Comparing land use planning approaches in the Mekong Delta, Vietnam

Nguyen Hieu Trung

Promotor:

Prof. dr. ir. A.K. Bregt
Hoogleraar in de Geo-informatiekunde
Wageningen Universiteit

Co-promotoren

Dr. ir. M.E.F. van Mensvoort
Universitair docent, Laboratorium voor Bodemkunde en Geologie
Wageningen Universiteit

Dr. Le Quang Tri
Associate professor College of Agriculture
Can Tho University, Vietnam

Promotiecommissie:

Prof. dr. ir. E.M.A. Smaling	Wageningen Universiteit, Nederland
Prof. dr. A.M.J. Kreukels	Universiteit Utrecht, Nederland
Dr. R. P. Rötter	Alterra, Nederland
Dr. Chu Thai Hoanh	IWMI-SEA, Malaysia

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Nguyen Hieu Trung

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CONTENTS

Chapter 1

General introduction

1 General introduction

1.1 Background

In the period 1975 – 1986 all of Vietnam had a centrally planned economy decreed by five-year plans with production targets. In the southern part of the country most agriculture was still done by smallholder private farming but at that time the agricultural services of every province also operated a number of large-scale communal state farms. These farms produced not only industrial crops such as sugar cane and pineapples but also rice or, in the coastal zone, shrimp. Private farmers and state farms had to sell pre-determined quantities of rice with fixed prices to the government. Land use was planned by local and provincial authorities, guided by the Ministry of Planning and supported by the National Institute for the Agricultural Planning and Projection (NIAPP).

In 1986 economic liberalization was accomplished through the Vietnamese "Doi Moi" policy. State farms were reformed to co-operatives where land use decisions were left to the farmers. Private farmers negotiated with the local authorities on long term lease contracts for land use rights and were free to decide on land use by themselves. These dramatic changes made it necessary for NIAPP and the Ministry of Planning to adjust their role. From top-down centralized planning institutions they had to change to a role as advisor in land use and planning. However, the current planning and management system is still influenced by the legacies of the centralized command economy. The planning system basically follows the same system as before when often government interfered arbitrarily in the production and distribution process (Quang, 2003; Rock, 2004). All "planning" is viewed as a top-down process of implementing the planned investment of state resources, rather than a means of guiding and controlling private development or investment for the public interest (Lawrie, 2000 as cited by Quang, 2003). This situation started from the macro level in the provinces, but is also found in the districts and sometimes right down to the hamlet level (Christ and Kloss, 1998; Rock, 2004). A provincial macro level Land Use Plan is to be drafted every ten years and updated every five years. According to the Land Law, the prescribed contents of every macro level Land Use Plan are (Rock, 2004): (i) Survey, study and compile the natural, economic and social conditions, analyze the present land use and evaluate the land potential; (ii) Identify land use orientations and objectives in the planning period; (iii) Determine land distribution when needed in the light of socio-economic development, defence and security; (iv) Determine land areas to be reserved for the implementation of works and projects; (v)

Determine measures for improved land use and environmental protection and (vi) Suggest methods to implement the Land Use Plan.

In Vietnam the FAO Framework for Land Evaluation was used most widely as a methodology for land use advice. Mekong Delta wide studies (NEDECO, 1991; van Mensvoort et al., 1993), and studies at district level (NIAPP, 1999; Tri et al., 2003; Tri et al., 1993) were carried out. Some studies were a purely biophysical assessment of crop growth possibilities. Others were enhanced with economic data on the evaluated land use systems. The FAO method was also the basis for a NIAPP land use planning study of Vinh Loi district (NIAPP, 1999). The strongly contrasting Land Use Types (LUT) such as extensive and intensive shrimp, mangrove forestry, double or single rice with often unknown or hard-to-determine requirements (salt water versus fresh water, tidal movement, growth conditions of mangrove trees) made a reliable assessment difficult. The approach was rather top-down with limited interdisciplinary interaction and weak communication with the local stakeholders. This results in conflicting interests between stakeholders (Hoanh, 1996; Quang, 2003; Rock, 2004). Other problems also surfaced such as the environmental effects of shrimp cultivation, the unreliable yields of shrimp and the refusal to accept the proposed land uses by the local people. Most of the land use plans in the coastal areas of the Mekong Delta are not sufficient and fail implementation (Hoanh, 1996; PCBL, 2001). This is clearly illustrated by the field situation in the Vinh Loi coastal zone. Farmers tend to quickly shift their land use system regardless of the governmental land use plan when they learn of a higher benefit from another LUT. In 1998/1999 a land use plan for Bac Lieu province was proposed (NIAPP, 1999). In 2001 an adjustment plan for the coastal zone was made (NIAPP, 2001). This adjustment plan for the period 2001-2010 emphasized the need for a change from rice cultivation to combined rice-shrimp farming systems. However, already in 2003, the recommended combination of rice and shrimp farming systems can hardly be found in the study area; the majority of the farmers had already abandoned the rice cultivation and changed their land use to monoculture of shrimp. The change to semi-intensive shrimp is irreversible so the adjustment plan made in 2001 already fails application by 2003 (Kempen, 2004). Therefore, it is essential to introduce a land use planning approach that can overcome the above-mentioned problems and better support the land users and other stakeholders in land use of the coastal areas of the Mekong Delta.

A multitude of recent land use analysis and planning methods is available, e.g. the Land Use Planning (LUP) guidelines by FAO (FAO, 1993), the Participatory Land Use Planning (PLUP) methodology (Amler et al., 1999; FAO, 1991), the Conversion of Land Use and its

Effects (CLUE) of Veldkamp and Fresco (1996), the Trade-Off Model (Stoorvogel, 2001), the Land Use Planning and Analysis System (LUPAS) (described by Rötter et al., 2005; and van Ittersum et al., 2004) and many others. Recently, LUP concepts have undergone some important changes (Ceccarelli, 1997) that would be desirable for inclusion in this study:

- more integrated and coordinated approaches (Amler et al., 1999; Mohamed et al., 2000; Muchena and van der Bliek, 1997);
- a shift from mainly "statutory" and "prescriptive" to "purposive" functions (Antoine et al., 1997; Dent, 1991; van Ittersum et al., 2004);
- more focus on solving the conflicting interests of different stakeholder groups (Amler et al., 1999; Armitage and Garcha, 2001; Rabbinge and Latesteijn, 1998);
- more participation of interest groups in the planning process and more integration of local knowledge with scientific and technical knowledge (Amler et al., 1999; Cain et al., 2003; Dent, 1991; Rötter et al., 2005).

Land use studies can be conducted at many research levels (Hoosbeek and Bryant, 1992) with different degrees of complexity (from empirical to mechanistic), degrees of computation (from qualitative to quantitative) and at different scales (world, continent, region, province, district, village). Depending on planning objectives, data and tools available, financial and human resources and complexity of the study area, the appropriate research approach should be determined. The advantages and disadvantages of a LUP approach vary depending on place, time and on available data, biophysical characteristics, and prevailing political conditions (Albrecht et al., 1996; Illsley, 2003; McCall, 2003). However, so far, there has been no comparative study in which LUP methods of different levels of complexity and computation are applied to the same study area and for the same planning period.

1.2 Research objectives

Available LUP approaches can advise on land use, but each one is developed for a particular purpose, or covers only part of the land use planning sequence set out by FAO (1993). This makes it hard to choose a "most suited" LUP approach for the coastal zone of the Mekong delta. Several approaches might be suitable, but there is no objective way of comparing the approaches. Therefore, this study selects different approaches of different levels of complexity and intensity of computation. So the overall objective of this research is **to apply different land use planning approaches to the coastal zone of the Mekong Delta in Vietnam, compare them objectively for their pros and cons and aim to derive a most suited approach.**

More specific objectives to achieve the overall goal are addressed in the coming chapters:

- Apply LUP approaches of different level of complexity and intensity of computation to the same study area in the coastal zone of the Mekong Delta, Vietnam;
- Develop a framework for comparing land use planning approaches;
- Apply this comparison framework to the selected planning approaches; and
- Evaluate the results and formulate implications for land use planning in the coastal zone of the Mekong Delta, Vietnam.

1.3 General description of the research methodology

1.3.1 Selecting LUP approaches for the study

It is practically impossible to compare all the available LUP methodologies in this study, so a rigorous selection needs to be made. Three methodologies were selected based on historical use in Vietnam, differences in planning philosophy, level of complexity and intensity of computation. They are the FAO Guidelines for LUP combined with a multi-criteria evaluation (FAO-MCE), the Participatory Land Use Planning (PLUP), and the Land Use Planning and Analysis System (LUPAS).

The most widely used LUP approach in Vietnam so far, the FAO Guidelines for LUP (FAO, 1993), is selected as a starting point. It is extended with the Multi Criteria Evaluation (MCE) technique, which began to emerge in land use planning during the 1970s (Eastman et al., 1998; Malczewski, 1999; Voogd, 1983). MCE serves to investigate a number of choice-possibilities in the light of multiple criteria and conflicting objectives or development targets (Voogd, 1983). In doing so, it is possible to generate compromising alternatives and rank them according to their attractiveness (Jansen and Rietveld, 1990) for different development targets. FAO-MCE is a semi-quantitative and mechanistic approach.

The centralized governmental Land Use Planning of the eighties and early nineties in the past century, with its top-down and forceful methods, made farmers reluctant to accept advise on land use. Some experiences in land evaluation (Tri et al., 1996; van Mensvoort, 1996; Xuan and Matsui, 1998), showed successful when an approach is used that involves farmers into the decision-making process. Therefore, in this study a Participatory Land Use Planning methodology (PLUP) is selected. PLUP, in which the local community of the planning area participates, is a qualitative empirical approach, which has gained increasing recognition as an important tool for realizing sustainable resource management. Several people and organizations were involved in defining the methodological framework (such as Amler et al., 1999; Antunes et al., 2004; FAO, 1990; Hardcastle et al., 2004; Hytonen et al., 2002; Matthies and Krömker, 2000; WB, 1996). Participatory methods can mobilize local knowledge and resources for self-reliant development and, in the process, reduce the government development assistance cost. People's participation is also recognized as an essential element in strategies for sustainable agriculture, since the rural environment can only be protected with the active collaboration of the local population (FAO, 1991; WB, 1996).

The third selected methodology is LUPAS (The Land Use Planning and Analysis System) because it can quantify conflicts in rural development goals, land use objectives and resource use and it is developed especially for the Tropical Asian region (Rötter et al., 2005). LUPAS has been applied to rice-based cropping systems of South-East Asia. It is a state-of-the-art computerized decision support system for strategic planning based on interactive multiple goal linear programming (IMGLP) (De Wit et al., 1988; Nijkamp and Spronk, 1980). LUPAS uses a set of common tools for yield estimation, quantification of input–output relations of production activities and optimization of land use at regional scale under alternative sets of multiple objectives and constraints (Rötter et al., 2005; van Ittersum et al., 2004). LUPAS addresses the questions “what would be possible” or “what would have to be changed”? It can be used for scenario analysis of complex problems such as conflicts in land use (Hoanh et al., 2000). This makes the methodology interesting for application in the coastal zone of the Mekong Delta. The LUPAS methodology was developed under the Systems Research Network for Eco-regional Land Use Planning in Tropical Asia (SysNet) project (1996-2000). SysNet is a systems research network in South and South-east Asia, established to develop and evaluate methodologies to generate options for policy and technical changes.

1.3.2 Applying LUP approaches

For a sound comparison of the three selected approaches their planning objectives, planning periods and planning areas should be the same. In this study the planning objective is to improve income of the people living in the study area, the planning is for the year 2004, and the planning area is in two villages: Vinh My A and Vinh Thinh Villages, Vinh Loi district, Bac Lieu province. The reasons for selecting these two villages are that they are located in the coastal zone, where land use is highly contrasting (fresh water versus salt water conditions, low versus high inputs, environmental effects of land use) and quickly shifting. Besides, this area is one of the study areas of the MHO8 project (Integrated Management of Coastal Resources in Mekong Delta, Vietnam, cooperation between Can Tho University and Wageningen University). This project carried out research on biophysical and socio-economic conditions of the study area, so the data for this study area are available.

1.3.3 Comparing LUP approaches

The three methodologies will be compared for their credibility and acceptability by the stakeholders in land use. Land use plans will be made with the three proposed methods and the opinion of various stakeholders on the outcome will be asked. The land use plans made in one year will be compared to the actual use of a later year and the realization of the plans will be studied by using GIS overlaying technique. An uncertainty analysis will be carried out in which the quality of the available data, calculation parameters, and the mathematical formulas applied in the LUP approaches will be screened.

As for the acceptability of the Land use plans an expert consultation will be used and the approaches' requirements in terms of time, cost, equipment, and skill will be compared.

1.4 Thesis structure

As seen from Figure 1.1 the thesis has seven chapters. **Chapter 1** (this chapter) defines the problems in land use planning of the coastal areas in the Mekong Delta, Vietnam, and from the problem definition it raises the research objectives and briefly describes the research methodologies.

Chapter 2 presents the biophysical, social, and economic characteristics of the study area. The chapter has four parts corresponding to the administrative levels: regional, provincial, district and village.

Chapters 3, 4 and **5** describe the application of the FAO-MCE, PLUP and LUPAS approaches to the study area. Each chapter has four parts: (i) literature review, (ii) steps in performing the approaches, (iii) presentation and discussion of the results, and (iv) review of the approaches' advantages and disadvantages.

Chapter 6 evaluates and compares the LUP approaches based on the results of chapters 3, 4, and 5. The first part describes the methodological framework that was developed for the comparison. The second part presents the actual comparison of the approaches and the last part discusses the findings.

Finally, **Chapter 7** summarizes the thesis and suggests further research.

A comprised version of this thesis has been accepted for publication in the book entitled "Effective Land-Water Interface Management for Solving Agriculture-Fishery-Aquaculture Conflicts in Coastal Zones" that will be published by CABI in the CA (Comprehensive Assessment) series of CGIAR, the Consultative Group on International Agricultural Research.

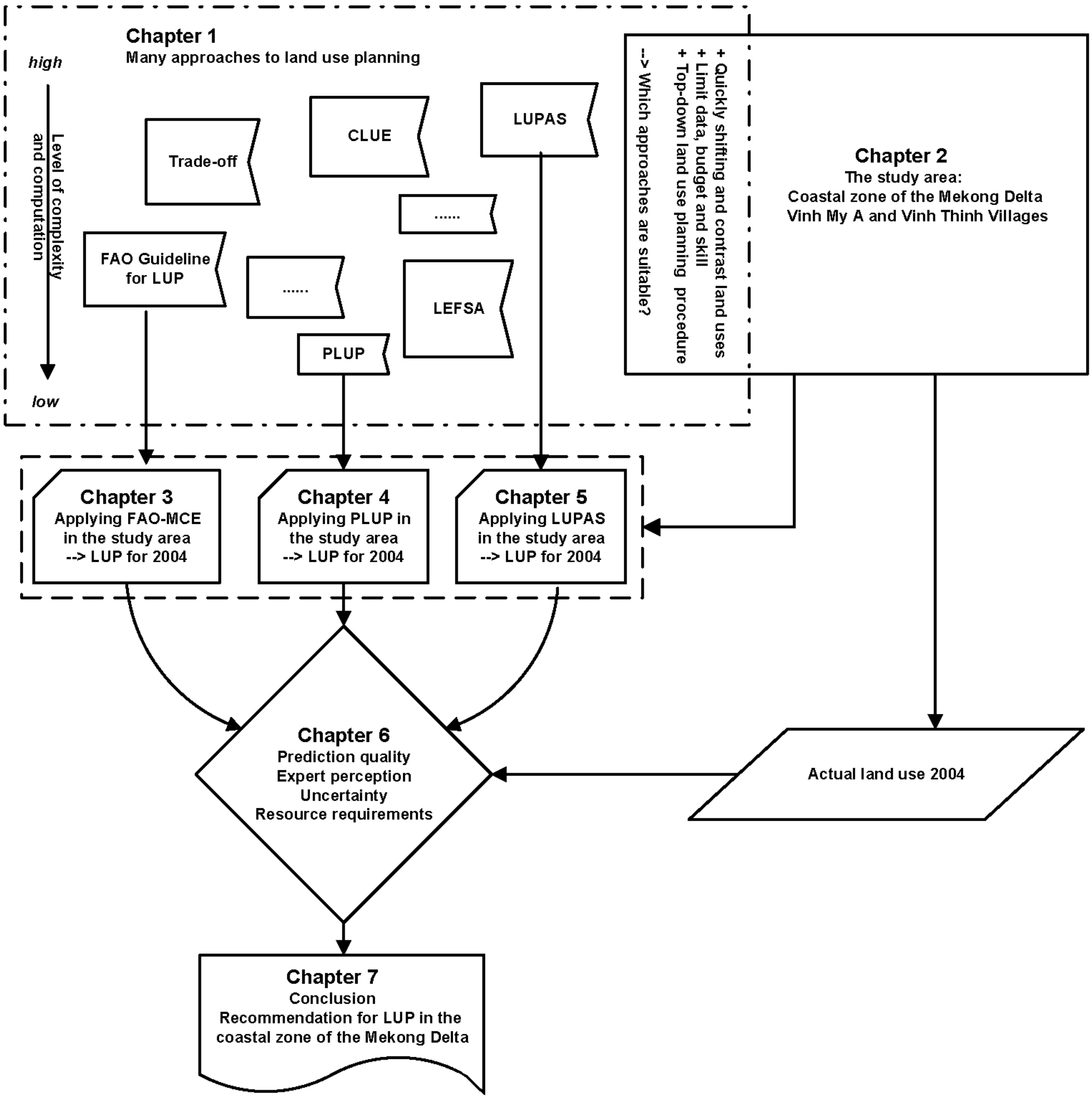


Figure 1.1 Conceptual framework and the outline of the thesis

Chapter 2

The study area

2 Introduction to the study area

This chapter describes the biophysical, social, and economic characteristics of the study area, which consists of the Vinh My A and Vinh Thinh villages in the coastal part of Bac Lieu province, Mekong Delta. Here the land use varies strongly and shifts quickly. Productivity and sustainability are threatened by shortage of fresh water, salt-water intrusion, acid sulphate soils, large-scale destruction of mangroves, and pollution of estuarine water-bodies. The chapter has four parts corresponding to four administrative levels: regional, provincial, district, and village.

2.1 The Mekong Delta

The Mekong Delta starts at Phnom Penh Cambodia, where the river divides into two main distributors' branches, the Mekong (Song Tien) and the Bassac (Song Hau). Subsequently the Song Tien divides into six main channels and the Song Hau into three to form the nine "dragons" of the outer Delta in Vietnam. The Delta comprises a vast triangular plain of approximately 5.5 million of hectares, almost entirely below five meters above sea level. It extends about 270 km from its apex at Phnom Penh to the coast with a coastline of about 600 kilometers. Approximately 1,600,000 ha of the inner Delta lies within Cambodia; the remaining 3,900,000 ha is the most southern part of Vietnam. The Delta is the result of sedimentation and erosion, the sediment varying in depth from at least 500 m near the river mouths to only a few meters at some places in the inner Delta. The combined action of river deposits and sea wave activity has produced a coast belt of slightly higher elevation. At this moment the sediment deposition continues most remarkably near the tip of the delta (the Ca Mau Peninsula) where land grows at a rate of 150m per year in some places (Hashimoto, 2001).

The Mekong River Delta can be divided into six agro-economic zones: (1) the Plain of Reeds; (2) the Long Xuyen Quadrangle; (3) the Central Fresh Water Alluvial Area; (4) the Trans Bassac Depression; (5) the Ca Mau Peninsula (6) and the Coastal Area (see Figure 1) (NEDECO, 1993; Xuan and Matsui, 1998). The population of the delta is over 16.9 million inhabitants in 1996 (22% of the national population) and about 17.1 million in 2004 (VCPFC, 2004). It is the most productive agricultural and aquaculture area in Vietnam (NIAPP, 1999; Wilder and Phuong, 2002). It contributes about 55 percent of the national aquatic production and about 51 percent of the export of aquatic produce (Quang, 2002). The delta contributes 50-55 percent to the national shrimp production and about 70-80 percent to the shrimp export (Thanh, 2002). However, according to the report on the National Program on Hunger

Eradication, Poverty Reduction and Employment, at the end of 2002, the number of poor households is still high in Mekong Delta, more than 10% of the households. The coastal zone is among the poorest areas of the delta (Minot et al., 2003). Moreover, the production of the coastal zone is threatened by shortage of fresh water, salt-water intrusion, acid sulphate soils, large-scale destruction of mangroves, and pollution of estuarine water-bodies (Hoanh et al., 2002; MRC, 2003; Quang, 2002)

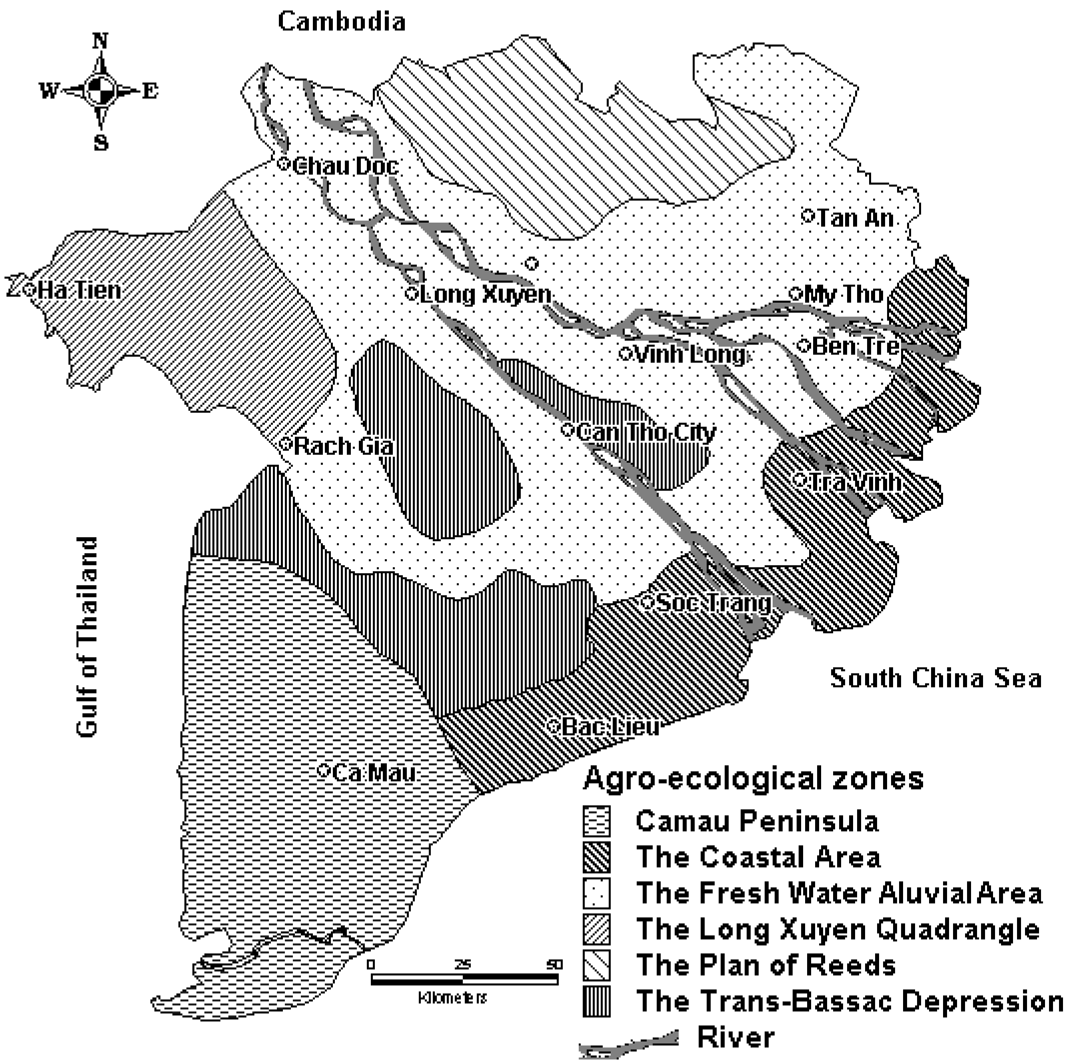


Figure 2.1 The Agro-Ecological zone of the Mekong delta (Source: Xuan and Matsui, 1998)

The Gulf of Thailand, west of the delta, has a diurnal tide, while the East Sea (internationally known as the South China Sea, Southeast of the delta) has a semi-diurnal tide. This difference is caused by a threshold at the entrance of the Gulf of Thailand. The average daily tidal range varies between 3.5m and 4.5m in the East Sea and between 0.5 and 0.8m in the Gulf of Thailand (NEDECO, 1993). The tidal effects extend throughout the Delta area in Vietnam and about 500,000 ha are affected by seawater intrusion during the dry season. Salinity penetrates inland through various branches of the Mekong and canals over 20 to 65 km from the shore. Because of the large inflow of fresh water from the Mekong Delta, salinity along the eastern coast of the delta is very low, particularly during the rainy season. Towards the end of the rainy season in September to October, the combination of floodwater from the rivers, local rainfall and tidal inundation can result in the flooding of 3,400,000 hectares in the Vietnamese portion of the Delta (NIAPP, 2001).

2.2 Bac Lieu Province

Bac Lieu province is located at latitude 9°00' - 9°38'09"N and longitude 105°14'15" - 105°51'54"E in the South-West part of the Mekong delta. It borders Can Tho and Kien Giang provinces to the North, Soc Trang province to the East and Northeast, Kien Giang and Ca Mau provinces to the West and Southwest and the Eastern Sea tot the Southeast. With 56 km of coastline, Bac Lieu has great potential for aquaculture and fishery. Moreover, Ganh Hao, Cai Cung, Chua Phat and Nha Mat estuaries are places where infrastructure for aquaculture and fishery can be developed (PCBL, 2001).

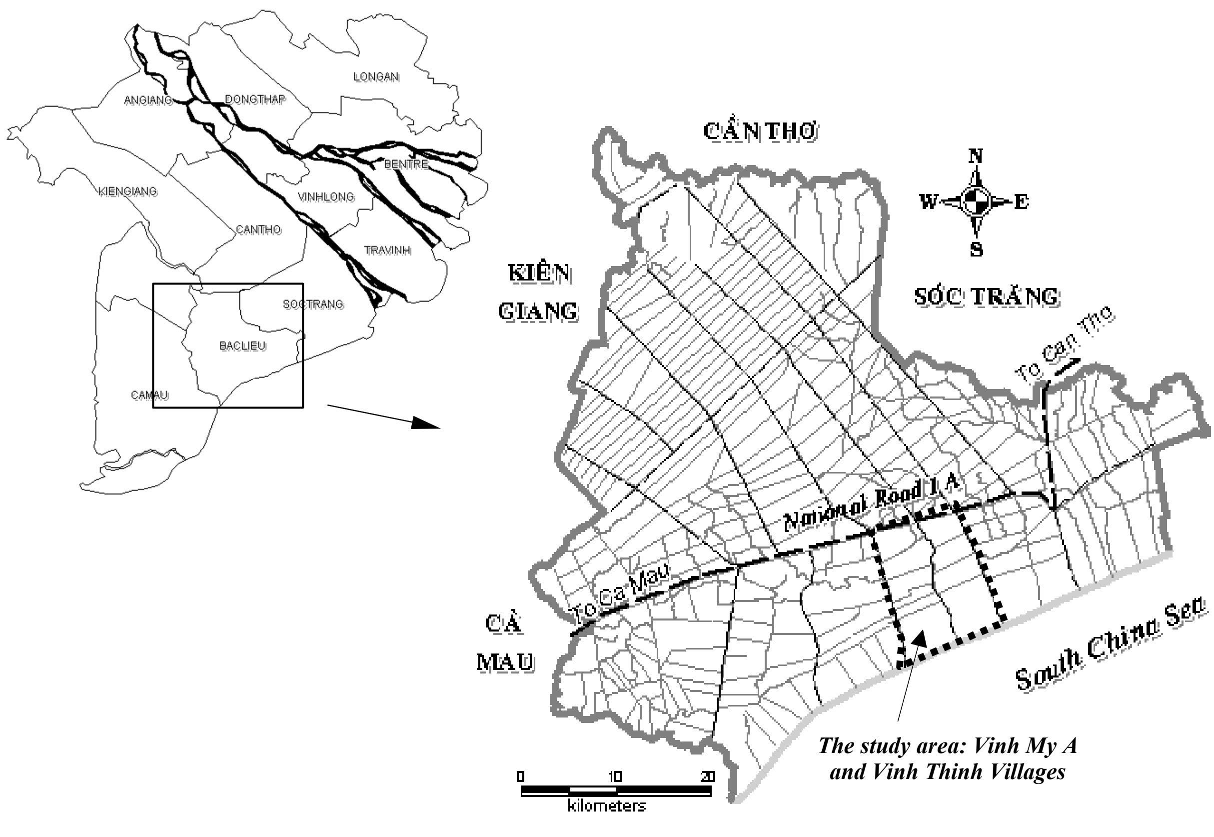


Figure 2.2 The study area

Bac Lieu has an area of approximately 241,813 ha plus 12,377 ha of shore. In 2000, the total population in the province is 754,000 inhabitants or a density of 294 inhabitants/km^2. Seventy-five percent of the people (565,000) live in the rural area. Bac Lieu province has five districts named Gia Rai, Vinh Loi, Hong Dan, Phuoc Long and Bac Lieu Town. Given the physical conditions of the province, two ecological areas are distinguished: (i) the inland area with fresh water (north of National Road 1A - NR1A) and (ii) the coastal area with salt water intrusion (south of NR1A) (PCBL, 2001).

2.2.1 Natural conditions

Climate

The Bac Lieu climate is strongly influenced by the sea. Two seasons are distinguished: a dry season from May to November and a rainy season from December to April. Humidity, temperature and wind do not fluctuate much during the year. Bac Lieu province almost never experiences storms or tropical hurricanes. However, in recent years, the weather seems to have changed unpredictably (e.g. the destructive storm Linda in 1997, PCBL, 2001).

Landform and soils

Bac Lieu province is flat and low lying. In the southern part of NR1A the terrain is sloping from the coast to inland (elevation runs from 0.8m to 0.4m above MSL) with coastal ridges running parallel to the shoreline. The part north of NR1A has lower terrain (elevation between 0.2m and 0.3m above MSL). The average inland-directed slope is about 1 - 1.5cm km^{-1}. With such a kind of terrain, salt water gets inland by high tide and submerges depressions. These can serve for aquaculture or fishery (PCBL, 2001).

The 1999 soil map (scale 1:25,000) prepared by the Southern Sub-Institute of Agricultural Planning and Design shows five main soil types in Bac Lieu Province:

- Saline Soils (Salic Fluvisols): 90,752 ha (37,5%)
- Acid Sulphate Soils (Thionic Fluvisols): 128,804 ha (53,3%)
- Alluvial soils: 5,064 ha (2,1%)
- Sandy soils (Arenosols): 452 ha (0.2%) and
- Garden soils, raised beds (Anthrosols): 11,330 ha (4.7%)

Saline and Acid Sulphate soils cover over 90% of whole area (219.556 ha), concentrating in the unproductive areas for agriculture in the parts directly north and south of NR1A (PCBL, 2001).

Hydrological regime

The hydrological regime of Bac Lieu province strongly depends on rainfall, terrain and tide. The East Sea coastline has an irregular semi-diurnal tide (van Loon, 2005) and has been under strong influence of flows in the sea. In the past 30 years (1968 - 1998) the coastline from Go Cat to Ganh Hao has eroded over distances varying from 0.1 - 0.5 km while the part from Go Cat to Bac Lieu Town has silted up over 0.4 - 1.5 km. After completing the sluice gate system for saltwater protection along NR1A (works were carried out within the large scale Quan Lo Phung Hiep Project), the part north of NR1A now has the diurnal tide regime of the West Sea through the Cai Lon River. The part south of NR1A is completely under the influence of the semi-diurnal tidal regime of the East Sea with an average tidal amplitude of 2.85m. This makes it easy to drain this area, or to remove salt, drain toxic substances from acid sulphate soils and get seawater for aquaculture, salt cultivation and mangrove forest (PCBL, 2001).

Surface Water

Thanks to the Quan Lo Phung Hiep salinity protection project (north of NR1A), enough fresh water is available for all-year agricultural production in the East part of the province. However, because the salinity protection system is not yet completed, the West part still can gets intruded with salt surface water from the West Sea (February – April). During that time it is possible for farmers to raise brackish water shrimp. The part south of NR1A, where all canals are intruded by salt water, has favourable hydrological conditions for aquaculture and salt production, even in the rainy season (PCBL, 2001).

Ground water

Deep groundwater from wells has good quality for domestic consumption. The capacity can reach 3.68 million m^3 per day (PCBL, 2001). In some areas, farmers use ground water for irrigating upland crops.

2.2.2 Social, economic and infrastructural conditions in Bac Lieu

Social condition

Compared to most other provinces in Vietnam, Bac Lieu has a small land area and low population density (754,053 inhabitants, 294 inhabitants/km2). Approximately 75% of the population lives in rural areas and 60% is 18–60 year of age. Ethnically the area is dominated by Kinh Vietnamese (89%) with Khmer (8%) and Chinese (3%) minorities (BLSB, 2000). The distribution of the population is uneven, settlements are mainly in long, narrow strips along roads and canals from where transportation is convenient (PCBL, 2001).

Economic conditions

Average increase in GDP of the province was 9.5% between 1996 and 1999, and it rose to 12.5% in 2000. GDP per person in 2000 was 4.2 million Vietnamese Dongs (VND, or about $ 260) while this number was 4.3 million VND for the whole Mekong delta in 1999. Agriculture dominates the economy (62% of the GDP in 1999 and 60.35 of the GDP in 2000). Industry and services have increased but are still low (PCBL, 2001).

Infrastructure

The infrastructure (transportation, electricity, water, etc.) of Bac Lieu does not develop in a synchronous way. In rural areas, waterways are the main means of transportation. Irrigation systems north of NR1A are developed thanks to the Quan Lo Phung Hiep Development Project. Although aquaculture is an important activity in Bac Lieu province, only 38 enterprises supplied shrimp post larvae in 2000, and they could only meets 10 - 15% of the demand of all farmers in the province (PCBL, 2001).

2.2.3 Land use

About 89% of Bac Lieu's land, corresponding to about 215,400 ha, is used for agriculture, aquaculture, fishery, forest and salt cultivation. Agriculture is mainly practiced north of the NR1A, where salinity intrusion is prevented by the sluices of the Quan Lo Phung Hiep project. The total agricultural land is about 154,200 ha (2000), of which about 121,800 ha were used for annual crops (mainly rice) and about 32,334 ha for permanent crops (fruit gardens). Agriculture land has declined significantly since 1999 as many farmers turned their rice fields into shrimp ponds, even inside the Quan Lo Phung Hiep salinity protection areas, north of NR1A. To the South, where saline water has free access, aquaculture is mainly practiced. The total aquaculture land of Bac Lieu was about 53,300 ha with about 44,500 ha for shrimp. Bac Lieu has about 3,000 ha of land for salt production and about 5,000 ha of forest (Gowing, 2002; Hoanh et al., 2002; NIAPP, 1999; PCBL, 2001).

2.3 Vinh Loi district

Vinh Loi district has 1 town and 12 villages with a total area of about 62,000 ha. Ecologically, Vinh Loi can be divided into two parts: The part North of the national road 1A which belongs to the Quan Lo Phung Hiep project and where the land is protected from the salinity intrusion, and the part south of the NR1A (i.e. the study area for this thesis), where saline water has free access.

Most crops (rice, vegetables and upland crops) are cultivated in the rainy season and aquaculture (shrimp, salt, crab, artemia) can be seen in the dry season. In the south of NR1A and the Western part of the north of NRA1, where saline water is available in the rainy season, shrimp cultivation is practiced throughout the year. Ground water is also used in the dry season for irrigation of upland crops. The land use of Vinh Loi district in 2000 is presented in Table 2. 1.

Table 2.1 Land use of Vinh Loi district in 2000 in ha (NIAPP, 2001)

Land use	*Total*	*North of NR1A*	*South of NR1A*
Total natural land	*59,670*	*37,253*	*22,417*
I/ Agriculture	*44,618*	*33,317*	*11,301*
1/ Annual crops	*39,480*	*29,189*	*10,291*
- Rice	*38,950*	*29,029*	*9,921*
+ 1 rice crop	*9,471*	*0*	*9,471*
+ 2 rice crops	*22,340*	*21,890*	*450*
+ 3 rice crops	*7,119*	*7,119*	*0*
+ Rice-vegetable	*20*	*20*	*0*
- others	*530*	*160*	*370*
2/ Permanent crops (fruit tree)	*5,138*	*4,128*	*1,010*
II/ Aquaculture land	*4,655*	*445*	*4,210*
+ Mono shrimp	*4,583*	*373*	*4,210*
+ Fish	*72*	*72*	*0*
III/ Salt land	*1,298*	*0*	*1,298*
IV/ Forest	*2,762*	*0*	*2,762*
V/ Infrastructure	*3,194*	*2,100*	*1,094*
VI/ Residential land	*916*	*671*	*245*
VII/ others	*2,227*	*720*	*1,507*
Sedimentation land	*5,718*	*0*	*5,718*

Vinh Loi has advantages and disadvantages for agriculture, aquaculture and forestry development. As for its natural conditions, it has both fresh and brackish ecosystems, so the province can diversify its land use. A 1999 land evaluation study by the National Institute of Agriculture Planning and Projection (NIAPP), shows that most of the area in Vinh Loi is suitable for agriculture and aquaculture. However, due to the rapid shift from the main fresh water land use system (rice) to a brackish water land use system (shrimp) without proper planning, the soil and water conditions changed accordingly, negatively affecting the province's agricultural production. These changes also strongly alter the ecological system.

As for the social and economic conditions, the advantage of Bac Lieu province in general and Vinh Loi district in particular is that there is enough labour to intensify and extend land use. Disadvantages of Bac Lieu are the presence of a water management system which was designed for rice cultivation (and not for shrimp), the lack of experience in shrimp cultivation with farmers and local authorities, lack of capital, and an insufficient credit policy.

2.4 The study area: Vinh My A and Vinh Thinh villages

Vinh My A and Vinh Thinh are two villages to the south of NR1A. Vinh My A village, located nearest to NR1A, has a total area of 5,158 ha. In 2000, the agriculture land was 4,005 ha, and aquaculture land was 177 ha. The population is about 17,700. Vinh Thinh village with its population of about 10,500 inhabitants is bordered by Vinh My A village in the north and the sea in the south. Vinh Thinh's area is about 6,534 ha with 2,195 ha agriculture land, 1,669 ha was aquaculture land, 808 ha salt, and 1,250 ha mangrove forest (Figure 2.3) (NIAPP, 2001). However, most of the area is now (2005) used for shrimp cultivation. There are two shrimp cultivation techniques: improved extensive and semi-intensive with a difference in level of applied technology, feeding strategy, recruitment system (natural recruitment for improved extensive or stocking with larvae from hatcheries for semi-intensive), stocking density and use of chemical inputs. The risks involved in shrimp cultivation are due to shrimp disease, water pollution, lack of technology and capital, bad farm management and the quality of shrimp larvae (Kempen, 2004).

There is a thin strip of strongly exploited mangrove forests along the coast. Farmers practice a government controlled forest-shrimp system. Further inland from the mangrove zone salt production is seen, sometimes in combination with shrimp. Rain-fed rice can still be found in the northern and central part of the area. Most farmers can grow only one high yielding variety per year in the wet season because salinity intrusion in the dry season inhibits a second crop. Sometimes a single rice crop is combined with vegetables in the dry season, but this is limited to areas where fresh groundwater is available for irrigation. Combined rice-shrimp systems were also expected but no farmers were practicing the rice-part of this system during the rainy season of 2003 because there had not been enough rainfall to flush the accumulated salt from the soil in the beginning of the rainy season (Kempen, 2004; van Mensvoort and Tri, 2002).

Four soil types are found (NIAPP, 1999). More than half of the area (5025 ha) has non-acid or weak acid alluvial soils which are slightly saline in the dry season. Severe acid sulphate soils (ASS), which are strongly saline in the dry season, can be found along the coast (3134 ha).

These soils extend approximately four kilometers land-inwards. The remaining two soil types are weakly ASS (685 ha) and severe ASS (968 ha), both with moderate salinity in the dry season. They are found further inland. NIAPP did not clearly define the degree of salinity (Kempen, 2004)

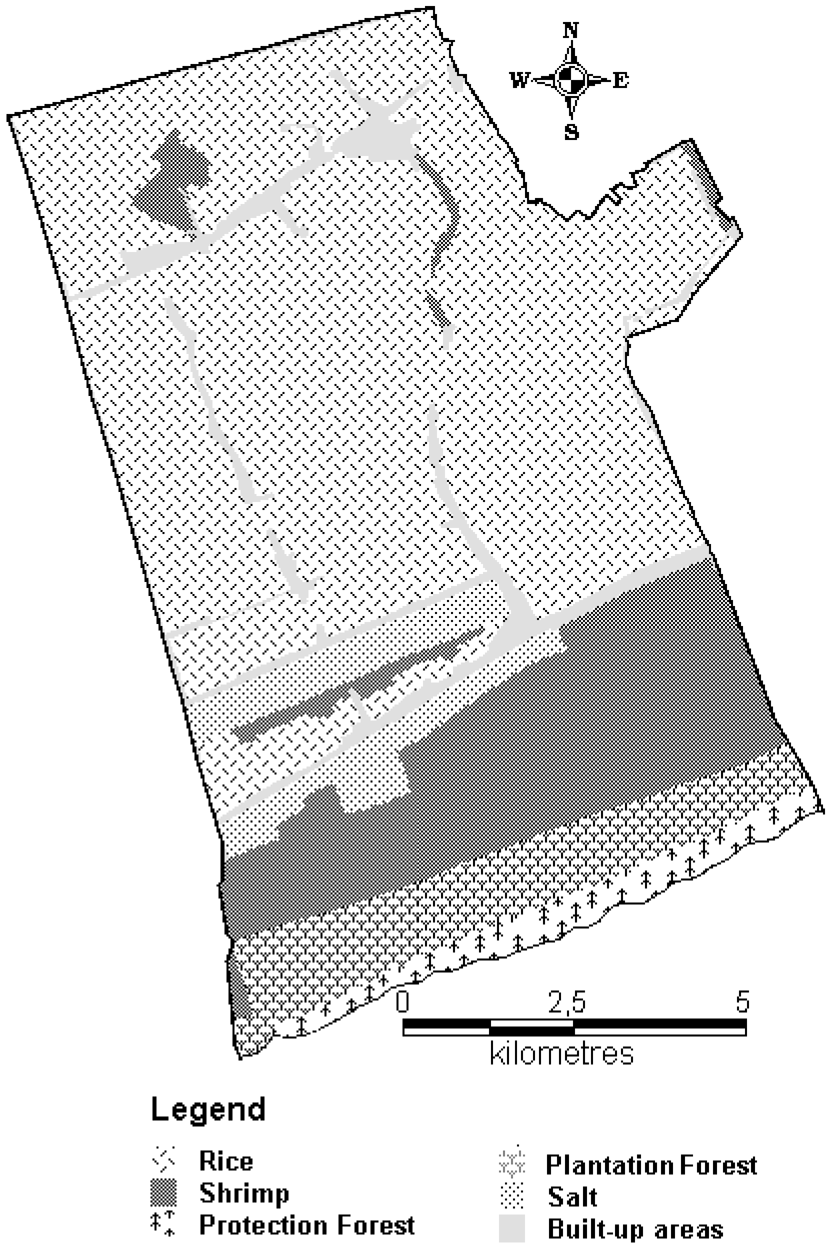


Figure 2.3 Land use in 2000 (NIAPP, 2001)

Descriptions of major land use types in the study area are presented in Table 2.2 below.

Table 2.2 Description of main land use types in the study area

No	Land use types	Description	Crop calendar
1	Vegetables	Including onion, shallot, pumpkin, cabbage, watermelon and others. Mainly practiced in well drained high areas , using fresh water [1]	All year round
2	Rice	One wet season rice	Jul/Aug. to Dec/Jan
3	Rice-vegetables	One summer-autumn rice (using rain water) and watermelon (using ground water)[1]	Rice: May to Aug. Watermelon 1: Oct to Nov/Dec Watermelon 2: Dec to Jan/ Feb
4	Extensive shrimp	Relying entirely on natural tidal movements for water exchange and seed supply. Ponds are large and a single gate is used for both supply and drainage of water. Production is not enhanced by artificial stocking; additional food or fertilizers and predators are rarely controlled. Yields are low.[2]	Jan to Aug
5	Modified extensive shrimp	Minimal artificial stocking of shrimp fry either from the wild or from hatcheries, and some supplementary feeding, usually with trash fish. Some efforts are made to control predators and weed growth. This system requires a higher investment and better management skills than extensive culture does [2]	Jan to Aug
6	Semi intensive shrimp	Ponds are smaller (500-2000 m^2) and have two gates – one for water supply and one for drainage. Pond preparation consists of excavation, drying and fertilizing the soil, and protecting the area from predators. Shrimp is either wild or artificially bred and is fed daily by local foodstuffs, industrial feed or a combination of both. Capital inputs and management requirements are higher compare to those of extensive systems[2]	Jan to Aug
7	Intensive shrimp	Relying solely on hatchery-reared juveniles and requiring water pumps, aeration, artificial feeds and exclusion of predators. capital investment and management requirements are also correspondingly higher than for other systems[2]	Jan to Aug
8	Salt	Practiced near the coast[1]	Nov to April
9	Rice-shrimp	Carried out in areas where salinity fluctuates sufficiently to allow rice production during the rainy season and shrimp production during the dry season. Usually one crop each of rice and shrimp are harvested each year[2]	Rice: Aug to Dec Shrimp: Jan to Aug
10	Forest-shrimp	Shrimp is cultivated in the mangrove forest area. The proportion of shrimp area and forest area is 30-40% [2]	Jan to Aug
11	Salt or artemia - shrimp	Carried out where salinity fluctuates sufficiently to allow shrimp production during the rainy season and salt or artemia (brine shrimp) production in the dry season [2]	Jan to Aug

[1] *Defined in NIAPP (1999)*

[2] *Defined in Martinelli (2000)*

Chapter 3

FAO approach to land use planning

N.H.Trung, B. Kempen

3 FAO approach to land use planning

This chapter describes the application to the study area of the FAO methodology for land use planning, combined with a multi-criteria evaluation (FAO-MCE). The approach includes biophysical evaluation, socio-economic evaluation, environmental evaluation, and scenario analysis. The case study shows that the FAO-MCE approach allows the integration of a biophysical land evaluation with socio-economic and environmental appraisals. Scenario analysis can help the decision-maker to trade-off between different possibilities and development targets. However, the results show only the land allocation, they fail to locate conflict areas. The sources of result uncertainties are pointed out. Firstly, the static description of the biophysical condition seems not suitable to describe the quick land use changes in the coastal area. A second source of uncertainty is the selection of socio-economic and environmental criteria and the method to quantify them. The justification for the importance of the selected criteria may be unclear. It depends much on the expertise of the land use planners or decision makers. The third uncertainty relates to the standardization schema of the evaluation criteria, different standardization methods lead to different land suitability patterns.

3.1 Background

The land use planning procedure described in the FAO guidelines (1993) contains ten steps: (1) Establishing goals and terms of reference; (2) Organizing the work; (3) Analyzing the problems; (4) Identifying opportunities for change; (5) Evaluating land suitability; (6) Appraising the alternatives: environmental, economic and social analysis; (7) Choosing the best options; (8) Preparing the land use plan; (9) Implementing the land use plan; (10) Monitoring and revising the plan.

A major activity of the FAO method is selecting land use alternatives based on land evaluation (steps 5 to 7). Land evaluation can be summarized as the process of matching land requirements and land qualities to assess land use suitability. Land use requirements are physical conditions that affect the yield stability, the suitability, and the management of land utilization types (LUT) (Fresco et al., 1992). The process of land evaluation includes:

- Identifying, selecting and describing relevant LUTs for the area under consideration.
- Mapping and describing the land units of the study area.
- Assessing the suitability of different land units for the selected LUTs. The land suitability classification has a more realistic meaning when results of the matching

exercise are not only based on biophysical conditions, but also critically reviewed for environmental and economic impact and social consequences.

LUT selection is based on governmental development objectives, current land use, promising farming systems, requirements of food consumption and food commodity, apparent agro-climatic suitability, and market orientation. Socio-economic considerations also play an important role in the selection process as well as in LUTs description (Huizing, 1991). FAO (1993) noted that proposed land uses have to be examined bearing the capabilities and incentives of individual land users in mind. However, there is no clear way to do this in a semi-quantitative approach with simple comprehensive, pragmatic methods.

In a land use planning process, conflicts tend to occur between the different stakeholders. The decision-maker has to trade-off between different conflicting goals. A technique for trade-off is the Multi-Criteria Evaluation (MCE). The MCE technique began to emerge during the 1970s. It serves to investigate a number of choice-possibilities in the light of multiple criteria and conflicting objectives or development targets (Voogd, 1983). With this method, it is possible to generate compromising alternatives and rankings of alternatives according to their attractiveness for different development targets (Jansen and Rietveld, 1990).

In general, multi criteria decision making problems involve six components (Keeney and Raiffa, 1976; Malczewski, 1999; Pitz and McKillip, 1984 as cited by Malczewski, 1999):

(i) A *goal* or set of goals the decision maker (interest group) attempts to achieve. In the LUP context, the goal may be to improve life quality, increase income, or protect the environment in a particular region;

(ii) The *decision maker* or a group of decision makers involved in the decision-making process, having preferences with respect to *evaluation criteria*. The preferences are typically operationalized in terms of weights assigned to the evaluation criteria, called *priority weights* (Yager, 1998). A priority weight expresses the importance of a criterion relative to the other criteria for a certain goal;

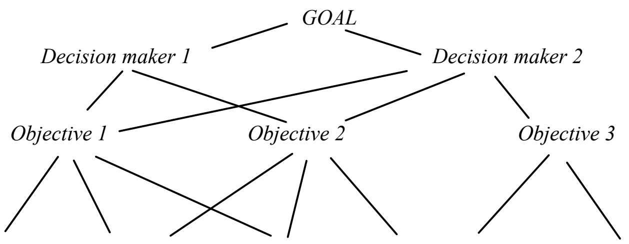
(iii) A set of *evaluation criteria* on the basis of which the decision makers evaluate alternative courses of action. A criterion is a standard of judgment or a rule to test the desirability of alternative decisions (Hwang and Yoon, 1981). A goal is evaluated based on its criteria. For example, the goal economic development can be evaluated by the criteria benefit/cost (b/c) ratio or total income of the alternative LUTs. The impact levels of criteria to that goal are taken into account by means of *priority weights* (Yager, 1998); In the MCE, it is crucial to select the right key criteria, quantify them, and determine their importance for the selected goals by giving weights to the relevant criteria (Beinat and Nijkamp, 1998; Malczewski, 2004);

(iv) A set of *decision alternatives* (choice possibilities), that is, decision or action variables. In LUP, these are the alternative LUTs that biophysically suit the study area;

(v) A set of uncontrollable variables or *states of nature*. The state of nature can be a state of economy (e.g. recession, inflation), a weather condition (rain, drought), or other situation over which the decision maker has little or no control (Malczewski, 1999). In LUP, state of nature is the biophysical suitability of LUTs in a land mapping unit (LMU); and

(vi) A set of outcomes or consequences associated with each alternative-criterion pair, called criterion scores (Malczewski, 1999). The criterion scores can be quantitative or qualitative and can have different measurement units. For different criteria to be compared, they need to be standardized.

The relationships between the elements of multi criteria decision-making problems can be visualized in a so-called *evaluation or decision matrix* (Figure 3.1).



State of environment

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	....	Criteria n
Preferences	Weight 1	Weight 2	Weight 3	Weight 4	.....	Weight n
Alternative 1 (LUT 1)	Criterion score 1,1	Criterion score 1,2	Criterion score 1,3	Criterion score 1,4		Criterion score 1,n
Alternative 2 (LUT 2)	Criterion score 2,1	Criterion score 2,2	Criterion score 2,3	Criterion score 2,4		Criterion score 2,n
Alternative 3 (LUT 3)	Criterion score 3,1	Criterion score 3,2	Criterion score 3,3	Criterion score 3,4		Criterion score 3,n
. ...						
Alternative m (LUT m)	Criterion score m,1	Criterion score m,2	Criterion score m,3	Criterion score m,4		Criterion score m,n

Figure 3.1 Framework for multi criteria decision analysis (After Malczewski, 1999)

For selecting the most suitable alternative, weighted linear combination (WLC) is used. WLC is a relatively simple and widely used MCE method (Beinat and Nijkamp, 1998; Chen et al., 2001; Eastman et al., 1998; Malczewski, 2004; Voogd, 1983), applying the following formula:

$$S = \sum_{i=1}^{n} W_i x_i$$

In which S is the suitability score of a land use alternative for a defined LUP goal. This score is based on the standardized criterion score x and the priority weight W assigned to that criterion on basis of the chosen LUP goal. The alternative i will be judged better than alternative j' if Si > Sj'.

3.2 Application of FAO-MCE to the study area

3.2.1 Approach

Figure 3.2 presents how the approach was performed. The first step was the *biophysical land evaluation*. Biophysical land evaluation (LE) is a process of matching LUTs' requirements and land mapping units' (LMU) qualities to assess land use suitability (FAO, 1976). An LMU is a tract of land that is biophysically relatively homogeneous at the scale level concerned (Zonneveld, 1997). In this study the LE was performed by the National Institute of Agriculture Planning and Projection (NIAPP) in 1999.

In the second step*, the socio-economic assessment*, LUTs' socio-economic criteria were evaluated. These criteria were: gross income, investment costs, variable costs, total costs, benefit/cost ratio, labour days, accessibility, and financial risk. In the accessibility analysis, a model called the "Accessibility Analyst" and developed by the CIAT, the Institute for Tropical Agriculture (http://www.ciat.cgiar.org/access), was used. It calculates the travel time from any given geographical location to its nearest target location. In this study these locations were the local markets where farmers could sell their products. The financial risk was evaluated based on two sub criteria: product price fluctuations and crop failure risks.

In step 3, *the environmental assessment*, the LUTs' impacts on the surrounding environment were judged based on five criteria: sedimentation, salinization, groundwater use, water pollution with organic wastes or nutrients, and the use of fertilizers or chemicals. The degree of environmental impact of each criterion is determined from farmer interviews, expert knowledge, and literature research. Values of environmental criteria are called environmental impact scores.

In step 4, *standardization*, the socio-economic criterion scores were standardized.

In step 5, *Calculation of suitability scores,* the LUTs' suitability score per LMU for the chosen planning goals was determined by using the WLC formula (see page 23). The priority weight W indicates the criterions' level of importance for each LUP goal, e.g. for economic development, the income may be judged more important than the benefit/cost ratio, and will thus receive a higher weight.

The LUT i will be judged better than LUT j' if Si > Sj'. It should be noted that this judgment is true only when all LUP goals are of the same priority, while in reality the decision makers' preferences on the LUP goals can be different. Thus, *scenarios analysis* needs to be performed (step 6).

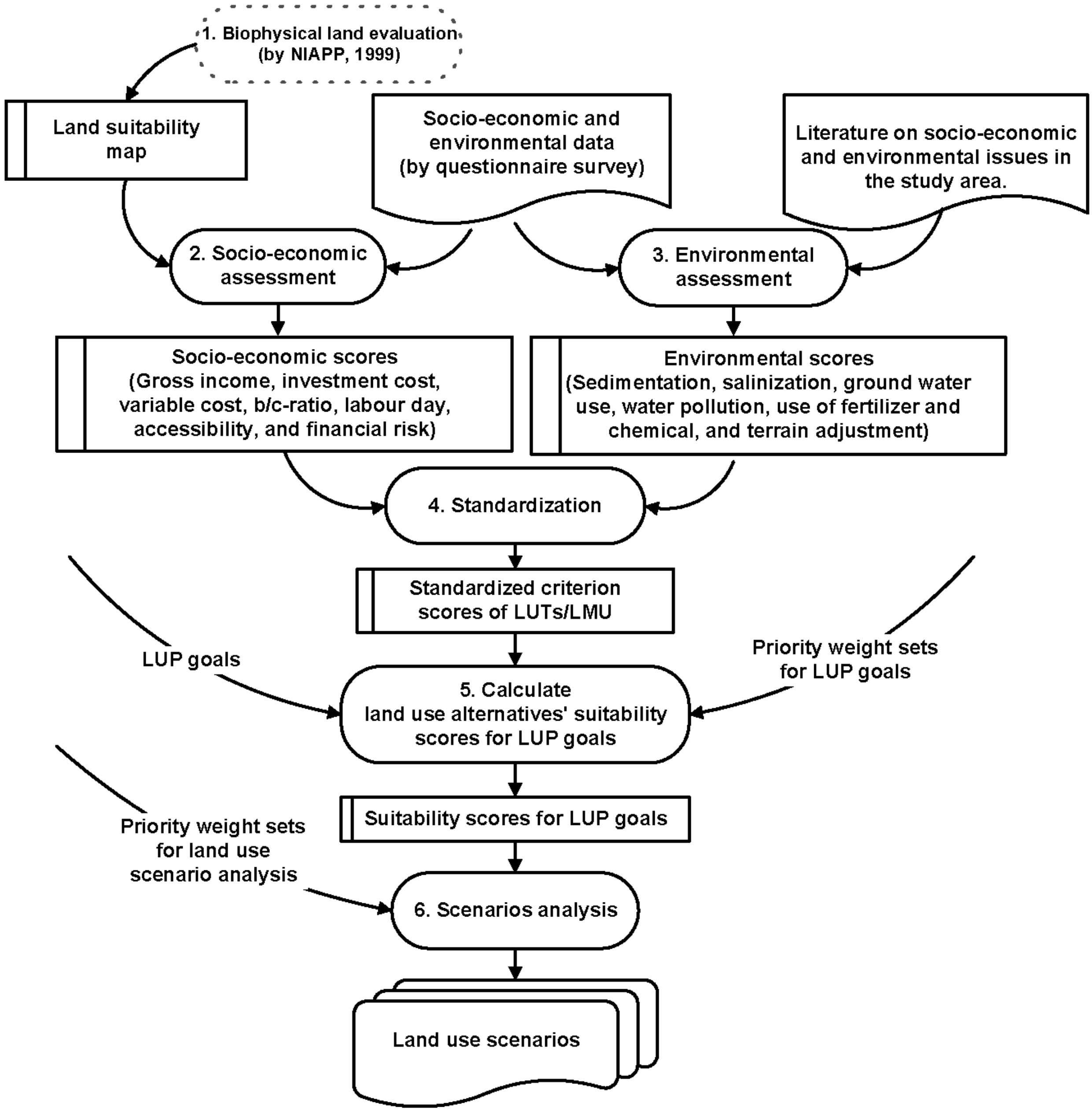


Figure 3.2 Integrating FAO approach with MCE

Step 6, *scenario analysis*. A land use scenario can be defined on the basis of one or more LUP goals. When multiple goals are used to define a land use scenario, priority weights are assigned to these LUP goals (e.g. 25% weight for economic development, 75% weight for environmental conservation), and then the WLC can be applied for the alternative LUTs. For a given set of priority weights, the best alternative LUT for an LMU is the one with the highest final evaluation score.

3.2.2 Results and discussion

Biophysical assessment

There are eight Land Mapping Units (LMUs) present in the studied area (NIAPP, 1999) (Figure 3.3). For each LMU, eight alternatives LUT were evaluated. The LMU were identified using the following land characteristics: soil type, topography (m), duration of the wet season (months), tidal amplitude (m), inundation depth (cm), and inundation duration (months). The characteristics of the LMUs and the result of this biophysical land evaluation by NIAPP (1999) are shown in tables 3.1 and 3.2.

Table 3.1 Characteristics of the land mapping units present in the study area (NIAPP, 1999).

LMU	*Soil Type*	*Elevation (m)*	*Duration Wet Season (months)*	*Inundation*		*Tidal Amplitude (m)*
				Time (months)	*Depth (m)*	
3	*Non or weak acid, alluvial soils, slightly saline*	*0.6-0.8*	*6*	*6*	*<0.4*	*2.5-3.0*
4	*Non or weak acid alluvial soils, slightly saline*	*0.4-0.6*	*6*	*6*	*<0.4*	*<2.5*
16	*Weak ASS, moderately saline*	*0.4-0.6*	*6*	*6*	*0.4-0.6*	*2.5-3.0*
24	*Severe ASS, moderately saline*	*0.4-0.6*	*6*	*6*	*0.4-0.6*	*2.5-3.0*
25	*Severe ASS, strongly saline*	*0.8-1.0*	*6*	*6*	*0.4-0.6*	*2.5-3.0*
27	*Severe ASS, strongly saline*	*>1.0*	*6*	*6*	*<0.4*	*2.5-3.0*
28	*Severe ASS, strongly saline*	*>1.0*	*6*	*Tidal*	*0.4-0.6*	*3.0-3.5*
29	*Severe ASS, strongly saline*	*>1.0*	*6-7*	*Tidal*	*>0.6*	*>3.5*

Table 3.2 Land suitability classification after biophysical land evaluation (NIAPP, 1999).

LMU	*S1*	*S1/S2*	*S2*	*S2/S3*	*S3*	*N*
3	*SR, DR, RV*		*RS*		*m-e S, s-I S*	*SS, FS*
4	*SR, DR, RV*	*RS*			*m-e S, s-I S*	*SS, FS*
16, 24	*m-e S*		*RS, s-I S*		*SR, DR, RV*	*SS, FS*
25			*RS, m-e S, s-I S*			*SR, DR, RV, SS, FS*
27, 28	*m-e S*	*SS*	*m-s S, FS*			*SR, DR, RS*
29	*FS*			*SS*	*m-e S, s-I S*	*SR, DR, RS*

SR = Single Rice	*m-e S = Modified Extensive Shrimp*	*S1 = highly suited*
DR = Double Rice	*s – I S = Semi- Intensive Shrimp*	*S2 = moderately suited*
RV = Rice – Vegetables	*SS = Salt – Shrimp*	*S3 = marginally suited*
RS = Rice – Shrimp	*FS = Forest – Shrimp*	*N = unsuited*

According to the NIAPP land evaluation, rice or rice and vegetables were most suitable in LMU 3 and 4, while shrimp cultivation was suitable in LMU 16, 24, 25, 27 and 28. However, according to the survey in 2003, shrimp systems were found in all LMUs and sometimes with success (Kempen, 2004). The 1999 NIAPP suitabilities for shrimp appeared to be outdated. The shrimp systems suitabilities were updated using yield data acquired from the survey of 2003.

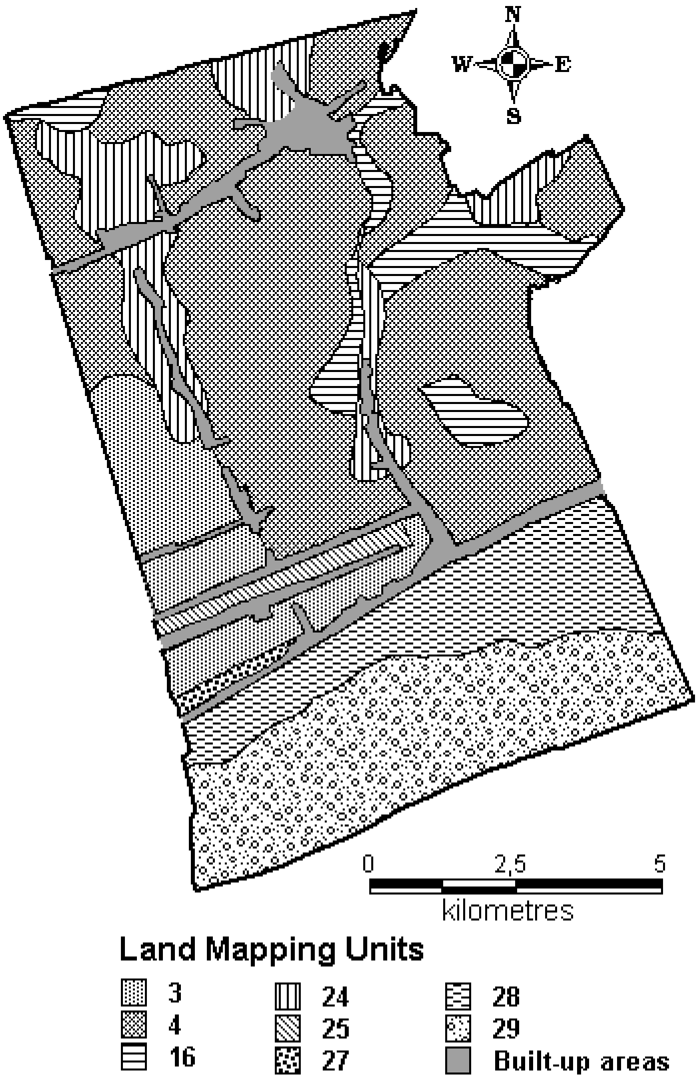


Figure 3.3 The land mapping units of the study area (NIAPP, 1999)

Socio-economic assessment

Data from NIAPP (2001) and the new data gathered from farm households through a questionnaire survey were used to quantify the gross income, investment costs, variable costs, total costs, benefit/cost ratio, and labour days of the alternative LUTs, but only for the LMUs that they are suitable (Kempen, 2004).

For this survey, at least four farmers in each land use system (LUS) were interviewed. This resulted in 74 interviews for the six different LUTs that were presented in the study area. Two LUTs were not in actual operation, they are double rice and rice-vegetable. Farmers were asked to quantify: yield, benefit, initial investment costs, variable costs (labour, machinery, fuel, seed, shrimp stock, shrimp food, fertilizer, pesticide and other chemical), other income sources, available capital, credit, labour days, family size, and family labourers. Besides socio-economic data on the LUTs, farmers were also asked about socio-economic and biophysical constraints that limit their production: credit availability and land degradation (such as salinization, acidification, or loss of produce caused by sedimentation). This information was used to strengthen the biophysical land evaluation and the (qualitative) environmental assessment.

The interview results show that the values of the socio-economic criteria of the LUTs largely varied. The variation was not only large between the different LMUs but also within LMUs, especially for shrimp cultivation. This large difference was one of the characteristics in the study area and very likely in the whole coastal zone of the Mekong Delta (Thanh, 2002). This variation was caused by differences in farm management, water quality, technology, credit, farming experience and last but not least luck (Kempen, 2004).

Two sub criteria were used to evaluate the financial risk (part of the socio-economic assessment) of the LUTs: product price fluctuations and crop failure risks. Values representing the sensitivity of an LUT for the two financial risk criteria were scaled from 1 (low) to 4 (very high). For calculating the financial risk score, a weight was given to the sub criteria. By using a weight, the decision-maker can put an accent on the sub criteria to judge the most important factor determining the financial risk of a certain LUT. In this study the chosen weights were 0.4 and 0.6 for product price fluctuations and crop failure risks, respectively. The pair-wise comparison method (Saaty, 1980) in combination with expert knowledge and farmer interview results was used to assign the values (Table 3.3). The main shrimp systems' risks were the crop failure risks. This risk can be reduced when shrimp is combined with another crop such as rice or forest. Among the aquaculture systems, modified extensive shrimp had the highest financial risk because of having both a high crop failure risk and also high product price fluctuations. Rice crops suffer fewer financial risks due to stable yields and prices, but vegetable cultivation suffers high price fluctuation.

Table 3.3 Assigned values to LUTs for calculating the financial risk score.

	Weight	*s-I S*	*m-e S*	*F-S*	*R-S*	*SR*	*DR*	*R-V*	*Salt*
Product price fluctuations	0.4	2	3	3	2	1	1	3	4
Crop failure risks	0.6	3	4	2	2	1	2	2	1
Financial risk score		***0.65***	***0.90***	***0.60***	***0.50***	***0.25***	***0.40***	***0.60***	***0.55***

SR = Single Rice *DR = Double Rice* *R-V = Rice – Vegetables* *s – I S = Semi- Intensive Shrimp*
m-e S= Modified Extensive Shrimp *F-S = Forest – Shrimp* *R-S = Rice – Shrimp*

The accessibility analysis shows that farmers could reach the markets within 90 minutes from any location in the study area. This time span is supposed to be enough to keep their products fresh. Therefore, the accessibility is not seen as a limiting factor for the socio-economic development in the study area.

Environmental assessment

Because quantitative data were lacking, the environmental assessment was done qualitatively. The degree of environmental impact of each criterion was determined by the farmer interviews, expert knowledge and literature research (Hoanh et al., 2000; Honculada-Primavera, 1994; Páez-Osuna et al., 1998; Populus et al., 2002; Tripathi et al., 2000).

Four classes of negative environmental impact were distinguished: very high, high, medium and low negative environmental impact. Each class had an impact value: 4, 3, 2 and 1, respectively. For each LUT, impact values were assigned to each environmental criterion. These impact scores were added up and divided by 20, the maximum score that could be attained in this case (5 criteria times the maximum score 4).

Table 3.4 shows the environmental impact scores in the environmental assessment analysis. The results show that semi-intensive shrimp had the highest score, and thus the worst environmental impact. These shrimp systems had many problems: sedimentation and water pollution had the highest possible values but chemicals and salinization were also high. Chemicals and fertilizer use were the main problems in double rice cultivation.

Table 3.4 Assigned values for calculating the environmental impact score.

	s-I S	*m-e S*	*F-S*	*R-S*	*SR*	*DR*	*R-V*	*Salt*
Sedimentation	4	3	3	3	1	1	1	3
Water pollution	4	3	3	2	1	1	1	1
Chemical & Fertilizer Use	3	2	2	3	2	3	3	1
Salinization	3	3	3	1	1	2	1	2
Groundwater Use	1	1	1	1	1	1	3	1
Environmental impact score	***0.75***	***0.6***	***0.6***	***0.5***	***0.3***	***0.4***	***0.45***	***0.4***

SR = Single Rice *DR = Double Rice* *R-V = Rice – Vegetables* *s – I S = Semi- Intensive Shrimp*
m-e S = Modified Extensive Shrimp *F-S = Forest – Shrimp* *R-S = Rice – Shrimp*

Standardization

A standardization scheme was designed for the socio-economic values (Table 3.5). The scheme consists of five qualitative classes: very low, low, medium, high, and very high. Each class represents an indexed criterion score interval: 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8 and 0.8-1.0, respectively. Each criterion score class corresponds with a quantitative class of the indicators. These classes were defined by analyzing the socio-economic situation of the farming community in the study area and finding out what they perceive as a high, a medium or a low income, costs, etc.

Table 3.5 Standardization scheme for the socio-economic indicator values.

Class	Criterion Score	Income (Md/ha/y)	Investment Costs (Md/ha/y)	Variable Costs (Md/ha/y)	Total Costs (Md/ha/y)	b/c Ratio	Labour req. (days)
Very High	0.8-1	200-400	20-40	100-200	100-200	2-4	500-1000
High	0.6-0.8	50-200	10-20	50-100	60-100	1.5-2	250-500
Medium	0.4-0.6	15-50	5-10	20-50	25-60	1-1.5	100-250
Low	0.2-0.4	5-15	2.5-5	5-20	7.5-25	0.5-1	50-100
Very Low	0-0.2	0-5	0-2.5	0-5	0-7.5	0-0.5	0-50

Md = Million of Vietnamese Dong

Over-all suitability score calculation

In this study three LUP goals were considered: economic development, social security, and environmental sustainability. The priority weight sets of socio-economic and environmental criteria for these three goals are presented in Table 3.6. Income and benefit/cost ratio were the main criteria for economic development, with income slightly more important (0.6 vs. 0.4). Four criteria were important for social security: financial risk, labour requirement, b/c ratio and environmental impact with a decreasing importance in this order. The environmental impact was used as the sole criterion for environmental sustainability.

Table 3.6 Priority weight sets for the three LUP goals of the case study.

	Economic Development	Social Security	Environmental Sustainability
Income	0.60		
Investment costs			
Variable costs			
Total costs			
b/c ratio	0.40	0.20	
Labour requirement		0.30	
Financial risk		0.40	
Environmental impact		0.10	1.00

The WLC formula (see page 22) was applied for suitable LUTs on all LMUs. Here, at the bottom of Table 3.7, only the results for three selected LUTs in LMU 16 are presented. With the used priority weight sets, it can be concluded that when only the economic development is considered, rice-shrimp is the most suitable LUT, and when only the goals social security and environmental sustainability are taken into account, single rice is the most suitable LUT for LMU 16.

Table 3.7 Criterion scores and final suitability scores for three LUTs in LMU 16.

		Single Rice	*Rice-Shrimp*	*Modified Extensive Shrimp*
Criteria	*Income*	0.36	0.63	0.29
	Investment costs	-	0.92	0.75
	Variable costs	0.80	0.66	0.79
	Total costs	0.87	0.70	0.79
	b/c ratio	0.93	0.94	0.55
	Labour requirement	0.31	0.60	0.51
	Financial risk	0.25	0.50	0.90
	Environmental risk	0.30	0.50	0.60
LUP Goals	***Economic development***	**0.6**	**0.8**	**0.4**
	Social security	**0.7**	**0.6**	**0.3**
	Environmental sustainability*	**0.7**	**0.5**	**0.4**

*** Environmental sustainability is 1- environmental risk**

Scenarios analysis

Table 3.8 presents the priority weighting sets that were given to the LUP goals in this study. The second and third scenarios show the results when the accent is placed on social security. They seem the same but the difference is that the second has an emphasis on job creation (high weight for labour day criterion) and the third has its accent on minimizing financial risk (high weight for financial risk criterion).

Table 3.8 Priority weight sets applied to the LUP goals.

	Economic development	*Social security*	*Environmental sustainability*
Scenario 1	1.0	0	0
Scenario 2	0	1.0	0
Scenario 3	0	1.0	0
Scenario 4	0.25	0	0.75
Scenario 5	0.33	0.33	0.33
Scenario 6	0.75	0.25	0
Scenario 7	0.25	0.75	0
Scenario 8	0.60	0.20	0.20

The WLC formula was used again to define land use scenarios. Table 3.9 demonstrates an example of calculating the final suitability score of the same three LUTs in LMU 16 with priority weight set of 0.6, 0.2, and 0.2 for economic development, social security and environmental sustainability, respectively (scenario 8). Because it has the highest final suitability score, rice-shrimp is the most suitable for LMU 16.

Table 3.9 Calculation of final suitability scores for the three LUTs of LMU 16.

	Priority weight	***Single Rice***	***Rice-Shrimp***	***Modified Extensive Shrimp***
Economic development	*0,60*	***0,6***	***0,8***	***0,4***
Social security	*0,20*	***0,7***	***0,6***	***0,3***
Environmental sustainability	*0,20*	***0,7***	***0,5***	***0,4***
Final suitability score		***0,6***	***0,7***	***0,4***

Similar calculations were done for all mapping units and for a large number of scenarios. The results of all these scenario analyses show that when a high priority was given to economic development, most of the LMUs were assigned to semi-intensive shrimp. When social security has a high priority, most land is assigned to grow rice-vegetable or single rice. However, according to farmers, the vegetable market is small in the study area. When environmental sustainability has a high priority, most land is assigned for single rice. Due to the low income from rice, farmers might not accept this scenario. When all targets have the same priority, single rice is the main LUT. Forest-shrimp is mainly advised near the coast, rice-vegetable and rice-shrimp in the high land and near to canals. Figure 3.4 presents two rather contrasting land allocation maps which resulted from scenario 5 (same priority for all goals) and scenario 6 (higher priority for economic development). The plans generated with these scenarios do not include a complete feasibility analysis in terms of labour, capital, and technology.

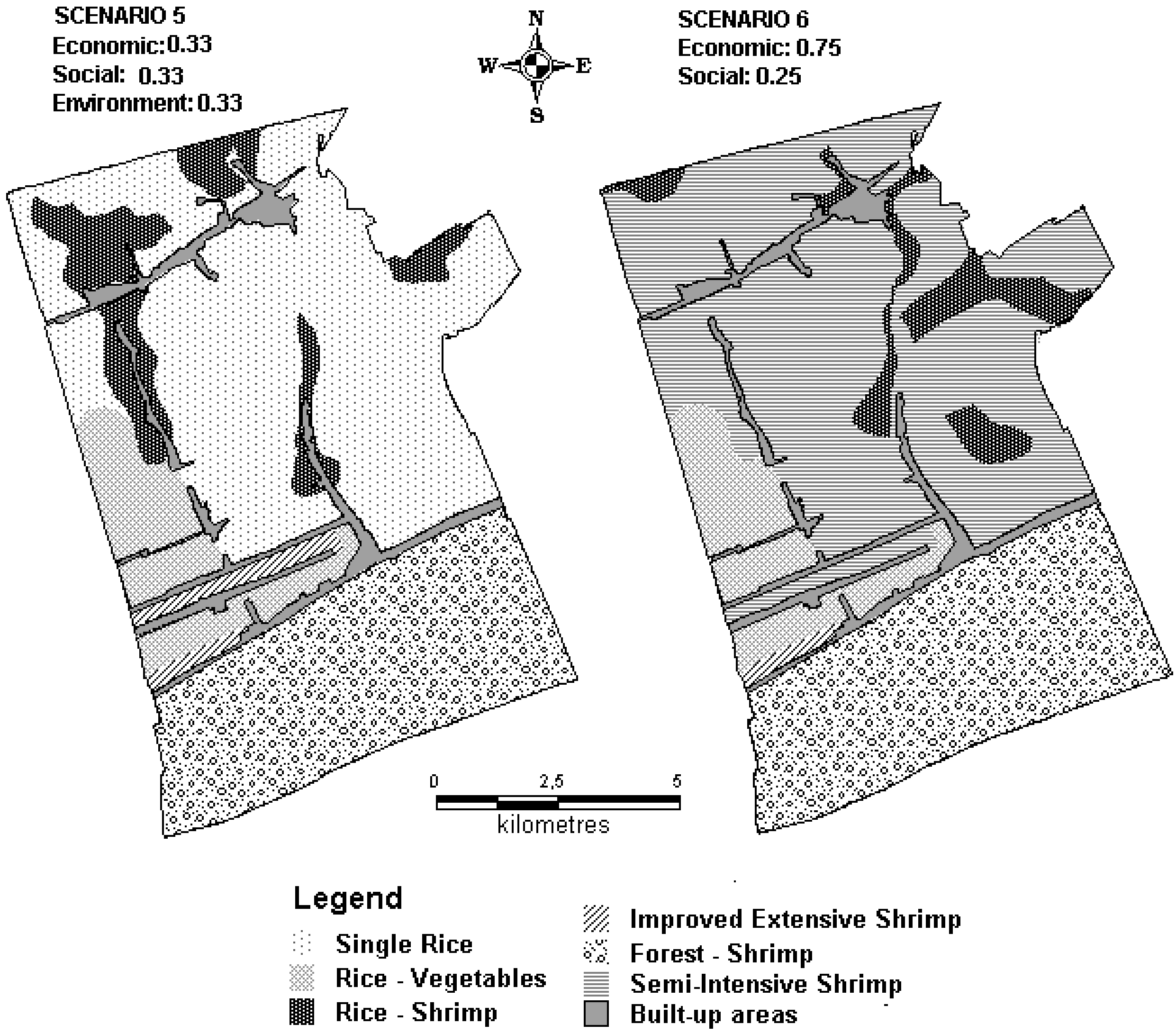


Figure 3.4 Land use scenario 5, same priority for all development targets, and scenario 6, more priority for economic development (Kempen, 2004)

Discussion: Proposal for a 2004 Land use plan based on FAO-MCE

As demonstrated in the previous paragraphs, the FAO-MCE can generate a large number of land use plans depending on biophysical, environmental and economic aspects of land use and priorities set by planners. There is not one “optimal” plan. In this thesis, however, we try to compare methods of land use planning for one study area. That is why we combined the results of various scenarios to come to a FAO-MCE land use plan. Figure 3.5 presents that plan based on land use scenario analysis. It gives priority to economic development while attempting to also reduce the environmental and financial risk, giving priority, e.g. to economic development in one unit, and/or environmental protection in another . The main problem faced here was the fact that the FAO method ties the study to the land units which were based, it is believed, on an incomplete dataset whereby a reasonable operational basis for shrimp farmers was not included. In order to make their cultivation possible, the shrimp farms should be located close to a canal for proper access to a salt-water source. Since large infrastructural works as the excavation of new canals are out of the reach of individual farmers or groups of farmers, the existing main canal system was taken into consideration and the distance to a main canal (as source for water management of shrimp ponds) was introduced as a factor, which increased the number of land units. For areas close to the main canals the semi-intensive shrimp was selected as best option, while for land further away from the canals rice is the best option. The combination of rice-shrimp is a safer alternative in the north of the study area, close to the Quan Lo Phung Hiep salinity protection area. In this system rice is cultivated in the rainy season and extensive shrimp in the dry season. The reason is that the nearby water control activities influence water quality (lengthening of the fresh water period and possibly more polluted water) and this may make single shrimp cultivation risky (Kempen, 2004).

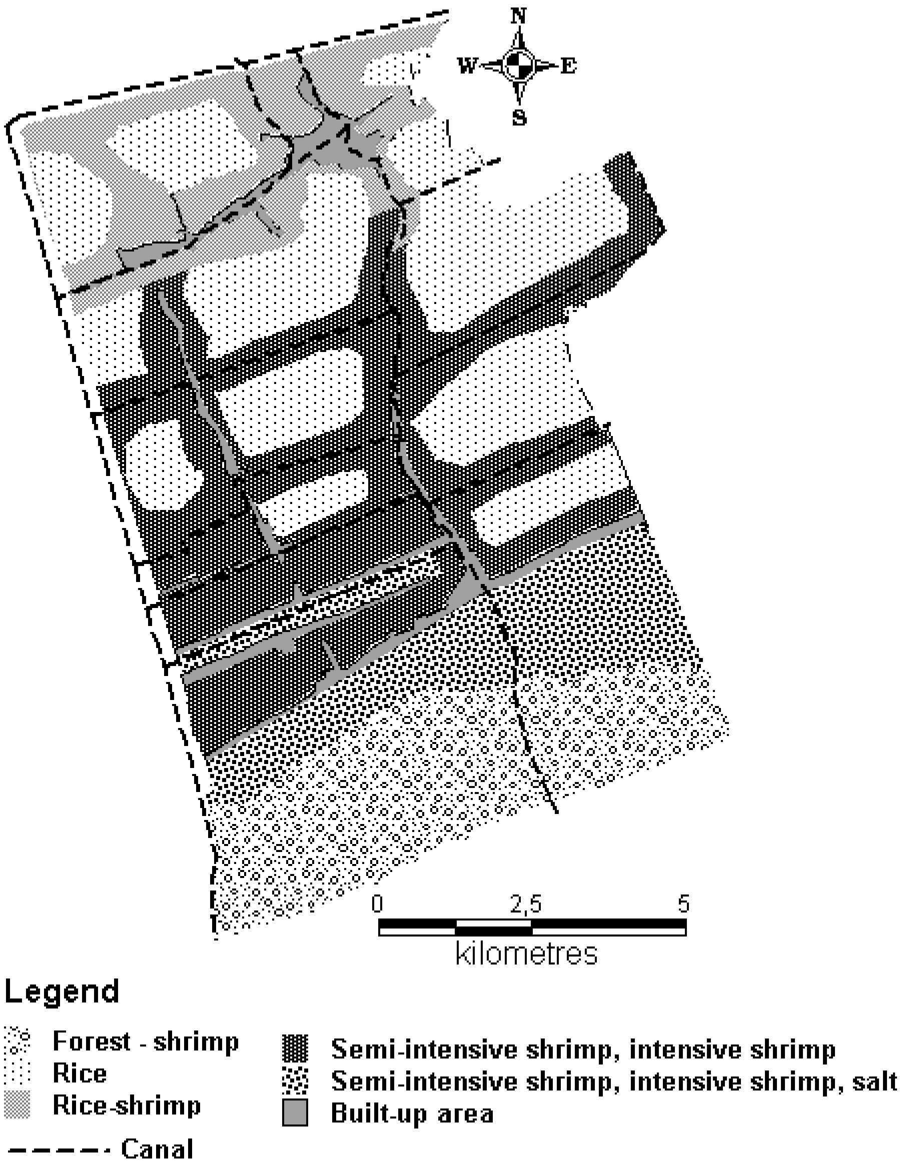


Figure 3.5 The proposed land use plan for 2004 (Kempen, 2004)

3.3 Conclusion

The FAO-MCE approach allows the integration of the biophysical land evaluation and the socio-economic and environmental appraisal. Scenario analysis can help the decision-maker to trade-off between different possibilities and goals. The results of this study show that when a high priority is given to economic development, semi-intensive shrimp is the best option for land use and that when social security and environmental sustainability have higher priority, either rice-vegetable or single rice is. When all goals have the same priority, single rice is the main LUT; forest-shrimp is mainly advised near the coast; and rice-vegetable and rice-shrimp are proposed in the high land and near canals.

In the LUP resulted from the approach, only one LUT is allocated for each LMU, which makes the approach less realistic when LMUs are large. This is likely to be a main drawback of the approach. Another disadvantage of the approach is that its results show only the land allocation, it cannot locate land use conflict areas. Therefore it would be better to also consider the resources availability and farmers acceptability in the final decision-making stage of this methodology.

The uncertainty of this study lies first in the biophysical land evaluation data. Its static description of the biophysical conditions does not seem suitable to describe the rapid and extreme changes that are going on in the coastal area. The second source of uncertainty is the possibly subjective justification on the importance of the chosen socio-economic and environmental criteria since the land use planners or decision makers might select and justify the criteria in their own subjectivity. The third problem relates to the standardization of evaluation criteria. Different standardization methods may lead to different land suitability patterns (Malczewski, 2004).

Chapter 4

Participatory land use planning (PLUP)

This chapter is based on: Trung, H.N., L.Q.Tri, M.E.F. van Mensvoort and A.K.Bregt., 2004. *GIS for Participatory Land Use Planning in the Mekong Delta, Vietnam*. In: Zazueta F., S. Ninomiya, R. Chitradon, eds. *Proceeding of the 2004 AFITA/WCCA. The 4th International Conference of the Asian Federation of Information Technology in Agriculture and the 2nd World Congress of Computers in Agriculture and Natural Resources. August 9-12, 2004. Bangkok, Thailand*. Hydro and Agro Informatics Institute, National Science and Technology Development Agency, Thailand.

4 Participatory land use planning (PLUP)

A participatory land use planning approach (PLUP) was carried out in the study area. The PLUP was done twice (2002 and 2003). Groups of farmers were selected to discuss the land characteristics, the biophysical, social and economic constraints, and the preferences for future land use. A geographic information system (GIS) was used for analyzing the land use change, the realization of the farmers' preference, the change in preference and the preference conflicts between groups of aquaculture and agriculture farmers. Results show that land use in the study area was very dynamic. Within one year, more than half of the study area has changed; agriculture was mostly replaced by aquaculture. Only half of the farmers' preferences were realized, mostly in aquaculture. The farmers' preference changed largely from agriculture to a mixture of agriculture and aquaculture, or to aquaculture alone. The reasons for the above changes were the high benefit from aquaculture, the inevitable salt-water intrusion and the government policy giving priority to aquaculture development. There was a difference in preference of the agriculture farmers and the aquaculture farmers due to differences in biophysical and economic considerations. The study results not only provide researchers and local planners with valuable information about the study area, but also enrich experience in applying PLUP in the Mekong Delta.

4.1 Background

People's participation in rural development was formulated in the mid-1970s. In 1980, the FAO launched the People's Participation Program (PPP). Since then, PPP has implemented pilot projects throughout the developing world in an attempt to test and develop an operational method of people's participation for incorporation in larger rural development schemes (FAO, 1990). In recent years, participatory land use planning has gained international recognition as an important tool for reaching sustainable resource management by local communities. Several studies have been reported on PLUP. Nidumolu et al. (2004) have reviewed a number of case studies in Burkina Faso, Australia, New Zealand, Zimbabwe, and India. The Working Group on Land Use Planning for the Asian-Pacific Region of GTZ has described their case studies in China, Thailand, Sri Lanka, India (Albrecht et al., 1996). Others case studies have also been conducted in Cambodia, Thailand, Lao and Vietnam (Christ, 1999; Rock, 2004; Sawathvong, 2003). Moreover, PLUP is applied widely in forestry (Buchy and Hoverman, 2000; Garcia Perez and Groome, 2000; Hannah et al., 1998; Hytonen et al., 2002; Oltheten, 1995).

Several organizations have been involved in defining the methodological framework for PLUP. FAO/UNEP/GTZ (1999) have defined that participatory land-use planning is a systematic and iterative procedure carried out in order to create an enabling environment for sustainable development of land resources which meets people's needs and demands. It assesses the physical, socio-economic, institutional and legal potentials and constraints with respect to an optimal and sustainable use of land resources, and empowers people to make decisions on how to allocate those resources. The World Bank (1996) has pointed out that participation is a process through which stakeholders influence and share control over development initiatives and decisions and resources which affect them. FAO experience has shown that through participatory programs and activities it is possible to mobilize local knowledge and resources for self-reliant development and, in the process, reduce the cost to governments of providing development assistance. People's participation is also recognized as an essential element in strategies for sustainable agriculture, since the rural environment can be protected only with the active collaboration of the local population (FAO, 1991).

The PLUP approach focuses on the capacities and needs of local users, based on the assumption that sustainable resources management can be achieved only if natural resources are managed by the local population. This basic principle requires a strong bottom-up planning perspective. LUP is done both by and for the actual land users with minimal involvement of official or professional land use authorities. Consequently, LUP focuses on the village or traditional community boundaries. This is contrast to planning for large “functional” areas such as watersheds or larger administrative units (Christ, 1999).

The main objective of PLUP can be defined as to create the framework for sustainable land use that is socially acceptable, environmentally sound, politically desired and economically viable. This objective is pursued by assisting local stakeholders in planning the use of locally available resources and to strengthen their capacities for managing the resources in a sustainable way. PLUP tries to identify land use options, which are acceptable to all stakeholders and satisfy the needs of all parties involved. Local land users must agree with the results of the planning process, as they will have to live with it. LUP resulting in regulations and prohibitions trying to prevent local people from carrying out land use activities which they practice for reasons are bound to fail (Christ, 1999).

Participatory land use comprises a number of tasks, typically carried out in a step-wise approach. The tasks required can be derived from four simple questions (Christ, 1999): (i) What is the present land use situation? (ii) What needs to be changed, what not? (iii) How can the changes be made and what are the best options? (iv) How, when and by whom can the changes be implemented?

4.2 Application of PLUP to the study area

4.2.1 Approach

A modified participatory rural appraisal (PRA) was used based on the toolbox designed by Ticheler et al. (2000) and on experiences from an earlier study in the same area by Feitsma et al. (2002). The approach tried to avoid Feitsma's reported difficulties regarding communication, lack of secondary data, large and scattered hamlets and limited time. In this approach, groups of about 10 key informants (experienced farmers) were formed in each hamlet. In total 26 of these groups were interviewed. The PLUP was repeated twice, in 2002 and 2003. To have a thorough set of perspectives, agriculture farmers and aquaculture farmers were grouped separately. In each group, farmers participated in reviewing the hamlet's land-use history, described their land conditions and production systems, explained the reasons for land-use change, defined the socioeconomic factors that affect the change decisions, drew a sketch map showing the land use and land constraints of their hamlets, and proposed the preferred future land use (see appendix 1). Transect walks were also conducted to verify the farmers' resource map. During the transect walk, farmers were asked for information on the land and the land-use types they practiced. To facilitate the discussion, in each group two researchers were involved. The first one initiating the debate by hint questions, he/she also helps the villagers on drawing the resource sketch map, graphs or tables. The second person is responsible for taking notes. The time needed for completing the land use plan of a hamlet was one day.

GIS has been used for combining maps of hamlets and for analyzing the land use change, realization of preference, preference change and preference conflicts. The analysis flowchart is presented in Figure 4.1

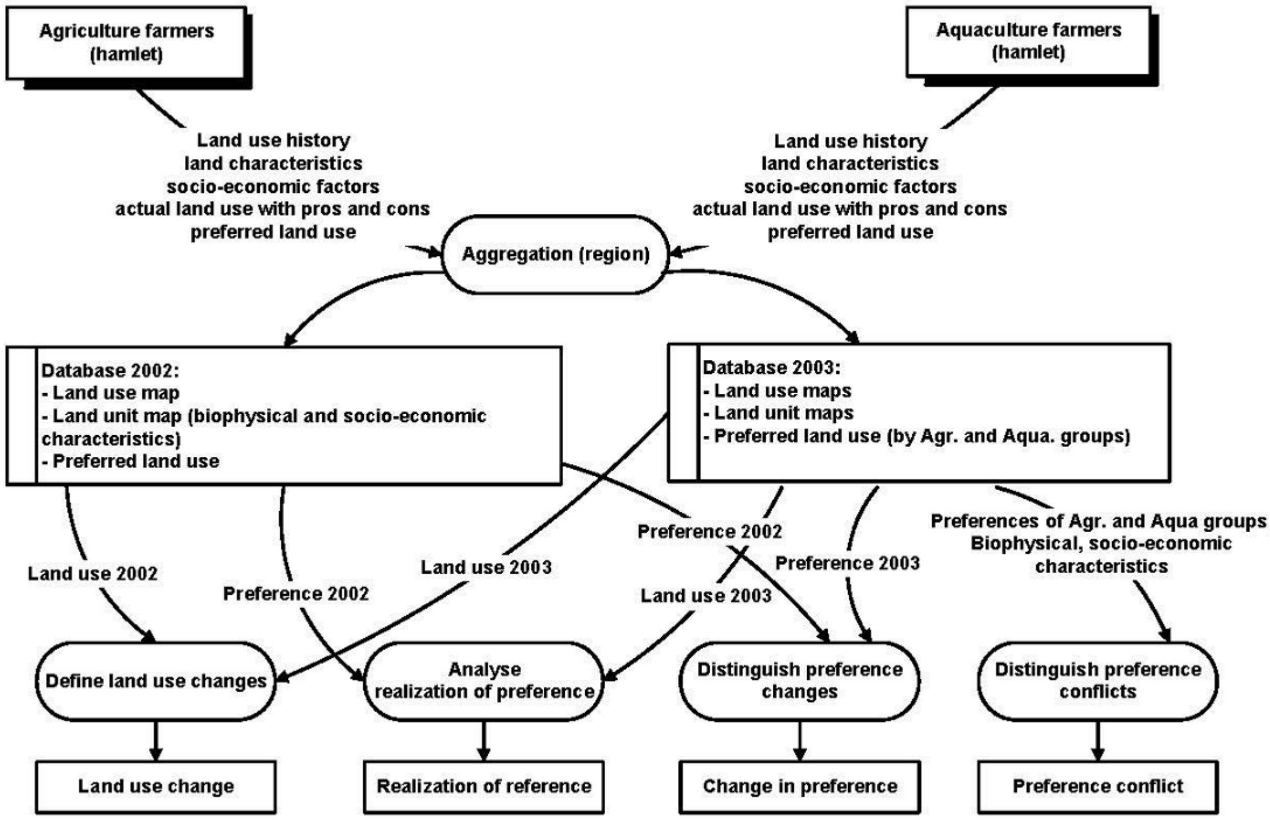


Figure 4.1 Analyzing of results

4.2.2 Results and discussion

Land use history

There were three distinguished periods of land use change in the study area. The first period was before 1975 (wartime): In the high land (no salt water intrusion), extensive cultivation of crops such as traditional rice and vegetables (shallot, ginger, sesame, coriander, salad, watermelon, okra, etc.) were practiced. In the depressed areas with salt-water intrusion throughout the year, mainly natural fish and natural shrimp were kept. Along the coast, there was mangrove forest, and salt pans existed further inland.

The second period was from 1975 to 1999-2000: In the high land, agriculture became more intensified thanks to a better infrastructure (such as canals, dikes, sluice gate, etc.) and the introduction of new high yielding rice varieties (IR26, IR42, IR68, OM83, and MTL84). Vegetables were also practiced along the canal banks. In the coastal areas, mangrove forest was cut down for shrimp and salt production.

The third period was from 1999-2000 to the present: In the high land, thanks to the high benefit from shrimp, rice fields are converted to shrimp ponds, but with little success due to a lack of knowledge on shrimp cultivation and shrimp diseases (Kempen, 2004). Vegetables are planted along canal banks. Some farmers combine one rice crop and vegetables in the rice field (Koopmanschap et al., 2002; Tri et al., 2002). In the depressed areas, modified-extensive shrimp and semi-intensive shrimp systems have been introduced. The mangrove forest remained as a narrow trip along the coast (Koopmanschap et al., 2002). Further in land, mangrove-forests, salt pans, and artemia (a tiny salt tolerant crustacean of which the eggs are a high value export product) ponds can be found.

Land use change 2002-2003

The land use in the study area has been very dynamic and there was a strong trend towards aquaculture or to a mixture of agriculture-aquaculture (Table 4.1). Within one year, the land use in more than half of the study area changed (58%), mostly from agriculture to aquaculture (13.7%); from agriculture to mixed agriculture-aquaculture (11.9%); from mixed salt-aquaculture or mixed forest-aquaculture to aquaculture (8%), and from agriculture to aquaculture (7.8%). Figure 4.2 shows the locations of the changes. It should be noted that of the unchanged areas, more than 64% was already used for aquaculture and more than 20% for a mixture of aquaculture with something else. This means that aquaculture has become the dominant production activity in the study area.

Table 4.1. Land use change 2002 2003

Land use 2002	*Land use 2003*	*Change area (ha)*	*Percentage*
Agriculture	*Agriculture*	*674.56*	*6.94*
Agriculture	*Aquaculture*	*761.62*	*7.84*
Agriculture	*Fallow*	*2.69*	*0.03*
Agriculture	*Mixed aquaculture agriculture*	*1157.87*	*11.92*
Aquaculture	*Agriculture*	*33.19*	*0.34*
Aquaculture	*Aquaculture*	*3259.95*	*33.56*
Aquaculture	*Fallow*	*40.19*	*0.41*
Aquaculture	*Mixed aquaculture agriculture*	*256.74*	*2.64*
Aquaculture	*Mixed forest aquaculture*	*157.54*	*1.62*
Fallow	*Aquaculture*	*78.16*	*0.80*
Mixed aquaculture agriculture	*Agriculture*	*156.98*	*1.62*
Mixed aquaculture agriculture	*Aquaculture*	*1331.24*	*13.70*
Mixed aquaculture agriculture	*Fallow*	*68.66*	*0.71*
Mixed aquaculture agriculture	*Mixed aquaculture agriculture*	*79.06*	*0.81*
Mixed forest aquaculture	*Agriculture*	*0.79*	*0.01*
Mixed forest aquaculture	*Salt + Atermia*	*501.92*	*5.17*
Mixed forest aquaculture	*Aquaculture*	*74.4*	*0.77*
Mixed forest aquaculture	*Mixed forest aquaculture*	*297.1*	*3.06*
Mixed aquaculture salt + mixed forest aquaculture	*Aquaculture*	*782.06*	*8.05*

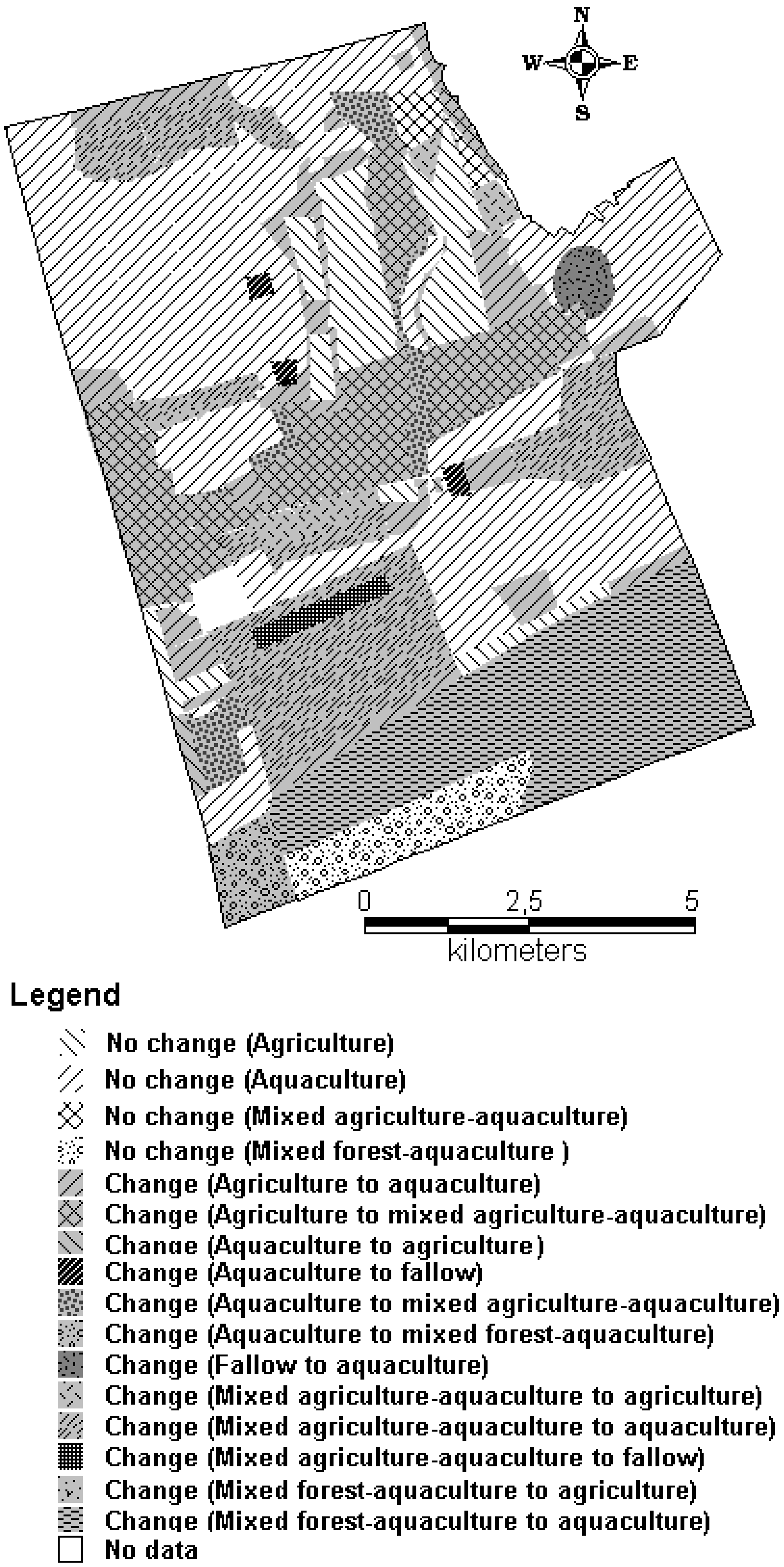


Figure 4.2 Land use change 2002-2003

Realization of preferences

Table 4.2 presents a comparison between the farmers' preferences in 2002 and the actual land use in 2003. The land-use change in 2003 was more than could be expected from the preference expressed by both agriculture and aquaculture farmers in 2002 (Figure 4.3). Half of the preferences were realized, mostly in aquaculture.

Table 4.2 Realization of preferences

Preference 2002	*Land use 2003*	*Change area (ha)*	*Percentage*
Agriculture	*Agriculture*	*577.35*	*5.94*
Aquaculture	*Aquaculture*	*4434.97*	*45.65*
Agriculture	*Aquaculture*	*941.93*	*9.70*
Aquaculture	*Agriculture*	*115.1*	*1.18*
Agriculture	*Mixed aquaculture agriculture*	*927.29*	*9.55*
Aquaculture	*Mixed aquaculture agriculture*	*562.96*	*5.79*
Mixed aquaculture agriculture	*Agriculture*	*168.31*	*1.73*
Mixed aquaculture agriculture	*Aquaculture*	*1631.7*	*16.80*
Mixed aquaculture agriculture	*Mixed aquaculture agriculture*	*14.5*	*0.15*
Mixed aquaculture agriculture	*Fallow*	*2.69*	*0.03*
Agriculture	*Fallow*	*24.33*	*0.25*
Aquaculture	*Fallow*	*84.52*	*0.87*
Aquaculture	*Mixed forest aquaculture*	*157.54*	*1.62*
Agriculture	*Mixed forest aquaculture*	*71.53*	*0.74*

In many of the areas where plans could not be realized, aquaculture or mixed agriculture-aquaculture was practiced instead of the preferred agriculture. In other locations, aquaculture was also practiced instead of the preferred mixture of agriculture-aquaculture. The main reasons for those changes were that aquaculture has a higher profit than rice (Be et al., 2003; Tri et al., 2002), and that increasing salt-water intrusion due to the expansion of aquaculture forces farmers to plan for aquaculture as other agricultural practices become virtually impossible because of the lack of fresh water (Kempen, 2004). Moreover, according to the adjustment plan for the coastal areas of Bac Lieu, the government was advised to invest in dredging existing canals and excavating new canals for aquaculture development (PCBL, 2001).

Only about 1.7% of the areas where plans were not realized remained agriculture even though the farmers would have preferred mixed agriculture-aquaculture. The reasons according to the farmers were: lack of capital, little knowledge on aquaculture and doubts of shrimp success. Besides the high investment cost and high demand regarding management, shrimp cultivation encounters a number of risk such as shrimp diseases (Brennan et al., 1999; MRC, 2003), frequently occurring weather shock, poor water quality, and unstable market (Kempen, 2004; Tri et al., 2002). The realization of preferences in the study area is mapped in Figure 4.3. It shows that most of the not realized plans are in the Northern half of the study area. This is where the change from riceland to shrimp occurred or is still taking place.

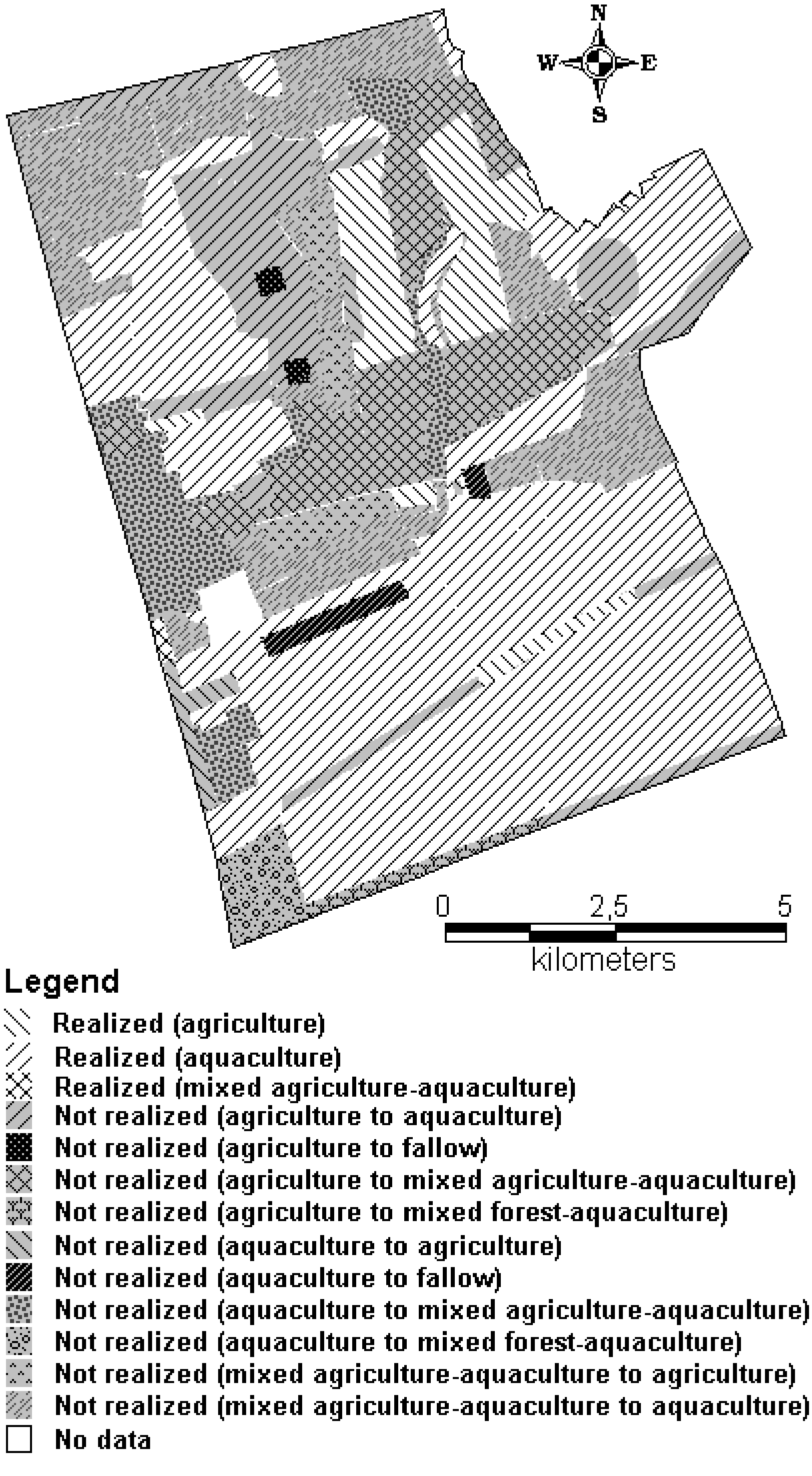


Figure 4.3 Realization of the farmers' preferences

Change in preferences

Table 4.3 presents the changes in the farmers' preferences over one year (2002, 2003). It shows that the preference to aquaculture was quite consistent; about 50% of the total area has that same preference in both years.

The major change in farmers' preference was the increased preference for aquaculture at the expense of agriculture (Figure 4.4). While in 2002 the farmers' preference for agriculture covered 27% of the area, in 2003 this was only 4%, in which vegetables were the main preference. The preference change from agriculture to aquaculture or to mixed agriculture-aquaculture was about 23.6% of the total area and again is found in the Northern half of the study area. The preference change from mixed agriculture-aquaculture to mono aquaculture covered 17.6% of the area. The main reason for this preference change was similar to that of preference realization: high benefit of aquaculture, the inevitable salt-water intrusion, and the government policy giving priority to aquaculture development.

Table 4.3 Preferences change

Preference 2002	*Preference 2003*	*Change area (ha)*	*Percentage*
Agriculture	*Agriculture*	*333.63*	*3.43*
Agriculture	*Aquaculture*	*1690.26*	*17.40*
Agriculture	*Mixed aquaculture agriculture*	*601.72*	*6.19*
Aquaculture	*Aquaculture*	*4917.65*	*50.62*
Aquaculture	*Agriculture*	*46.68*	*0.48*
Aquaculture	*Mixed aquaculture agriculture*	*390.76*	*4.02*
Mixed aquaculture agriculture	*Agriculture*	*18.04*	*0.19*
Mixed aquaculture agriculture	*Aquaculture*	*1714.17*	*17.65*
Mixed aquaculture agriculture	*Mixed aquaculture agriculture*	*1.81*	*0.02*

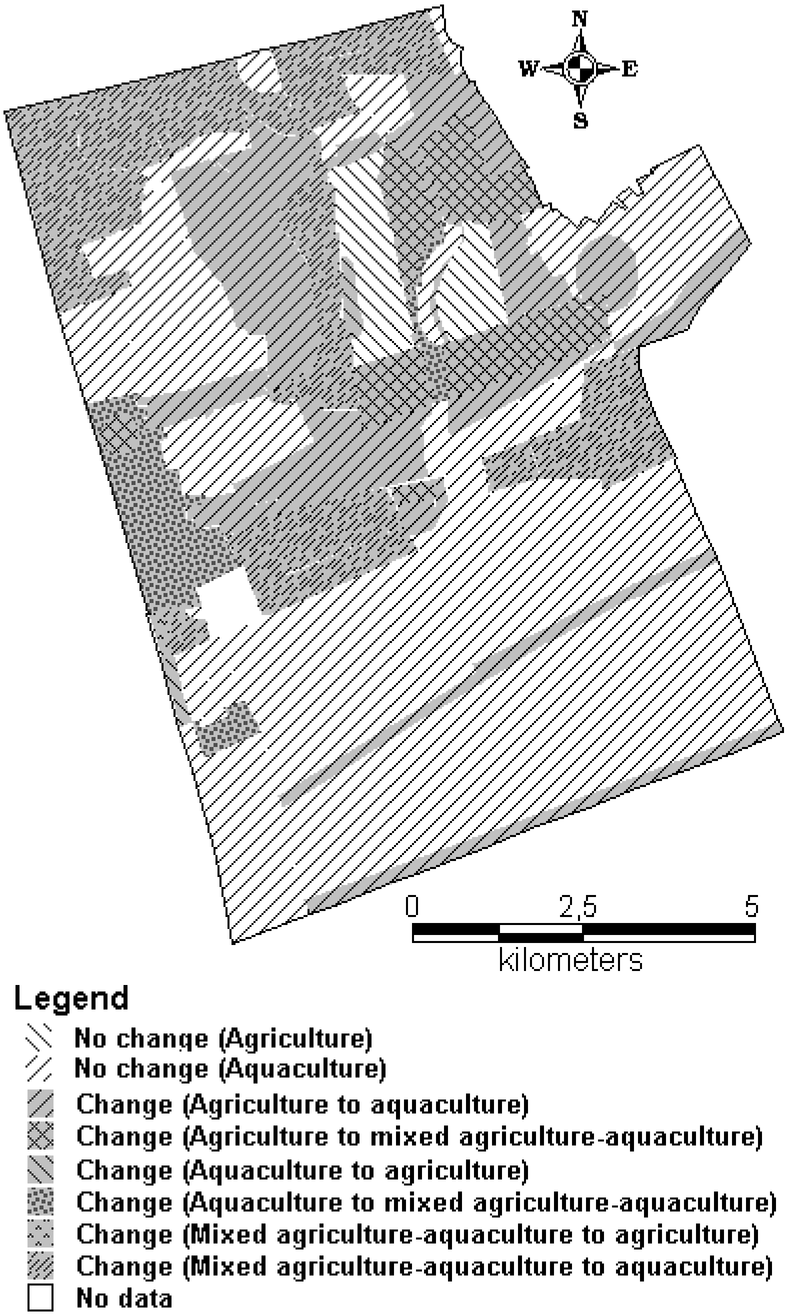


Figure 4.4 Preference change

Preference conflicts

Conflicts in preference were analysed for all seven hamlets with both the agriculture and aquaculture groups. The 2003 preference maps of both groups were overlaid to delineate the areas of preference conflict. The difference in preference was classified into five levels (Figure 4.5): (i) same land-use preference, (ii) partly different preference based on natural conditions: some farmers in one group partly agree with the land use plan by the other group because they had similar ideas about the natural conditions, for example, in the centre-West part of the study area, rice-shrimp system was agreed by both groups because this area does not have enough saline water for more intensive shrimp but still has good conditions to grow one rice crop in the rainy season; (iii) partly different preference based on economic considerations: some farmers in one group partly agree with the land use plan by the other group because of similar economic reasons, for example, in the central-East part of the study area, farmers agreed to cultivate rice-shrimp because rice yield were declining, but a change to shrimp cultivation only requires very high investments and is therefore too risky for them; (iv) completely different preference based on natural conditions, and (v) completely different preference based on economic considerations. In most of the cases, the aquaculture groups wanted to convert part of the agricultural land into shrimp land while the agriculture groups wanted to continue cultivating their crops. The agriculture groups either lacked capital and knowledge on aquaculture or believed that rice and vegetables were less risky and still profitable.

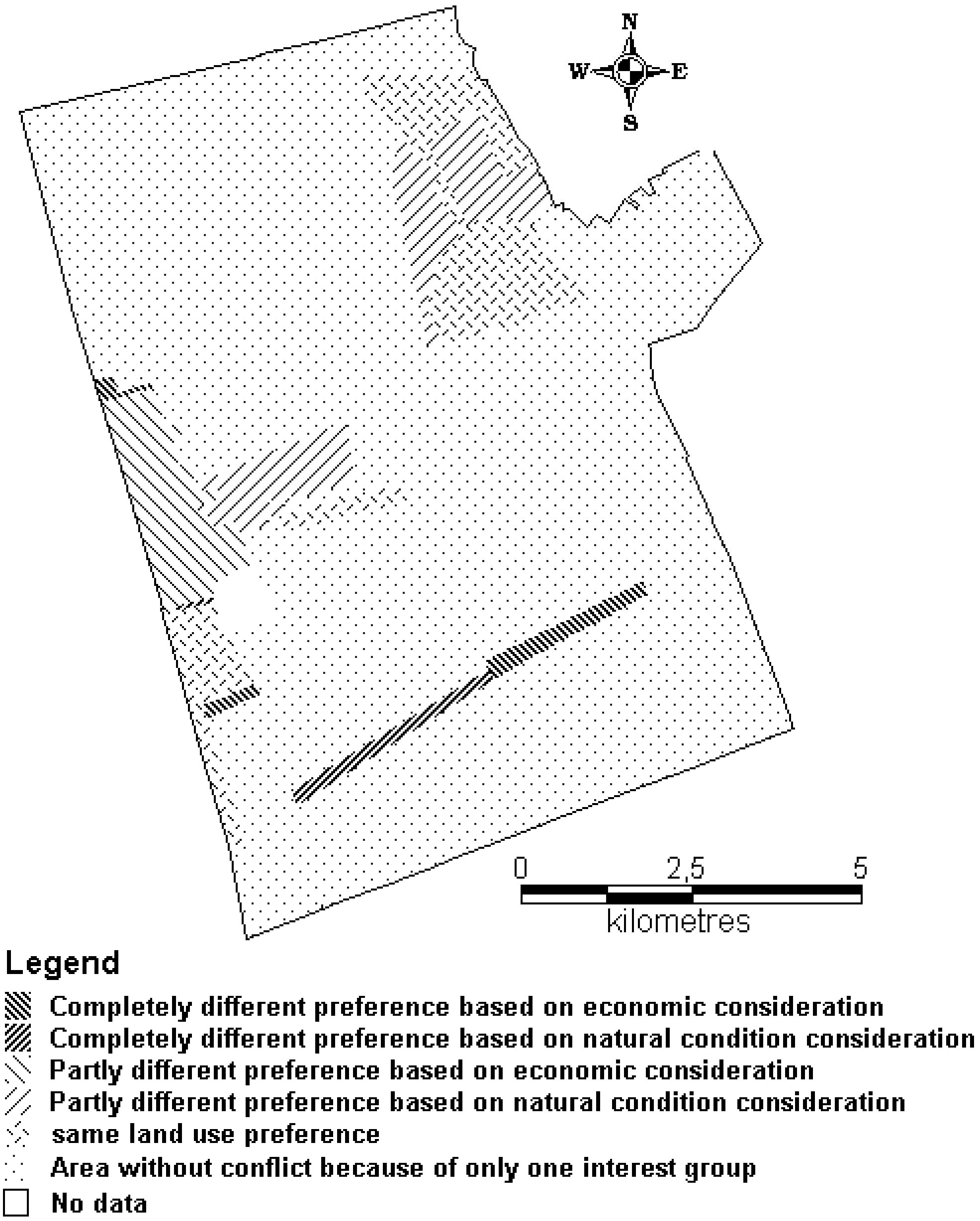


Figure 4.5 Preference conflict

Land use plan for 2004

For an objective comparison of the three LUP approaches used in this thesis, land use plans for 2004 needed to be formulated. The farmers' preferences for 2004 of two farmer groups were incorporated (Figure 4.6). In the areas where preference conflicts occurred, the actual land use in 2003 was used. The actual land use is important because once an area was used for aquaculture, that land can only be used for aquaculture in the next year due to soil salinization. This leads to a problem in the central-West part of the study area. Even though the agriculture farmers prefer to cultivate rice, this area was already used for rice-shrimp in 2003, so it was planned for rice-shrimp or single shrimp (extensive, semi-intensive shrimp). Similarly in the central-East area agriculture farmers cultivated rice in 2003 and their preference for 2004 was rice but because the rice yields had decreased significantly due to salinity intrusion from the surrounding areas, this area was planned for rice-shrimp. The Southwest area, where the agriculture farmers preferred to cultivate vegetable and the aquaculture farmers preferred to cultivate semi-intensive shrimp, was planned for semi-intensive shrimp because that was the main land use in 2003. In the Southeast area, the agriculture farmers preferred only shrimp while the aquaculture farmer preferred forest-shrimp, so for the 2004 plan the forest-shrimp was selected as it is the more environmental friendly land use type.

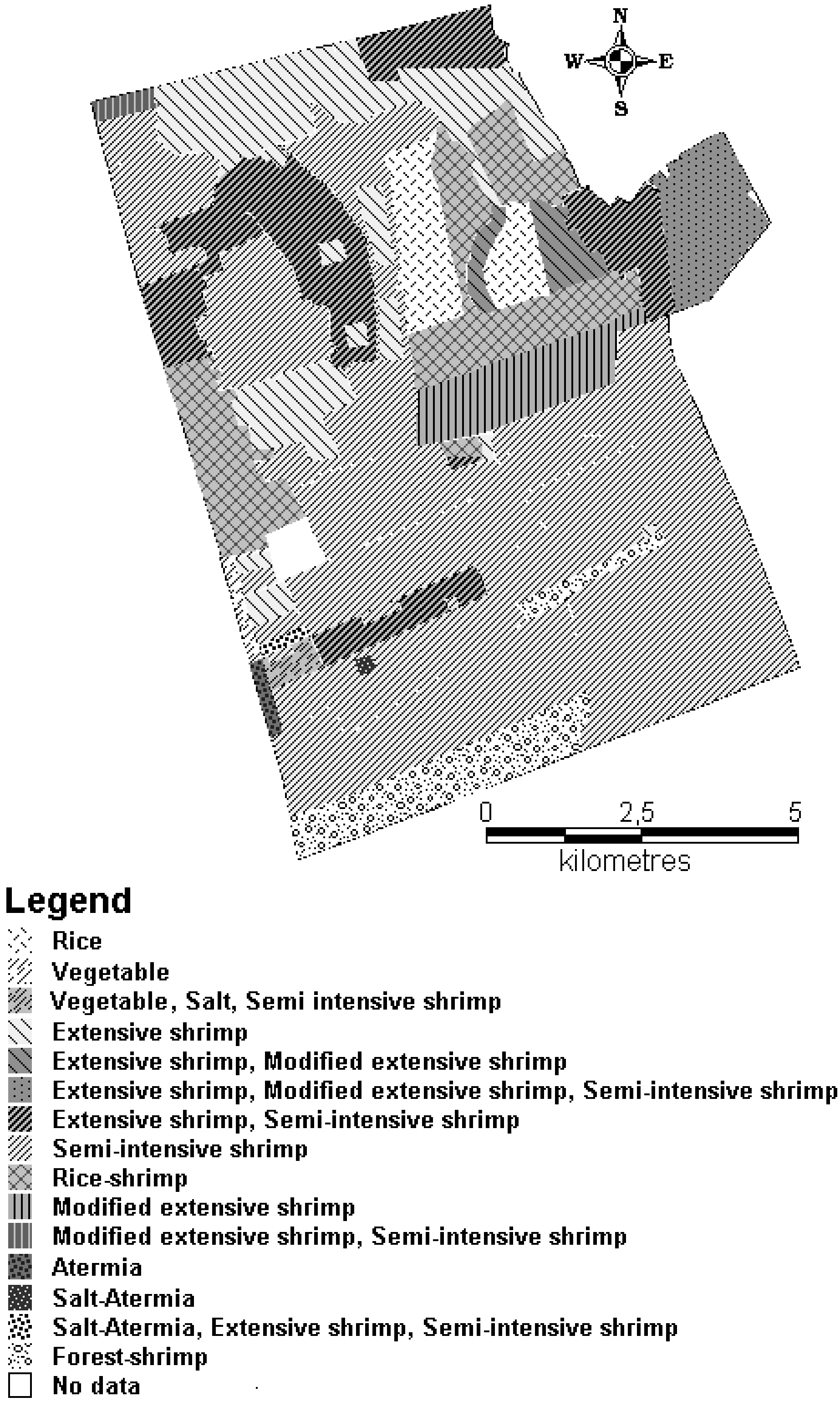


Figure 4.6 Land use plan for 2004

4.3 Conclusion

Land use in the study area has been very dynamic. Within one year more than half of the study area changed, agriculture was mostly replaced by aquaculture. Only half of the farmers' preferences were realized, mostly in aquaculture. The farmers' preference changed largely from agriculture to a mixture of agriculture and aquaculture, or to aquaculture alone. There was a difference in preferences between the agriculture farmers and the aquaculture farmers, caused by differences in their biophysical and economic considerations. GIS is a useful tool to support the data analysis and results presentation.

The PLUP approach is a good tool to get farmers involved into the land use planning approach. Farmers have an opportunity to present their knowledge on the land, express what they need and their opinions on how to use the land.

In the PLUP, farmers got involved with enthusiasm, but this attitude often receded if the discussion was too long (Fagerstrom et al., 2003; Feitsma et al., 2002). In our experience, the discussions should remain shorter than 3 hours.

Separating the aquaculture and agriculture villagers into focus groups can make discussions more specific. Moreover, this can reduce boredom among participants and superficial discussions (Feitsma et al., 2002; Moris and Copestake, 1993). From the land use preference proposed by different villager groups, the potential land use conflict can be derived. This information is very valuable for land use managers, planners and decision makers.

The presence of a hamlet leader during discussions and during farmer interviews usually makes villagers hesitant to give their ideas that differ from the government target (Feitsma et al., 2002). A solution to this difficulty is that the hamlet leader should be invited to lead one of the researcher in a transect walk during the villagers discussion.

By answering the discussion leader's questions, farmers empirically defined the boundaries of the land units based on their knowledge about soil, water and terrain conditions of the study area. However, the questions were raised by outsiders who might tend to refer to issues important to the researcher, not to the farmers. This may result in a loss of issues important to the farmers. Thus, the discussion leader's skill is of great importance. He or she should be able to lead discussion in a way the farmers can give their best description of their land. The accuracy of the land units' boundary can be improved by transects walks together with individual interviews. Using cadastral maps can also help to increase the spatial accuracy.

The study provides the researchers and local land use planners with valuable information about the farmers' perspectives on land use. Through this study considerable experience was gained in applying PLUP in the Mekong Delta.

Chapter 5

Land use planning and analysis system (LUPAS)

5 Land use planning and analysis system (LUPAS)

This chapter describes the application of the LUPAS method to the study area. The development targets and resources availability of the study area were translated into mathematical formulas and solved by a multiple linear programming software. By gradually imposing constraints and goal restrictions, the land use planner and policy maker can recognize which input to be invested and if their goals are feasible. Risk analysis was performed in the cases of salt and shrimp market change, and in case of shrimp disease outbreak. The case study shows that by analyzing different scenarios, the LUPAS model can be used to identify the main constraints to development and the potential of the studied areas if those constraints are overcome. Moreover, LUPAS is used to evaluate whether goals for development are feasible and if yes, how the resources should be best used to optimize goal achievements. However, LUPAS is still a top-down approach even though the stakeholder participation can be illustrated in the form of goal restrictions. The farmers' involvement was difficult in this approach. This chapter also indicates sources of uncertainty of the approach results. The first main source of uncertainty is in the assumptions made on the productions' input-output data, which was based on secondary information, e.g. the input-output of shrimp production. The other source of uncertainty may occur when formulating the objectives, constraints and goals to the model

5.1 Background

The LUPAS methodology was developed under the Systems Research Network for Eco-regional Land Use Planning in Tropical Asia (SysNet) project (1996-2000). The SysNet is a systems research network in South and South-east Asia, established to develop and evaluate methodologies for enhancing strategic land use policies. The network consisted of five partners: national agriculture research and extension institutions (NARES) of India, Malaysia, the Philippines and Vietnam, and the coordinator - The International Rice Research Institute (IRRI). Furthermore, SysNet received scientific and technical support from various research groups of Wageningen University and Research Centre.

In the frame work of the SysNet project, LUPAS has been applied in four case study regions: the Haryana, India (Aggarwal et al., 2001; Aggarwal et al., 2000), Kedah-Perlis Region, Malaysia (MARDI, 2000; Tawang et al., 2000), Ilocos Norte Province, Philippines (Laborte et al., 2001; Lansigan et al., 2000) and Can Tho Province, Vietnam (Aggarwal et al., 2000; Laborte et al., 1999). These study regions differ considerably in biophysical and socio-economic conditions and present a cross-section of intensively cultivated agricultural areas in tropical Asia (Rötter et al., 2000a; Rötter et al., 2000c; Rötter et al., 2005). The overall discussion on these four case study regions is described in Rötter et al.(2000c; 2005) and van Ittersum et al.(2004). These case study regions illustrated that LUPAS can be used to evaluate and analyze the consequences of specific goals for which improved options for development may be suggested. By testing different scenarios, we can answer the question whether the goals for development are feasible, and if yes, at what cost (Aggarwal et al., 2000; Lai et al., 2000; Lansigan et al., 2000). Later, another application was performed for Bac Kan province, Vietnam (Bui et al., 2002).

LUPAS is a computerized decision support system based on the interactive multiple goal linear programming (IMGLP) approach (De Wit et al., 1988; Nijkamp and Spronk, 1980). LUPAS can be applied for scenario analysis of a complex problem such as conflicts in land use (Hoanh et al., 2000; Rötter et al., 2005).

LUPAS (Figure 5.1) consists of four main parts (Laborte et al., 2001; Rötter et al., 2000b; Rötter et al., 2000c; Rötter et al., 2004; van Ittersum et al., 2004): (i) Resource balance and land evaluation, (ii) yield estimation, (iii) input-output estimation, and (iv) Interactive multiple goal linear programming.

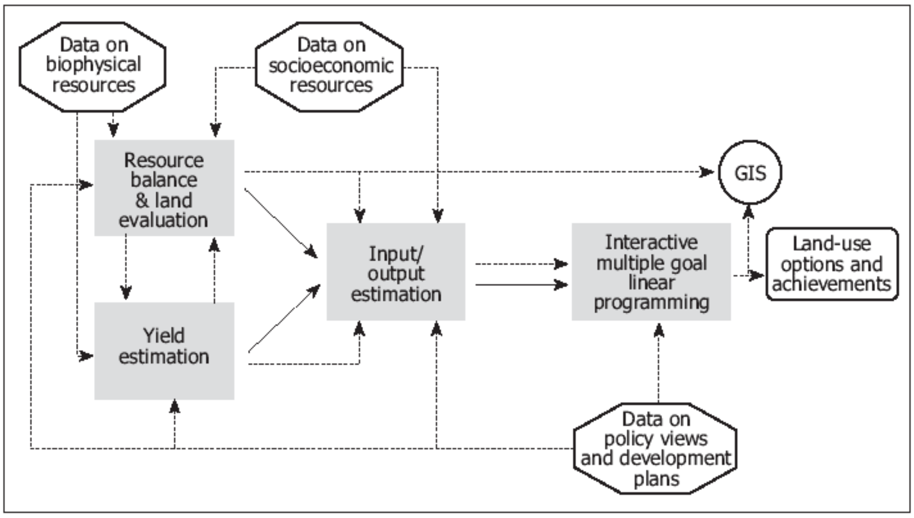


Figure 5.1 Components of LUPAS (Rötter et al., 2000c)

Resource balance and land evaluation

The resource requirements of many Land Use Types (LUTs), are generally similar which creates competition for their use. The "Resource Balance and Land Evaluation" component is critical in determining resource availability and subsequently the potential or limitation of production activities in a particular area (Ismail et al., 2000). The main functions of this component are (Hoanh et al., 2000; Ismail et al., 2000): to identify land units, to estimate available resources, to identify promising land use types and possible technical levels applied in each land unit, to formulate the objectives of development for various land use scenarios, and to identify demand for product and potential changes.

In LUPAS, the study area is divided into land units. A land unit (LU) is a unique combination of an agro-ecological unit and an administrative unit (e.g. hamlet, village, and province). This combination helps socio-economic data collected from administrative units be incorporated in the quantitative evaluation stage (Bui et al., 2002). A LU is considered as the smallest calculation unit (MARDI, 2000). LUs can be obtained by the overlay technique in GIS (Hoanh et al., 2000). The LU map can be used for spatial display of input and output data, as well as for IMGLP analysis results (Ismail et al., 2000).

The promising LUTs and possible technical levels are those either representing major production activities or having great potential on each LU. The promising LUTs and possible technical levels can be determined by qualitative land evaluation, statistical analysis of experimental and survey data, literature review or expert consultation (Hoanh et al., 2000).

The assessment of resource availability such as labour, capital, land or water can be done by means of land evaluation (FAO, 1993) and literature review.

The development objectives can be based on policy views. Policy views represent stakeholders' perceptions on what goals the development should focus on. Policy views are acquired from various policy documents, formal discussions with stakeholders and farm surveys (MARDI, 2000).

Production demand information is important in land use planning. This information is employed to set the boundaries for intended production levels of the various products (Ismail et al., 2000). The estimation of product demand is based on the statistical analysis of market or local demands (Hoanh et al., 2000).

Yield estimation

This component is for estimating the actual and attainable yield of main products from promising LUTs for each agro-ecological unit at possible technology levels. Van Diepen (2000) reviewed various yield estimation techniques that can be applied in LUPAS. The main tools and techniques used for yield estimation are crop yield simulation or statistical models, expert judgment, and farm surveys (Hoanh et al., 2000; Rötter et al., 1998).

Input-output estimation

For each technical level, the corresponding inputs used and outputs produced are estimated. Examples of inputs are total input cost, water quality and quantity, labour requirement, capital, and biocides. Examples of outputs are revenue, yield, crop residues, water table change, and biocide residues of promising LUTs. The inputs and outputs are estimated by using crop models, statistical analysis of experimental and survey data, or expert judgment (Hoanh et al., 2000).

Interactive multiple goal linear programming

The functions of this component are (Hoanh et al., 2000): (i) to generate land use options for each scenario by optimizing selected objective functions under explicit goal constraints, (ii) to identify and analyze conflicts in land use objectives and land resources, (iii) to identify the effects of government policy, (iv) to analyze risk of land use options, and (v) to analyze spatial and temporal distribution of resources to land use types.

The objectives of development are translated into objective functions. The constraints are based on the resources available such as limited labour resource, capital limitation. The goal restrictions are formed based on the development targets such as the minimum rice production for food security.

Scenarios are built to explore the future land use when the biophysical, socio-economic or the development goals change. The results of different land use scenarios are analyzed to show trade-offs between costs and benefits of attaining different goals (Laborte et al., 1999). The main points to be considered when analyzing results of a scenario are (Hoanh et al., 2000):

- How much can be achieved for the optimized objective function in the studied scenario?
- How much can be achieved for other objectives considered in the scenario? Do these achievements increase or decrease compared with optimal values when optimizing the objectives?
- How much resources (land, capital, labour) are used in the scenario? Where and when are they in surplus or short supply?
- How much land is allocated to each land use type and where?

The results are usually presented in graphical or tabular forms, and mapped by geographic information system (GIS).

The IMGLP model can be developed in the mathematical programming software such as XPRESS-MP (Dash Associates Ltd, http://www.dash.co.uk) or GAMS (GAMS Development Corporation, http://www.gams.com). For interactive land use scenario analysis, a user interface should be developed.

5.2 Application of LUPAS to the study area

5.2.1 Approach

Scenario construction

Based on the existing land use planning documents (NIAPP, 1999; PCBL, 2001), the annual development strategy documents and the actual land use of the study area, the following objectives and goal restrictions are distinguished: Maximizing the total regional income from agriculture and aquaculture produce; realizing the strategic rice, shrimp, salt, and vegetable production quota; and protecting the mangrove forest. However, since the study objective of this thesis is to compare the land use plan generated by LUPAS with the results of the other two LUP methodologies, FAO-MCE (Chapter 3) and PLUP (Chapter 4), the case study was narrowed to optimizing the total income of Vinh My A and Vinh Thinh villages at two scenarios:

- All of the farmers apply the actual technical level: this refers to the production techniques currently practiced by the majority of the farmers in the study area.
- All of the farmers apply the improved technical level: this refers to a higher level of production, bringing the ‘attainable yield’ (Tawang et al., 2000). This presents the yield attained by advanced farmers in the study area.

In order to assess the effect of different resource constraints on the total income of the study area, different sets of constraints and goals restrictions were imposed:

- Biophysical and socio-economic resource constraints: (i) The total area of all LUTs allocated in a LU must be less than or equal to the total available area of that LU; (ii) The total labour needs for all planned production activities in a village must be less than or equal to the total available of that village. (iii) The total capital need for the allocated LUTs in a LU must be less than or equal to the total available capital of that LU.
- Goal restrictions: (i) The total rice, shrimp, salt, and vegetable productions of the study area must be greater or equal to the rice, shrimp, salt, and vegetable productions required/targeted by the local government; (ii) The total mangrove forest areas allocated in the study area must be greater or equal to the mangrove forest area that is target by the local government.

Since shrimp and salt are very unstable products in terms of price and yield, the following risk analyses were conducted under each scenario: (i) the salt price drops from 300 VND/kg to 140 VND/kg (this happened in March 2004); (ii) the shrimp price drops from 140,000

VND/kg to 70,000 VND/kg (this happened in June 2004); (iii) the yield of shrimp is assumed to be equal to the average minimum yield of the study area (0.15 ton/ha). Because the shrimp price is based on the number of shrimp per kilogram, the average shrimp price of a yield of 0.15 ton/ha was assumed to be 50,000 VND/kg.

Resource balance and land evaluation

Land units: There are two villages in the study area, Vinh My A and Vinh Thinh. Socio-economic data on labour, capital and development objectives are available at village level, so village boundaries were used to reflect the socio-economic variation in the study area.

The NIAPP study (1999) on land evaluation for the coastal area of Bac Lieu province classified the study area into 8 bio-physical land mapping units. The characteristics of land mapping unit were based on soil type, topography, rainfall duration, tidal fluctuation, inundation depth, and inundation duration (see Table 3.1 in Chapter 3). Overlaying the biophysical land mapping unit map with the village boundary map resulted in 30 land units.

Resources availability

Available land: Available land area for the production activities in the study area was determined by excluding the built-up area and the protected area. The total available area of the study area is 10,700 hectares.

Available labour: Available labour in the study area was estimated based on the total population. The total population of Vinh My A and Vinh Thinh is 17,700 and 10,480 respectively (NIAPP, 1999). Tri et al. (2002) shows that 60% of the study area population is between 18 to 60. In the study area many labourers are under 17 years of age. Besides, the labour force may also come from the adjacent villages. Thus, the available labour for each village is assumed to be 60% of the total population of the village plus 10% of total population of the surrounding villages. The monthly available labour (expressed in labour day/month) of a village can be estimated as the total available labour in the village times 6 days per week times 4 weeks per month.

Available capital: Because data on capital used were not available, it was estimated from the current input cost for actual land use plus the available credit. In the case study, the actual land use map of 2002 (Chapter 4) was used to generate the available capital map. Each LU is assigned a value of available capital, which is the average input cost of the actual land use types in the LU plus the average available credit.

Water resources: The water resource is a characteristic of a LU. In this study, water resource is taken into account in terms of the promising LUTs' suitability level. The suitability of LUTs in LU affects their input and output.

Promising land use types

Promising land use types are based on the actual land use, the land suitability class from land evaluation, and the policy view. The following LUTs were considered in this study: (i) single rice, (ii) rice-vegetable, (iii) vegetable, (iv) extensive shrimp, (v) modified extensive shrimp, (vi) semi-intensive shrimp, (vii) salt, (viii) salt-shrimp, (ix) forest-shrimp, (x) rice-shrimp and (xi) mangrove forest. The detailed description of the LUTs is presented in Table 2.2 (Chapter 2).

Yield and input-output estimation

The input-output situation is described by total input cost, labour requirement, and revenue of each promising LUT per LU. Yield and input-output of LUTs is estimated based on the technical levels defined above:

- The current technical level: yield and input-output is the recent average value from the field survey or the previous studies such as Be et al.(2003), Kempen (2004), NIAPP (1999), Tri et al. (2002), PCBL (2001).
- The improved technical level: yield and input-output are the recent maximum value from the field survey or the previous studies.

5.2.2 Results and discussion

A LUPAS model for the case study

A LUPAS model for the case study has been developed using the GAMS software. The model includes several modules for data input, and optimization of scenarios. Besides, a data transformation tool was built to integrate the model with GIS (see appendix 2).

In general, the model includes the following modules: (i) the 'data input' module for getting the data from the database, (ii) the 'declaration of objective, constraint and goal restriction functions' module, (iii) the 'defined models' module for defining the optimization sub-scenarios and (iv) the 'result' module for writing the sub-scenario' results in Microsoft Excel Comma Separated Values files (CSV) so that the results can be read by Microsoft Excel or by the GIS software.

According to the Statistical office of Vinh Loi district (2003), the production target set for the study area for the year 2004 were: Rice > 2,940 ton; Shrimp > 8,701 ton; Salt > 16,000 ton;

Vegetable > 1,590ton, and the forest area > 1,360 ha. Since that vegetable product was consumed locally, the total vegetable production should not be greater than the local demand, estimated at 3,000 ton.

Land use planning analysis

This section describes the use of the LUPAS model to analyse the influences of different resource constraints and goal restrictions on the total income of the study area. From this the land use options can be proposed. The combinations of objective function with sets of constraints and/or goal restrictions constitute a total of 16 sub-scenarios. The description of sub-scenarios is presented in Table 5.1.

Table 5.1 Description of sub-scenarios

Sub-scenarios	*Constraints*			*Goal restriction*				
	Land	*Labour*	*Capital*	*Rice*	*Salt*	*Shrimp*	*Vegetable*	*Forest*
1	•							
2	•	•						
3	•		•					
4	•	•	•					
5	•	•	•	•				
6	•	•	•		•			
7	•	•	•			•		
8	•	•	•				•	
9	•	•	•	•		•		
10	•	•	•		•	•		
11	•	•	•	•			•	
12	•	•	•	•	•	•	•	
13	•	•	•		•	•	•	•
14	•	•	•	•	•		•	•
15	•	•	•	•		•	•	•
16	•	•	•	•	•	•	•	•

Sub-scenario 1 represents the most favourable conditions, i.e. when only land constraints occur. This is the ideal condition, hard to achieve in reality. However, it can be used to evaluate the potential total income from agriculture and aquaculture at the actual biophysical conditions. Increases in resource constraints and goal restrictions are meant to figure out which constraints and goal restrictions most affect the overall goal, so that the trade-off between the goals can be analyzed for the more feasible and sustainable land use plan. The sub-scenarios 4 to 16 represent a number of technical levels, showing all the resource constraints and different sets of goal restrictions that are close to reality.

Land allocation

The figures in Tables 5.2 and 5.3 illustrate that the allocation of LUTs in both scenarios, present technical level and improve technical level, has a similar trend. When capital is enough (sub-scenarios 1 and 2), the semi-intensive shrimp is the main alternative (54% and 70% in scenario 1 and scenario 2 respectively). When capital is limited (sub-scenario 3), the modified extensive shrimp, vegetables, and forest-shrimp are the best substitutions. At the present technical level, the shrimp target goal is not feasible (sub-scenarios 7, 9, 10, 12, 13, 15 and 16).

When both capital and labour are limited (sub-scenario 4), the modified extensive shrimp area is reduced but still be the major land use in the study area. The other major LUT is forest-shrimp. Vegetable is also selected for higher income if more market is available. Rice and rice-shrimp areas are allocated to a small area.

Except for the case of no resources limitations (sub-scenario 1), 100% of available land is never used. This implies that for maximum income, some land should be left abandoned so that the capital and labour resources can be used effectively in order to generate more income. For each technical level, 16 sets of land allocation maps can be drawn by linking to GIS. Figure 5.2 presents an example of how the model allocates LUTs in the study area.

Table 5.2 Percentage of land allocated for LUTs in scenario 1* (the present technical level)

Sub-scenarios	*SR*	*V*	*RV*	*eS.*	*m-eS*	*s-IS*	*S*	*F*	*FS*	*R S*	*SS*
1	*0*	*8*	*0*	*0*	*18*	*54*	*0*	*0*	*17*	*1*	*1*
2	*2*	*4*	*0*	*0*	*3*	*54*	*0*	*0*	*16*	*1*	*4*
3	*0*	*8*	*0*	*0*	*59*	*0*	*0*	*0*	*17*	*1*	*1*
4	*1*	*8*	*0*	*0*	*45*	*1*	*0*	*0*	*17*	*1*	*11*
5	*4*	*8*	*0*	*0*	*45*	*1*	*0*	*0*	*17*	*1*	*10*
6	*1*	*8*	*0*	*0*	*45*	*1*	*4*	*0*	*17*	*1*	*7*
8	*1*	*2*	*0*	*0*	*45*	*1*	*0*	*0*	*17*	*1*	*10*
11	*5*	*2*	*0*	*0*	*46*	*1*	*0*	*0*	*17*	*1*	*10*
14	*5*	*2*	*0*	*0*	*52*	*1*	*4*	*6*	*11*	*1*	*0*

*Note: * Sub-scenarios 7, 9, 10, 12, 13, 15 and 16 are not feasible at the present technical level.*
SR: Single rice; V: Vegetable; RV: Rice_Vegetable; eS: Extensive shrimp;
m-eS: Modified extensive shrimp; s-IS: Semi-intensive shrimp; S: Salt; F: Mangrove forest;
FS: Forest_Shrimp; RS: Rice_Shrimp; SS.: Salt_Shrimp

Table 5.3 Percentage of land allocated for LUTs in scenario 2 (improved technical level)

Sub-scenarios	*SR*	*V*	*RV*	*eS*	*m-eS*	*s-IS*	*S*	*F*	*FS*	*RS*	*SS*
1	*0*	*8*	*0*	*0*	*0*	*73*	*0*	*0*	*17*	*1*	*1*
2	*3*	*4*	*0*	*0*	*0*	*70*	*1*	*0*	*0*	*1*	*0*
3	*0*	*8*	*0*	*0*	*51*	*0*	*0*	*0*	*11*	*1*	*1*
4	*0*	*8*	*0*	*0*	*45*	*0*	*0*	*0*	*11*	*1*	*7*
5	*3*	*8*	*0*	*0*	*45*	*0*	*0*	*0*	*11*	*1*	*6*
6	*0*	*8*	*0*	*0*	*45*	*1*	*3*	*0*	*11*	*1*	*4*
7	*0*	*8*	*0*	*0*	*45*	*0*	*0*	*0*	*11*	*1*	*7*
8	*0*	*2*	*0*	*0*	*46*	*0*	*0*	*0*	*11*	*1*	*6*
9	*3*	*8*	*0*	*0*	*45*	*0*	*0*	*0*	*11*	*1*	*6*
10	*0*	*8*	*0*	*0*	*45*	*1*	*3*	*0*	*11*	*1*	*4*
11	*3*	*2*	*0*	*0*	*46*	*0*	*0*	*0*	*11*	*1*	*6*
12	*3*	*2*	*0*	*0*	*46*	*0*	*3*	*0*	*11*	*1*	*3*
13	*0*	*2*	*0*	*0*	*46*	*1*	*3*	*6*	*11*	*1*	*4*
14	*3*	*2*	*0*	*0*	*46*	*0*	*3*	*6*	*11*	*1*	*3*
15	*3*	*2*	*0*	*0*	*46*	*0*	*0*	*6*	*11*	*1*	*6*
16	*3*	*2*	*0*	*0*	*46*	*0*	*3*	*6*	*11*	*1*	*3*

Note:
SR: Single rice; V: Vegetable; RV: Rice_Vegetable; eS: Extensive shrimp;
m-eS: Modified extensive shrimp; s-IS: Semi-intensive shrimp; S: Salt; F: Mangrove forest;
FS: Forest_Shrimp; RS: Rice_Shrimp; SS.: Salt_Shrimp

Technical levels and total income

Tables 5.4 and 5.5 illustrate that by improving cultivation technology to the recent optimal level, the total income of the study area can increase at least two times except for the ideal condition where no capital limitation is involved (sub-scenario 1 and 2). It is obvious that, at the improved technical level, the management is more effective, leading to higher benefit.

Available resources and total income

Labour: Tables 5.4 and 5.5 show that the income reduction at the improved technical level is higher than at the actual technical level when labour resource constraint is involved. The figures also show that when the capital constraint is taken into account (sub-scenario 3 to 16), the total labour requirement is much lower compared to the available labour. This can be explained by the fact that, due to the labour limitation, the optimization model reduces the semi-intensive shrimp area with high labour requirement and high benefit (tables 5.2 and 5.3).

Capital: The lack of capital is the main constraint for maximizing income of the study area (sub-model 3). In both scenarios, the maximum income decreases significantly if the capital is limited (from 1,944 million VND to 1.110 million in the first scenario and from 6,378 million

VND to 2,046 million VND in the second scenario). This is obvious because when capital suffices, land is allocated for semi-intensive shrimp which requires highest capital and brings the highest benefit. On the contrary, when capital is limited, land is allocated for those LUTs with less capital requirement and lower benefit e.g. modified extensive shrimp, vegetable (see tables 5.2 and 5.3).

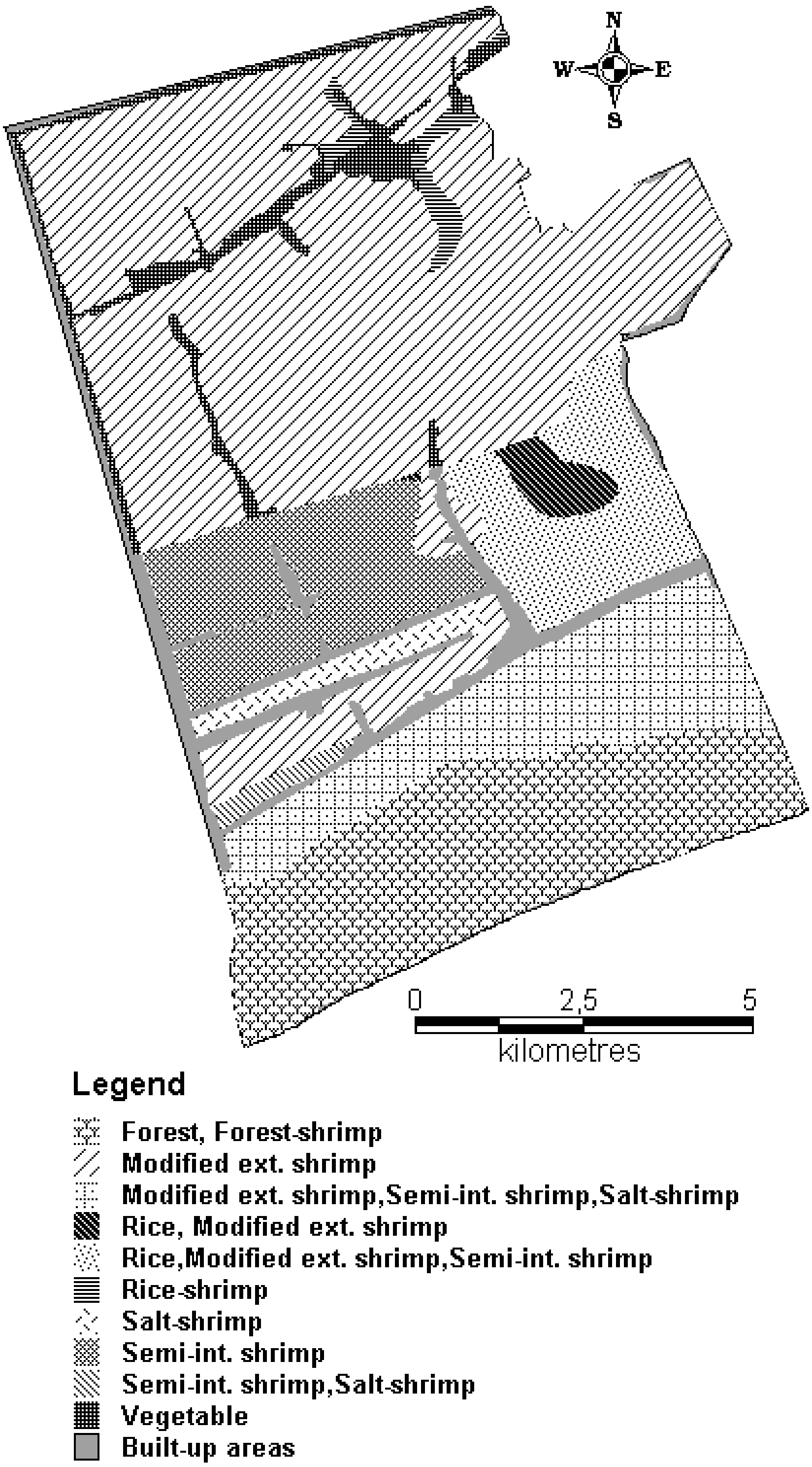


Figure 5.2 Land allocation map for sub-scenario 14 (with rice, vegetable, salt and forest goals) at the present technical level

Goal restriction and income

Tables 5.4 and 5.5 show that when more goal restrictions are imposed, from sub-scenario 4 to sub-scenario 16, the income of the study area does not change very much in both scenarios (present technical level and improved technical level).

At the present technical level, the shrimp production goal of 8,700 ton cannot be achieved (sub-scenarios 7, 9, 10, 12, 13, 15, 16) even when no other goals are imposed (sub-scenario 4). Moreover, the total income decreases slightly when rice, salt and forest area goals are imposed.

At the improved technical level, with higher shrimp yield, the shrimp production is very high compared to the actual target. Imposing rice, vegetable and mangrove forest goals decreases the total income because of loss of land allocated for the more profitable shrimp LUTs (see Tables 5.2 and 5.3).

Table 5.4 Results of maximizing income at present technical level.

Sub-scenarios	*Income (10^6 VND)*	*Production (ton)*				*Environment*	*Resource used*		
		Rice	*Shrimp*	*Salt*	*Vegetable*	*Forest (ha)*	*Land (%)*	*Capital (10^6 VND)*	*Labour (10^6 days)*
1	1,944	351	22,611	0	15,115	1,096	100	1,241	1.85
2	1,694	1,474	20,485	0	7,208	1,050	84	1,188	1.39
3	1,110	351	9,123	0	15,115	1,096	87	186	1.41
4	973	738	8,025	0	15,115	1,096	83	178	1.29
5	972	2,940	7,990	0	15,115	1,096	86	177	1.29
6	957	738	7,865	16,000	15,115	1,096	83	178	1.29
7	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
8	968	738	8,071	0	3,000	1,096	76	174	1.17
9	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
10	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
11	968	2,940	8,045	0	3,000	1,096	80	175	1.18
12	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
13	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
14	916	2,940	7,737	16,000	3,000	1,360	81	181	1.10
15	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA
16	NA	NA	Infeasible	NA	NA	NA	NA	NA	NA

Table 5.5 Results of maximizing income at improved technical level.

Sub-scenarios	*Income (10^6 VND)*	*Production (ton)*				*Environ-ment*	*Resource used*		
		Rice	*Shrimp*	*Salt*	*Vegetable*	*Forest (ha)*	*Land (%)*	*Capital (10^6 VND)*	*Labour (10^6 days)*
1	*6,378*	*539*	*49,966*	*6,365*	*15,115*	*1,096*	*100*	*1,637*	*2.05*
2	*5,501*	*2,735*	*43,656*	*8,433*	*7,208*	*0*	*79*	*1,500*	*1.41*
3	*2,047*	*524*	*14,027*	*6,365*	*15,115*	*712*	*73*	*218*	*1.17*
4	*1,984*	*524*	*13,591*	*29,718*	*15,115*	*712*	*73*	*218*	*1.17*
5	*1,978*	*2,940*	*13,531*	*26,824*	*15,115*	*712*	*76*	*218*	*1.18*
6	*1,984*	*524*	*13,591*	*29,718*	*15,115*	*712*	*73*	*218*	*1.17*
7	*1,984*	*524*	*13,591*	*29,718*	*15,115*	*712*	*73*	*218*	*1.17*
8	*1,980*	*524*	*13,636*	*27,393*	*3,000*	*712*	*76*	*214*	*1.05*
9	*1,978*	*2,940*	*13,531*	*26,824*	*15,115*	*712*	*76*	*218*	*1.18*
10	*1,984*	*524*	*13,591*	*29,718*	*15,115*	*712*	*73*	*218*	*1.17*
11	*1,974*	*2,940*	*13,577*	*24,498*	*3,000*	*712*	*69*	*214*	*1.06*
12	*1,974*	*2,940*	*13,577*	*24,498*	*3,000*	*712*	*69*	*214*	*1.06*
13	*1,972*	*524*	*13,584*	*27,824*	*3,000*	*1,360*	*72*	*214*	*1.06*
14	*1,966*	*2,940*	*13,524*	*24,929*	*3,000*	*1,360*	*75*	*214*	*1.07*
15	*1,966*	*2,940*	*13,524*	*24,929*	*3,000*	*1,360*	*75*	*214*	*1.07*
16	*1,966*	*2,940*	*13,524*	*24,929*	*3,000*	*1,360*	*75*	*214*	*1.07*

The risks

Three scenarios have been analyzed: (i) the salt price drops from 300 VND/kg to 140 VND/kg (this happened in March 2004); (ii) the shrimp price drops from 140,000 VND/kg to 70,000 VND/kg (this happened in June 2004); and (iii) the yield of shrimp is assumed to drop to the average minimum yield of the study area 0.15 ton/ha (e.g. because of a shrimp disease outbreak) with a corresponding price of 50,000 VND/kg.

The results show that the salt price change does not affect much the total income because salt is not a main product of the study area. However, when shrimp price reduces 50%, the total income also decreases 50% and if the shrimp yield drops to the average minimum yield of the study area, no income is earned. This implies that when the shrimp price reduces, and especially, when shrimp yield drops, the land use options for high income with high proportion of shrimp land is very risky. It should be noted that the land that has been used for salt, modified extensive shrimp, semi-intensive shrimp is hard to convert back to the other LUTs such as rice, and vegetable. Thus, for sustainable land use, the proportion of shrimp land should not be too high if the management technology is not improved so that shrimp disease outbreak can be prevented.

The LUPAS Land use plan for 2004

The land use plan for 2004 was proposed (Figure 5.3) based on the results of sub-scenario 14, and at the present technical level. This sub-scenario takes into account the governmental goals for 2004 (Rice > 2,940 ton; Salt > 16,000 ton; Vegetable > 1,590 ton, and the forest area > 1,360 ha), without the shrimp production goal which was not feasible (Sub-scenario 16). The plan also takes into account the labour and budget limitations. Since the model allocates the LUTs to the LU randomly based on the model's suggested LUTs' areas, a reallocation of the LUT is necessary. The reallocation is made first according to the land suitability of the LUTs and second based on the proportion of LUTs' area to the LU. For example, if the assigned area of an LUT is too small compared to the area of the LU, that LUT should be allocated to a smaller LU. The vegetable market was also considered. Since vegetables can easily be bought from the land north of NR1A and at a cheap price, it should not be allocated to the areas near the NR1A but better to areas along the roads/dikes near the coast and provide there for local consumption. The combined rice-shrimp system was allocated to land near the NR1A because there much fresh water is available and this is the area recently used for rice. More intensive shrimp systems were allocated seaward close to the forest belt.

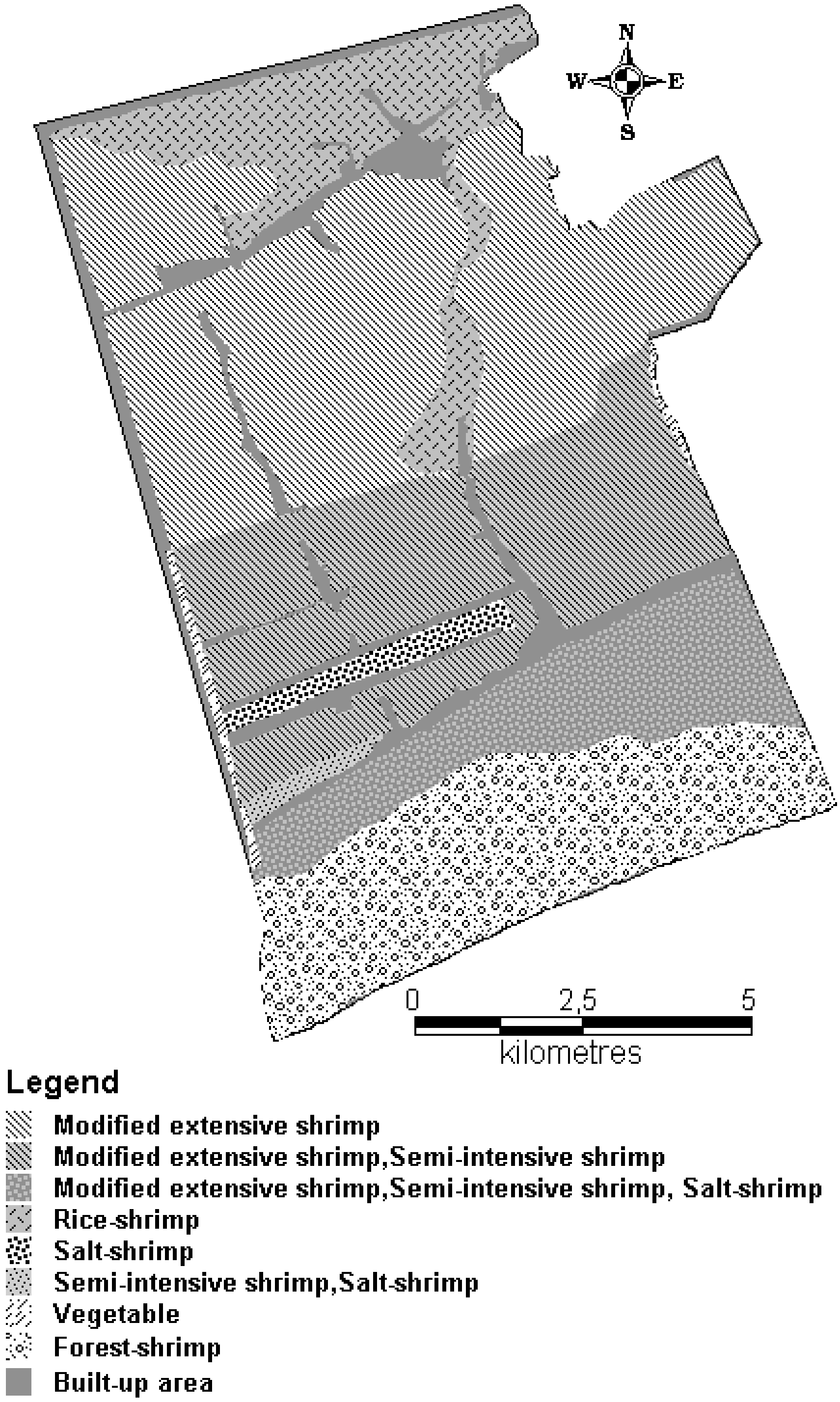


Figure 5.3 Land use plan for 2004.

5.3 Conclusion

The case study shows that by analyzing different scenarios, the LUPAS model can be used to point out the main constraints of the development and the potential of the studied areas if those constraints are overcome. Moreover, LUPAS is used to evaluate whether development goals are feasible and if yes, how the resources should best be used to optimize goal achievements (Rötter et al., 2004). This valuable information supports the land use planners, and policy makers in setting up feasible development goals and effective investments.

The scenario analysis shows that:

(i) For maximizing the total income of the study area, the model assigns a high proportion of land area to shrimp LUTs. This can be very risky in case of a shrimp yield decline due to disease.

(ii) A twice-higher income can be achieved by improving cultivation technology to the existing maximum level.

(iii) Capital and cultivation techniques are the main constraints. Labour problems can be solved by using machines, especially in land preparation and harvesting.

(iv) Goal restrictions (upper limit of production targets) slightly affect the total income but strongly influence land allocation. Thus, by changing goal restrictions, the risk can be reduced, for example, reducing the shrimp production target.

There are three difficulties that this study experienced when applying LUPAS. First, the study results may not be precise because it depends very much on the assumptions made on the input-output data (Tawang et al., 2000). The estimation of input-output data was based on secondary information. Its accuracy may deteriorate in case of unexpected events such as drastic changes in demand for certain resource from other sectors as a result of a change in government policy or ecological situations (Ismail at al., 2000). Second, the methodology required not only certain level of skill on modeling techniques but also knowledge on defining and reflecting the problems to the model (Tawang et al., 2000). One must define the suitable scenarios for analysis, right constraints and goal restrictions in order to answer the study questions. Finally, this approach is still a top-down approach even though the stakeholder participation can be illustrated in the form of goal restrictions. The approach cannot clearly show the potential conflict areas, so the plan may easily fail implementation (Lai et al., 2000).

Chapter 6

Comparing land use planning approaches

This chapter is based on: Trung, N.H. L.Q.Tri, M.E.F. van Mensvoort and A. Bregt, *in press*. *Comparing Land-Use Planning Approaches in the Coastal Mekong Delta of Vietnam.* In: Hoanh, C.T., T. P. Tuong, J. W. Gowing and B. Hardy, eds. *Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts.* CABI Publishing, UK.

6 Comparing land use planning approaches

This chapter evaluates and compares the LUP approaches based on the results drawn from chapters 3, 4, and 5. The LUP approaches were compared in terms of credibility and acceptability. The credibility criteria are the prediction quality and the uncertainty of the LUP approach. The acceptability criteria are the stakeholders' agreement on the approaches' results and the resource requirements to carry out the LUP approaches.

6.1 Background

So far, no literature on comparison of different LUP approaches at different level of complexity in the same study area and planning period has been found. In fact, the existing LUP methodologies were evaluated separately and mainly based on the experience accumulated from studies at different places or time periods (e.g. Bouman et al., 2000; Rock, 2004; Rötter et al., 2005; van Duivenbooden, 1995) or with different land use goals (e.g. Beinat and Nijkamp, 1998). A relatively qualitative comparison of the LUP methods was done by van Duivenbooden (1995). In his study, main characteristics of nine LUP methods were reviewed and evaluated. The author regarded the following characteristics of the LUP methods as advantages: multi-disciplinarily, multi-scale, systems approach, geo-referenced, identification of constraints, scenario analysis, effect analysis, farmers' goal including and visually clear presentation of results. He regarded the following characteristics as disadvantages: long time requirements, high data requirements, qualitative nature, no spatial analysis, no temporal analysis, complicated logistics and limited information. Duivenbooden also mentioned the tools used in the methods: literature review, remote sensing, survey and interview, experiments, modeling and GIS application. The results were presented in form of tables indicated the applicable characteristics of each LUP method.

Although not related to land use planning, the framework for comparing eutrophication models for water management developed by van der Molen (1999) was useful for this study. In his framework, the model's credibility and acceptability were compared. He defined credibility as the technical and scientific appropriateness of the models and defined acceptability as the users' perception on the practical value of the outcome. The distinction between credibility and acceptability is based on the presumption that validation results and uncertainties are specified by modelers, and acceptance criteria are made explicit by the users. In his framework, the criteria for credibility evaluation are the uncertainties of the model and the criteria for acceptability evaluation are the managerial aspects (constraints in time and money) and model results (if the approval of the results is made explicit and the consequences of the use of the results are discussed). The uncertainty of a model can be in data used, model structure (mathematical formulation, spatial and temporal aggregation, omission of variables, and numerical errors), model parameters, and model predictions (validation of results).

6.2 Framework for comparison of land use planning approaches

The comparison framework of LUP approaches used in this study was based on the framework developed by van der Molen (1999), but only the criteria that can be used to judge LUP approaches are used. The criteria for credibility are prediction quality and uncertainty of the LUP approach, and the criteria for acceptability are stakeholders' agreement on approaches' results and resource requirements (time, budget, skill).

6.2.1 Acceptability evaluation

Expert perception

Local managers, experts and scientists familiar with the study area were asked to compare the three LUP maps for 2004 as generated by the three approaches. They had no prior knowledge of what method produced what map. They were requested to study the maps for areas that were not appropriately planned according to their view and to indicated whether they agree, partly agree or disagree with the maps. An approach with higher agreement of the local experts, managers and scientists is considered as more acceptable.

Resource requirements

The applicability of an LUP approach not only depends on the quality of the results but also on its requirements in data, budget, equipment and skill. If the requirements are higher than what is available, execution of the LUP approach become problematic. In other words, an approach with higher requirements is regarded as less acceptable.

6.2.2 Credibility evaluation

Prediction quality

The three LUP maps produced for 2004 were compared to the actual land use map of 2004 to show how much was realized of each LUP. The results of this analysis demonstrate the prediction quality of the LUP maps. Approaches with a better prediction quality are supposed to have a better credibility.

Uncertainty of the approaches

The uncertainty of an LUP approach can be caused by the available data, the aggregation/estimation (in time and space) of parameters and variables, or by the mathematical formulation of the problems. The approach with a higher uncertainty has less credibility.

6.3 Comparison of the LUP approaches

6.3.1 Acceptability evaluation

Expert perception

Nine managers, nine local experts, and seven scientists were asked their opinion about the land use planning maps without their knowing which LUP approach produces which map. They should indicate whether they agree, partly agree, or disagree with the presented maps and what they think is wrong. The results are presented in Table 6.1.

The consulted managers were directors or deputy directors of various departments of the provincial government of Bac Lieu province (agriculture, aquaculture, science and technology, and land administration); head or deputy head of the agriculture office, agriculture extension centres, and aquaculture extension centres of Vinh Loi district and president or deputy president of Vinh My A and Vinh Thinh villages. The consulted local experts were staff of the agriculture and aquaculture extension centres of Vinh Loi district, and land administration experts of Vinh My A and Vinh Thinh people committee. The consulted scientists were: lecturers, researchers of Can Tho University, of NIAPP (National Institute of Agriculture Planning and Projection) in Ho Chi Minh city, and staff of Bac Lieu's Department of Science and Technology. They have previously worked in the study area.

Table 6.1 Results of expert perception analysis

Groups	*Level of agreement*	*Number*		
		LUPAS	*FAO-MCE*	*PLUP*
Managers: 9	*Agree*	*2 (22%)*	*3 (33%)*	*0*
	Partly agree	*7 (78%)*	*2 (22%)*	*5 (56%)*
	Disagree	*0*	*4 (44%)*	*4 (44%)*
Local experts: 9	*Agree*	*1 (11%)*	*1 (11%)*	*3(33%)*
	Partly agree	*8 (89%)*	*4 (44%)*	*2(22%)*
	Disagree	*0*	*4 (44%)*	*4 (44%)*
Scientists: 7	*Agree*	*1 (14%)*	*0*	*0*
	Partly agree	*6 (86%)*	*2 (29%)*	*2 (29%)*
	Disagree	*0*	*5 (71%)*	*5 (71%)*
All: 25	*Agree*	*4 (16%)*	*4 (16%)*	*3 (12%)*
	Partly agree	*21 (84%)*	*8 (32%)*	*9 (36%)*
	Disagree	*0*	*13 (52%)*	*13 (52)*

The results show that most of the interviewees partly agreed with the LUPAS land use plan map (85%). The main argument why they did not choose "fully" is that there was not enough fresh water or an inadequate irrigation system for rice and rice-shrimp. Other reasons were that the study area was covered by aquaculture, which reduces possibilities for rice production, and the allocated area for rice was quite small compared to the others LUTs. The percentage of interviewees that fully agreed with the LUPAS map and FAO-MCE map were the same (16%) and a little less for the PLUP map (12%), while over half of the interviewees disagreed with both FAO-MCE and PLUP maps (52%). The main reason again was the lack of fresh water or an inadequate irrigation system for rice. Besides, 20% of the interviewees disliked the PLUP map because of its scattered land use allocation and 28% of them noted that artemia and salt were not economically productive. The interviewees also pointed out that the introduction of shrimp in the protected forest area would have negative implications (8%, 8% and 16% for LUPAS, FAO-MCE and PLUP maps).

Appreciation for LUPAS map is the same by all three groups, while for FAO-MCE and PLUP maps differences can be observed. While no scientist fully agreed, and the same proportion of them partly agreed or disagreed with both FAO-MCE and PLUP maps, 33% managers agreed with the FAO-MCE map but none of them with the PLUP map. On the contrary, 33% local experts agreed with PLUP map but only 11% with the FAO-MCE map. The numbers of managers that partly agreed with the PLUP map was higher compared to the local expert and scientist groups (56%, 22% and 29%). The results suggested that the perception of the local experts and local managers was somewhat closer to the farmers' perception than what the scientist had perceived.

Resource requirements

FAO-MCE requires many data, both qualitative and quantitative. Compared with the PLUP approach, the cost to carry out the FAO-MCE approach is higher when the cost for land evaluation is taken into account, and the time for analysis is longer. The FAO-MCE requires modeling and statistical analysis skills. GIS software is needed for analysis and presentation. Excluding the land evaluation performed by the NIAPP, this study took about four local staff men-months to perform data acquisition, and six experts man-months to perform data analysis and modeling. The total estimated cost to implement the FAO-MCE in this study area was about 206.5 million VND (about 20,650 VND[1]/ha). This cost already includes the cost for land evaluation but does not include the cost for GIS software.

PLUP. Since most of the approach's activities are carried out during discussions with farmers, the discussion leader's communication skill is of vital importance. The data in PLUP

[1] 1 Euro = 20.000VND

are qualitative and acquired directly from the farmers at low cost. The main expenditure is for field trips. The cost for data analysis is also low, and no high-tech equipment is needed. Simple GIS software is required to integrate and analyze data. In this study, with an area of about 10,000 ha, each PLUP required eight experts man months, in which about four local staff man-months to facilitate the PRA and transect walks, about two experts man-months for data input and about two expert man-months for GIS analysis. The total estimated cost for the PLUP implementation in this study area was about 46.4 million VND/time (about 4,650 VND/ha).

LUPAS. Compared to the PLUP and the FAO-MCE approaches, the LUPAS required more detailed and quantitative data. Consequently, the cost to carry out the approach was higher. Moreover, the estimation of the input-output parameters and the development of the IMGLP model require more time and money. The approach requires not only skills in modeling but also knowledge on definition and translation of problems into the model. Excluding the land evaluation work performed by NIAPP, eight expert man-months for data input and ten expert man-months for modeling training and model development were used. The total estimated cost for implementation of the LUPAS in this study area was about 241 million VND (about 24,000 VND/ha). This cost already included the cost for land evaluation but did not include the cost for GIS and the linear programming software (GAMS).

6.3.2 Credibility evaluation

Prediction quality

Table 6.2 shows that land use in 2004 looks most like the PLUP map, next like the LUPAS map and least like the FAO-MCE map (75%, 62% and 33% correspondingly). The areas planned for aquaculture agree best: 96% in PLUP map, 95% in LUPAS map and 76% in FAO-MCE map. For agriculture 20% of the FAO-MCE map agrees while only 3% for the PLUP and the LUPAS maps does. This is because the LUPAS and the PLUP map plan mainly aquaculture, while the FAO-MCE map has more agriculture and mixed agriculture-aquaculture.

Most realized areas of the PLUP map are for aquaculture (96%). In the unrealized area, 40% were intended for mixed agriculture-aquaculture, 14% for mixed forest-aquaculture and 22% for aquaculture (Table 6.3 and Figure 6.1). The agriculture area planned in the PLUP map is realized and quite consistent.

Table 6.2 Realization of the LUP approaches' land use planning maps

			% in the realized area			% in the unrealized area		
	Realized	*Unrealized*	*Agriculture*	*Aquaculture*	*Other*	*Agriculture*	*Aquaculture*	*Other*
PLUP	*75*	*25*	*3*	*96*	*1*	*8*	*35*	*58*
FAO-MCE	*33*	*67*	*20*	*76*	*4*	*39*	*10*	*52*
LUPAS	*62*	*38*	*3*	*95*	*1*	*8*	*37*	*54*

Table 6.3 Realization of PLUP planning

Description	*Area (ha)*	*% of realized or unrealized*	*% of the total area*
Realized			
Agriculture	*201*	*3*	
Aquaculture	*7007*	*96*	
Mixed forest-aquaculture	*80*	*1*	
Total realized	***7288***		***75***
Not realized			
Agriculture to aquaculture	*192*	*8*	
Aquaculture to agriculture	*527*	*22*	
Aquaculture to fallow	*14*	*1*	
Mixed agriculture-aquaculture to agriculture	*654*	*28*	
Mixed agriculture-aquaculture to aquaculture	*286*	*12*	
Mixed forest-aquaculture to agriculture	*11*	*0*	
Mixed forest-aquaculture to aquaculture	*344*	*14*	
Mixed salt-aquaculture to aquaculture	*53*	*2*	
Mixed salt-aquaculture to salt	*3*	*0*	
Salt to aquaculture	*7*	*0*	
Aquaculture to mixed salt-aquaculture	*44*	*2*	
Aquaculture to salt	*215*	*9*	
Artemia to agriculture	*26*	*1*	
Total not realized	***2375***		***25***

The realized part of the FAO-MCE plan is mainly for aquaculture (76%) and much less for agriculture (20%). The farmers who did not realize their agriculture plans mostly turned to aquaculture (39%). The mixed systems of agriculture-aquaculture were also often not realized (19%). Near the coast, aquaculture was practiced instead of mixed forest-aquaculture (12%) and mixed salt-aquaculture (17%). However, some planned aquaculture areas were used for agriculture (10%). See Table 6.4 and Figure 6.1.

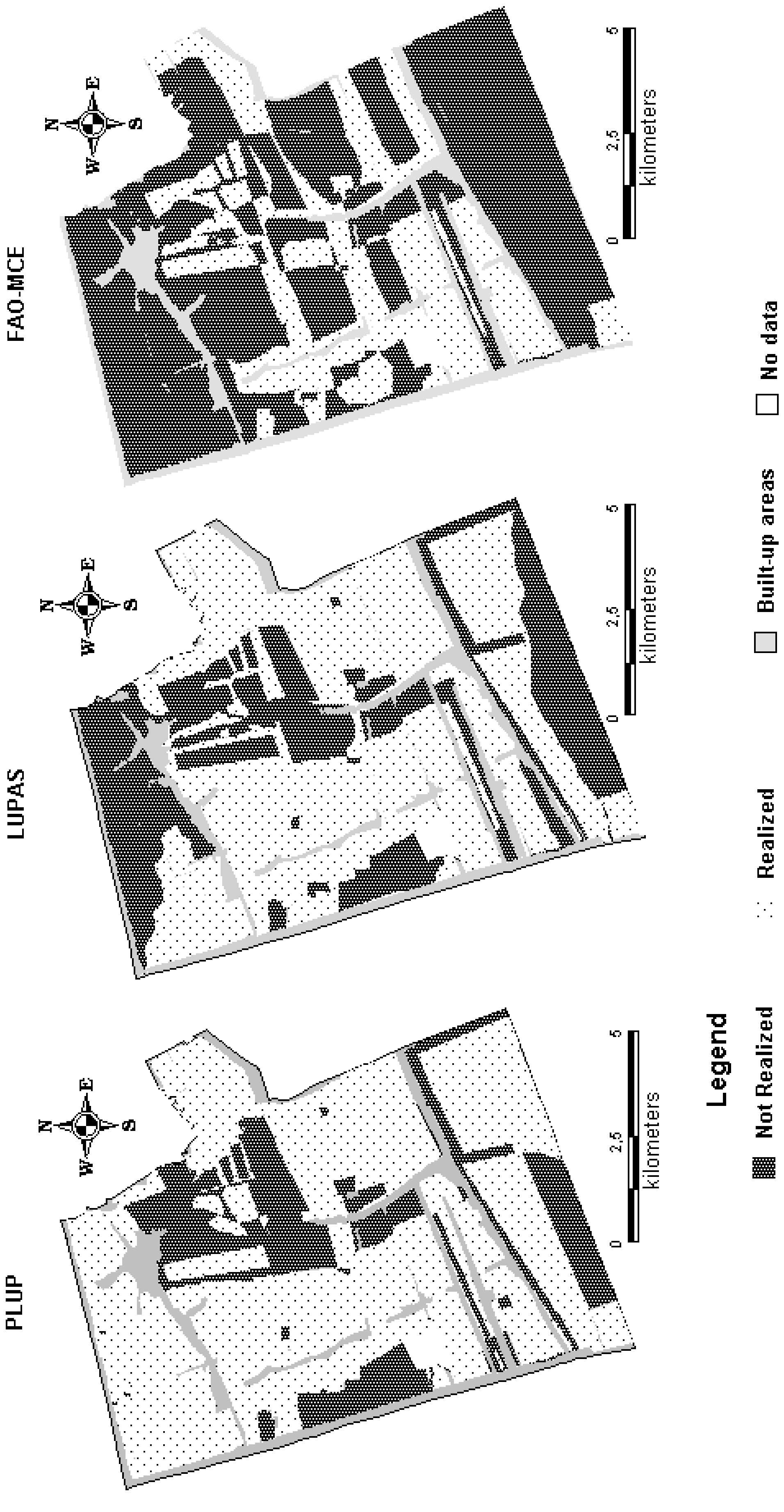


Figure 6.1 Realization of land use plans for 2004 by PLUP, LUPAS, and FAO-MCE

Table 6.4 Realization of FAO-MCE planning

Description	*Area (ha)*	*% of realized or unrealized*	*% of the total area*
Realized			
Agriculture	*554*	*20*	
Aquaculture	*2145*	*76*	
Mixed forest-aquaculture	*70*	*2*	
Mixed salt-aquaculture	*44*	*2*	
Total realized	***2813***		***33***
Not Realized			
Agriculture to aquaculture	*2236*	*39*	
Aquaculture to agriculture	*551*	*10*	
Agriculture to fallow	*15*	*0*	
Mixed agriculture-aquaculture to agriculture	*68*	*1*	
Mixed agriculture-aquaculture to aquaculture	*1018*	*18*	
Mixed forest-aquaculture to aquaculture	*665*	*12*	
Mixed salt-aquaculture to aquaculture	*975*	*17*	
Mixed salt-aquaculture to mixed forest-aquaculture	*3*	*0*	
Mixed salt-aquaculture to salt	*209*	*4*	
Mixed agriculture-aquaculture to fallow	*3*	*0*	
Mixed forest-aquaculture to salt	*1*	*0*	
Mixed salt-aquaculture to agriculture	*34*	*1*	
Total not realized	***5779***		***67***

Most realized areas of the LUPAS map were also in aquaculture (95%). However, a relatively large part of the planned aquaculture was not realized (37%). The other main unrealized areas were the mixed agriculture-aquaculture area (29%) and the forest-aquaculture area (18%). See Table 6.5 and Figure 6.1.

The tables and figures also show that in all of the plans, the mixed systems, e.g. agriculture-aquaculture, salt-aquaculture, forest-aquaculture were mostly not realized (56%, 53% and 53% in PLUP map, FAO-MCE map and LUPAS map respectively). That is because one of the crops was far less profitable than the other, as the case of rice in rice-shrimp, salt in salt-shrimp and forest in forest-shrimp. An exception was the partly protected coastal area where 70% of the land must be forestation according to government regulation). Especially, it is more difficult to realize the rice-shrimp due to the salinity intrusion from the surrounding shrimp fields even in the rainy season (see also Chapters 3 and 4).

Table 6.5 Realization of LUPAS planning

Description	***Area (ha)***	***% of realized or unrealized***	***% of the total area***
Realized			
Agriculture	*192*	*3*	
Aquaculture	*5401*	*95*	
Mixed forest-aquaculture	*71*	*1*	
Total realized	***5664***		***62***
Not Realized			
Agriculture to aquaculture	*276*	*8*	
Agriculture to salt	*1*	*0*	
Aquaculture to agriculture	*1057*	*31*	
Aquaculture to fallow	*14*	*0*	
Aquaculture to mixed forest-aquaculture	*3*	*0*	
Aquaculture to salt	*204*	*6*	
Mixed aquaculture-agriculture to agriculture	*145*	*4*	
Mixed aquaculture-agriculture to aquaculture	*861*	*25*	
Mixed aquaculture-agriculture to fallow	*4*	*0*	
Mixed forest-aquaculture to aquaculture	*621*	*18*	
Mixed forest-aquaculture to salt	*1*	*0*	
Mixed salt-aquaculture	*44*	*1*	
Mixed salt-aquaculture to agriculture	*1*	*0*	
Mixed salt-aquaculture to aquaculture	*172*	*5*	
Mixed salt-aquaculture to salt	*5*	*0*	
Total not realized	***3409***		***38***

Overlaying the three "realization" maps in Figure 6.1 yields a map that presents the areas where all LUP maps were and were not realized (Figure 6.2). The area where no LUP map was realized covers about 14% of the study area. Three different areas can be distinguished. The first area is near the coast, which was planned for mixed forest-aquaculture but now used for sole aquaculture. The second area stretches along the Truong Son dike, which was planned for aquaculture but now used for salt. The reason for this change (as explained by the farmers) was that they did not have enough money for intensive shrimp while extensive shrimp can be very risky compared to salt. The third area is the one along canal Cai Huu, from Vinh My A People Committee down to canal Co Tu, and another one along canal Cai Cung. These areas were planned for aquaculture or mixed agriculture-aquaculture but now is used for rice. They are quite interesting areas because most of the farmers there tried to keep on cultivating rice. For them rice gives enough revenues and a stable income. Moreover, some native farmers buy land in other places outside the study area for shrimp cultivation. Apparently, these areas where all LUP maps were not realized cannot be planned correctly by any of our three methods. This is caused by the farmers' motives that do not agree with the logic of land use planning.

The areas where all LUPs were realized comprise about 22% of the study area. Most of these areas were planned for aquaculture and only a small part near the coast was for mixed forest-aquaculture.

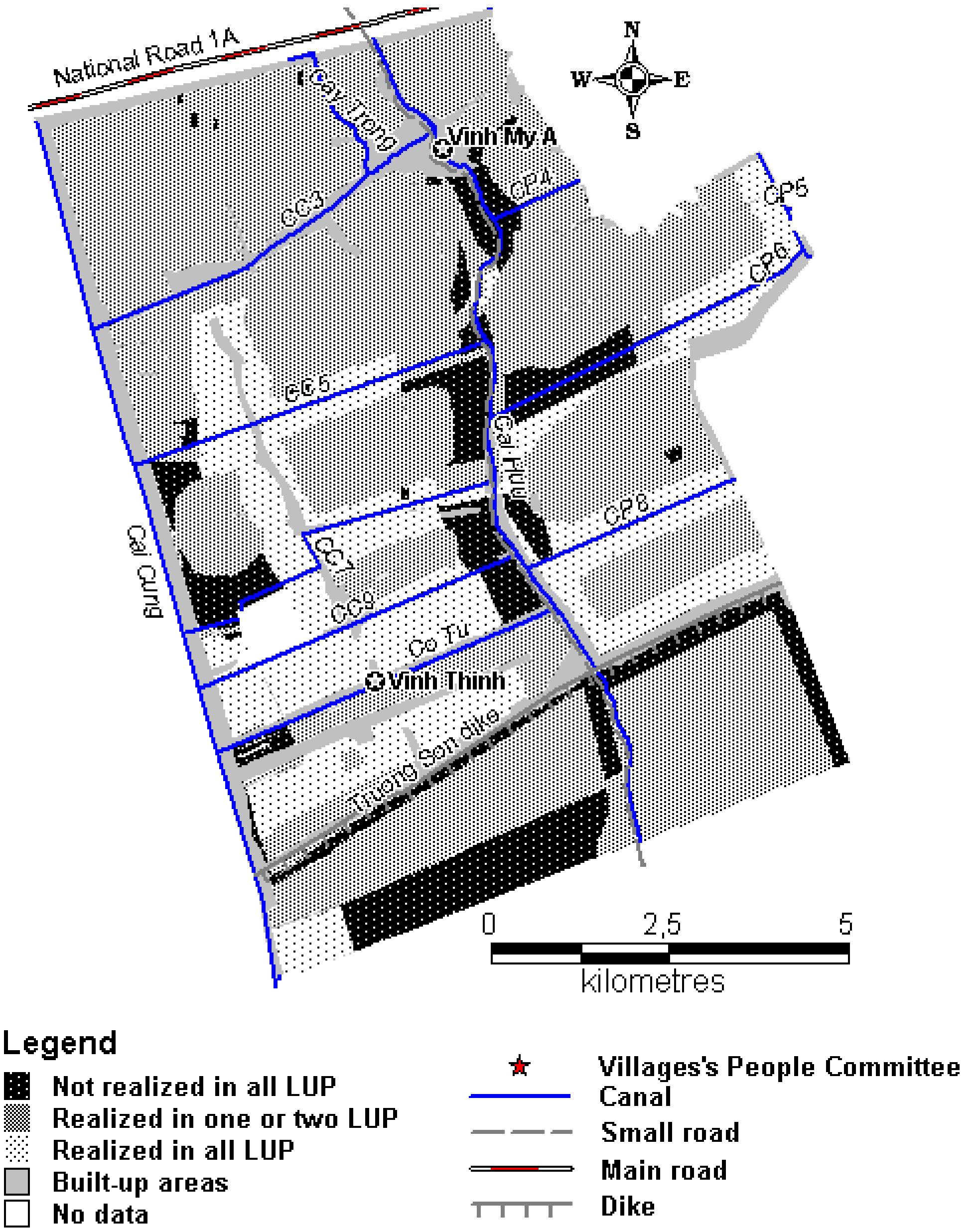


Figure 6.2 Combination of the realization maps (see Figure 6.1)

Source of uncertainty

Uncertainty of the FAO-MCE approach

The results of the biophysical land evaluation by NIAPP of 1999 differed from the actual land use seen during the shrimp yield survey in 2003 (Kempen, 2004). Some reasons are that the suitability classification framework is possibly not optimal, the natural conditions such as weather and water conditions may change, the farmers themselves may apply new farming techniques, or insufficient farms were interviewed. Therefore, more field surveys have been performed and more up-to-date and detailed LMU have been identified. However, the variability is still high, e.g. data on shrimp yields. Moreover, since farmers normally do not record their daily expenditure, it is hard to collect detailed and accurate socio-economic data.

In the MCE, it is crucial to select the right key criteria for each planning goal, quantify them, and determine their importance. The results of this study depend very much on the knowledge of experts and stakeholders, especially of the decision makers who set the priority weights (Beinat and Nijkamp, 1998).

Uncertainty of the PLUP approach

The acquired data by the PRA tool used in PLUP are qualitative and may have a low spatial accuracy (e.g. boundary of the resources map was drawn subjectively according to farmers' experiences). However, the information suffices to show the farmers' perceptions on the land biophysical conditions and farmer's preferences. The data accuracy can be improved by transect walks, additional interviews, and by using Global Positioning System (GPS) and GIS (Bojorquez-Tapia et al., 2001).

The participant's knowledge and willingness to cooperate, and the facilitator's communication skills are the main factors affect to the data quality. Moreover, dividing the participants into focus groups makes the discussion more specific, reducing boredom among participants and prevents superficial discussions (Moris and Copestake, 1993). The presence of the hamlet leader in the discussion and during farmer interviews also makes villagers hesitant to spell out their ideas that may differ to those of the authority.

Uncertainty of the LUPAS approach

Besides the uncertainty in the land evaluation data as discussed before in FAO-MCE approach, LUPAS has more uncertainty in estimating the input-output of the land use systems. The accuracy may deteriorate at unexpected events such as drastic changes in demand for a certain resource from other sectors as a result of a change in government policy or environmental conditions (Ismail et al., 2000; Rötter et al., 2005; van Ittersum et al., 2004). Since the constraints and goal restrictions strongly affect the results of the approach, it is vital to define sufficient scenarios for analysis and recognize the goal restrictions that are relevant to address the major questions of the case study.

6.3.3 The overall comparison

Tables 6.6 presents an overall ranking of the LUP approaches' credibility and acceptability when applied to the study area. The basic assumption of this ranking is that all criteria are taken into account with the same weight. The numbers in the table (called ranking value) only indicate the level of credibility or acceptability. A low ranking value indicates a high credibility or acceptability.

Acceptability

The previous evaluation shows that the scientists, local experts and local managers appreciate the LUPAS map the most, FAO-MCE map next and PLUP map last. For comparing the resource requirements, a pair-wise comparison method has been applied. Between the PLUP and FAO-MCE and between PLUP and LUPAS, it is clear that PLUP requires less than FAO-MCE and LUPAS because the latter require quantitative data, more cost and more advance skills. LUPAS requires more resources than FAO-MCE and PLUP. LUPAS requires more detailed quantitative data, higher cost and more advance skill on modeling. Thus, the rank for resource requirements is 1: PLUP, 2: FAO-MCE and 3: LUPAS. The overall rank, which is supposed to be the sum of the acceptability in results (experts' perception) and resource requirements ranking values, is the same for three LUP approaches (Table 6.2).

Credibility

Based on the 'prediction quality' evaluation above, we can rank the 'prediction quality' of the LUP approaches as following 1: PLUP, 2: LUPAS and 3: FAO-MCE.

Uncertainty in data and uncertainty during implementation of the LUP approach (approach uncertainty) give the overall uncertainty of the results. In PLUP and FAO-MCE, the proportion of approach uncertainty is higher than that of data uncertainty while in LUPAS both data and approach uncertainty contribute the same proportion of uncertainty to the overall results.

Between PLUP and FAO-MCE, the data uncertainty of FAO-MCE is higher than the PLUP because the land evaluation data used in FAO-MCE is quite static while the actual land characteristics quickly change because of the shrimp expansion. This dynamic change can be figured out by the farmers in PLUP. Between FAO-MCE and LUPAS, both LUP approaches have the same problems about the static land evaluation data. However, because of lacking socio-economic and environmental data, in FAO-MCE there are uncertainties when assigning environmental criterion scores. Moreover, these uncertainties may be reinforced when these criterion scores are multiplied with the priority weight. This makes the uncertainty of FAO-MCE higher than that of LUPAS. Thus the ranking of the LUP approaches according to 'source of uncertainty', is 1: PLUP, 2: LUPAS and 3:FAO-MCE with 1 as the highest certainty and 3 as the lowest one.

The overall credibility ranking, which is proposed as the summary of 'prediction quality' and the 'source of uncertainty' ranking values, is: first the PLUP, second the LUPAS, and last the FAO-MCE.

Table 6.6 The acceptability and credibility of PLUP, FAO-MCE and LUPAS when they are applied in the coastal zone of the Mekong Delta, Vietnam. (Lower values indicate higher acceptability and credibility)

	PLUP	***FAO-MCE***	***LUPAS***
Acceptability			
-Experts' perception	*3*	*2*	*1*
-Resource requirement	*1*	*2*	*3*
+ data	*Qualitative*	*Quantitative, qualitative*	*Detailed quantitative*
+ budget	*Lowest (4,650 VND/ha)*	*Medium (20,650 VND/ha)*	*Highest (24,000 VND/ha)*
+ skill	*-Communication skill* *-GIS analysis: data aggregation, overlaying*	*-Medium skills on modeling and statistic analysis* *-GIS analysis: Linking of thematic data and spatial data*	*-Advance skill on modeling* *-GIS analysis: Linking thematic data and spatial data*
Total acceptability	***4***	***4***	***4***
Credibility			
-Prediction quality	*1*	*3*	*2*
-Sources of uncertainty	*1*	*3*	*2*
+ data uncertainty	*- Boundary of the land units, qualitative data* *- Can be improved with low cost (time and money): through transect walks, crosscheck with the additional interview, using GPS, GIS*	*- Land evaluation and criterion scores.* *- Need to be improved due to:* *+ Quick change in biophysical and socio-economic conditions* *+ High dispersion of shrimp production*	*- Same level of important with the approach uncertainty.* *- Land evaluation and input-output data* *- Need to be improved due to:* *+ Quick change in biophysical and socio-economic condition* *+ High dispersion of shrimp production*
+ approach uncertainty	*- Main source of uncertainty* *- Participants' knowledge and willingness to cooperate and facilitator's communication skills: quite acceptable in the case study*	*- Main source of uncertainty* *- Knowledge and expertise of the experts decision markers when giving weights and score: Need to be improved in the case study due to lack of knowledge on socio-economic and environmental criteria.*	*- Same level of importance as data uncertainty* *- System analysis, formulation of objective, constraints and goal restrictions: quite acceptable in the case study*
Total credibility	***2***	***6***	***4***

6.4 Conclusion

Between LUP maps, the three consulted groups judge LUPAS map similarly (and most favourably) but local experts and local managers judge the PLUP map higher than the scientists do. This implies that the perception of the local experts and local managers is somewhat closer to the farmers' perception than what the scientists perceive.

Interestingly, the PLUP map, which is the most disagreed by the scientists, is the most realized by the farmers. The reason for this may be that the PLUP map, drawn by the farmers, was based on the actual land use and was applied for a short term while the other approaches aim at optimized resource use and was used for a long term.

Most interviewees do not choose agriculture in their planning because they fear water management problems. In reality, however, in some places despite all of these problems farmers still continue rice crops as long as the biophysical conditions allow them to do so. The reasons explained by the farmers here are that rice is their staple food and the basis of their farming. They did not want to take risks with shrimp, which requires high capital and technical skill (see also Chapter 4).

In PLUP, the attitude of the key farmers and the skill of the discussion facilitator during the PRA are the most important. In the FAO-MCE approach, it is crucial to detect the right key criteria for each planning goal, qualify them and determine their importance. Land evaluation studies supply the input for both LUPAS and FAO-MCE approaches. However, their static description of biophysical conditions seems not suitable to describe the quick changes in the coastal area as explained above. Accurate transfer of the socioeconomic characteristics of the study area into the model and obtaining precise data on production systems are challenges to applying both LUPAS and FAO-MCE approaches in the coastal area of the Mekong Delta.

The analysis shows that with the dynamic and contrasting land uses like in the coastal zone of the Mekong Delta, PLUP seems the most suitable approach since it is capable of acquiring up-to-date information on actual land conditions and presenting the farmers' land-use preference. In PLUP, the places and causes of land-use conflicts can be defined. This can help land-use planners to find solutions to achieve an acceptable land-use plan. However, for a sustainable land-use plan over a longer term that can optimize the use of resources and balance different stakeholders' priorities, these LUP approaches should be integrated.

In comparison of the LUP approaches' credibility and acceptability, the ranking of LUP approaches according to the 'experts' perception' and the 'prediction quality' criteria is quite straightforward. However, it can be difficult to rank the acceptability of LUP approaches according to 'resource requirements' since there may be different opinions on how the resource requirements affect the overall acceptability. Some may argue that an LUP approach that has high resource requirements but can successfully solve the problems at hand and give more accurate results can be still accepted. However, when the users' resources are limited, a method with lower and affordable requirements is the only option.

Similarly, ranking the credibility of LUP approaches based on 'source of uncertainty' cannot be simple due to two factors. First, the data used in each approach are acquired or estimated by different ways and for different desired levels of details. Second, the proportions of uncertainty in data and during implementation of the approach contributing to the overall uncertainty are different among LUP approaches.

When the LUP approaches are compared, difference weights can be applied for different criteria according to the evaluator's point of view. For example, in this case study, when we assume that 'expert perception' and 'resource requirement' are equally important for the total acceptability, the three LUP approaches have the same acceptability level, but when one claims that 'resource requirement' is less important, the LUPAS approach is more acceptable than the FAO-MCE and PLUP approaches.

Chapter 7

Discussion, evaluation and further research

7 Discussion, evaluation and further research

In this study three different Land Use Planning (LUP) approaches have been applied for the same study area. The planning intention (land use plan 2004) of the three approaches is the same, which allows besides method comparison also comparison of the planning results. For this comparison a framework with indicators is developed. This chapter discusses the implications and the limitations of the study for land use planning in general and in the coastal zone of the Mekong Delta, Vietnam in particular. Recommendation for further researches is presented at the end of the chapter.

7.1 Applying the land and use planning approaches

The first LUP approach that was applied in this study is the most popular one in Vietnam: the FAO land evaluation with multi-criteria evaluation (FAO-MCE). The FAO-MCE allows the integration of biophysical land evaluation with socio-economic and environmental appraisal. It was able to analyze the trade-offs between development targets by analyzing different scenarios defined by different priority weigh sets. The application of FAO-MCE showed that: (i) it did not indicate the feasibility of the scenarios and the acceptance of them by the farmers; (ii) its results were strongly affected by the priority weights, which reflect the land use planner's perception of the importance of the socio-economic and environmental criteria, and the decision maker's perception of the importance of the planning goals; (iii) in the study area the biophysical land evaluation is too general and static. It could not deal with the quick changes in biophysical conditions due to the water quality change (fresh water to brackish water) in the coastal area.

The second LUP approach was a participatory land use planning method (PLUP). PLUP is still not widely used in Vietnam, but it is gaining attention from the stakeholders in the land use planning process. The advantage of the PLUP is that it can reduce the land-use conflicts by taking into account the farmers' preference changes and preference conflicts. The application of PLUP showed that: (i) the communicative skills of the discussion facilitator are very important, while also the knowledge and willingness to cooperate of participants and the organization of discussion groups strongly affect the success of PLUP. (ii) Separating the aquaculture farmers from agriculture farmers to form focus groups makes the discussion more specific because this reduces boredom among participants and prevents superficial discussions (Moris and Copestake, 1993). Also, the different perceptions between farmers groups can be distinguished.

The third method applied was LUPAS, which is aimed at optimizing the use of resources. Through the application of LUPAS, the government's development goals are evaluated on their feasibility. By scenario analysis, LUPAS can identify the main constraints that hamper the realization of these development goals. LUPAS is used in Vietnam by Lai (2000) and Bui et al. (2002).The experience with LUPAS showed that: i) it uses the biophysical land evaluation of FAO as a starting point while this evaluation is too static to describe the dynamic change of the coastal zone of the Mekong Delta. (ii) There is large uncertainty in the input-output data for shrimp production systems, which influences the accuracy of the model's results.

The study also provides insight in the applicability in terms stakeholders and spatial extent of the different LUP approaches. The results illustrate that PLUP can easily be implemented at the village level and that local experts can perform this approach with ease. LUPAS can be used at village level however it is more suitable for applications at the provincial level because in Vietnam the development goals are set at this level. And due to its high requirements in modeling skills and detailed quantitative data, the application of LUPAS is limited to research institutions. The FAO-MCE approach takes an intermediate position. It can be used at village level, but overall it is more suited to be applied by land use planners and scientists at the provincial land use planning agencies.

7.2 Application problems

The application and the comparison of the three land use planning approaches in the same study area were not easy. The following main difficulties were encountered: (i) in both FAO-MCE and LUPAS the land evaluation for shrimp culture performed by NIAPP did not match with the field survey. Even in the same land unit and at the same technical level, the shrimp yield was highly varying. There are many reasons for this variation such as shrimp disease, water pollution, water regime change, not precise land unit definition or wrong sampling points. In order to solve this problem, additional interview survey data was used. (ii) The input-output data of most land use systems at different technical levels were not available. To estimate them, the land suitability map and the actual mean and maximum input-output values of the land use systems in the study area was used. (iii) In some practical cases of the PLUP approach the intervention of the head of the commune during the farmer discussion was a problem. To solve this, he was asked to lead another researcher for a transect walk. The second problem was the changes of farmers' attitude during the discussion if the discussion was too long or when wine had been served. The third difficulty in the application of the

PLUP was the selection of the right participants. In this study, the local experts of the Agriculture Extension Centre were asked for advice. (iv) There were a number of difficulties in comparing the LUP approaches. Firstly, there was no existing framework for comparing LUP approaches. An existing framework for comparing eutrophication water management models was modified to compare the LUP approaches. The selected comparison criteria worked well as a good first approximation, but certainly more research needs to be done in order to identify appropriate criteria and their weights. Secondly, the comparison of the LUP approaches' credibility was based on the LUP approaches' plans for 2004 and the actual land use in 2004. We must, however, realize that the planning horizons for the three methods differ. The PLUP is more focused on short term objectives, while FAO-MCE and LUPAS are more focused on short- and mid term goals. This might give PLUP an advantage in the comparison on credibility. A comparison of a land use plan e.g. 2010 eliminates this effect.

7.3 Implication for LUP in general

Planning in a dynamic and contrasting land use area is always a challenge. As a result of this dynamic nature of the system also the land characteristics might change (soil and water salinization and acidification, terrain change, etc.). FAO-MCE and LUPAS are less flexible in handling these changes, as they require more intensive data collection and processing activities. A participatory method like PLUP is more flexible in detecting these changes, but understanding of the underlying biophysical and socio-economical processes is often missing. Therefore, I am a strong supporter of an integration or combined use of the different LUP approaches. A bottom-up approach using a participatory method, which involves farmers in the LUP approach, can be used to distinguish the conflicts among stakeholders. A top-down approach using linear programming can be used to analyze the feasibility of the government goals and also to recommend optimized land use options. Multi-criteria evaluation method can be used to support land use planners in their final decision on how to allocate land use.

In the proposed integrated approach, three groups of stakeholders should be involved: scientists/experts, decision makers, and farmers. The PRA should be carried out first by the farmers with the support of experts/scientists to obtain data on biophysical conditions, the farmers' perceptions, and actual or possible land use conflicts. These data will be used to generate a land unit map. In the next step, the scientists will analyze the data acquired from the first step and validate them with the available data on land characteristics of the study area. Subsequently, scenario analysis by LUPAS is used to check the feasibility of the goals set by the decision makers and it is also used to check if the LUPs proposed by LUPAS have any conflicts with the farmers' preferences. If the goals are not feasible, the decision makers, with the scientists' support, should adjust their goals. Scenario analysis in LUPAS provides different land use plans. The decision makers have to formulate a final LUP from these scenarios. Multi-Criteria Evaluation (MCE) is a suitable tool to support the decision makers in this task. The criteria for the planning goals should be defined and evaluated by the experts/scientists. There are two ways to apply MCE here. The first way is that the decision maker decides on one priority weight set based on his own policy and the farmers' perception. The scientists apply the MCE to achieve a LUP. This LUP, before being issued for implementation, should be discussed with the farmers to get their feedback. If the farmers do not agree with the LUP, negotiation can follow or a new LUP can be proposed through the repeating of the MCE with different priority weights. The second way to apply MCE is that the decision maker proposes different priority weight sets. The outcome of the MCE will be different LUPs. The different plans are discussed with the stakeholders and a final one is selected.

7.4 Implications for the coastal area in the Mekong Delta

The overall credibility comparison of the three LUP approaches showed that PLUP was the most credible LUP approach for the coastal zone of the Mekong Delta. Its LUP map was realized by most farmers and had less uncertainty than the FAO-MCE map and the LUPAS map. This method appears to be capable of coping best with the dynamic and contrasting land use of the study area. However, one main limitation remains: PLUP relies only on the farmers' perceptions, which are mostly concerned with the short-term objective to increase their income at the farm level and neglects the long-term objective to optimize the use of the resources at the regional level. The decision makers have to trade-off among different priorities of different groups of stakeholders. Therefore, an integration of PLUP with LUPAS and the Multi-Criteria Evaluation (MCE) tool used in FAO-MCE as discussed above is recommended for land use planning in the coastal zone of the Mekong Delta.

The results of the PLUP application showed that land use in the study area was very dynamic. Land use was changed from rice and mixed systems towards more intensive forms of aquaculture, even in the forest area. These changes have caused conflicts between the farmers who want to convert their land to shrimp cultivation (using brackish water) and the farmers who want to keep cultivating rice (using fresh water), and between the government who want to conserve a sustainable environment and the farmers who want to increase their income. From the PLUP results, we can also observe that the farmers' changes in preferred land use depend not only on the benefit and capital requirements of the productions, and the biophysical condition of the land but also on the risk of converting to new production systems. It should be noted that the shrimp yield in the study area is highly varying, due to the quality of shrimp larvae, the farmers' skills in shrimp cultivation, and the quality of surface water. According to the farmers, the problems they are facing are lack of technical skills and capital for intensive aquaculture and the incompatibility between the current water management system and the actual land use (both aquaculture and agriculture). This was also confirmed by the LUPAS results.

Scenario analysis in both FAO-MCE and LUPAS showed that to increase income of the farmers in the study area, more land should be used for intensive shrimp. However, the LUPAS results show that besides the negative environmental impact such as water pollution and land degradation (EJF, 2003; Martinelli, 2000), the economic risk becomes high if the market price of shrimp suddenly drops or a shrimp disease outbreak occurs. The area for rice-shrimp and forest-shrimp system, as said to be a sustainable and economical farming system (Be et al., 2003; Thanh, 2002), is diminishing because rice crop and forest are far less profitable than shrimp cultivation. Vegetables are a promising alternative to increase the income of the farmers in the study area, but a more stable market is clearly necessary.

Therefore, when planning for the coastal area of the Mekong Delta, we should take into account the following issues:

- A top-down planning approach based on government's targets, which is common in Vietnam, is not always feasible because of the lack of data on the availability of resources and on the conflicts of interest between the farmers and the government. Instead, it would be advisable to use an optimal land use planning approach based on resource availability (land, capital, labour) and the farmers' preference.
- The recent land use developments in the coastal areas of the Mekong Delta are facing number of potential risks: (i) the risk of shrimp failure because of bad shrimp post larvae, water pollution, or low level of knowledge in shrimp cultivation; (ii) the risk of benefit reduction due to price competition from other markets; and (iii) the environmental threats such as water pollution, loss of biodiversity because of the overuse of chemicals and loss of forest areas for shrimp cultivation.

7.3 Further research

The study shows that there is a mutual effect between farmers' preferences on land use and the actual land use change in the coastal zone of the Mekong Delta. It is recommended that a systematic acquisition of farmers' preferences through PRA techniques should be carried out. This acquisition provides valuable information for defining the drivers of land use change in the coastal area of the Mekong Delta.

The study showed that the quantitative LUP approaches (such as LUPAS, FAO-MCE) are less credible when they are applied in the coastal area of the Mekong Delta. One of the reasons is the lack of quantitative socio-economic and environmental data, and the poor georeferencing of existing data. For FAO-MCE, it is essential to have detailed information on the effect of different land use systems on the sustainability (in socio-economic and environmental sense) of the coastal area of the Mekong Delta. For LUPAS, it is essential to have more data on the input-output of production systems (shrimp, rice-shrimp, fresh-shrimp) in different biophysical conditions and at different technical levels so that we can develop an expert system for quantifying the input-output structure of actual and alternative land use systems of the coastal area of the Mekong Delta (called Technical Coefficient Generators, Hazell and Norton, 1986).

It is recommended to test the proposed framework for comparing LUP approaches in another study area to evaluate its "credibility and acceptability". The framework should also be applied using other LUP approaches. Also is it necessary to further develop and test the criteria for evaluating credibility and acceptability.

Finally, I propose to apply and test the proposed integration of LUP approaches in the coastal zone of the Mekong Delta. This integration provides a more balanced view on the planning directions and challenges, leading to better land use options of the coastal zones of the Mekong Delta in Vietnam.

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Summary

Land use planning in the coastal zone of the Mekong Delta is challenged by strongly contrasting and quickly shifting land use systems. In addition to that, the planning procedures applied in Vietnam are viewed by many stakeholders as top-down processes that, in many cases, lead to incomplete or even failed implementation. Therefore, it is essential to have a land use planning (LUP) approach that can overcome these problems. It is not possible to choose a "most suited" land use planning method for the coastal Mekong Delta because existing methods were developed for other purposes or cover only a part of the land use planning sequence set out by FAO. In this study, three different approaches were selected and applied to the same study area in order to compare their pros and cons. The selection of the LUP methods was based on historical use in Vietnam, differences in planning philosophy, level of complexity and intensity of computation. They are:

(i) the FAO Guidelines for LUP extended with the Multi Criteria Evaluation technique. This approach is the most widely used in Vietnam;

(ii) A Participatory Land Use Planning (PLUP). In this approach the local community of the planning area participates;

(iii) LUPAS (Land Use Planning and Analysis System), a multiple goal linear programming based approach, which can quantify conflicts in rural development goals, land use objectives and resource use. LUPAS is developed especially for the Tropical region of Asia.

These LUP approaches were applied in a study area comprising two coastal villages: Vinh My A and Vinh Thinh in Bac Lieu province. The detailed biophysical, social, and economic characteristics of the study areas are presented in **Chapter 2**.

The application of FAO-MCE is described in **Chapter 3**. The approach includes six steps: (i) biophysical evaluation; (ii) socio-economic assessment; (iii) environmental assessment; (iv) standardization; (v) calculate suitability scores and (vi) scenario analysis. The case study shows that FAO-MCE allows the integration of a biophysical land evaluation with socio-economic and environmental appraisals. Scenario analysis can help the decision-maker to trade-off between possibilities and development targets. However, the results show only the land allocation but cannot point out land use conflict areas. This approach also did not include resource requirements (labour, capital, water) so the possibilities for realization still remain uncertain. The chapter also indicates the sources of uncertainty in the results. The first source

is in the land evaluation data. A static description of the biophysical conditions does not seem so suited to describe the quick changes in land use and its requirements in the coastal area. The second source is the uncertainty in the selection of socio-economic and environmental criteria and their quantification. The third source is in the justification of the importance of the criteria, which can be subjective because of prior knowledge/expertise of the land use planners or decision makers.

The application of PLUP, a bottom-up LUP approach, is presented in **Chapter 4**. The PLUP was done twice (2002 and 2003). In all hamlets two groups of farmers – an agriculture group and an aquaculture group - discussed land characteristics, biophysical and socio-economic constraints, and land use preferences for the next year. A geographic information system was used to analyze the land use change, the realization of the farmers' preference, the changes in preference, and the preference conflicts between groups of aquaculture and agriculture farmers. The results show that PLUP can provide planners with useful information about farmer's perceptions on land and land use. The results also show that conflict areas and conflict reasons can be identified and discussed by the farmers. The main factors that affect the quality of the results are the level of knowledge and willingness to cooperate of the participants and the communication skills of the discussion leader. Besides, how the meetings are organized is also very important. For example, separating the participants into focus groups helps make the discussion more specific and targeted.

Chapter 5 describes the application of LUPAS in the study area. The development target and resource availability of the case study area were translated into mathematical formulas and solved by multiple linear programming software. By gradually imposing constraints and goal restrictions, the land use planner and policy maker can check the feasibility of development goals, define the main constraints, the required investments, and the potential of the study areas. Risk analysis was performed in the cases of salt and shrimp market changes, and in case of shrimp disease outbreaks. LUPAS is a top-down approach even though the stakeholder participation can be illustrated via goal restrictions. Farmers are not directly involved in this approach. The chapter also indicates sources of uncertainty of the results. The first main source of uncertainty lies in the assumptions made on the productions' input-output data, which were based on secondary information, e.g. the input-output of shrimp production. The other source of uncertainty may occur during the formulation of the objectives, constraints, and goals of the model.

Chapter 6 compares the three LUP approaches in terms of acceptability and credibility. The acceptability was based on the expert's perceptions of the results and the resource requirements in terms of data, budget, equipment, and skill. The credibility was based on the prediction quality and the approaches' uncertainty. The results show that the perception of the local experts and local managers on the land use was somewhat closer to the farmers' perception than to the scientists' perception. For resource requirements LUPAS was the most expensive and requires detailed quantitative data and modeling skills while PLUP was the cheapest and requires mainly good communication skills. Regarding the uncertainty of the approaches, in PLUP the keys are the farmers' willingness to cooperate and the discussion facilitator's communicative skill during the PRA. In FAO-MCE it is crucial to detect the right key criteria for each discipline, quantify them and determine their importance. Moreover, FAO-MCE's results depend very much on the experts or decision makers who set the priority weights. In conclusion, with the dynamic and contrastive land use as that of the coastal zone of the Mekong Delta, PLUP seems to be the most suitable approach. However, for a sustainable land use planning which can optimize the use of resources and balance different stakeholders' priorities, these LUP approaches should be integrated.

Finally, **Chapter 7** discusses the implications and the limitations of the study for land use planning in general and in the coastal zone of the Mekong Delta, Vietnam in particular. A recommendation for further research is presented.

Samenvatting

Landgebruiksplanning in the kuststreek van de Mekong delta, Vietnam wordt bemoeilijkt door sterk contrasterende (eg. rijst versus garnalen) en snel veranderende landgebruikssystemen. Verder wordt landgebruiksplanning door vele belanghebbenden in Vietnam ervaren als een van boven af geregeld process dat, in vele gevallen, gedoemd is gedeeltelijk of geheel te mislukken. Het is essentieel een methode van landgebruiksplanning toe te passen die deze problemen kan vermijden. Er bestaat geen “meest geschikte” methode voor de Vietnamese kuststreek omdat bestaande methoden andere doeleinden voor ogen hadden of slechts een klein deel van het landgebruiksplanningstraject als beschreven door FAO behelzen. In de onderhavige studie worden drie verschillende benaderingen voor landgebruiksplanning geselecteerd en toegepast op hetzelfde studiegebied. Een vergelijking van de voor- en nadelen van de benaderingen is uitgevoerd.

De selectie van de drie benaderingen is gebaseerd op historisch gebruik in Vietnam, verschillen in planning filosofie, niveau van complexiteit en hoeveelheid rekenwerk. De benaderingen zijn:

(i) De FAO “Guidelines for Land Use Planning” uitgebreid met een Multi Criteria Evaluatie (FAO-MCE). Deze methode wordt het meest gebruikt in Vietnam;

(ii) Een Participatieve Landgebruiksplanning (PLUP). De plaatselijke bevolking van het studiegebied neemt deel aan het planningsproces;

(iii) LUPAS (Land Use Planning and Analysis System) is een methode gebaseerd op multiple goal linear programming die de doelstellingen van landgebruiksplanning, conflicten in die doelstellingen en het gebruik van de bestaansbronnen kan kwantificeren. LUPAS is speciaal ontwikkeld voor het tropsiche deel van Azie.

Deze drie LUP benaderingen zijn toegepast in een gebied aan de kust bestaande uit twee dorpen: Vinh My A and Vinh Thinh, Bac Lieu provincie. De biofysische, sociale en economische kenmerken van dit studiegebied zijn beschreven in **Hoofdstuk 2**.

Doe toepassing van FAO-MCE is beschreven in **Hoofdstuk 3**. De methode omvat zes stappen: (i) biophysische evaluatie; (ii) sociaal-economische beoordeling; (iii) milieukundige beoordeling; (iv) standaardisatie; (v) berekening van de geschiktheids-scores en (vi) scenario analyse. De studie laat zien dat FAO-MCE de integratie mogelijk maakt van een biophysische land evaluatie met sociaal-economische en milieukundige beoordelingen. Scenario analyse kan helpen bij het beoordelen van de voor en nadelen van de diverse opties en de

doelstellingen. De FAO-MCE methode geeft een bepaalde voorkeur voor een landgebruik aan voor alle landeenheden maar kan geen potentiele conflictgebied aanwijzen. De FAO-MCE aanpak beschrijft ook niet de benodigde produktiemiddelen zoals arbeid, kapitaal, beschikbaar water zodat onduidelijk blijft of het geadviseerde landgebruik ook werkelijk uitgevoerd kan worden. Er zijn een drietal bronnen van onzekerheid bij deze aanpak. Ten eerste de kwaliteit van de landevaluatiedata. De statische wijze van beschrijven van de biophysische situatie is niet zo geschikt voor een gebied met snelle en dramatische veranderingen in landgebruik en de eisen die deze veranderende vormen van landgebruik stellen aam het kustgebied. De tweede bron van onzekerheid is de selectie van de sociaal-economische en milieukundige criteria en hun kwantificatie. De derde bron zit in de mogelijke subjectiviteit van de planners die al voorkennis van het studiegebied hebben en die een rol laten spelen bij het toekennen van gewicht aan de diverse criteria.

Een participatieve aanpak (PLUP) wordt beschreven in **Hoofdstuk 4**. De PLUP werd twee maal uitgevoerd, in 2002 en in 2003. In alle gehuchten/wijken van de twee dorpen werden twee groepen boeren gevormd - een landbouwersgroep en een vissersgroep - die groepsgesprekken hielden over de eigenschappen van het land, de biophysische en de social economische beperkingen en de landgebruiksvoorkeuren voor het volgende jaar.Een geografisch informatie systeem is gebruikt om de veranderingen in landgebruik, de realisatie van de voorkeuren van de boeren, de veranderingen in voorkeur en de conflciten tussen de voorkeuren van de twee groepen in beeld te brengen en te analyseren. De resultaten laten zien dat de PLUP de planners bruikbare informatie kan verschaffen over de ideeën van de boeren over land en landgebruik. Conflictgebieden (en de redenen voor de conflicten) waar de plannen van de twee groepen boeren sterk afwijken kunnen worden aangegeven en terugggekoppeld worden naar de boeren. De belangrijkst factoren verantwoordelijk voor de kwaliteit van de resultaten zitten in het kennisniveau en de bereidheid tot samenwerking van de deelnemers en de comminatievaardigheden van de gespreksleiders. Het is ook van groot belang hoe de bijeenkomsten worden georganiseerd. Zo maakte het scheiden van de boeren in "focusgroepen" de discussies veel doelgerichter.

Hoofdstuk 5 beschrijft de toepassing van LUPAS op het studiegebied. De ontwikkelingsdoelstellingen en de beschikbare bestaansbronnen werden vertaald in wiskundige formules en opgelost met behulp van multiple goal linear programmering. Bij de toepassing van LUPAS worden steeds strengere eisen aan het land gesteld in termen van doelstellingen zoals verwachte hoeveelheden product. Op die manier kan de landgebruiksplanner de haalbaarheid van die doelstellingen controleren, de belangrijkste belemmeringen identificeren, de vereiste investeringen vaststellen en de potentiele productie van het gebeied in kaart brengen. Risico-analyse is uitgevoerd in de vorm van voorspellingen over de gevolgen van dramatische veranderigen in de zout of de garnalenprijs, of voor het geval er weer een uitbraak van de white spot ziekte onder garnalen zou plaatsvinden. LUPAS is een top-down methode ook al is het mogelijk de belangen van de stakeholders in ogenschouw te nemen bij het formuleren van de doelstellingen. Boeren worden niet betrokken bij LUPAS. De onzekerheden in de resultaten van de LUPAS toepassing worden veroorzaakt door noodzakelijke aannamen omtrent de input-output data omdat die gebaseerd zijn op secundaire informatie, bijvoorbeeld de data over garnalen productie. Onzekerheden kunnen ook voorkomen bij het formuleren van de doelen en de belemmeringen in het studiegebied.

Hoofdstuk 6 vergelijkt de drie LUP methoden voor wat betreft de graad van acceptatie en geloofwaardigheid. Acceptatie was gebaseerd op de meningen van diverse LUP experts die bekend waren met het studiegebied, en op de eisen die de studies stellen in termen van gegevens, budget, uitrusting en expertise. Geloofwaardigheid is getest via de kwaliteit van het voorspelde landgebruik en de onzekerheden in elk der methoden. De resultaten tonen aan dat de voorkeur van de locale experts en de locale managers meer lijkt op de wensen van de boeren dan de voorkeur van de wetenschappers. Wat betreft de eisen is LUPAS het duurst en ook het meest eisend in termen van data en kennis van modelleren, terwijl de PLUP methode het goedkoopst was maar hoge eisen stelt met betrekking tot communicatie. Het sucses van een PLUP is sterk afhankelijk van de medewerking van de boeren en de communicatieve talenten van de uitvoerders van de participatieve surveys. Bij FAO-MCE is de formulering en quantificatie van de sleutelcriteria de crunx van de methode. FAO-MCE's resultaten hangen sterk af van de experts die de gewichten toekennen aan de diverse prioriteiten. Gezien de extreem dynamische en contrasterende landgebruikstypen in het kustgebied van de Mekong delta lijkt PLUP de meest geschikt aanpak voor geloofwaardige landgebruiksplanning.

Tenslotte bespreekt **Hoofdfstuk 7** de implicaties en beperkingen van land use planning in het algemeen en voor de kuststrook in de Mekong delta in het bijzonder. Het hoofdstuk vat de voor- en nadelen samen van elk der drie methoden wanneer toegepast in een gebied met dynamisch landgebruik. Het hoofdstuk bevat ook aanbevelingen voor toekomstig onderzoek.

Tóm tắt

Trong những năm gần đây, công tác qui hoạch sử dụng đất ở vùng ven biển Đồng bằng Sông Cửu Long (ĐBSCL) đang chịu sự thách thức của việc chuyển đổi nhanh chóng các kiểu sử dụng đất có tính tương phản cao, không những về mặt tự nhiên mà còn về cả mặt kinh tế xã hội. Hơn nữa, phương pháp qui hoạch sử dụng đất của chúng ta lâu nay thường theo qui trình "trên-xuống", ít có sự tham gia của cộng đồng và thường chưa tính hết được hiệu quả sử dụng tài nguyên, nên các dự án qui hoạch đề ra thường kém khả thi, và đôi khi còn thất bại, gây lãng phí và ảnh hưởng rất lớn đến đời sống của người dân. Do đó, việc tìm kiếm một qui trình qui hoạch phù hợp để giải quyết các vấn đề nêu trên là việc làm hết sức cần thiết. Trên thế giới, nhiều phương pháp qui hoạch sử dụng đất đã được xây dựng và ứng dụng rộng rãi, tuy nhiên các phương pháp đó thường được xây dựng theo một quan điểm và mục tiêu qui hoạch cụ thể, hoặc chỉ tập trung giải quyết một khía cạnh trong toàn bộ quá trình qui hoạch sử dụng đất theo đề nghị của tổ chức Nông Lương Quốc Tế (FAO). Do đó, rất khó có thể nói được phương pháp qui hoạch nào thích hợp cho vùng ven biển ĐBSCL. Trong đề tài này, ba phương pháp qui hoạch sử dụng đất đã được áp dụng trên cùng một vùng nghiên cứu ở vùng ven biển ĐBSCL để có thể so sánh các ưu và nhược điểm của chúng một cách khách quan. Việc chọn các phương pháp qui hoạch cho nghiên cứu này thứ nhất dựa trên tính phổ biến, thứ hai dựa theo tiến trình qui hoạch (như "trên-xuống", "dưới-lên") và thứ ba là theo tính phức tạp (như sử dụng mô hình định lượng hay định tính) của các phương pháp. Các phương pháp đó là:

(i) Phương pháp của FAO dựa trên việc đánh giá thích nghi đất đai kết hợp với kỹ thuật đánh gia đa mục tiêu (FAO-MCE). Phương pháp này hiện đang được sử dụng rộng rãi ở Việt Nam. Đây là phương pháp theo tiến trình "trên-xuống".

(ii) Phương pháp "qui hoạch có sự tham gia" (PLUP: Participatory Land Use Planning). Trong phương pháp này, người dân địa phương được tham gia trực tiếp trong quá trình đánh giá tài nguyên và lựa chọn kiểu sử dụng đất. Đây là phương pháp theo tiến trình "dưới-lên".

(iii) Phương pháp qui hoạch tuyến tính. Trong đề tài một mô hình gọi tắt là LUPAS (Land Use Planning and Analysis System) được sử dụng, mô hình này có thể định lượng được các mâu thuẫn về mục tiêu hay chiến lược phát triển của vùng qui hoạch. Cũng như đưa ra được giải pháp sử dụng đất tối ưu nhất trong điều kiện tài nguyên cho phép. LUPAS được xây dựng bởi Viện Nghiên Cứu Lúa Thế Giới (IRRI) và đặc biệt sử dụng cho vùng nhiệt đới Á Đông.

Các phương pháp qui hoạch sử dụng đất nói trên được áp dụng trên cùng một vùng nghiên cứu thuộc 2 xã ven biển là xã Vĩnh Mỹ A và xã Vĩnh Thịnh thuộc huyện Vĩnh Lợi, tỉnh Bạc Liêu. Chi tiết về điều kiện tự nhiên, kinh tế xã hội và môi trường của vùng nghiên cứu được mô tả trong **Chương 2** của luận án.

Việc áp dụng phương pháp FAO-MCE trên vùng nghiên cứu được mô tả trong **Chương 3**. Phương pháp này bao gồm sáu bước: (i) đánh giá điều kiện tự nhiên; (ii) đánh giá kinh tế xã hội; (iii) đánh giá môi trường; (iv) chuẩn hóa các tiêu chí so sánh; (v) tính toán điểm thích nghi và (iv) phân tích viễn cảnh. Nghiên cứu này cho thấy phương pháp FAO-MCE có khả năng phân tích tổng hợp về kinh tế xã hội, môi trường và điều kiện tự nhiên một cách bán định lượng. Khả năng phân tích viễn cảnh của phương pháp này cho phép nhà qui hoạch hay người ra quyết định có những thông tin cơ sở để có thể đưa ra quyết định sử dụng đất sao cho khả năng phát triển của vùng nghiên cứu và những mục tiêu phát triển của các nhóm lợi ích khác nhau được cân bằng. Tuy nhiên, qui trình này không xét tới yêu cầu về tài nguyên (như yêu cầu về lao động, vốn, nguồn nước, v.v…) nên qui hoạch đề ra có thể không đạt được tính khả thi cao. Độ chính xác của phương pháp qui hoạch này phụ thuộc vào nhiều yếu tố. Yếu tố thứ nhất là từ công tác đánh giá điều kiện tự nhiên (đánh giá đất đai). Việc đánh giá đất theo FAO như hiện nay là một cách đánh giá "tĩnh", nó không thích hợp cho việc mô tả sự thay đổi nhanh chóng của vùng ven biển ĐBSCL. Yếu tố thứ hai là việc chọn và đánh giá các chỉ thị về kinh tế xã hội và môi trường. Các tiêu chí này có thể chủ quan hoặc do số liệu, thông tin thu được không đầy đủ. Yếu tố thứ ba là việc đánh giá mức độ quan trọng của các chỉ thị đó. Việc chọn lựa này có thể chủ quan theo kiến thức và kinh nghiệm của nhà qui hoạch và người ra quyết định. Yếu tố cuối cùng là việc chọn công thức chuẩn hóa các điểm số của các tiêu chí đánh giá. Công thức chuẩn hóa khác nhau có thể dẫn đến việc bố trí sử dụng đất khác nhau.

Chương 4 mô tả việc áp dụng phương pháp PLUP vào vùng nghiên cứu. Phương pháp này được lập lại hai lần vào năm 2002 và năm 2003. Ở mỗi ấp, hai nhóm nông dân, nhóm nông nghiệp và nhóm thủy sản, đã thảo luận về tính chất đất đai và những điều kiện bất lợi về tự nhiên cũng như kinh tế xã hội, và cuối cùng là đưa ra định hướng sử dụng đất của ấp trong năm tiếp theo. Công cụ phân tích của hệ thống thông tin địa lý (GIS) đã được sử dụng để phân tích sự thay đổi về sử dụng đất, phân tích việc thực hiện các hướng sử dụng đất mà chính nông dân đã định ra từ năm trước, và phân tích sự mâu thuẫn trong việc sử dụng đất của hai nhóm nông dân. Kết quả nghiên cứu cho thấy PLUP có thể cung cấp cho nhà qui hoạch các thông tin hết sức quan trọng về quan điểm của người dân liên quan đến tài nguyên đất đai và các yếu tố ảnh hưởng đến sự quyết định của họ trong việc thay đổi hệ thống canh tác. Các vùng có mâu thuẫn về sử dụng đất và nguyên nhân gây mâu thuẫn đã được người dân nêu rõ trong quá trình triển khai phương pháp qui hoạch này. Chương này cũng đã chỉ ra các yếu tố ảnh hưởng đến độ chính xác của phương pháp. Yếu tố thứ nhất và quan trọng nhất là mức độ hiểu biết và sự nhiệt tình của người dân trong quá trình thảo luận. Yếu tố thứ hai là khả năng truyền đạt, gợi ý của người hướng dẫn thảo luận cũng rất ảnh hưởng đến chất lượng của phương pháp. Và yếu tố cuối cùng cũng hết sức quan trọng là việc tổ chức buổi thảo luận, việc phân nông dân thành các nhóm khác nhau (nhóm nông nghiệp, nhóm thủy sản) làm cho việc thảo luận được tập trung và đỡ nhàm chán hơn.

Chương 5 mô tả việc áp dụng LUPAS vào vùng nghiên cứu. Các chỉ tiêu phát triển và nguồn tài nguyên của vùng nghiên cứu được chuyển đổi thành các hàm toán học và được giải bằng một phần mềm qui hoạch tuyến tính. Qua các kịch bản phân tích khác nhau (bằng cách tăng dần các điều kiện giới hạn và các chỉ tiêu về sản lượng), LUPAS cho thấy một cách định lượng các trở ngại chính của vùng nghiên cứu và tiềm năng của vùng nghiên cứu khi các trở ngại này được khắc phục. Hơn nữa, LUPAS có thể được sử dụng để đánh giá xem các chỉ tiêu đã đề ra có khả thi không và nếu có thì tài nguyên phải được dùng như thế nào cho tối ưu nhất. Một phân tích về rủi ro khi giá tôm và muối giảm xuống và khi dịch bệnh tôm xảy ra cũng đã được thực hiện trong chương này. Tuy nhiên, do LUPAS là một phương pháp tiếp cận theo hướng “trên-xuống”, nên nông dân khó có thể tham gia trực tiếp được vào trong phương pháp này. Sự chính xác của phương pháp này phụ thuộc vào hai yếu tố chính sau. Yếu tố thứ nhất là việc ước lượng đầu vào và đầu ra của các sản phẩm, đặc biệt là các kiểu sử dụng đất có tôm. Yếu tố thứ hai là sự xác lập một cách chính xác các công thức mô tả mục tiêu, các điều kiện giới hạn, và chỉ tiêu sản phẩm vào trong mô hình.

Chương 6 đánh giá và so sánh các phương pháp trên về tính tin cậy và tính chấp nhận dựa trên các kết quả thu được từ việc áp dụng chúng trên cùng một vùng nghiên cứu (thực hiện trong các Chương 3, 4 và 5). Tính chấp nhận được đánh giá dựa trên quan điểm của các chuyên gia về kết quả của các phương pháp và dựa trên yêu cầu về dữ liệu, tài chính, công cụ và kỹ năng cần thiết để thực hiện các phương pháp đó. Tính tin cậy được đánh giá dựa trên chất lượng dự đoán và mức độ tin cậy của từng bước trong quá trình thực hiện phương pháp. Kết quả so sánh cho thấy quan điểm của các chuyên gia và nhà quản lý ở địa phương về việc sử dụng đất gần với quan điểm sử dụng đất của người dân hơn so với các nhà khoa học. So sánh về yêu cầu để áp dụng các phương pháp, LUPAS có yêu cầu về kinh phí, về số lượng, mức độ chi tiết của số liệu định tính và kỹ năng thiết lập mô hình cao nhất, trong khi PLUP ít tốn kém nhất và chỉ đòi hỏi khả năng giao tiếp của người hướng dẫn thảo luận. Về tính tin cậy của các phương pháp, trong PLUP, sự nhiệt tình cộng tác của người tham gia thảo luận và khả năng giao tiếp của người hướng dẫn thảo luận là quyết định chính. Đối với FAO-MCE, việc chọn lựa chính xác các chỉ thị cho mỗi tiêu chí, cơ sở và phương pháp đánh giá các tiêu chí và cơ sở xác định mức độ quan trọng của chúng là các yếu tố hết sức quan trọng ảnh hưởng đến kết quả cuối cùng của phương pháp. Hơn nữa, kết quả của FAO-MCE cũng phụ thuộc rất nhiều vào các gia trọng mà các nhà qui hoạch đưa vào tính toán. Tóm lại, với tính nạhy cảm và tương phản của các hệ thống sử dụng đất đai ở vùng ven biển ĐBSCL, PLUP được xem như là phương pháp thích hợp nhất. Tuy nhiên, để có thể sử dụng tài nguyên một cách tối ưu và duy trì được tính bền vững của vùng, các phương pháp qui hoạch này nên được tích hợp lại.

Cuối cùng, **chương 7** thảo luận về kết quả của nghiên cứu này cũng như các giới hạn của nó trong qui hoạch sử dụng đất nói chung và cho vùng ven biển ĐBSCL, Việt Nam nói riêng. Và cuối cùng, một số kiến nghị cho các nghiên cứu sau này đã được đề nghị.

Appendix

Appendix 1. The PLUP interview sheet

Interview form (After Defoer et al., 2000)

Preparation: (to aid the farmer in locating their land in the map)

- Indicate specific features bordering the territory (such as rivers, roads, etc.).
- Mark and name neighbouring hamlets.
- Show the main roads and major footpaths, including those leading to neighbouring hamlets.
- Indicate the hamlet centre, schools, pagodas, churches, important shops, and other significant landmarks.

Discussion on the land use innovation:

1. The past

- Was there any big land use change event in the hamlet? If yes, when and why? (e.g. more rice and upland areas because of the construction of canal or using of pump-well or application of better soil reclamation technique, or because of government land use policy, etc.)

Note: remind the participants some main socio-economic events such as the formation and termination of agriculture cooperatives, the "doi moi" (renovation, 1988); and the passage of the land law in 1993; and other events respective to science and technology transfer such as the activities of agriculture extension services in the hamlet.

- What was the land use distribution and how important was it to their area?
- Did the changes give better or worse effect to the land and the farmers' income? Describe the effect and try to explain the reasons?

2. The present:

    - Have any farmers in the hamlet or the neighbouring hamlets tried new land use type? If yes, what were their names, where were their farm plots and were they successful? (This information will be used to select farmers for individual interviews)

- On what criteria the farmers make their decision on changing their land use? (e.g. quick cash return, less risk in terms of natural change and market stability, less labour requirement, low investment, high gross return, etc.)
- Who are the planners and decision-makers of the land use of the hamlet? How are farmers involved in the planning process?

Mapping of the resources: description of the natural condition, and the existing land use in the study area.

- Locate participants' land in the map, describe their land in terms of: actual land use, advantages and disadvantages, improvement needs, soil, and water condition, and the factors that, according to them, affect most to the production of their land. Mapping all this information and describe the thematic data in the forms of tables as following.

No	Name	Land use type	Yield	Class	Soil	Water	Weather	Other	Area (ha)
1	Nguyen Van A	Mono rice	3ton/ha	Pretty good	Acid sulphate soil	Saline 3 months	Good, enough rainfall	Easy to drain	2
		Rice – Shrimp	...	...	...	...	...	...	...
		Single shrimp	...	...	...	...	...	...	...
2	Trần Văn B	Salt	...	...	...	...	...	...	...

- Find areas with conditions similar to those of the participants' land. Describe and draw the boundaries of these areas in the map.
- Find the areas with conditions different to those of the participants' land. Describe and draw the boundaries of these areas in the map.
- Give all regions (land units) with identification codes (e.g. VM1, VM2). Estimate the area of the land units (LU).
- Name some households located near the boundaries of the LU. Locate them in the LU map. Discuss the LU map again for agreement among all participants. Describe the LU in the table as following:

LU	Describtion	Area	Soil	Land	Weather	Others	Actual land uses
VM1	Low land, acid soil with 6 months under saline intrusion.	12 ha	Acid sulphate soil	Saline 3 months	Good, enough rainfall	Easy to drain	- Extensive shrimp - Semi intensive shrimp
VM2	...	...					...

Defining the promising LUTs

Based on LU table and map resulted from the previous discussion:

- Discuss the monthly labour requirements (labour/ha/month), the use of fertilizer or food, the use of pesticide or chemical, and the total cost for practicing LUTs in each LU.
- Discuss on the yield (average, maximum), revenue and benefit of LUTs in each LU. Emphasize on the difficulties and risks of the LUTs (variation of yields, production prices, and market).
- Discuss how to overcome the difficulties and reduce the risks; and anticipate the support/help from the government.

3. The farmers' expected future

- The facilitator summarizes the land unit map and the difficulties and risk of the existing LUTs in each LU and ask the participants for their comments (add directly into the map).
- Discuss the other possible promising LUTs with their natural conditions, capital and labour requirements.
- Point at each LU and ask the participants for their referred LUTs to be practiced. Ask them for the reasons and discuss for a final agreement.
- Draw the land unit map in another piece of paper, put the name of participations' prefered LUTs in the LU.

Appendix 2. The LUPAS model for the study area

The LUPAS model for the study area contains 11 GAMS files (Figure A.1). For a certain scenario, a *scen.gms* file is run. First, it calls the *GetData.gms*, the *GetYeildData.gms* and the *GetPriceData.gms* to get all necessary data. For different scenarios, the corresponding input-output data files (yield, price, labour requirement, etc.) are indicated. Second, the objective, the constraint and the goal restriction functions are declared in the *DeclareVarFun.gms*. Third, the sub-scenarios are defined in the *DefineSubScen.gms*. A sub-scenario must have one objective function and at least one constraint or one goal restriction. Then, the *SolMaxInc.gms* solves the sub-scenarios. Finally, the *Result.gms* writes the results into the Microsoft Excel Comma Separated Values files (CSV) in order to present the results in forms of tables or thematic maps.

In the *results.gms*, the productions of each sub-scenario are calculated by the *CalProduction.gms*. The summary of all sub-scenarios' results is written in a CSV file by the *OverallResult.gms*. The *SubScenResult.gms* writes the results of each individual sub-scenario in a separate CSV file.

The GAMS files presented in this appendix are to run the 'present technical level' scenario.

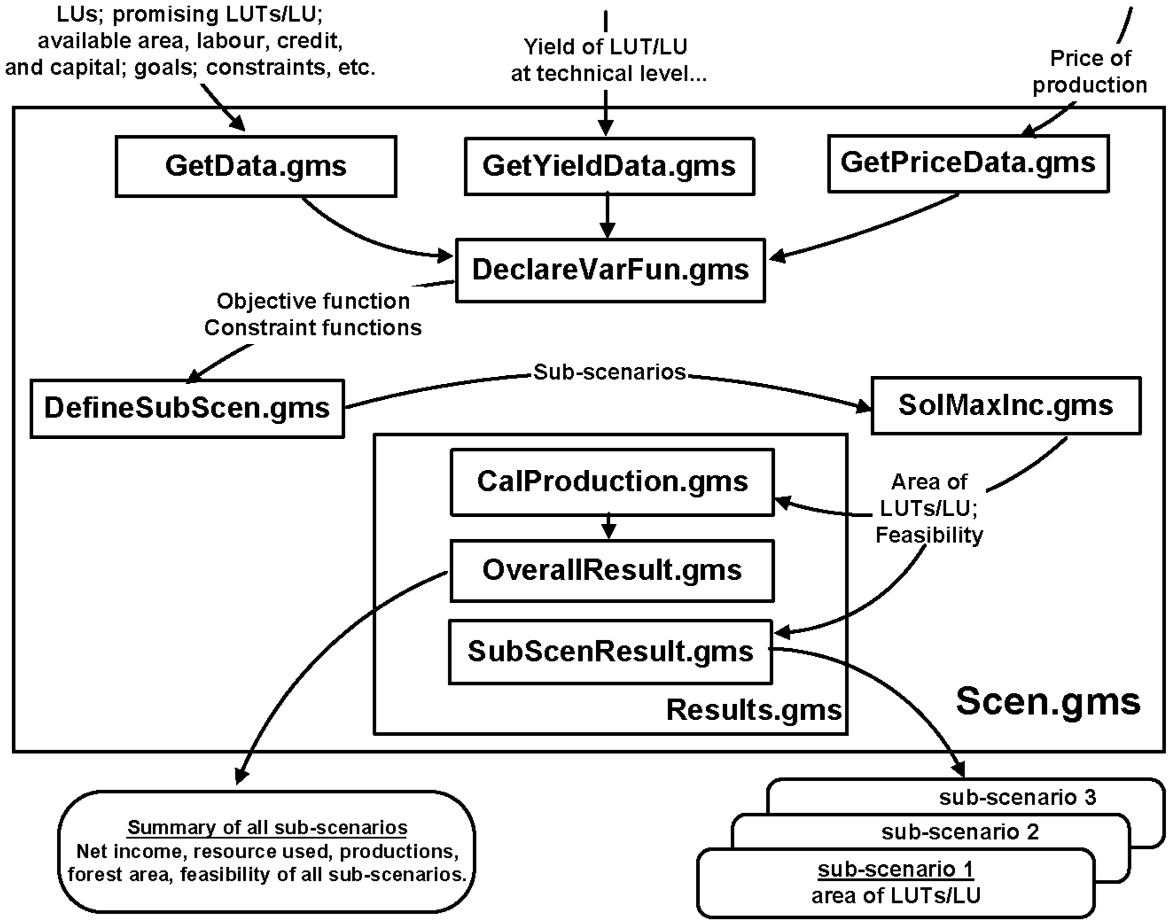

Figure A.1 The linkage of GAMS files to run a scenario.

A. The main program

Scen.gms

```
*-----------------------------------------------------------------------------------------------------------------------
*        SCEN.GMS
*        Author: Nguyen Hieu Trung, College of Technology, Can Tho University, Vietnam
*        Last updated: 20 Feb. 2003
*        This file is the main program file that links all corresponding files to run a land use planning
*        optimization scenario (e.g. present technical level or improved technical level).
*        This file is to run the present technical level scenario.
*-----------------------------------------------------------------------------------------------------------------------

* Call GetData.gms for all parameters, socio-economic and biophysical data
$include 'GetData.gms'

*    Call GetYieldData.gms for yield data that stored in the LUPProdPresent.csv file
$batinclude 'GetYieldData.gms' "'LUTProdPresent.csv'"

*    Call getpricedata.gms for production price data that stored in the ProPrice.csv file
$batinclude 'GetPriceData.gms' "'ProdPrice.csv'"

*    Call DeclareVarFun.gms for for declaring variables and functions of scenario 1 (present technical level)
$batinclude DeclareVarFun.gms "'scen1'"

*  Call DefineSubScen.gms to define sub-scenario
$include "DefineSubScen.gms"
set i /1*6/;

Parameter
* Define a temporary matrix to save the sub-scenarios' results
LUTA(byScen,byLU,byLUT)

* Define a temporary vector to save the sub-scenario status (e.g. feasible, infeasible)
modstatus(byScen)

* Define a temporary vector to save models' results
MaxIn(byScen);
option iterlim = 20000000;
option Reslim = 2000;

*------------------------------------------------------------------------------
*       SOLVE THE MAXIMIZE INCOME MODELS
*------------------------------------------------------------------------------

* Call the SolMaxInc.gms file to solve the scenarios:
* Maximum regional net income with only area constraint
$batinclude SolMaxInc.gms "MaxIncome1" "'1'" "ONIn"
```

```
* Maximum regional net income with area and labour constraints
$batinclude SolMaxInc.gms "MaxIncome2" "'2'" "ONIn"

* Maximum regional net income with area and capital constraints
$batinclude SolMaxInc.gms "MaxIncome3" "'3'" "ONIn"

* Maximum regional net income with area, labour and capital constraints
$batinclude SolMaxInc.gms "MaxIncome4" "'4'" "ONIn"

* Maximum regional net income with production target: Rice
$batinclude SolMaxInc.gms "MaxIncome5" "'5'" "ONIn"

* Maximum regional net income with area, labour and capital constraints, and salt target
$batinclude SolMaxInc.gms "MaxIncome6" "'6'" "ONIn"

* Maximum regional net income with area, labour and capital constraints, and shrimp target
$batinclude SolMaxInc.gms "MaxIncome7" "'7'" "ONIn"

* Maximum regional net income with area, labour and capital constraints, and vegetable target
$batinclude SolMaxInc.gms "MaxIncome8" "'8'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; rice and shrimp targets
$batinclude SolMaxInc.gms "MaxIncome9" "'9'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; shrimp and salt targets
$batinclude SolMaxInc.gms "MaxIncome10" "'10'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; rice and vegetable targets
$batinclude SolMaxInc.gms "MaxIncome11" "'11'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; vegetable, rice and salt targets
$batinclude SolMaxInc.gms "MaxIncome12" "'12'" "ONIn"
* Maximum regional net income with area, labour and capital constraints; forest, vegetable, shrimp and
*  salt targets
$batinclude SolMaxInc.gms "MaxIncome13" "'13'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; forest, vegetable, rice and salt
*  targets
$batinclude SolMaxInc.gms "MaxIncome14" "'14'" "ONIn"

* Maximum regional net income with area, labour and capital constraints; forest, vegetable, rice and
*  shrimp targets
$batinclude SolMaxInc.gms "MaxIncome15" "'15'" "ONIn"
```

```
* Maximum regional net income with area, labour and capital constraints; forest, vegetable, rice, shrimp
* and salt targets
$batinclude SolMaxInc.gms "MaxIncome16" "'16'" "ONIn"


*---------------------Write results to text files-------------------
$include results.gms


*------------------------- End of the scen.gms --------------------------------------------
```

B. The sub-programs

GetData.gms

```
*   ------------------------------------------------------------------------------------------------------------
*   GET DATA
*   GetData.gms loads model's parameters from csv files such as name of land use types, villages,
*   development targets, and land units; social economic data: available labour, available capital, cost,
*   input-output, require labour, and require capital; biophysical data: area and land suitability.
*   ------------------------------------------------------------------------------------------------------------.
```

Sets

```
* Get list of production.
byPro    /
$include 'byPro.csv'
/

* Get list of LUT.
byLUT   /
$include 'byLUT.csv'
/

* Get list of months' names.
byMonth              Months /
$include 'byMonth.csv'
/

* Get list of villages' names.
byVill    /
$include 'byVil.csv'
/

* Get list of production targets' names.
byTarget  /
$include 'byTarget.csv'
/
```

```
* Get list of target scenario's names.
byTargetScenarios  /
$include 'byTargetScenarios.csv'
/
* Get list of sub-scenarios' code.
byScen  /
$include 'byScenario.csv'
/

* Get list of land unit.
byLU   /
$include 'byLU.csv'
/

Parameter
* Resource available
PromLUT(byLU, byLUT)                Promising LUT of LU
PresentLUTArea(byLU, byLUT)         Present LUT in LU
AvArea(byLU)                        Available area of LU
LUinVillage(byVill,byLU)            LU in village
AvLabour (byVill, byMonth)          Available labour of village per month
AvCapital(byLU)                     Available capital per LU
Credit(byLU,byLUT)                  Available credit for LUT per LU
ForestLUT(byLUT)                    LUT with forest
LUTPro(byLUT, byPro)                Name of production of LUT

* input-output
reqLab(byLUT, byMonth)              LUT labour requirement per month
LUTcost(byLU,byLUT)                 LUT cost in LU
LUTProYield(byLU,byLUT,byPro)  Yield of production per LUT per LU

* Indicate the production target and name of target scenario
Goal(byTarget,byTargetScenarios)

*---------------------------------
* Get data from csv files
*--------------------------------
*  Get promising LUT per LU
table PromLUT(byLU,byLUT)
$ONDELIM
$include 'PromLUT.csv'
```

```
$OFFDELIM;
* Get available labour per village
table avLabour(byVill,byMonth)
$ONDELIM
$include 'avLabour.csv'
$ONDELIM ;

* Get LUTs' labour requirement
table reqLab(byLUT,byMonth)
$ONDELIM
$include 'ReqLab.csv'
$OFFDELIM;

* Get area of LU
Parameter  avArea(byLU)                          /
$ONDELIM
$include 'avLUArea.csv'
$OFFDELIM
/;

* Get available capital per LU
parameter  avCapital(byLU)                    /
$ONDELIM
$include 'avCapital.csv'
$OFFDELIM
/;

* Get forest and LUT relation
parameter ForestLUT(byLUT)                    /
$ONDELIM
$include 'ForestLUT.csv'
$OFFDELIM
/;

* Get LU and Village relation
table LUinVillage (byVill,byLU)
$ONDELIM
$include 'LUin2Village.csv'
$OFFDELIM;
* LUTs cost
table  LUTcost(byLU,byLUT)
```

```
$ONDELIM
$include 'LUTcostP.csv'
$OFFDELIM;

* Get production and LUT relation
table LUTPro(byLUT,byPro)
$ONDELIM
$include 'LUTProd.csv'
$OFFDELIM;

* Get goal restriction scenario
table Goal(byTarget,byTargetScenarios)
$ONDELIM
$include 'Goals.csv'
$OFFDELIM;
*------------------------------------------------End GetData.gms-----------------------------------------
```

GetYieldData.gms

```
*   -----------------------------------------------------------------------------------------------------------------------
*   GET YIELD DATA
*   GetYielddata.gms get yield data from csv files. The name of the yield data file is stated in the
*   Scen.gms.
*   -----------------------------------------------------------------------------------------------------------------------
table LUTproyield(byLU,byLUT,byPro)
$ONDELIM
$include %1
$OFFDELIM;
*---------------------------------------End GetYieldData----------------------------------------------------
```

GetPriceData.gms

```
*   -----------------------------------------------------------------------------------------------------------------------
*   GET PRICE DATA
*   GetProceData.gms get production price from csv files. The name of the price data file is stated in the
*   Scen.gms.
*   -----------------------------------------------------------------------------------------------------------------------
parameter ProdPrice(byPro)   Price of produce /
$ONDELIM
$include %1
$OFFDELIM
/;
*--------------------------------------End GetPriceData---------------------------------------------------
```

DeclareVarFun.gms

```
*--------------------------------------------------------------------------------------------------------------------------
*     DECLARE VARIABLES AND EQUATIONS
*     This file declare the objective function and constraints or goals functions for the optimization
*     models. The objective function of this model is the total net income of the study area.
*     The constraints are:
*         - Total allocated land in a land unit must less than total available land
*         - Total required labour in a village must less than or equal to the available labour of the village
*           plus  the available labour from the neighbouring villages
*         - Total required capital of village must less than or equal to the available capital of the village
*     The goals are:
*         - Total rice produce must greater than the target rice production
*         - Total shrimp produce must greater than the target shrimp production
*         - Total salt produce must greater than the target salt production
*         - Total vegetable production must greater than or equal to the minimum requirement and must
*           less than or equal to the maximum requirement
*        - Total forest area must greater than or equal to the target forest area
*--------------------------------------------------------------------------------------------------------------------------
```

Free Variable

ONIn Objective: Net income

Positive variable

LUTArea(byLU,byLUT); Areas of LUT in a land unit (LU)

Equation

cPromArea(byLU,byLUT) Only promising LUT can be allocated in a LU

IncomeObj Objective function: total net income

cUpArea(byLU) Constraint: total allocated land in a land unit must less than total available land

cReqLab(byVill,byMonth) Constraint: total required labour in a village must less than or equal to the available labour of the village plus the neighbour villages

cReqCap(byLU) Constraint: total required capital of LU must less than or equal to the available capital of the LU

cRPro Goal: total rice produce must greater than or equal to the target rice production

cShPro Goal: total shrimp produce must greater than or equal to the target shrimp production

cSaltPro Goal: total salt produce must greater than or equal to the target salt production

cVegmin Goal: total vegetable production must greater than or equal to the minimum requirement

cVegmax Goal: total vegetable production must less than or equal to the maximum requirement

cForArea Goal: total forest area must greater than or equal to the target forest area

```
*----------------------------------------------------------------------------
* Calculate revenue per ha of each LUT in LU.
* Revenue per ha = sum of all LUTs' yield * corresponding production price
*----------------------------------------------------------------------------
```

Parameters Rev(byLU,byLUT);

*Rev(byLU,byLUT)= sum(byPro,LUTProYield(byLU,byLUT,byPro)**

ProdPrice(byPro)$(PromLUT(byLU,byLUT) eq 1));

```
*-------------------------------------------------------------------------------
*  Make sure only the cost of LU's promising LUTs is taken into account.
*-------------------------------------------------------------------------------

Parameter Cost(byLU,byLUT);

Cost(byLU,byLUT)= LUTcost(byLU,byLUT) $(PromLUT(byLU,byLUT) eq 1);

*-------------------------------------------------------------------
*              OBJECTIVES FUNCTION:
*   Net income of the study area  = sum of all net income from all LUs.
*   Net income of a LU = sum of all allocated LUTs in the LU.
*-------------------------------------------------------------------

InComeObj.. ONIn =e= sum((byLU,byLUT), (Rev(byLU,byLUT)-Cost(byLU,byLUT))*
              LUTArea(byLU,byLUT));

*------------------------------------------------------------------------------
*              CONSTRAINTS
*------------------------------------------------------------------------------

*------------------------------------------
*  Resource constraints
*------------------------------------------

* Total allocated land in a LU must less than its area.

cUpArea(byLU)..  sum(byLUT,LUTArea(byLU,byLUT)) =l= avArea(byLU);

* Assign 0 to the area of LUTs that are not suitable for a LU.

cPromArea(byLU,byLUT).. LUTArea(byLU,byLUT)$(PromLUT(byLU,byLUT)eq 0) =e= 0;

* Total required labour in a village must less than or equal to the available labour of the village plus the
* available labour from the neighbouring villages

cReqLab(byVill,byMonth)..
       sum((byLU,byLUT)$(LUinVillage(byVill,byLU) eq 1),LUTArea(byLU,byLUT)*
        ReqLab(byLUT,byMonth))=l= avLabour(byVill,byMonth);

*  Total required capital of village must less than or equal to the available capital of the village

cReqCap(byLU)..
       sum(byLUT,cost(byLU,byLUT)*LUTArea(byLU,byLUT))=l= AvCapital(byLU);


*------------------------------------------
* Goals (Production target)
*-----------------------------------------

*   Total rice produce must greater than the target rice production.

cRPro..Sum((byLU,byLUT)$ (LUTPro(byLUT,"lua") eq 1),
        LUTArea(byLU,byLUT)*LUTProYield(byLU,byLUT,"lua"))=g=Goal("rice",%1);

*   Total shrimp produce must greater than the target shrimp production

cShPro..Sum((byLU,byLUT)$ (LUTPro(byLUT,"tomsu") eq 1),
        LUTArea(byLU,byLUT)*LUTProYield(byLU,byLUT,"tomsu"))=g=Goal("shrimp",%1);
```

* Total salt produce must greater than the target salt production

cSaltPro..sum((byLU,byLUT)$ (LUTPro(byLUT,"muoi") eq 1),

*LUTArea(byLU,byLUT)*LUTProYield(byLU,byLUT,"muoi"))=g=Goal("salt",%1);*

* Total vegetable production must greater than or equal to the minimum requirement and must
*   less than or equal to the maximum requirement

cVegmax..sum((byLU,byLUT)$(LUTPro(byLUT,"rau") eq 1),

*LUTArea(byLU,byLUT)*LUTProYield(byLU,byLUT,"rau"))=l=Goal("Vegmax",%1);*

cVegmin..sum((byLU,byLUT)$(LUTPro(byLUT,"rau") eq 1),

*LUTArea(byLU,byLUT)*LUTProYield(byLU,byLUT,"rau"))=g=Goal("Vegmin",%1);*

* Total forest area must greater than or equal to the target forest area

cForArea..sum((byLU,byLUT),
*(LUTArea(byLU,byLUT)*0.6)$(ForestLUT(byLUT)eq1)+LUTArea(byLU,byLUT)$(ForestLUT(byLUT) gt 1))=g=Goal("forest",%1);*

*---End DeclareVarFun.gms---

DefineSubScen.gms

* --
*   DEFINE SUB-SCENARIO
*   This file defines optimization scenarios: maximizing total net income with
*   - Only land constraint
*   - Land constraint + Labour constraint
*   - Land constraint + Capital constraint
*   - Land constraint + Labour constraint + Capital constraint
*   - Rice goal
*   - Salt goal
*   - Shrimp goal
*   - Vegetable goal
*   - Salt and shrimp goals
*   - Rice and vegetable goals
*   - Rice, shrimp, salt and vegetable goals
*   - Shrimp, salt, vegetable and forest goals
*   - Rice, salt, vegetable and forest goals
*   - Rice, shrimp, vegetable and forest goals
*   - Rice, shrimp, salt, vegetable and forest goals
*---

* Only land constraint

model MaxIncome1 /InComeObj,cUpArea,cPromArea/;

* Land constraint + Labour constraint

model MaxIncome2 /InComeObj,cUpArea,cPromArea,cReqLab/;

* Land constraint + Capital constraint

model MaxIncome3 /InComeObj,cUpArea,cPromArea,cReqCap/;

* Land constraint + Labour constraint + Capital constraint

model MaxIncome4 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap/;

* All constraints + Goal: Rice

model MaxIncome5 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro/;

* All constraints + Goal: Salt

model MaxIncome6 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cSaltPro/;

* All constraints + Goal: Shrimp

model MaxIncome7 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cShPro/;

* All constraints + Goal: Vegetable

model MaxIncome8 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cVegmin,cVegmax/;

* All constraints + Goals: Rice,Shrimp

model MaxIncome9 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cShPro/;

* All constraints + Goals: Salt, Shrimp

model MaxIncome10 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cSaltPro,cShPro/;

* All constraints + Goals: Rice,Vegetable

model MaxIncome11 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cVegmin,cVegmax/;

* All constraints + Goals: Rice,Shrimp, Salt, Vegetable

model MaxIncome12 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cSaltPro,cShPro,cVegmin,cVegmax/;

* All constraints + Goals: Shrimp, Salt,Vegetable, Forest

model MaxIncome13 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cShPro,cSaltPro,cVegmin,cVegmax,cForArea/;

* All constraints + Goals: Rice,Salt,Vegetable, Forest

model MaxIncome14 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cSaltPro,cVegmin,cVegmax,cForArea/;

* All constraints + Goals: Rice,Shrimp,Vegetable, Forest

model MaxIncome15 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cShPro,cVegmin,cVegmax,cForArea/;

* All constraints + Goals: Rice, Shrimp, Salt, Vegetable, Forest

model MaxIncome16 /InComeObj,cUpArea,cPromArea,cReqLab,cReqCap,cRPro,cShPro,cSaltPro,cVegmin,cVegmax,cForArea/;

*---------------------------------End of DefineSubScen.gms--

SolMaxInc.gms

```
*-----------------------------------------------------------------------------------------------
*    Solve maximizing net regional income models
*    Parameter:
*         %1:  Name of sub-scenario
*         %2:  code of the sub-scenario
*         %3:  Name of optimization function
*-----------------------------------------------------------------------------------------------

* Maximizing the optimization function %3 with constraints and goal are set in sub-scenario %1
solve %1 using lp maximizing %3;

* Store the area of allocated LUTs/LU in a temporary matrix for production calculation.
LUTA(%2,byLU,byLUT) =  LUTArea.l(byLU,byLUT);

* Store the maximum income of the sub model number %2.
Maxin(%2) = ONIn.l;

* Check the model status.
modstatus(%2) =  %1.modelstat;
*  Assign 0 to the variable LUTArea for the next sub-scenario run.
LUTArea.l(byLU,byLUT) = 0;
*----------------------------------------End of SolMaxInc.gms---------------------------------------------
```

Results.gms

```
* -------------------------------------------------------------------------------------------------------------
*     RESULTS.GMS
*    Wile the scenario results into .csv text files
* -----------------------------------------------------------------------------------------------------------------

* Calculate all sub-scenarios' productions based on the LUT area per LU
$batinclude CalProduction.gms

* Put all sub-scenarios' productions results into a text file
$batinclude OverallResult.gms "Overalls1.csv" "'sen1'"

*--------------------------------------------------------------------------
* Put sub-scenarios' results into text files.
*--------------------------------------------------------------------------
$batinclude SubScenResult.gms "SubScen1s1.csv" "1"
$batinclude SubScenResult.gms "SubScen2s1.csv" "2"
$batinclude SubScenResult.gms "SubScen3s1.csv" "3"
$batinclude SubScenResult.gms "SubScen4s1.csv" "4"
```

```
$batinclude SubScenResult.gms "SubScen5s1.csv" "5"
$batinclude SubScenResult.gms "SubScen6s1.csv" "6"
$batinclude SubScenResult.gms "SubScen7s1.csv" "7"
$batinclude SubScenResult.gms "SubScen8s1.csv" "8"
$batinclude SubScenResult.gms "SubScen9s1.csv" "9"
$batinclude SubScenResult.gms "SubScen10s1.csv" "10"
$batinclude SubScenResult.gms "SubScen11s1.csv" "11"
$batinclude SubScenResult.gms "SubScen12s1.csv" "12"
$batinclude SubScenResult.gms "SubScen13s1.csv" "13"
$batinclude SubScenResult.gms "SubScen14s1.csv" "14"
$batinclude SubScenResult.gms "SubScen15s1.csv" "15"
$batinclude SubScenResult.gms "SubScen16s1.csv" "16"
*-----------------------------------------End of Results.gms---------------------------------------------
```

CalProduction.gms

```
* ----------------------------------------------------------------------------------------------------------------
*             CALCULATE PRODUCTIONS
*        This file calculates the total productions from the land allocation to put into the result files
*-------------------------------------------------------------------------------------------------------------------

* Declare parameters
parameter RicePro(byScen);
parameter ShrimpPro(byScen);
parameter LUIncomeHa(byScen,byLU);
parameter LURevHA(byScen,byLU);
parameter LUCostHA(byScen,byLU);
parameter SaltPro(byScen);
parameter VegPro(byScen);
parameter ForArea(byScen);
parameter LabourReqMonth(byScen,byVill,byMonth);
parameter TotalLabout(byScen);
parameter CapitalReqLU(byScen,byLU);
parameter TotalCapital(byScen);
parameter PLand(byScen);
parameter PLandunit(byScen,byLU);

*---------------------------------------
*    Recalculate productions based on the sub-scenario results.
*---------------------------------------
```

```
* Calculate rice production for each scenario
RicePro(byScen) =Sum((byLU,byLUT)$(LUTPro(byLUT,"lua") eq 1),
            LUTA(byScen,byLU,byLUT)*LUTProYield(byLU,byLUT,"lua"));

* Calculate shrimp production for each scenario
ShrimpPro(byScen)=Sum((byLU,byLUT)$(LUTPro(byLUT,"tomsu") eq 1),
           LUTA(byScen,byLU,byLUT)*LUTProYield(byLU,byLUT,"tomsu"));

* Calculate salt production for each scenario
SaltPro(byScen) =sum((byLU,byLUT)$(LUTPro(byLUT,"muoi") eq 1),
            LUTA(byScen,byLU,byLUT)*LUTProYield(byLU,byLUT,"muoi"));

* Calculate vegetable production for each scenario
VegPro(byScen) =sum((byLU,byLUT)$(LUTPro(byLUT,"rau") eq 1),
            LUTA(byScen,byLU,byLUT)*LUTProYield(byLU,byLUT,"rau"));

* Calculate forest area for each scenario
ForArea(byScen)= sum((byLU,byLUT),(LUTA(byScen,byLU,byLUT)*0.6)$(ForestLUT(byLUT)eq 1)+
            LUTA(byScen,byLU,byLUT)$(ForestLUT(byLUT) gt 1));

* Calculate labour requirement per month and total labour requirement for each scenario
labourReqMonth(byScen,byVill,byMonth)=sum((byLU,byLUT)$(LUinVillage(byVill,byLU) eq 1),
           LUTA(byScen,byLU,byLUT)* ReqLab(byLUT,byMonth));

TotalLabout(byScen)= sum((byVill,byMonth),labourReqMonth(byScen,byVill,byMonth));

* Calculate capital requirement per LU and total capital requirement for each scenario
capitalReqLU(byScen,byLU) = sum(byLUT,cost(byLU,byLUT)*LUTA(byScen,byLU,byLUT));

TotalCapital(byScen)=sum(byLU,capitalReqLU(byScen,byLU));

* Calculate revenue for each LU for each scenario
LURevHA(byScen,byLU)= sum(byLUT, Rev(byLU,byLUT)*LUTA(byScen,byLU,byLUT))/AvArea(byLU);

* Calculate cost for each LU for each scenario
LUCostHA(byScen,byLU)= sum(byLUT,Cost(byLU,byLUT)*LUTA(byScen,byLU,byLUT))/AvArea(byLU);

* Calculate netincome for each LU for each scenario
LUIncomeHA(byScen,byLU)=LURevHA(byScen,byLU)-LUCostHA(byScen,byLU);

* Calculate percentage of land used
PLand(byScen)= (sum((byLU,byLUT),LUTA(byScen,byLU,byLUT))*100)/sum(byLU, AvArea(byLU));

PLandunit(byScen,byLU)= (sum(byLUT,LUTA(byScen,byLU,byLUT))*100)/AvArea(byLU);
*----------------------------------------End of CalProduction.gms---------------------------------------------
```

OverallResult.gms

```
* ------------------------------------------------------------------------------
*            OVERALL RESULTS
*            Write all results (max income, all productions, forest are) into csv files
*------------------------------------------------------------------------------
file csv /%1/;
csv.pc = 5 ;
csv.pw = 500;
put csv;
* Write columns' name
put "Sub-scenario";  put 'Max benefit'; put 'Rice'; put 'Shrimp';put 'Salt';put 'Vegetable';put 'Forest'; put 'Req lab';put 'Req Cap'; put 'Status'; put 'rice target';put 'shrimp target'; put 'salt target'; put 'veg max target';put 'veg min target'; put 'forest target'; put /;

* Write sub-scenarios' results into the correspoinding columns and rows.
loop(byScen, put byScen.tl; put Maxin(byScen); put RicePro(byScen);put ShrimpPro(byScen);
put SaltPro(byScen);put VegPro(byScen);put ForArea(byScen);put TotalLabout(byScen);
put TotalCapital(byScen);put modstatus(byScen); put goal("rice", %2); put goal("shrimp",%2);
put goal("salt", %2);put goal("vegmax", %2);put goal("vegmin", %2);put goal("forest", %2);
put pland(byScen);
put/;);

* Write the monthly required labour and available labour of villages.
loop(byScen, put byScen.tl; put /;
loop(byVill, put byVill.tl; put "Lab Req"; put "Available Lab"; put/;
loop(byMonth, put byMonth.tl; put labourReqMonth(byScen,byVill,byMonth); put avLabour(byVill,byMonth); put/;);put/;); put/;);

* Write the required capital and available capital of each LU.
loop(byScen, put byScen.tl; put "Cap Req"; put "Available Cap"; put /;
loop(byLU, put byLU.tl; put capitalReqLU(byScen,byLU); put avCapital(byLU)put/;);
put/;);
putclose csv;
*-----------------------------------------End of OverallResult.gms---------------------------------------------
```

SubScenResult.gms

```
* ----------------------------------------------------------------------------------------------------------
*              SUB-SCENARIO RESULTS
*             Write the sub-scenario land allocation into csv files
*----------------------------------------------------------------------------------------------------------

file csv%2 /%1/;
csv%2.pc = 5 ;
csv%2.pw = 500;
put csv%2;

* Write the LUTs' area/LU
put "LU";Loop(byLUT, PUT byLUT.TL);PUT /
loop(byLU, put byLU.TL; LOOP(byLUT, PUT LUTA("%2",byLU,byLUT));put PLandUnit("%2",byLU);)
PUT /
put/
;

putclose csv%2;
*-----------------------------------------End of SubScenResult.gms----------------------------------------------
```

Appendix 3. The expert validation interview sheet

EVALUATION SHEET

Personal information

Full name:…………………………………………………………………..

Place of work (detailed e.g. office, department, institute)

………………………………………..

....

....

Position………………………………………………………………………………

Tasks related to land use planning:

……………………………………………………………………………………..………

…………………………………………………………………………….………………

……………………………………………………………………….……………………

………………………………………………………………….

Questions

1. Do you agree, partly agree or disagree with the maps? *(Check the box)*

Map A:

- ☐ Agree
- ☐ Partly agree
- ☐ Disagree

Map C:

- ☐ Agree
- ☐ Partly agree
- ☐ Disagree

Map B:

- ☐ Agree
- ☐ Partly agree
- ☐ Disagree

2. Could you please locate the inadequate area in each map? Please explain why do you thing it is not adequate? *(Use pen to draw the boundary of the inadequate areas in the maps)*

Maps	*Overall inadequate*	*Inadequate area no.*	*Reasons*
A		1	
		2	
B		1	
		2	

3. In your opinion, how the land use of the study area should be planned? *(Draw the boundary of the land use in the based map and give the explanation)*

Area no	Land use type	Reasons
1		
2		
3		
.		

Curriculum vitae

Nguyen Hieu Trung was born on the 5th of October in 1971 in Ha Son Binh province, Vietnam. He went to Chau Van Liem High School in Can Tho City during 1986-1989. In 1993, Trung graduated from Can Tho University, obtaining his B.Sc. degree in Civil Engineering. He has been since then working at the Department of Environmental and Water Resources Engineering (previously named as the Faculty of Water Management) at Can Tho University as a tenured lecturer.

In 1996, He was granted a Master's fellowship at the International Institute for Aerospace Survey and Earth Sciences (ITC) and Wageningen University, the Netherlands, by the NUFFIC's program "*Integrated Management of Coastal Resources in the Mekong Delta"* (MHO-8), a cooperation program between Can Tho University and Wageningen University. He received his M.Sc. degree in Geographical Information System for Rural Applications in 1998 and resumed his teaching position at Can Tho University in the same year.

In the second phase of the MHO-8 program (2000-2004), Trung began his PhD research as one of the main research topics of this program. From 1999 to 2002, he actively participated in two research projects, "Rice-shrimp Farming in the Mekong Delta: Biophysical and Socioeconomic Issues," funded by the Australian Center for International Agriculture Research (ACIAR), and "Change in Land and Water Use in the Mekong River Delta: Micro and Macro Perspectives," funded by the European Union.