (IWMI-SEA), Vientiane, Lao PDR*
3: CU-CIRAD project. Faculty of Science, Chulalongkorn University, Bangkok, Thailand. CIRAD, UPR Green, Montpellier, France.
4: Department of Biology, Faculty of Science, Chulalongkorn University, Thailand

Table A7 Local participants involved Companion modeling process in workshop in Bac Lieu province (25-26 August, 2008)

No.	Full name	Gender	Title	Location/Institution
1	Nguyen Van Loi	Male	Farmer	Phong Thanh village
2	Tran Trung Chinh	Male	Farmer	Phong Thanh village
3	Nguyen Quang Bui	Male	Farmer	Phong Thanh village
4	Nguyen Van Thiet	Male	Farmer	Phong Thanh village
5	Nguyen Van Du	Male	Farmer	Vinh Loc village
6	Nguyen Minh Duc	Male	Farmer	Vinh Loc village
7	Nguyen Van Dung	Male	Farmer	Vinh Loc village
8	Son Minh Ky	Male	Farmer	Vinh Loc village
9	Son Chi Linh	Male	Farmer	Vinh Loc village

Table A8 Can Tho University staff and scientists involved Companion modeling process in 2008
IN 2008

No.	Full Name	Gender	Title	Institution
1	Le Canh Dung	Male	Model designer	MDI-CTU[1]
2	Nguyen Nhị Gia Vinh	Male	Modeler	CTU
3	Chu Thai Hoanh	Male	Scientist	IWMI[2]
4	Christophe Le Page	Male	Modeler	CU-CIRAD[3]

1:Mekong Delta Development Research Institute (MDI),Can Tho University, Vietnam (CTU).
2:International Water Management Institute, Regional Office for Southeast Asia (IWMI-SEA), Vientiane, Lao PDR
3: CU-CIRAD project. Faculty of Science, Chulalongkorn University, Bangkok, Thailand. CIRAD, UPR Green, Montpellier, France.

Table A9 Local participants involved Companion modeling process in workshop held at Can Tho University (27 February, 2009)

No.	Full name	Gender	Title	Location/Institution
1	Nguyen Van Loi	Male	Farmer	Phong Thanh village
2	Tran Trung Chinh	Male	Farmer	Phong Thanh village
3	Nguyen Van Thiet	Male	Farmer	Phong Thanh village
4	Nguyen Van Dong	Male	Farmer	Phong Thanh village
5	Nguyen Van Dung	Male	Farmer	Vinh Loc village
6	Duong Hoang	Male	Farmer	Vinh Loc village
7	Dong Minh Chien	Male	Village officer	Vinh Loc village
8	Le Van Cuong	Male	Village officer	Phong Thanh village
9	Nguyen Van Tran	Male	District officer	Gia Rai district
10	Nguyen Trung Hieu	Male	District officer	Hồng Dân district
11	Lai Thanh An	Male	Province officer	Water Management Department
12	Phan Hong Thai	Male	Province officer	Agricultural & Rural Development Department

Table A10 Can Tho University staff and scientists involved Companion modelling process in workshop held at Can Tho University (27 February, 2009)

No.	Full Name	Gender	Title	Institution
1	Le Canh Dung	Male	Model designer	MDI-CTU[1]
2	Nguyen Nhị Gia Vinh	Male	Modeler	CTU
3	Christophe Le Page	Male	Modeler	CU-CIRAD[2]

1:Mekong Delta Development Research Institute (MDI),Can Tho University, Vietnam (CTU).
2: CU-CIRAD project. Faculty of Science, Chulalongkorn University, Bangkok, Thailand. CIRAD, UPR Green, Montpellier, France.

APPENDIX B ASSESMENT OF THE RESEARCH BY STAKEHOLDERS

CANTHO UNIVERSITY
MEKONG DELTA DEVELOPMENT RESEARCH INSTITUTE
PARTICIPATORY WORKSHOP - PROJECT CPWF N^{o}.25
(27 February, 2009)

ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF INTEGRATED RICE-SHRIMP FARMING: COMPANION MODELLING CASE STUDY IN BAC LIEU PROVINCE MEKONG DELTA, VIETNAM

INDIVIDUAL INTERVIEW QUESTIONNAIRE AND RESULTS ANALYSIS

Name of respondent:…………………………………………………………

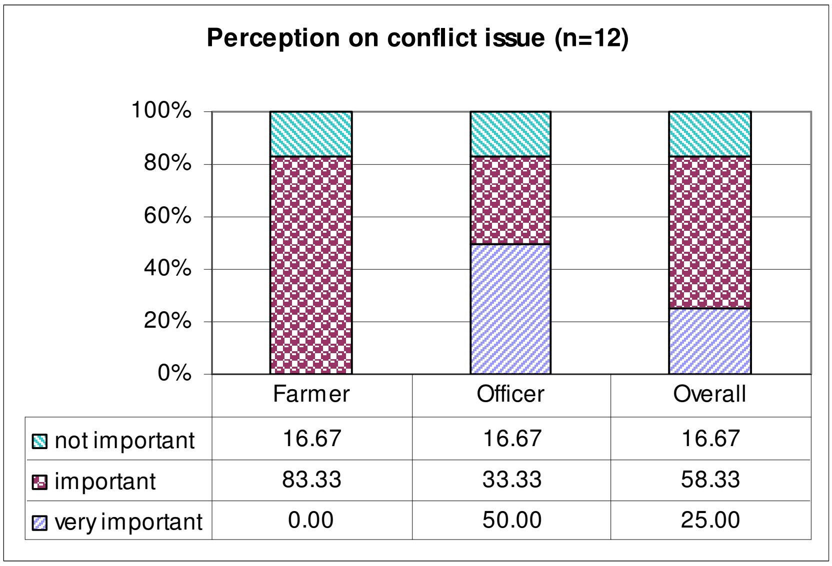
Title:
- ☐ farmer in PT village
- ☐ farmer in VL village
- ☐ officer in PT village
- ☐ officer in VL village
- ☐ officer in GR district
- ☐ officer in HD district
- ☐ officer of MARD of Bac Lieu province

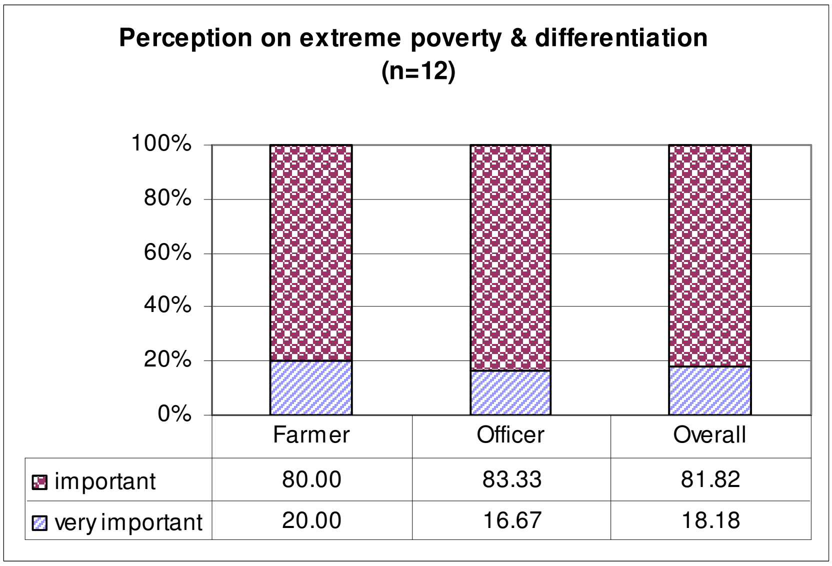
1. General section

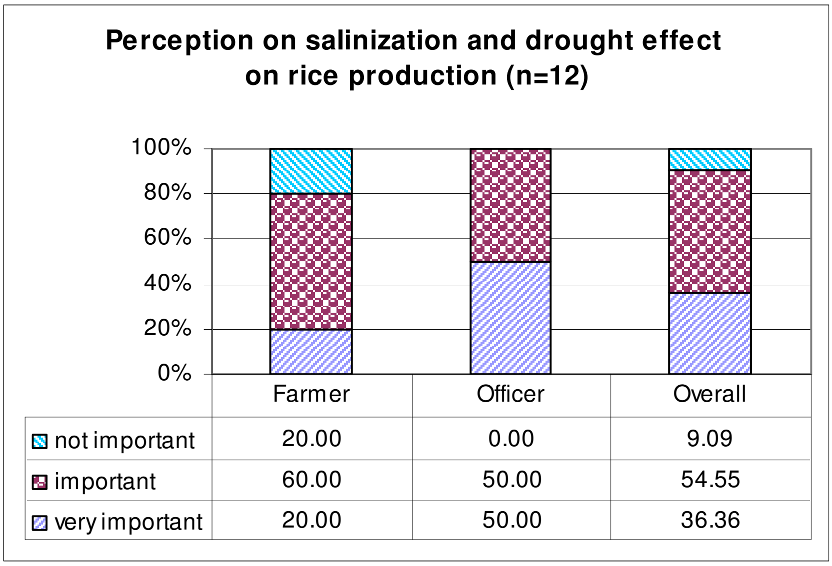
1.1 How do you think the importance of 3 topics targeted in this case study?

Topics	very importance	importance	not importance	no idea
Potential conflict between rice and shrimp due to prolong shrimp crop in rainy season				
Potential extreme poverty due to practicing of continuous shrimp monoculture				
Affect of salinization/drought on rice production due to practicing of continuous shrimp monoculture				

If said "not importance' in Q.1.1 or there is other important topic, please indicate
………………………………………………………………………………………
Why?...

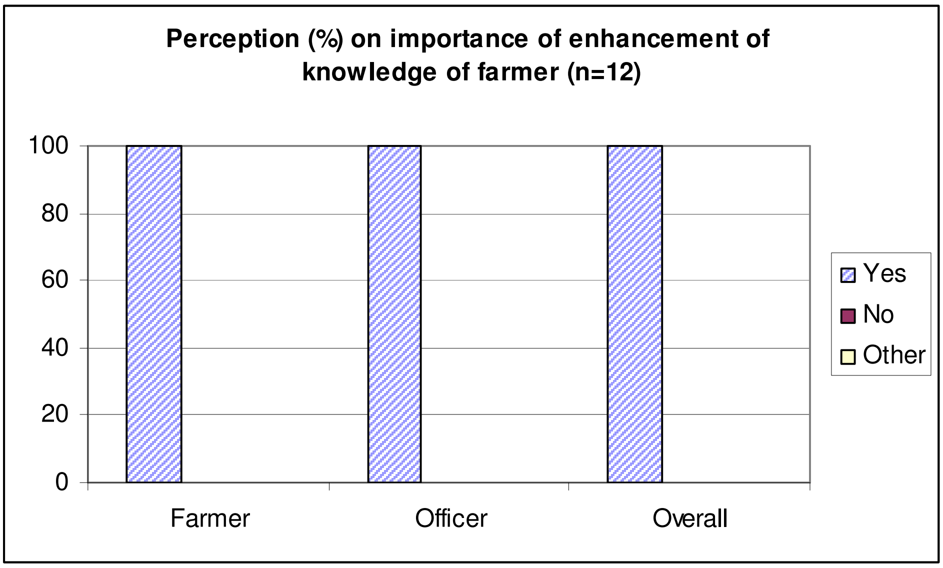

Perception on conflict issue (n=12)
100%
80%
60%
40%
20%
0%
Farmer
Officer
Overall
not important 16.67 16.67 16.67
important 83.33 33.33 58.33
very important 0.00 50.00 25.00


Perception on extreme poverty & differentiation (n=12)
100%
80%
60%
40%
20%
0%
Farmer
Officer
Overall
important 80.00 83.33 81.82
very important 20.00 16.67 18.18



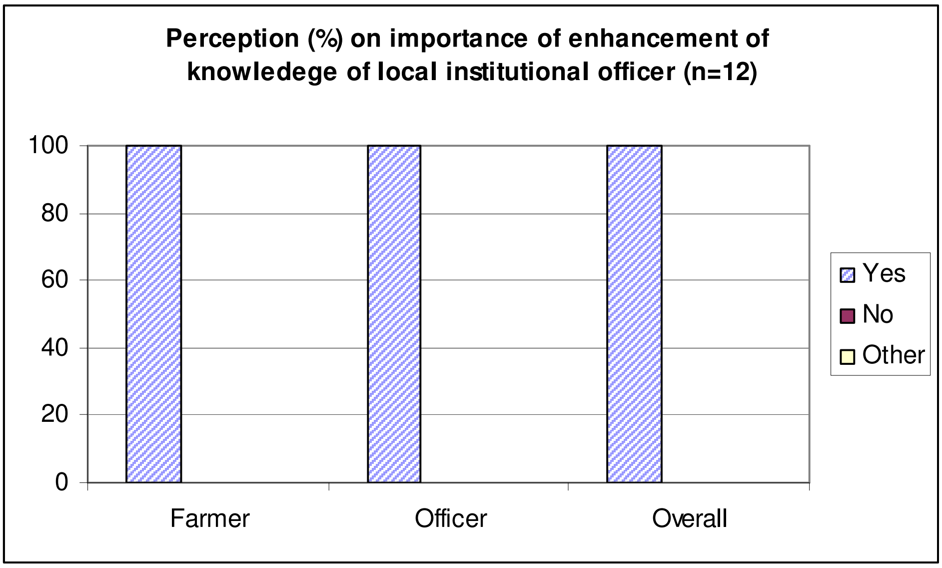
1.2 Do you think that enhancing knowledge as well as perception of farmers are a best solution to improve the current unsustainable farming?

☐ yes ☐ no ☐ other: ………………… Why……………..



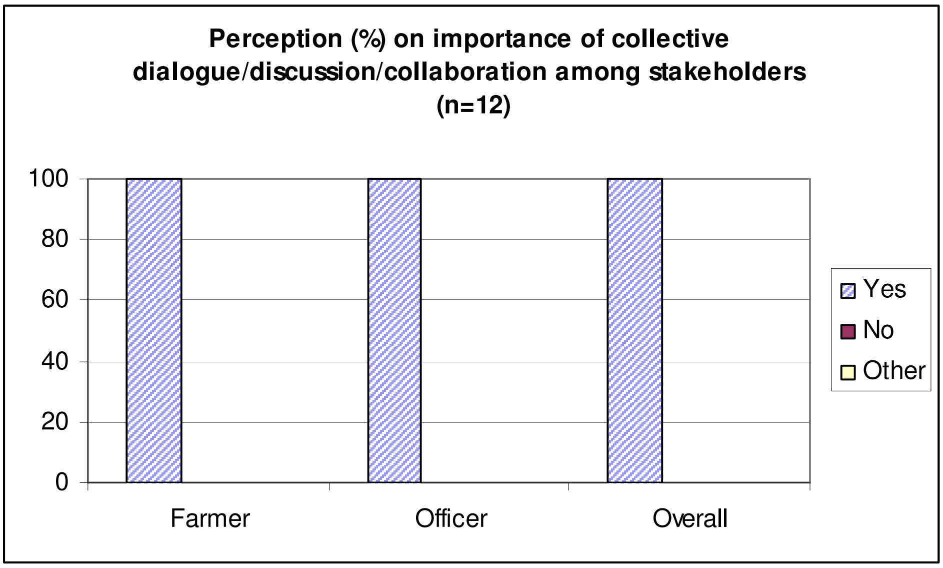
1.3 Do you think that enhancing knowledge as well as perception of officers/authorities are a best solution to improve the current unsustainable farming?

☐ yes ☐ no ☐ other: ………………… Why……………..



1.4 Do you think that collective dialogue/discussion and collaboration among farmers in different localities and local authorities are the best resolution for satisfying water demand for both down and up stream people?

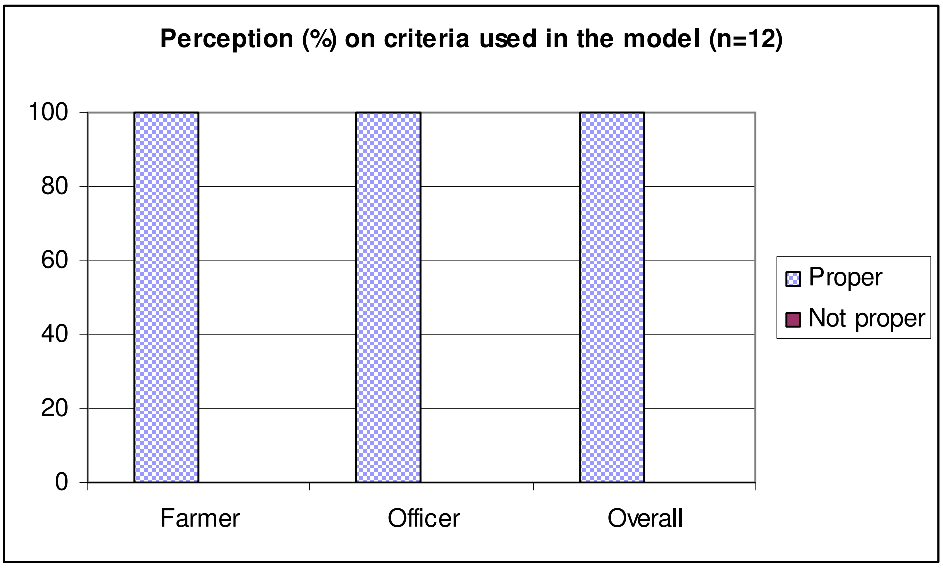
☐ yes ☐ no ☐ other: ………………… Why……………..



2. Technical section

2.1 Do you think the criteria to be measured in this case study is proper or not?

☐ proper ☐ not proper



2.2 If said no in Q.2.1 please propose another one?…………………………………………..

2.3 What point do you want to adjust/modify in the decision making diagram of

a) shrimp……………………………………………………………………………….

b) rice……………………………………………………………………………………

c) crab…………………………………………………………………………………..

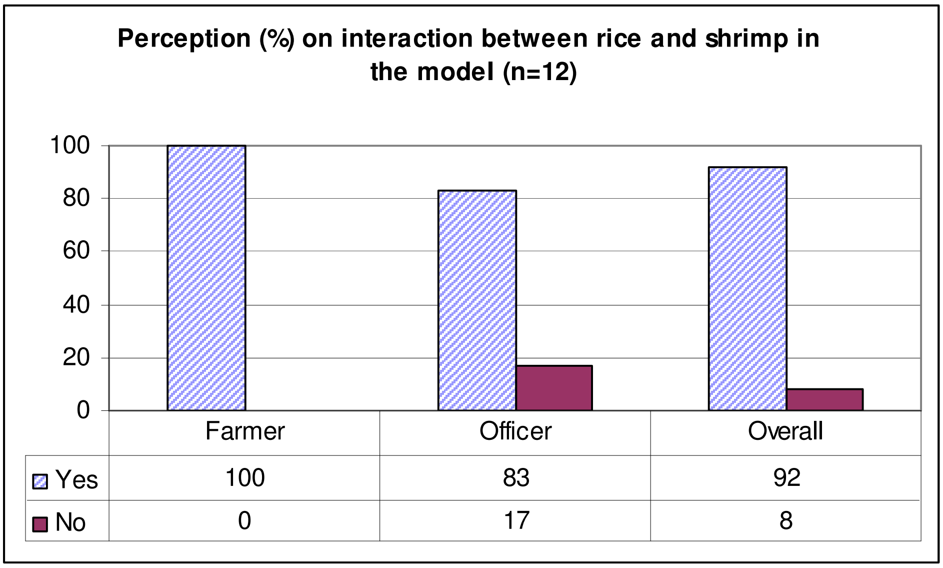
d) fish……………………………………………………………………………………

Answer:
- Shrimp crop: at least two months after stoking date farmer can detect the dead of shrimp seed
- Rice crop: change into higher production input cost and price of output
- Crab and Fish crop: can be stoked whole year round

2.4 Do you think is there interaction between shrimp and rice mentioned in the case study?

☐ yes ☐ no

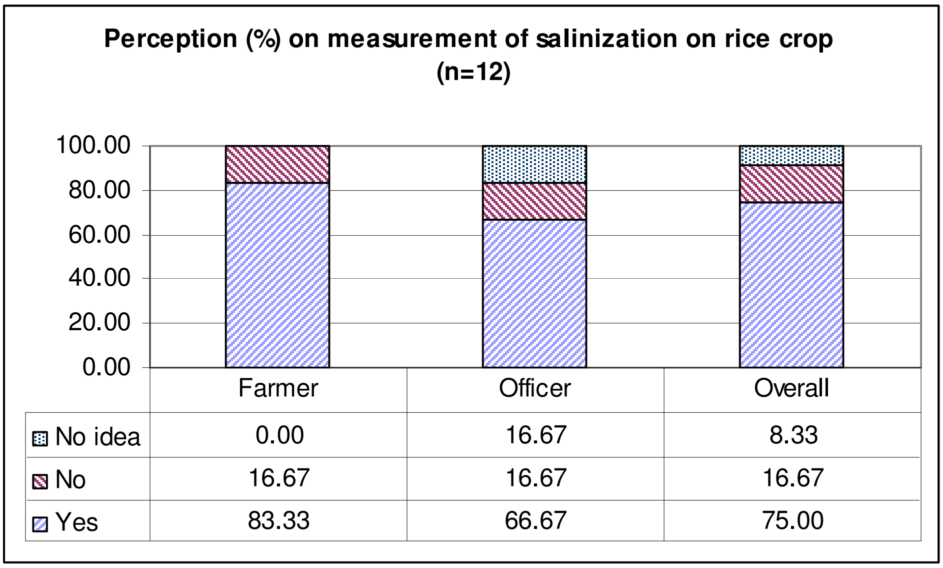
If said no in Q.2.4 please propose adjustment?



2.5 Do you think the way to measure effect of salinization and drought effect on rice production mentioned is proper?

☐ yes ☐ no

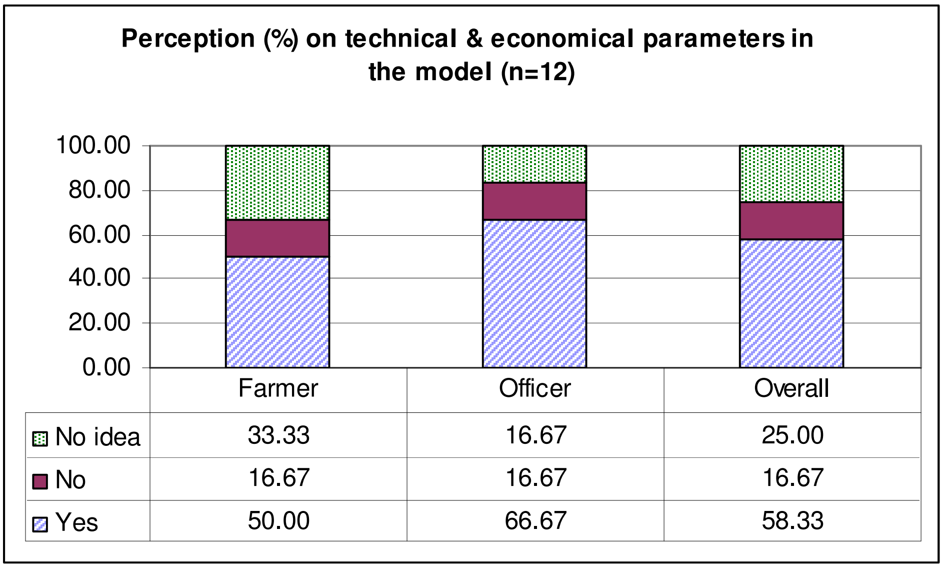
If said no in Q.2.5 please propose adjustment?



2.6 Do you think the technical and economic parameters mentioned in this case study is proper?

☐ yes ☐ no

If said no in Q.2.6 please propose adjustment?



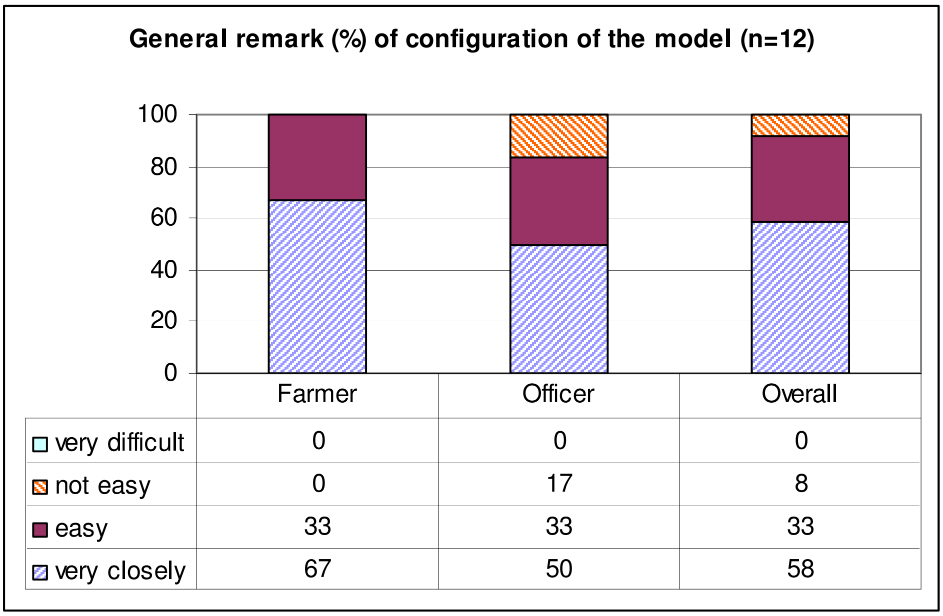
	Farmer	Officer	Overall
No idea	33.33	16.67	25.00
No	16.67	16.67	16.67
Yes	50.00	66.67	58.33

3. Model design and display section

3.1 The model is design to present two village of Phong Thanh and Vinh Loc connected by a common canal as configuration. Is it easy for you to recognize your own area/location?

☐ very easy ☐ easy ☐ not easy ☐ very difficult

If not easy or difficult to recognize, how is your suggestion?

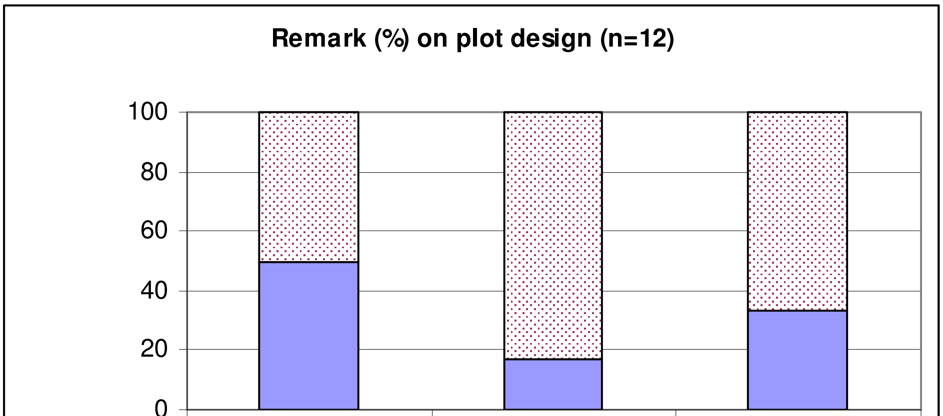


	Farmer	Officer	Overall
very difficult	0	0	0
not easy	0	17	8
easy	33	33	33
very closely	67	50	58

3.2 Do you think the farm plots as present in the model are quite close with yours in reality?

☐ very closely ☐ acceptable ☐ not acceptable ☐ too far from reality

If not acceptable, please give your suggestion…………………………………………………..

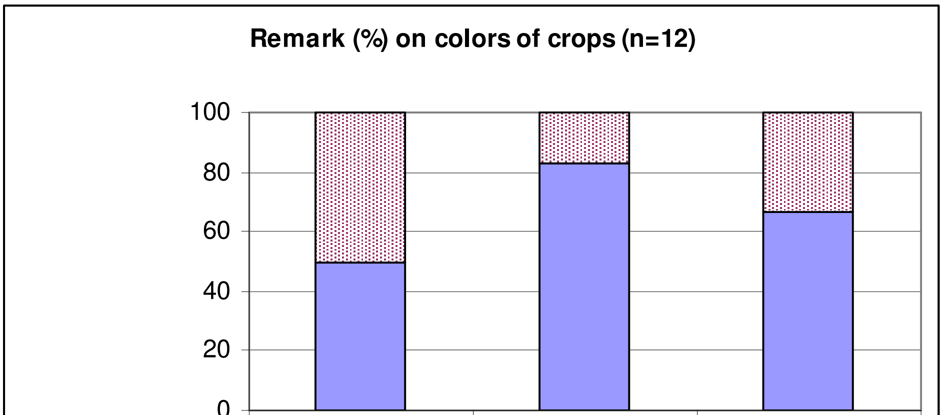


	Farmer	Officer	Overall
acceptable	50	83	67
closely	50	17	33

3.3 Can you easily detect your production crop by observing different colors used to describe shrimp, rice, fish and crab as in the model and their weekly changes in the simulation?

☐ very easy to imagine ☐ can be imagined ☐ can not be imagined ☐ too difficult to imagine

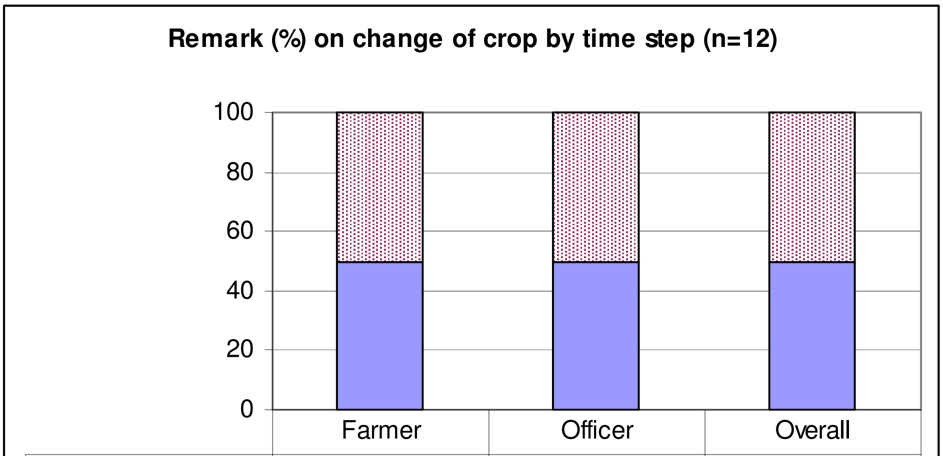
If can not imagine, please give your suggestion…………………………………………………..



	Farmer	Officer	Overall
can be imagined	50	17	33
easy imagine	50	83	67

3.4 Do you easily to understand the changes of crops in the model as it configured?

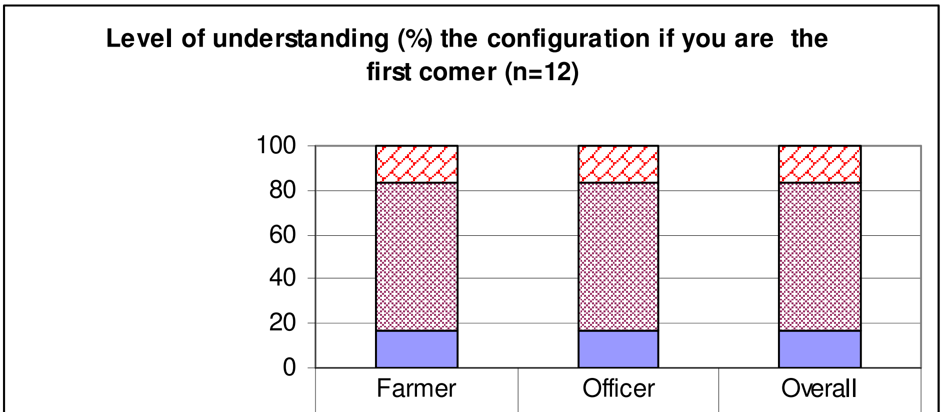
☐ very easy to understand ☐ can be understood ☐ can not be understood ☐ too difficult to understood



	Farmer	Officer	Overall
can be understood	50	50	50
easy understand	50	50	50

3.5 If you are the first time to come without participation of previous workshop of companion process can you easy to understand the design and configuration of the model as well as its consistency with the reality in your village?

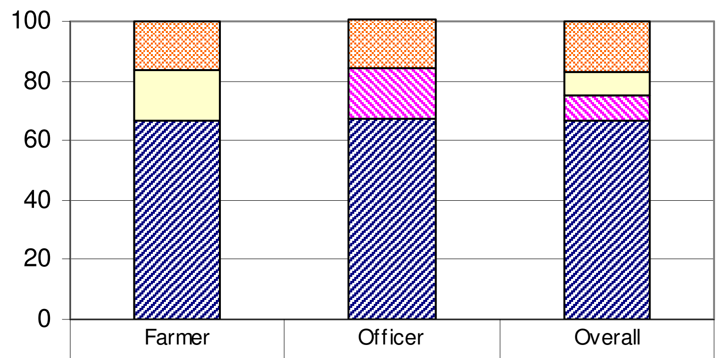
☐ very easy to understand ☐ can be understood ☐ can not be understood ☐ too difficult to understood



	Farmer	Officer	Overall
can not be understood	17	17	17
can be understood	67	67	67
easy understand	17	17	17

3.6 What did you learn from this model and simulation?

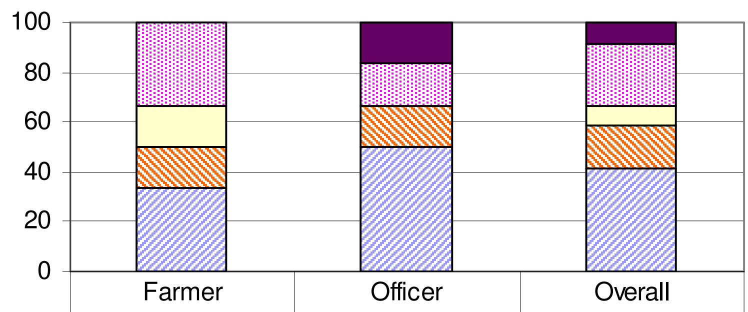
Learning (%) from the model & simulation (n=12)



	Farmer	Officer	Overall
No idea	17	17	17
Improving sustainability know ledge	17	0	8
Understand causality	0	17	8
Anticipation	67	67	67

3.7 What is most interesting in the model?

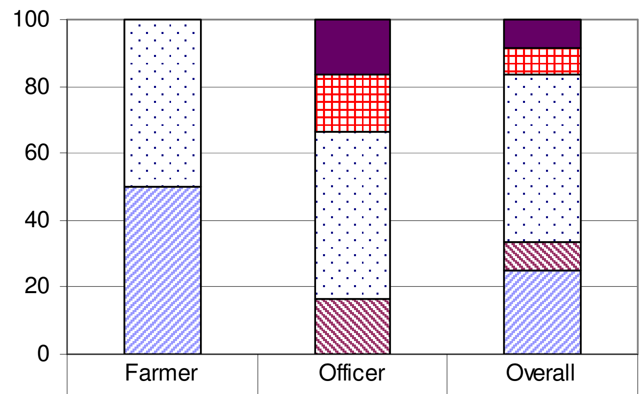
Most interesting (%) from the workshop (n=12)



	Farmer	Officer	Overall
No idea	0	17	8
General learning	33	17	25
Interaction	17	0	8
Exciting	17	17	17
Causality	33	50	42

3.8 What is you opinion about 3 scenarios of saline water supplied? Are there big differences among these scenarios?

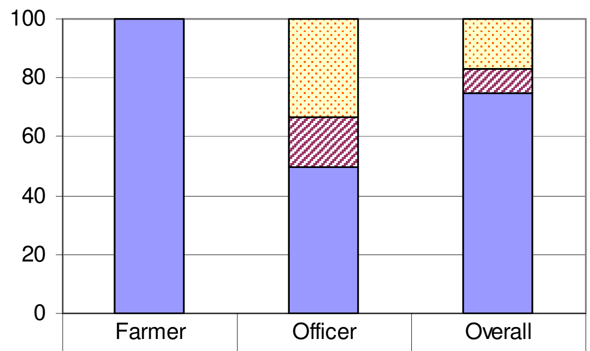
Remark (%) on 3 first water scenarios (n=12)



	Farmer	Officer	Overall
No idea	0	17	8
Not ideal	0	17	8
Not much consistent with reality	50	50	50
Not much different	0	17	8
Good	50	0	25

3.9 Will you talk with your neighbor and friends about this model, if so, what will you talk?

Post workshop talking (%) with neighbour/friend



	Farmer	Officer	Overall
Not yet exchange ideas	0	33	17
Talk good about model	0	17	8
Exchange ideas	100	50	75

3.10 Are you willing to participate in the new participatory simulations (with the computer model) in the future? (Answer: Yes for all, 100%)

BIOGRAPHY

The author who is responsible for this dissertation is Mr. Le Canh Dung. He was born on 21st April, 1964 at Quang Tri Province, Viet Nam. He works as a lecturer in the Mekong Delta Development Research Institute, Can Tho University, Viet Nam since 1986.

He graduated with Bachelor of Science in Agriculture (1982-1986) from the Faculty of Agriculture, Can Tho University, Viet Nam. He completed Master of Science in Agricultural and Natural Resource Economics (1997-1999) from the Department of Agricultural and Resource Economics, Kangwon National University, South Korea.

He started his doctorate study in second semester of the 2005 academic year in International Program of Agricultural Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand. He received scholarship from Challenge Program on Water and Food Project Number 25 (CPWF PN25) for his study in Thailand and field research in Viet Nam. The CPWF PN25 is a research project entitled “Companion modelling for resilient water management: Stakeholders’ perceptions of water dynamics and collective learning at the catchment scale”. Through this project he fulfilled his thesis research applying the innovative methodology of Companion Modelling for rice-shrimp farming in Bac Lieu Province in the Mekong Delta, Viet Nam. He was also received complementary financial grant from International Water Management Institute and ECHEL-Eau project, MAE-France for his six-month extended period in Chulalongkorn University, from November 2008 to April 2009.