Change in land and water use:

Micro and macro perspectives from the Mekong River Delta

Can Tho University IRD

Can Tho University and IRD (2001) Change in land and water use: micro and macro perspectives from the Mekong River Delta. Report to the European Union INCO-DC Project. 93 p.

/Vietnam / Mekong / water management/ water allocation / flood management / farming systems / cropping system / land use / rice / shrimp farming / salinity control / modelling

Acknowledgements

We would like to acknowledge the support of the European Community, INCO project, for the financial support provided to this study.

We would like to thank Prof. Nguyen Tat Dac, Sub-Institute for Water Resources Planning, for sharing the fruit of his experience with water modeling.

We would like to express our appreciation to Mr. Dang Ngoc Loi, Department of Agriculture and Rural Development (DARD) of Dong Thap Province. Mr. Lai Thanh An, DARD of Bac Lieu province, Mr. Tran Ngoc Lanh DARD Soc Trang, Mr. Do Tien DARD An Giang province, Mr. Tran Van Phan, Mr. Le Ngoc Lan, Mr. Nguyen Van Tinh, College of Technology, Cantho university for supporting data and helping us during the field trips.

And last but not least, we would like to thank Ms Quyen, Mr. Tuan, Mr. Bang and Mr. Hung. They not only did their job of translating but also became close friends of our French students and shared the joys and difficulties of their field works in the Mekong Delta.

Units used

VND: Vietnamese Dong 1 USD = 14,000 VND (value in 2000)

Cong: 1/10 hectare : 1000 m^2

*Cong*A: 1/7 hectare : 1428 m^2

Mm^3 Million m^3

cms m^3/s (discharge)

Introduction

The Mekong River delta produces more than half of the rice production of Vietnam and yields 40% of the national agricultural production. It is criss-crossed by a huge web of canals, both natural and man-made, which bring the water from the river to the most remote parts of the delta. Agriculture in the delta has long been constrained by natural factors; foremost are the flood (most especially in the northern part), the irregular rainfall pattern (which preclude rainfed agriculture almost half of the year), salinity intrusion in the dry season (coastal area); and soil problems (both acid-sulphate and saline soils).

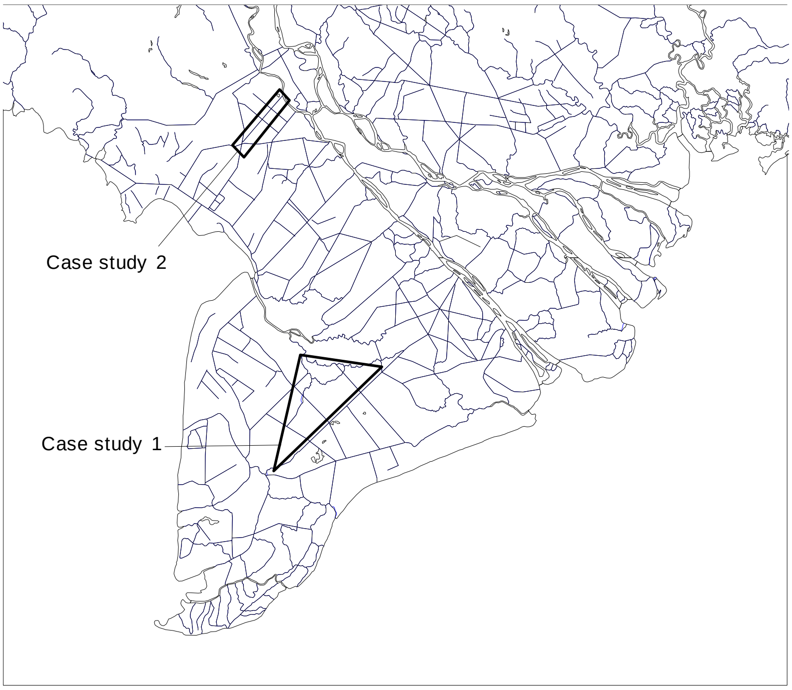
During the dry season water, the river flow is at its lowest. Except for specific location where the tidal effect in the main river arms allow irrigation by gravity at high tide, farmers in most areas must pump water directly from the adjacent canal onto their plots. The Mekong River flow is *unregulated*; no hydraulic structures allows one to direct or modify its flow. It penetrates inside the web of canals following a pattern dictated by the characteristics of the canals (width, depth, slope, roughness), and by how the abstraction of water is spatially distributed.

It follows that the availability of water in a given point in time and space depends on:

- the absolute discharge at the apex of the delta (Vietnamese side);
- the amount of water which flows to the sea, which is strongly conditioned by the degree of 'closure' of the Delta, that is the existence of control structure in the many channels which connect the sea with inland;
- the characteristics of the farmer's canal and how it is connected with the wider network;
- who is using how much water and where at the same time.

This clearly shows that the problem can be construed as an interaction between the micro and macro levels. What is happening at the local level impacts on the macro level and vice versa. This is a typical situation of irrigation schemes, and hydraulic networks in general, which usually requires some form of centralised management or coordination. In the Mekong Delta, the situation appears as peculiar because of the nature of the uncontrolled flow and network. Local dynamics of land and water use are rather determined by the will of provincial authorities to develop their local economy. Despite the centralised political system and planning, there does not appear to be a clear vision of how these different sub-regional or provincial development plans impact on the macro level, nor on how they will be impacted in return.

The present study endeavours to investigate both 'sides of the coin'. A first part will present general spatial data on land use and water resources in the delta. A second part will focus on local level agricultural dynamics, showing how land and water use are dramatically evolving in present times. A first case study will investigate changes occurring in the former floating rice area of the Long Xuyen Quadrangle, in the north of the delta. A second study will, at the other end, examine what is happening along the southern 'closing frontier' of the delta. It will analyse how the construction of regulators aimed at keeping fresh water inland during the dry season affects agricultural activities, farmers' income and strategies, and cropping intensity. A third part will present some macro characteristics of the delta and some results drawn from a hydraulic model used to test the impact of macro scenarios on salinity intrusion in the river mouth(s).



CONTENTS

Part I

Development of a GIS for water management in the Mekong Delta

Nguyen Hieu Trung

Nguyen Vo Chau Ngan

1 Introduction

The studies on water management in the Mekong Delta include many aspects in which large volume of spatial data have to be handled and analysed, e.g. data on natural resources, socio-economy and environment of the delta. Therefore, it is essential to develop a geographical information system for water management of Mekong Delta (hereafter named MKGIS). The GIS database is constructed at three levels of detail: region level, province level and water management project level. In addition, two water management models are integrated with the MKGIS.

The objectives have been achieved by the following steps:

- Define the information need
- Contact water management institutions of the provinces in the Delta (such as hydraulic divisions of Provincial Agriculture and Rural Development Departments) and use the literature and data existing at Cantho University
- Design appropriate data structure for the MKGIS
- Input data into the database
- Develop data transformation programmes for integrating water management models with the GIS

The MKGIS is developed under the MapInfo package.

2 Methodology and results

2.1 The system's structure

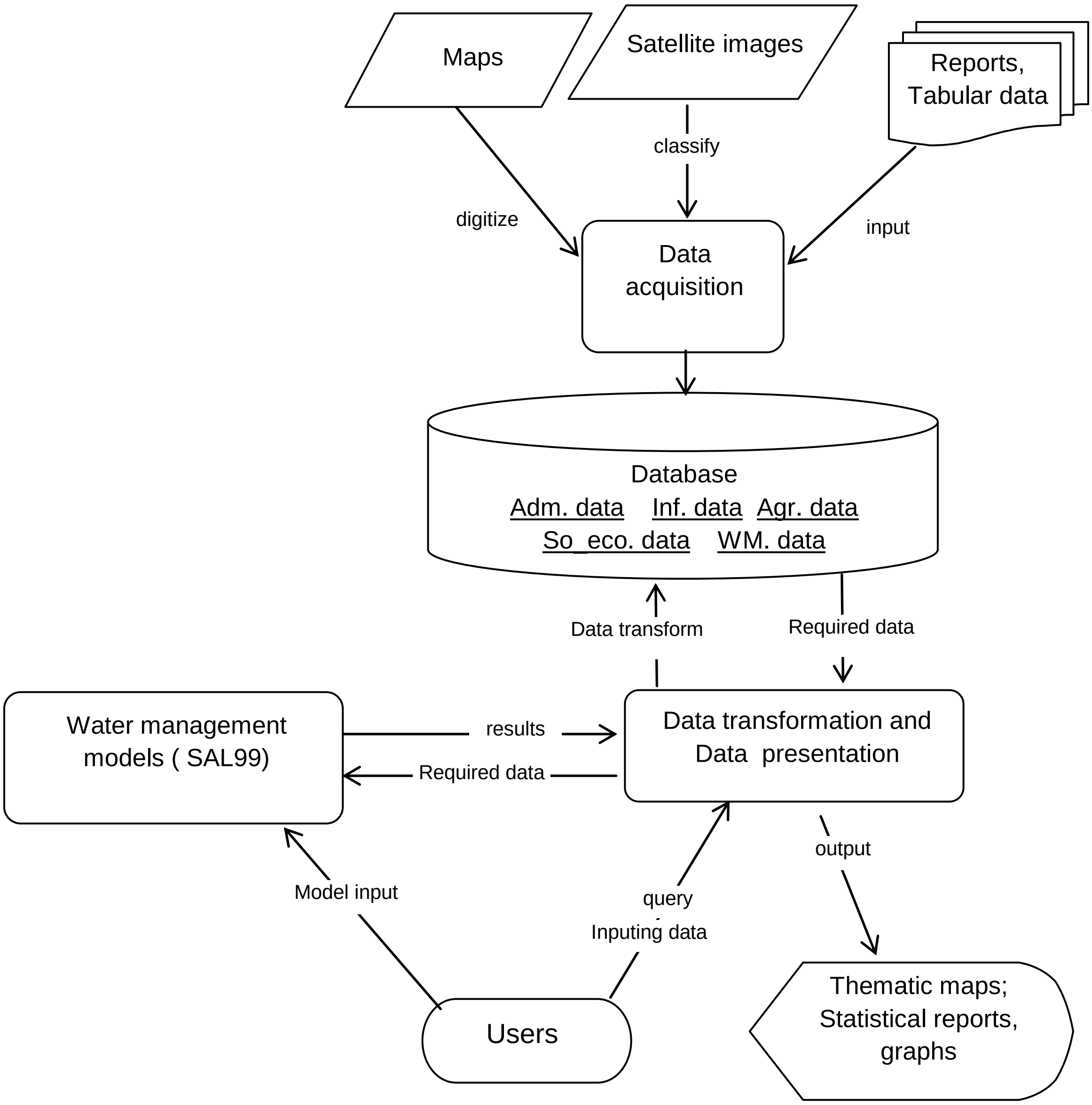
The system in general includes 2 processes (Figure 1):

Data acquisition: in this process raw data such as paper maps, satellite images and attribute data are input into the system database.

Since the data formats of the water management models are different from the data format of the MKGIS, there should be a *data transformation process* to integrate them into the MKGIS (for data input and for mapping the results).

The water management model integrated into the MKGIS is the SAL99 model which is used for defining the water regime and saline intrusion.

FIGURE 1. THE GENERAL OVERVIEW OF MKGIS:



Data were collected from different sources such as:

- Hydraulic Divisions of provinces in the Mekong delta
- Department of Soil Science, College of Agriculture, Cantho University
- Institute of Farming System and Rural Development, Cantho University
- College of Technology, Cantho University

The data have been collected are:

- Maps on land use map of the Mekong Delta at different period (1974,76,91,96). (prepared by the *Sub-Institute for Water Resources Planning and Management*, and the *Integrated Resources Mapping Centre* (IRMC))

- Topographic map of the Mekong delta (1:250,000)
- Water management networks and infrastructure map of Long Xuyen Quadrangle (prepared by the *Sub-Institute for Water Resources Planning and Management*)
- Water management and infrastructure map of the Quang Lo Phung Hiep project (prepared by the *Hydraulic division of Bac Lieu province*)
- Soil map of the Mekong delta (prepared by the S*oil Science Department, Cantho University*)
- Topology map of Longxuyen Quadrangle (1:50.000, collected from the Hydraulic division of An Giang province)
- Topology map of Dong Thap province (collected from the Agriculture and Rural Development of Dong Thap province)
- Quick-look Spot images of the Mekong Delta.
- Attribute data on soil, canal, hydraulic construction, rainfall and evaporation of the Mekong Delta (from hydraulic divisions of provinces in MKD and from the Mekong Delta Master Plan)

Most of the maps were copied from the originals and not in the same scale. This raised many difficulties in correcting and geo-referencing the maps in order to digitize them.

2.2 The database structure

The system's database consists of tables with the structure as follow:

Administrative data:

Province(pro_id, name, NatLand, AraLand, population ,PopDensity, Wsarea98, WSyield98,…Saarea98, SAYield98,…,WinterArea98, WinterYield98 ...)

In which:

Pro-id: is the provincial identify number (for data linked)

Name: is the name of the province

NatLand: is the area of natural land of the province

AreLand: is the area of arable land of the province

Population: is the population of the province

PopDensity: is the population density of the province

WSare98: is the total area of Winter-Spring rice in 1998

WSyield98: is the average yield of the Winter-Spring rice in 1998.

SAarea98: is the total area of Summer- Autumn rice in 1998

SAyield98: is the average yield of the Summer- Autumn rice in 1998.

WinterArea98: is the total area of winter rice in 1998

WinterYield98: is the average yield of the winter rice in 1998.

District(dis_id, pro_id, name, population,...)

In which:

Dis_id: is the identify number of the district

Pro-id: is the identify number of the province which the district belong to

Name: is the name of the district

Population: is the population of the district

Village(Vil_id,dis_id,name, population,...)

In which:

Vil_id: is the identify number of the village

Dis_id: is the identify number of the district which the village belong to

Population: is the population of the village

Because data at district and at village level are not available the study did not conduct for these level of detail.

Land use data:

Landuse74(lu_id, CroppingSystem, area)

Landuse76(lu_id, CroppingSystem, area)

Landuse91(lu_id, CroppingSystem, area)

Laneuse96(lu_id, CroppingSystem, area)

In which:

Lu_id: is the land use type

CroppingSystem: description of the cropping system of the land unit such as: 3 rice crops per year or Shrimp_rice or Shrimp_forest, etc.

Area: area of land use type

Canal system:

MainCanal(Mcanal-id, Name, ExcaYear, MaintYear, length, AverWidth, BotElev)

2ndCanal(2ndcanal-id, Name, ExcaYear, MaintYear, length, AverWidth, BotElev)

In which:

MCanal_id: is the identify number of the main canal

2ndcanal_id: is the identify number of the secondary canal

Name: is the name of the canal

ExcaYear: is the year when the canal was excavated

MaintYear: is the year when the canal was maintained

Length: is the length of the canal

AverWidth: is the average width of the canal

BotElev: is the level of the bottom of the canal

Dike system

Dike(dike-id,canal-id, BuiltYear, MaintYear, length, TopWidth, TopElev,)

In which:

Dike_id: is the identify number of the canal

BuiltYear: is the year when the dike was built

MaintYear: is the year when the dike was maintained

Length: is the length of the dike

TopWidth: is the width of the top of the dike

TopElev: is the level of the top of the canal

Hydraulic construction:

Sluice(Sluice-id, canal-id, name, purpose, capacity)

Where:

Sluice_id: is the identify number of the sluice

Canal_id: is the identify number of the canal where the sluice gate located

Name: is the name of the sluice gate

Purpose: is the purpose of the sluice, e.g. for flood control or for salinity control, etc.

Capacity: is the capacity of the sluice gate

ElePuping(P-id, canal-id, village-id, purpose, capacity)

P_id: is the identify number of the pumping station

Canal_id: is the identify number of the canal where the pumping station located.

Village_id: is the identify number of the village where the pumping station located

Purpose: is the purpose of the pumping station, e.g. for irrigation or for drainage or for both

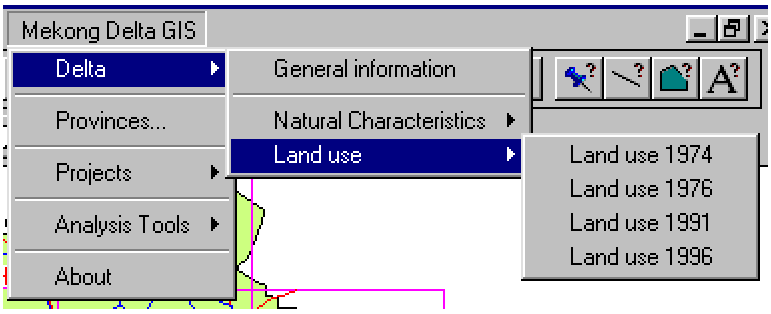
Capacity: is the capacity of the pumping station

2.3 *The system's interface*

2.3.1 Menus

The system's interface was designed using the MapBasic programming language. The structure of the interface is as figure 2.

FIGURE 2. THE MKGIS'S INTERFACE

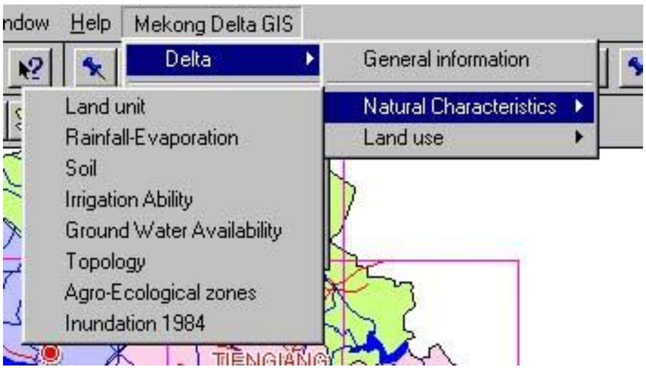


For data querying, the user can select the sub-menu "Delta" or "Provinces" for information at the level of whole delta or at provincial level. The sub-menu "projects" allows the user view the maps of water management project in the Mekong Delta.

2.3.1.1 *Information on the Mekong Delta*

At the delta level, general information can be obtained such as the population, population density, cultivated area and yield of rice of provinces in the MKD.

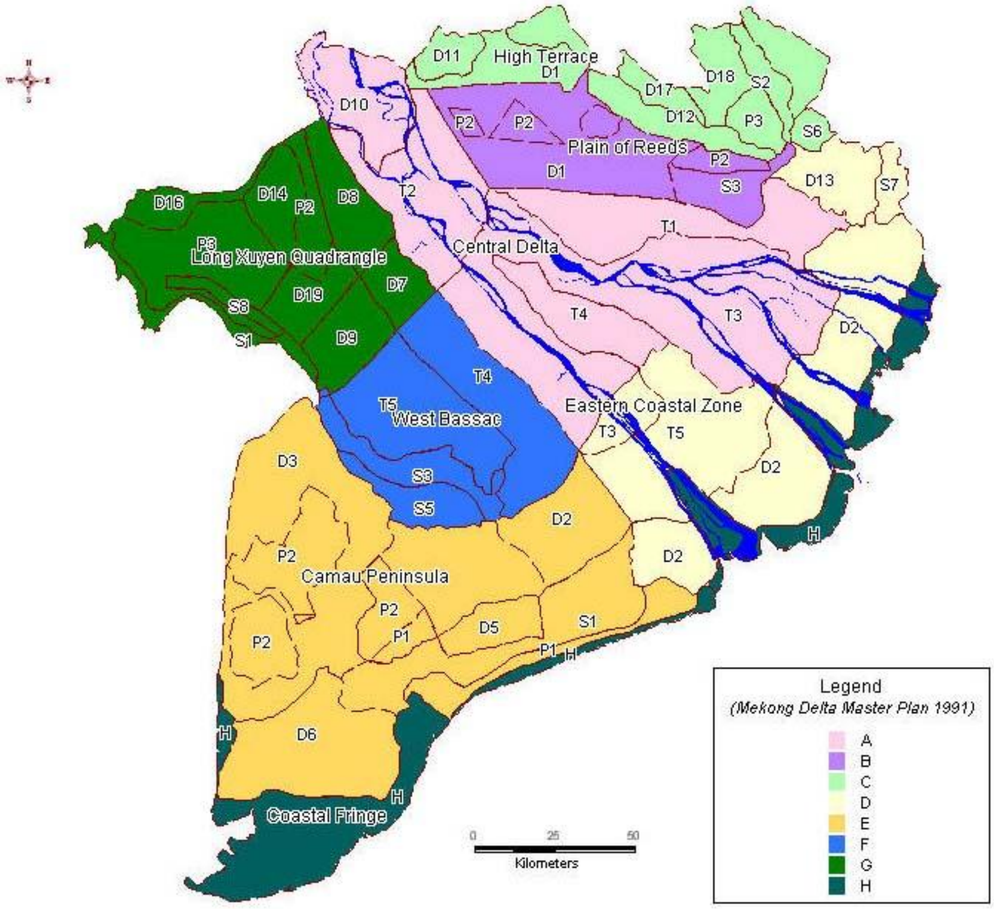
FIGURE 3. MENU "NATURAL CHARACTERISTICS"



The "Natural characteristics" sub-menu presents:

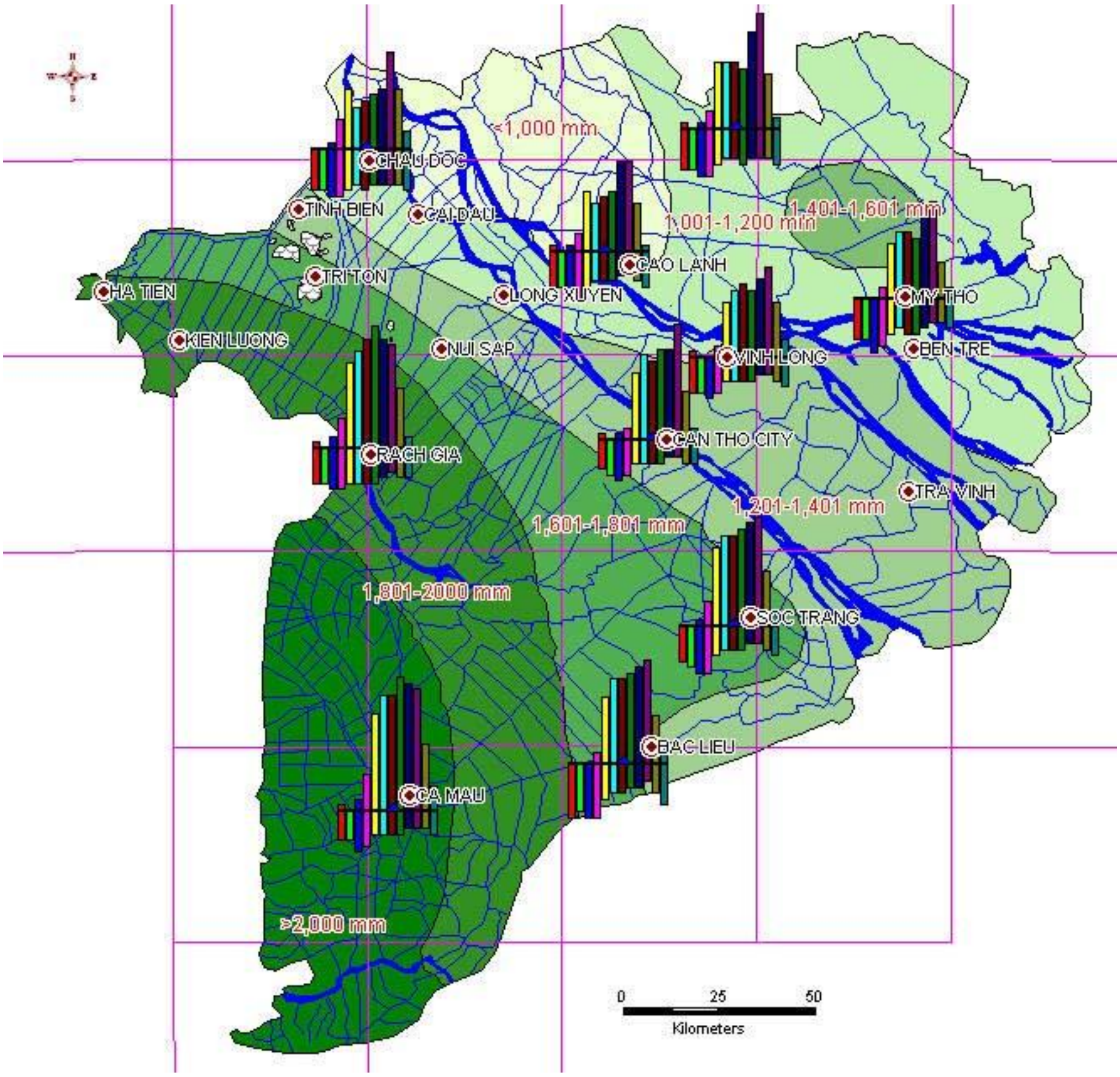
- The land unit map (land units are defined by the climatic, hydrological, and soil conditions of land)

FIGURE 4. THE LAND UNITS MAP OF MEKONG DELTA



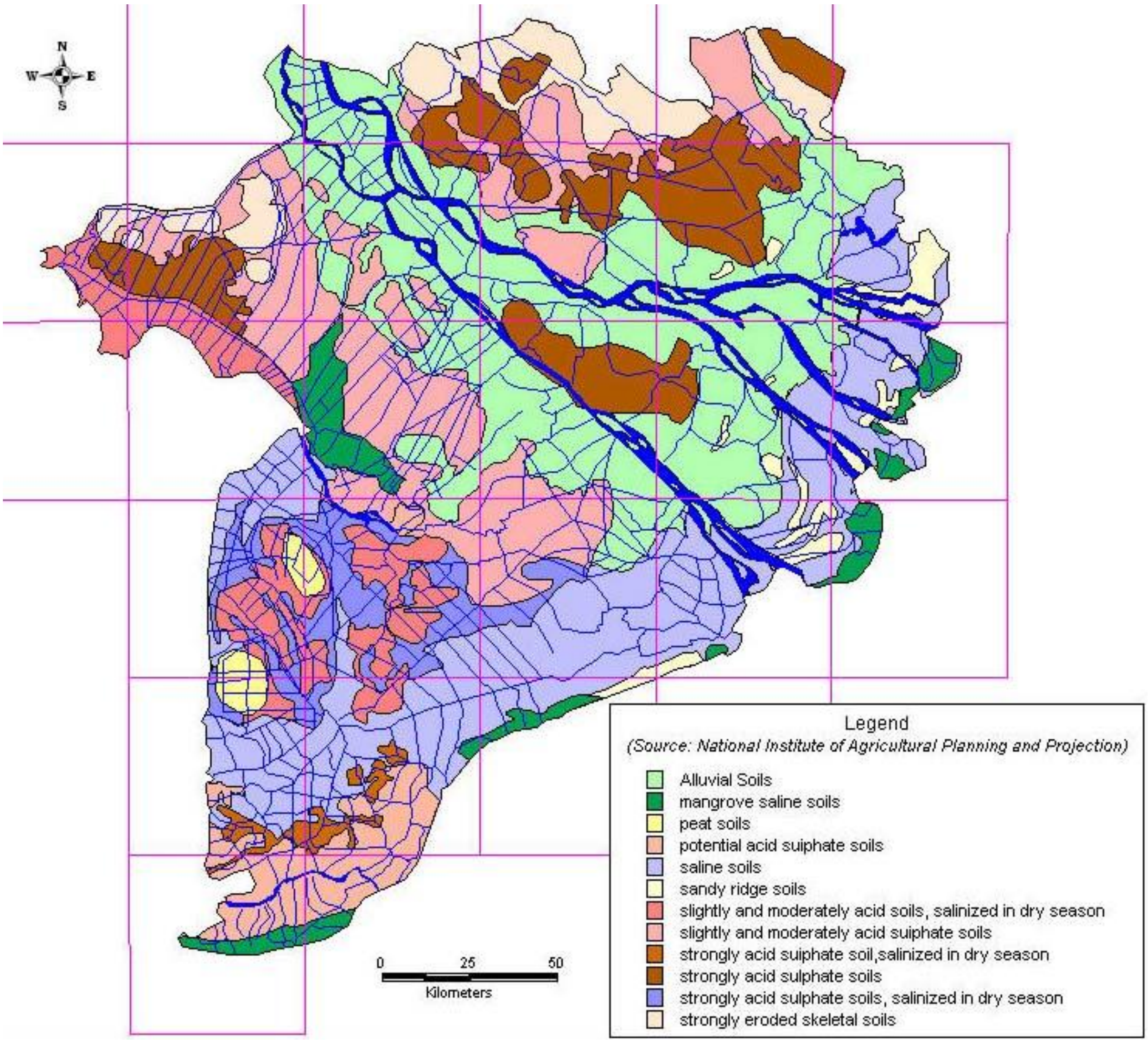
- Average rainfall and average evaporation :

FIGURE 5. MEAN MONTHLY RAINFALL AND EVAPORATION OF MEKONG DELTA



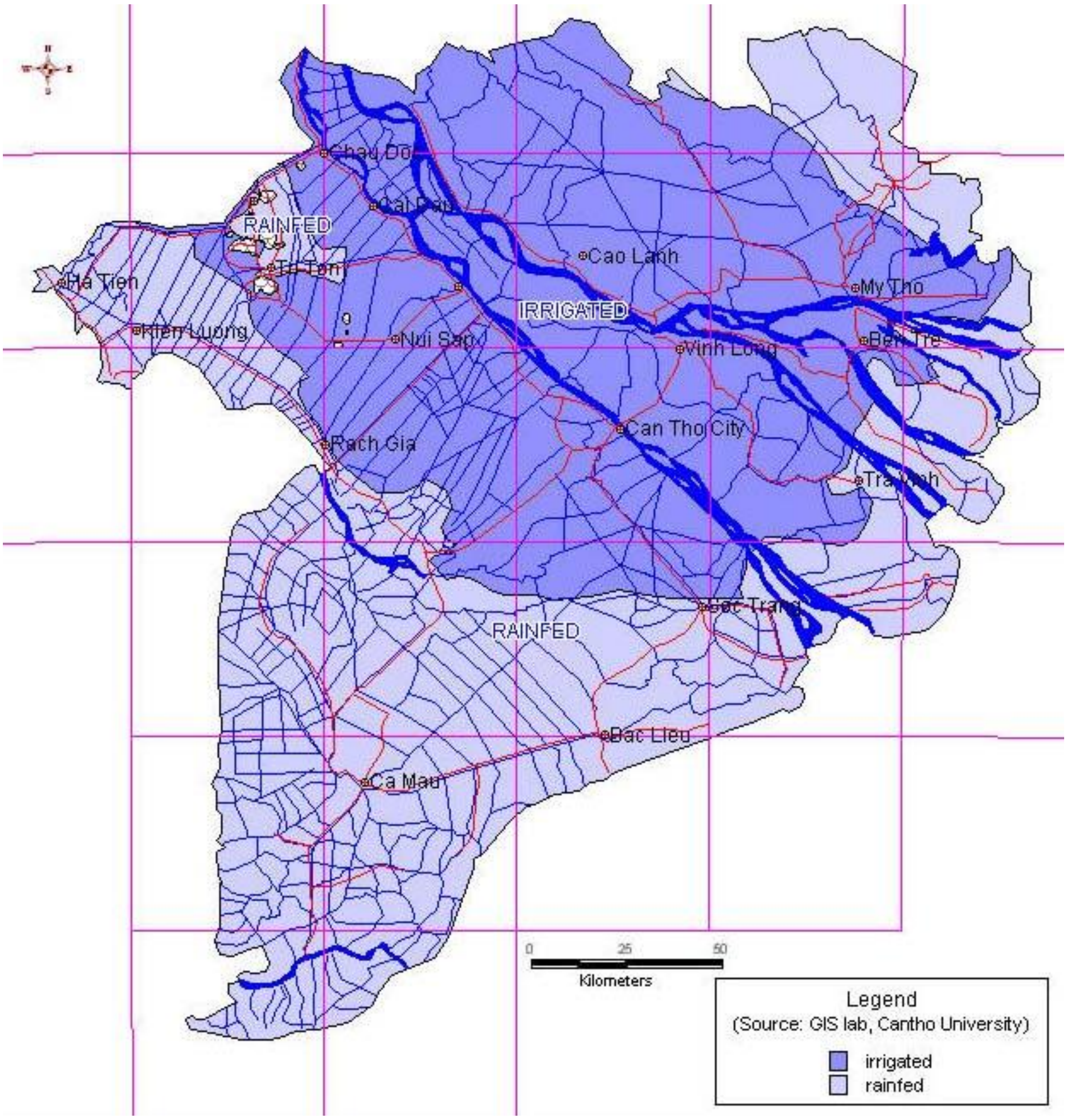
- Soil map

FIGURE 6. SOIL TYPES MAP OF MEKONG DELTA



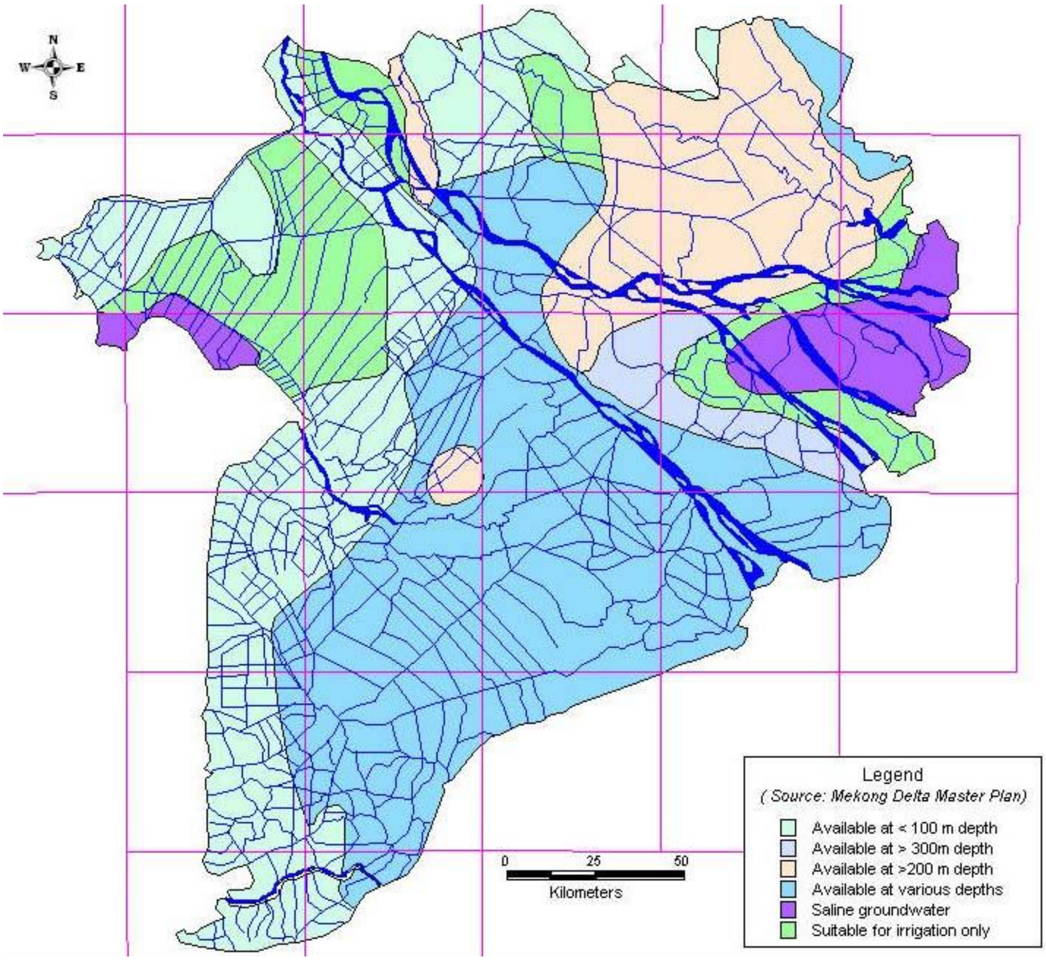
- Irrigation ability

FIGURE 7. THE IRRIGATION ABILITY MAP OF MEKONG DELTA



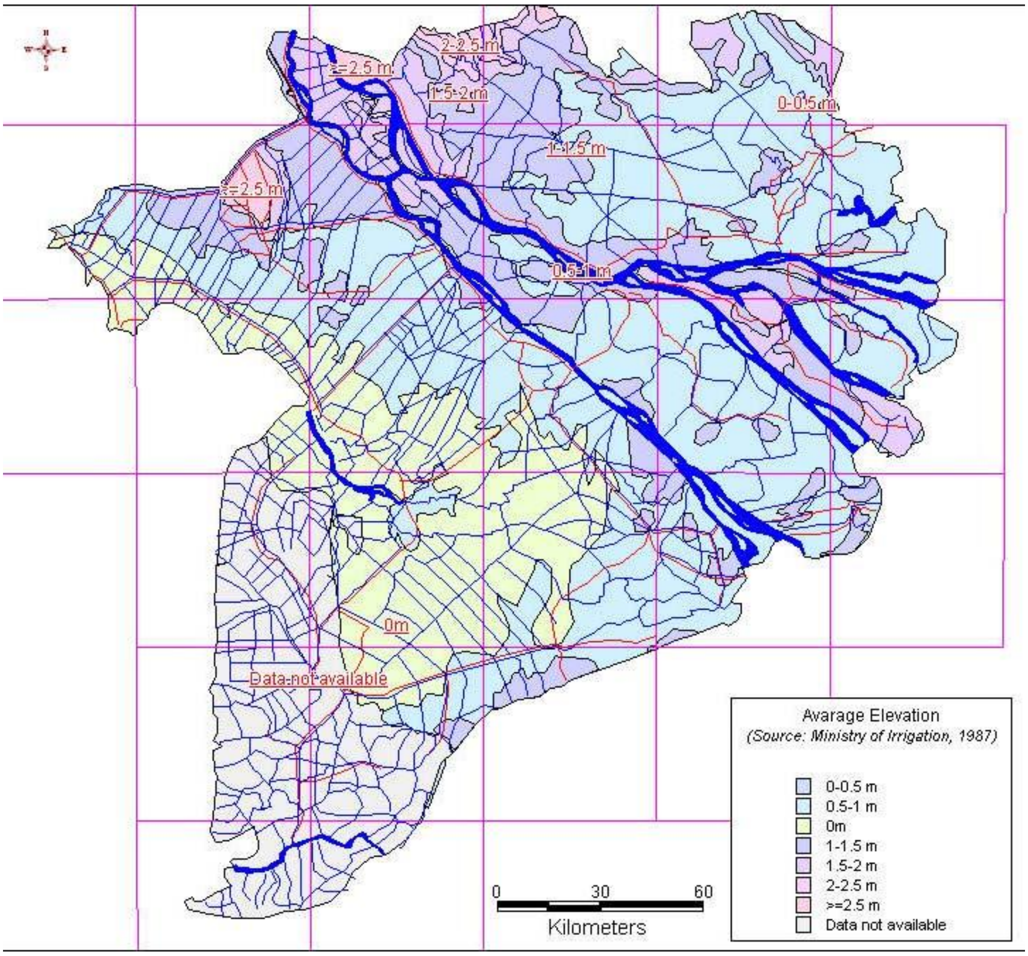
- Ground water availability

FIGURE 8. GROUND WATER AVAILABILITY MAP OF MEKONG DELTA



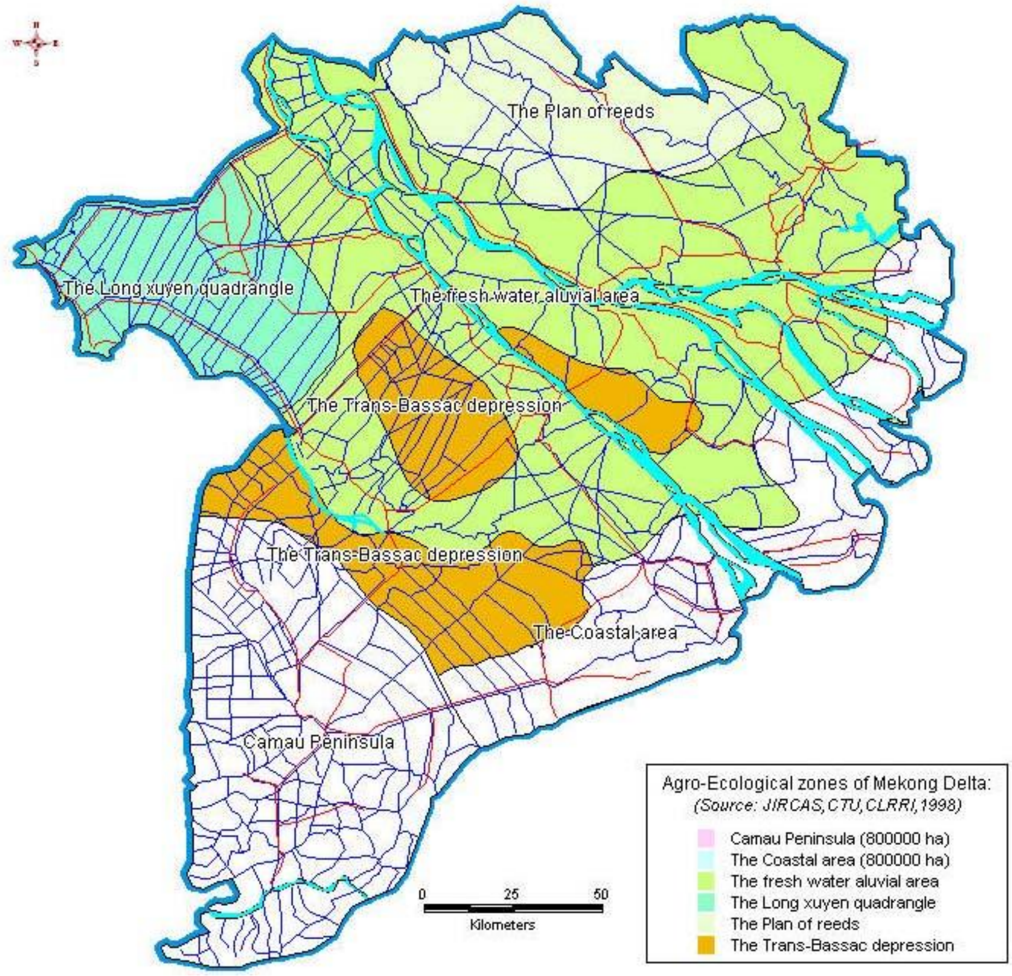
- Topology

FIGURE 9. TOPOLOGY MAP OF MEKONG DELTA



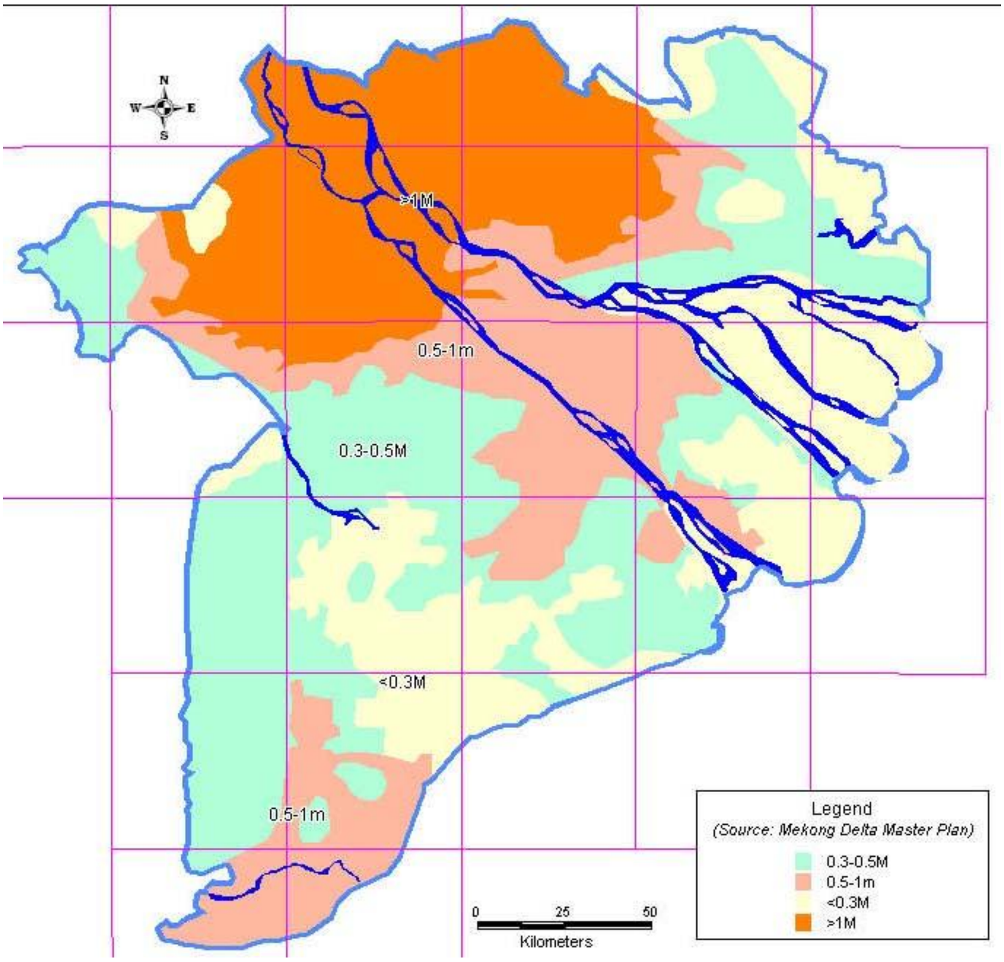
- Agro-economic zones

FIGURE 10. AGRO-ECONOMIC ZONES MAP OF MEKONG DELTA



- Inundation

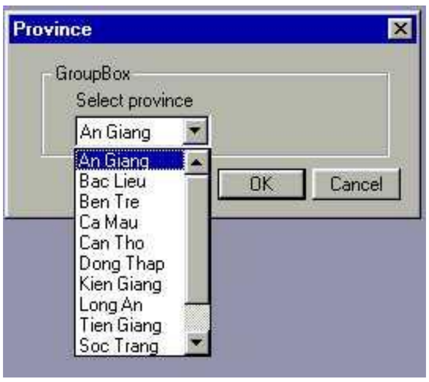
FIGURE 11. INUNDATION MAP OF MEKONG DELTA



2.3.1.2 Provincial level

At the provincial level, the user can select the province through the province dialog box (fig. 3). For each province, information about administration, hydraulic system, hydraulic constructions, and land use can be accessed.

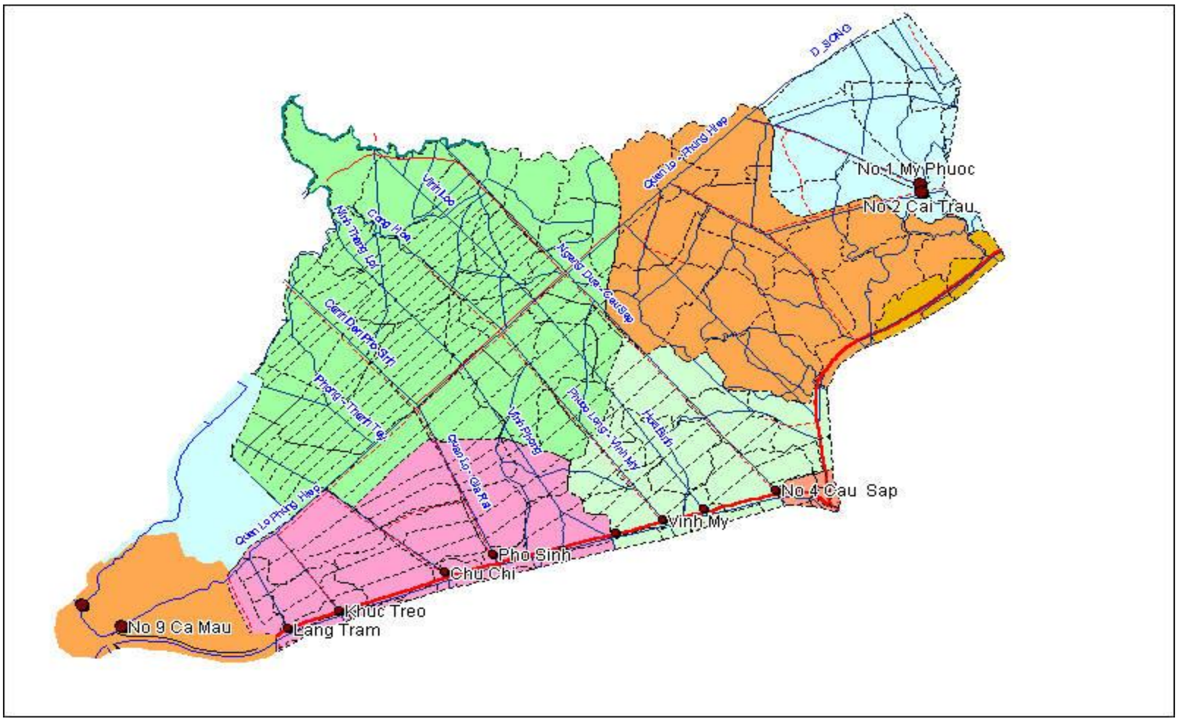
FIGURE 12. DIALOG BOX "PROVINCE"



2.3.1.3 Projects

In MKD, many water management projects have been developed. The “projects” sub-menu presents some main projects in the area such as the Quang Lo Phung Hiep Project (Salinity control), the Flood control project in Long Xuyen Quardrangle and Plain of Reeds, the South Man Thich project.

FIGURE 13. QUANG_LO_PHUNG_HIEP SALINITY CONTROL PROJECT



2.3.1.4 Tools

In the “Analysis tools” menu, the “sal 99” sub-menu allows the user to input the topology data for the SAL99 model (the input for SAL99 model are ASCII files); these files have to be prepared by an editing tool with defined formats, which is not very user friendly. By using the tool, users simply select the branch or node for inputting their data. A transformation program will be run later in order to transform the Mapinfo table into the SAL99 model files (see more in the modelling study).

A base map of hydraulic network have been developed with all of the basic data about each hydraulic object, hydraulic objects are sluice gate, pumping station, canal.

Along the canal, the calculation points are also located. The results from the SAL99 model are water level, discharge and salinity at calculation points. For presenting the results, we can generate the contour of water level or salinity by using MapInfo tools.

FIGURE 14. HYDRAULIC NETWORK FOR WATER MANAGEMENT MODEL

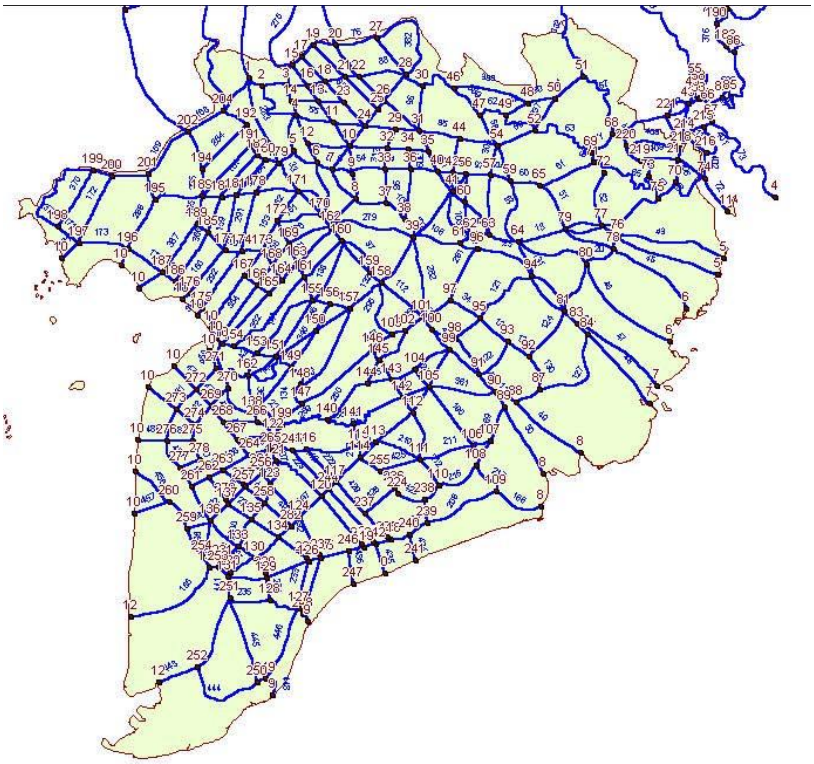


FIGURE 15. ISOHYETAL LINES (G/L) IN APRIL 1996

3 Conclusion and recommendations

The study has achieved the main objective to build a geographical information system to support water management of the of the Mekong Delta. The GIS is developed with user-friendly interface for unprofessional GIS users.

The data structure of the MKGIS is designed in 3 level of details: region level, province level and water management project level. At the region level, the user can acquire information on administration, land use, land units, hydraulic constructions, soil, mean monthly rainfall and mean monthly evaporation, irrigation ability, ground water availability, topology, inundation, agro-economic zones, and general plan for water management of the Mekong delta.

At the provincial level, the user can find the administrative boundary of districts of each province. Information on hydraulic construction, land use of 2 provinces: Angiang and Baclieu are also available in the system.

Besides, information on some water management projects in the Delta also provided in the system (Quang Lo Phung Hiep salinity control project, Long Xuyen Quadrangle flood control project, Plain of Reed flood control project)

Considering the lack of accurate and reliable data due to the time and financial limit, more works should be done on data acquisition for upgrading the accuracy of the system. At the provincial level, only two provinces have detail data on water management construction, while the other provinces have only the data on administrative, main road system and main canal, and their data are not updated. At the project level, more updated data also need to be acquired and input because the general plan for the delta is been altered constantly.

Part II

Local dynamics in land and water use : a case study in the coastal area of the Mekong Delta

Olivier Joffre

François Molle

Nguyen Hieu Trung

1 Introduction

The Mekong Delta is the main « rice bowl » of Vietnam. The land use will continue to be agriculture oriented, or more specifically, rice oriented. One of the natural constraints to the improvement of rice cultivation in the Mekong Delta is the saline intrusion during the dry season in the coastal area and Ca Mau peninsula. Saline water intrusion results from the influence of the China Sea and Gulf of Thailand tides during the low flow of the Mekong River. During the past decade, the Vietnamese government has planned and constructed new water control infrastructures, like sluices gates and embankments, in the saline intrusion area in order to intensify rice cropping. The main project, called Quan Lo Phung Hiep Project (QLPH) (450 000 ha) is located in the Ca Mau peninsula and includes a major portion of Soc Trang, Bac Lieu and Ca Mau provinces (see Figure 1).

The necessity to protect potentially productive land from saline intrusion boosted by the excavation of canals has long been recognised. In 1932, Henry mentions that "the [canal] network has provoked the salinisation of adjacent land in the driest periods of the year to such an extent that it now calls for the construction of protective infrastructures at the tail end of canals, close to the sea." The development of the QLPH area was targeted by the government as a priority as early as 1974. It was included in the master plan at the onset of the 1990s decade and a feasibility study was carried out in 1992 (ESSA, 1992). A total of 40 secondary canals were excavated during the 1991-97 period (225 km in length) and the Project was recently included as part of a IDA loan managed by the World Bank. The loan is supposed to be used for the following activities:

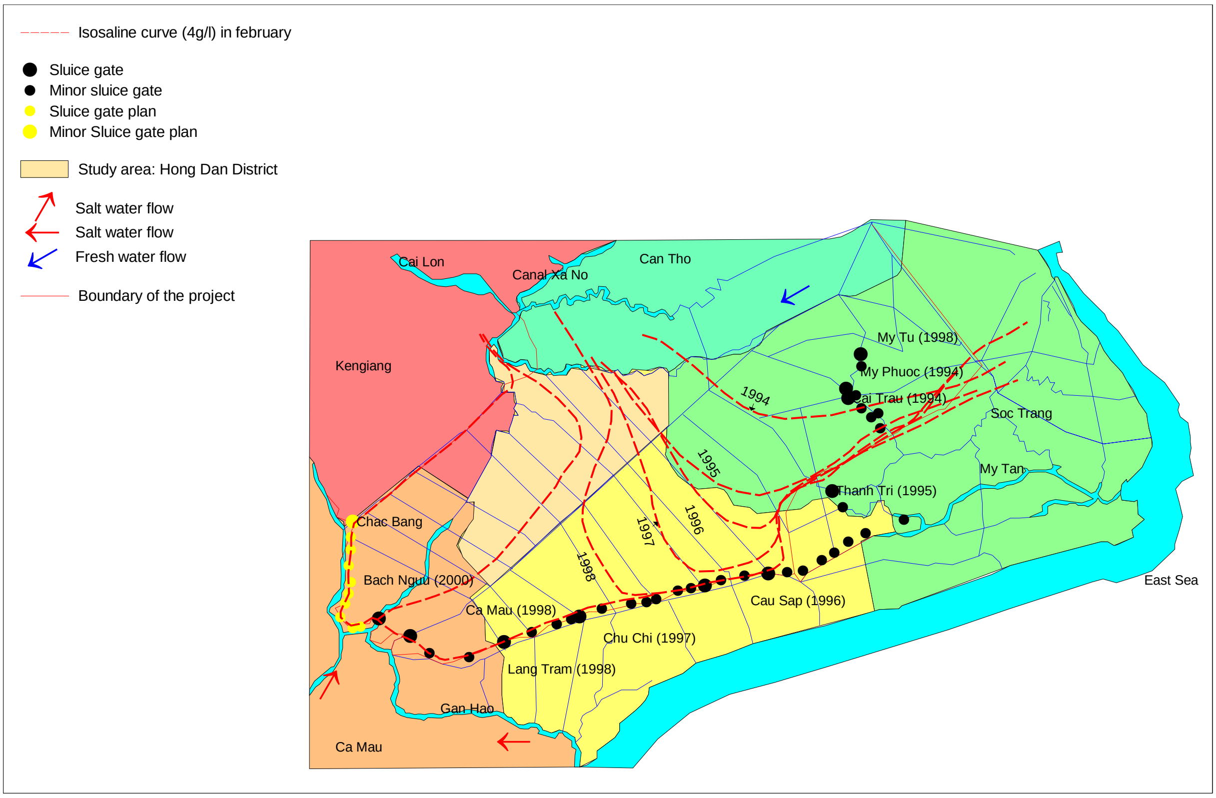
- To develop and rehabilitate the irrigation system in order to improve water control and allow more intensification and diversification
- To control salinity to protect soils and increase the availability of fresh water
- To improve drainage to protect crops against flooding
- To improve the availability of drinking water and to carry out research on groundwater
- To improve the road network, bridges and fluvial transportation
- To set up organisations and farmers participation for water management and the establishment of Hydraulic Companies[1]
- To develop agricultural extension and research for crop diversification

This study was carried out to understand the dynamics of land use and cropping patterns, reflecting farmer’s strategies in response to changes in environmental conditions (water quality). This study may help predict possible changes in land use following other hydraulic intervention aimed at preventing further salinity intrusion.

[1] One of the covenants is that the Government is committed to set a decentralised management body in charge of management, maintenance and of the collection of a water fee.

This chapter gives some information on the dynamic of land use in the upper part of the Quan Lo Phung Hiep area, Hong Dan District, and attempts to establish correlations between agricultural change, natural environment, and farming systems characteristics.

FIGURE 1: QUAN LO PHUNG HIEP PROJECT



2 General land use in the area before the closure

Traditionally one rice crop ("*Mua*") is grown (using traditional varieties with long maturation period), during the rainy season (July/August to Dec/Jan) after the rain has flushed out the salinity from the root zone of the soil. This rice was rainfed but transplanted. The study area was partly cropped with *Mua* rice as soon as the beginning of the century (Robequain, 1939), but extremely acid[2] or ill drained land remained fallow as late as 1985 (western part and central of the study area).

Since 1980, traditional rice varieties have been gradually replaced by modern short-duration high yielding varieties (HYVs) in areas that enjoy more favourable water conditions (north eastern part of the area, on alluvial soils), or where saline intrusion appears only after December and where the inundation period is shorter (on higher land). First, farmers shifted to two rice crops per year using one short time varieties for the first crop (summer - autumn or *He Thu*: May to July) followed by one traditional rice. More recently (beginning of the 1990s), farmers began to use short cycle varieties for the two crops : summer - autumn or *He Thu*: May to July, followed by autumn -winter or *Thu Dong* (Sep to Dec). This change was allowed by the short inundation period and the use of pump to drain out the water.

On the deep acid sulphate soils, farmers had been cultivating *Mua* for a long time and they began to use short cycle varieties only after closure of the area, because growing two rice crops was too risky, particularly in December, depending only on rainfall. Farmers have to wait for rainfall to leach out the acidity and this delays broadcasting and shifts cropping calendars. In most cases, farmers cannot drain water out in September-October which delays the broadcasting of the second crop.

On shallow acid sulphate soils, farmers have grown pineapple or sugarcane since 1985, mostly in the central part of the study area. In the western part, farmers raised natural shrimps between 1986 and 1992, then shifted to *Tiger monodon*. In the first case, canal water was admitted into the plots at high tide and later drained, while shrimps were retained by setting adequate nets at the outlet of the plot. This area located in the western part is newly colonised. Before the construction of the secondary canals, it was flooded fallow land. As shrimp farming needs saline water, this study will describe the evolution of shrimp farming in line with the change in water quality. However, it can be seen from this description of land use that saline water was not the only environmental constraint in rice intensification, as soil quality also determines land use.

3 Water control infrastructure and improvement of rice cultivation

Two high yield rice crops can be grown only if the period between the end of the inundation period and the beginning of the salinity intrusion is longer than the duration of the *Dong Xuan* (Dec. to March) rice crop (Tuong *et al.*, 1989). Since the main constraint for rice production

[2] Acid soils can be classified in two types: shallow acid-soils are acid in the 0-50 cm upper layer and are therefore considered less favourable for agriculture, or severely acid (they usually correspond to lower lands in depressions). In deep acid soils, in contrast, acidity is found in deeper layers and they are therefore considered moderately acid.

in the area was the high salinity in the dry season, one of the strategies for increasing rice production was to prolong the salinity-free period and to increase the supply of fresh water to the area. This would allow farmers to grow rice during the dry season and harvest 2 or 3 rice crop *per* year. The salinity rate determines if water can be used for irrigation during the dry season. The commonly accepted limit of salinity for irrigation water is 4 g/l.

In 1994, the government began to construct a series of embankments and sluices gates along the periphery of the project area that is directly exposed to the tidal influence of the China sea and of the Gulf of Thailand. The saline water frontline first follows the coastal river, and then increase from the Southwest to the Northeast (see Figure 1).

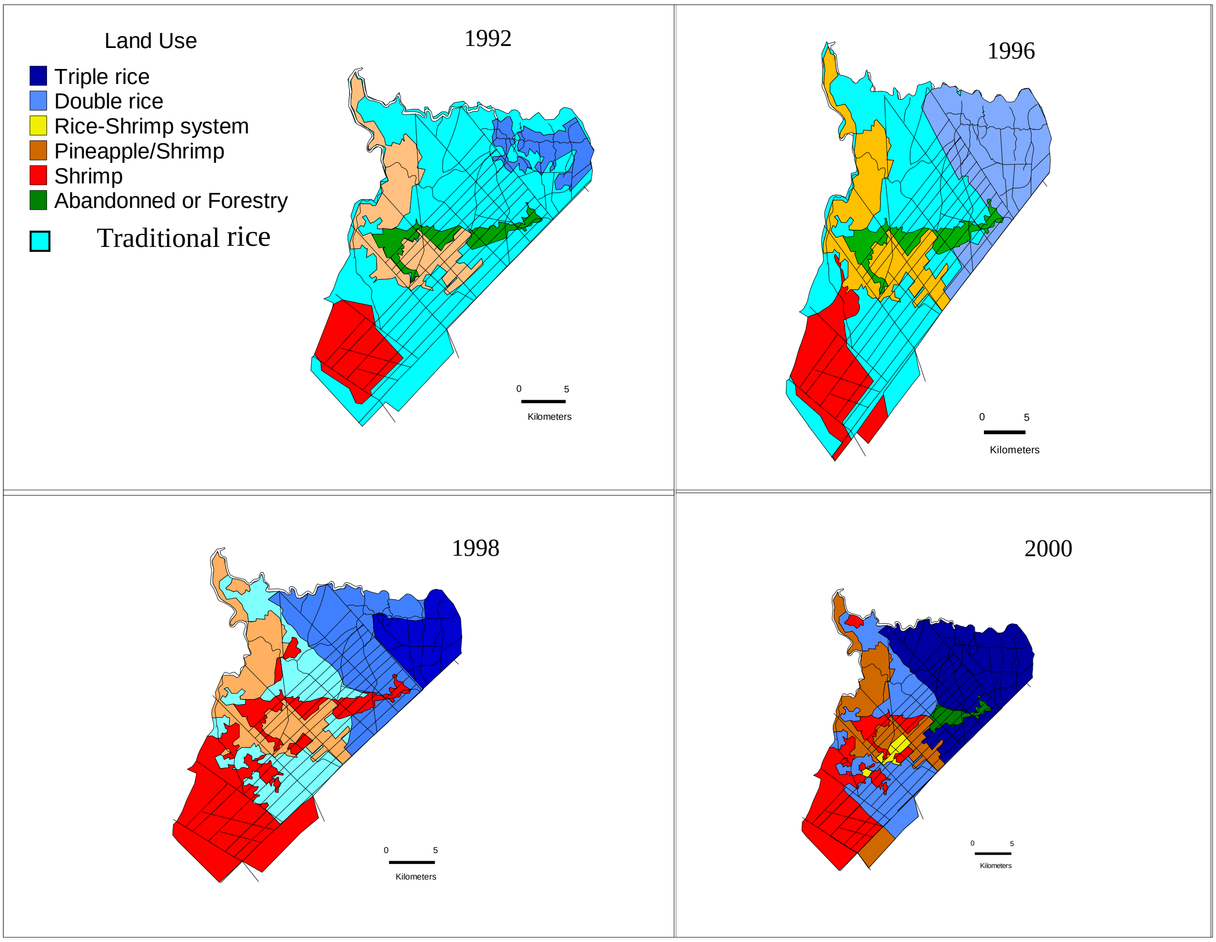
All the main rivers and main canals directly connected to the sea have been (or will be) closed with sluice gates in order to block inflow from the sea. At the same time, the canal network within the project area was also improved to enhance the transfer of fresh water from the Bassac River to the project area, and also to improve the leaching of the acid water at the beginning of the rainy season (ESSA, 1992).

At present (year 2000), 10 sluices gates have been completed, and most of the area is now protected from saline water. The secondary canal network is also almost complete.

4 Change in land use

From 1996 up to present times, salinity intrusion disappeared progressively in the district. The evolution of the land use can be seen in Figure 2. There is two opposite gradients of cropping pattern change. First, from the east to the west, double and triple rice cropping area expanded, following the receding of saline water. Second, from 1990 to 1998, shrimp farming progressed from the west to the east. Fallow land and pineapple fields were progressively converted into shrimp ponds.

FIGURE 2: EVOLUTION OF THE LAND USE IN HONG DAN DISTRICT



At present, four different main cropping patterns can be observed in the district.

- Triple rice cropping

Located in the east side of the district, this land use pattern is expanding towards the west, following the fresh water front. This area includes alluvial soil and deep acid soils.

- Double rice cropping

Located in the central and the western part of the district, the area is characterised by deep acid soils. This area includes the area free from salinity in 2000 and a part of the district where saline water is still present.

- Shrimp farming

Located in the western part of the district, this area expanded toward the east since 1996 and progressively receded westward, along with fresh water progression after 1998. Shrimps can be found on deep and shallow acid soils and low lands. This land was most of the time fallow land, or cultivated with pineapple on raised beds. Presently, farmers raise shrimps and fish at the same time in the pond.

<u>- Rice-Shrimp System</u>

Located only in 2 hamlets, this system appeared in 1999, under the influence of the agricultural extension service. This system can be done only on deep acid sulphate soils; on shallow acid sulphate soils, rice will die after one month, when the roots enter the acid layers.

We can summarise the change in agriculture from the 1980s up to now as follows:

TABLE 1: CHANGE IN CROPPING PATTERNS IN THE STUDY AREA

Soil type	**1980 to 1990**	**1990**	**1996**	**1997**	**1998 to 2000**
Alluvial soil	1rice to 2 rice crops		3 rice		
Deep ASS					
-rice land	1 traditional rice			2 rice :zone 1B, HT/DX° 2 rice :zone 2A, HT/TD	1999 :3 rice (zone 1B,2A) 2 rices (zone,3A, 4A)
- pineapple land	fallow land converted to pineapple	pineapple converted to shrimp pond *(T.m)*			
- fallow land (deep flood depth)		shrimp pond *(T.m)*			traditional rice (98/99) shrimp followed by traditional rice (2000)
Shallow ASS					
- pineapple land	fallow land converted to pineapple	pineapple converted to shrimp pond *(T.m)*			
Fallow land	natural shrimp	Tiger monodon			

As a preliminary conclusion we can say that the duration of salinity periods in the canals network is not the only factor which influences land use and the change in cropping pattern. The nature of the soils and the elevation of the fields are also crucial factors dictating cropping patterns. The development of the irrigation network is also important to rice and shrimp farmers for both irrigation and drainage. In addition, the historical background of the area is also important, as shown by the case of pineapple which has been developed under the influence of the provincial planning.

5 Conditions for the change from traditional to irrigated rice

Various investments are needed to allow the change from one traditional rice to irrigated rice. First, dikes have to be build around the fields on low lands, in order to protect the fields from flooding. When the shift from one to two or three rice crops occurred later, this was indicative of the fact that more investments were needed.

Second, a network of tertiary canals and ditches is needed to allow irrigation and drainage. Most of this network was already built in the eastern part of the district, where double cropping had been practised for a long time.

Irrigation by gravity is no more possible in the district because of the absence of the tidal effect. All the farmers use low lift pumps to irrigate their fields. These pumps, commonly referred to as 'shrimp tail pumps', are an adaptation of the motor used for powering boats. The propeller is enclosed in a metal box, with admission of water on one side, and rejects water into a hose. Therefore most farmers own such pumps and only a few of them, most of the time poorer farmers, rent a pump to irrigate or drain their field. With this very simple technology, access to power for irrigation was not a constraint for farmers. Also, a few farmers diversified their activities, renting out their pump to other farmers (pumping service).

One of the most important constraints to change was the dependence between neighbours. A change in cropping systems is possible only if all the farmers in a given hydraulic unit decide to change their cropping system at the same time. Co-ordination of the cropping calendar is needed in order to reduce (or spread) damage from rats, and also because of the impact of lateral seepage on non-cultivated plots. Some farmers cannot change their cropping systems because their neighbours do not have the capacity to finance the investments needed for double or triple rice cropping.

Soil acidity is the last constraint for rice intensification. Some fields located on acid soils cannot grow HYVs. Acidity has to be leached out during many years in order to ‘clean’ the soil and to allow the use of short cycle varieties. A longer period of fresh water allows rice intensification. The field level, dependence between neighbours and soil acidity, are factors which have to be considered for rice intensification.

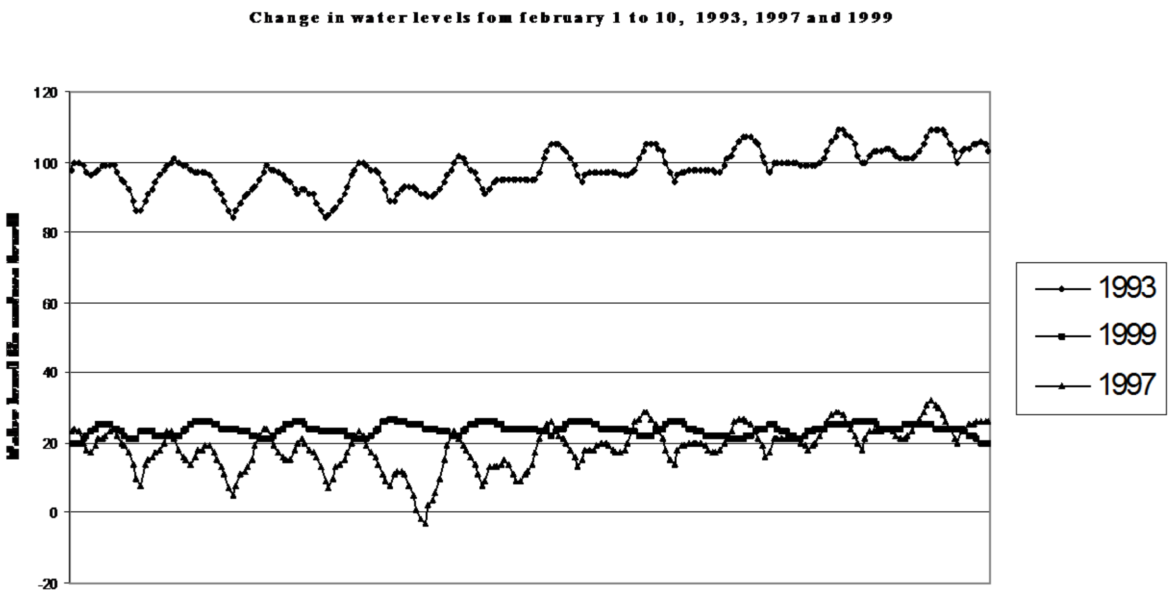
All these constraints have shaped the transformation of rice cropping systems but have not been sufficient to deflect an extremely rapid evolution. At present three main rice systems can be observed:

- The *He Tu* rice crop is established in May-June and harvested in August-September; the *Tu Dong* is sown just after and is harvested in December.
- A *He Tu* crop is grown but the second crop, *Dong Xuan*, is established only at the end of the rainy season (late November, early December). This post-monsoon crop will rely mostly on irrigation but will escape any risk of flooding.
- The *He Tu* and *Dong Xuan* crops are followed by the *Sa Chia* crop, planted between March and May-June (fully irrigated crop).

In case of triple cropping, it is observed that farmers do not carry out any land preparation. Stubbles are burnt and rice is sown directly on the non-tilled land. Mechanised land preparation is now adopted by almost all farmers.

The closure of the delta has also had another significant impact. In the dry season, because of the vanishing influence of the tidal effect, water levels in the canals have dropped dramatically. Figure 3 shows that the water levels tends now to be even and that the average elevation has dropped by 60 cm. This means that while more fresh water is made available, its use is made contingent upon pumping it from the canals onto the plots.

FIGURE 3. CHANGE IN WATER LEVELS (DRY-SEASON)



6 Access to the means of rice production

The intensification of the production from one traditional rice, or two rice crops, to three rice crops per year implies a control of water and of operations such as land preparation or threshing. Moreover, intensification is possible only if the supply of input (labour, equipment, capital) is sufficient to allow the change in cropping pattern. It was hypothesised that such a dramatic transformation of cropping techniques and cropping intensity would be faced with significant bottlenecks and that local arrangements (factor markets, exchanges, sharing) would reflect these tensions.

6.1 Access to water and water management

The change from one or two rainfed rice crops to three crops, or from one traditional crop to *He Tu* and *Dong Xuan* crops, requires a good access to water for irrigation during the dry season and access to canals to drain rain water for the second crop. No severe constraint regarding these factors could be observed in the area. Most farmers have their own pump to irrigate and drain their fields. During the first years, only some farmers rent pump from others. We can explain this by the fact that farmers already have a pump for boat transportation or have access to credit to buy a pump. During the same time the irrigation network was developed. Farmers had to dig a tertiary canal at an interval of 500 m.

Several arrangements are possible to access water and to carry out the pumping operations needed. Farmers with plots located along the canals tend to use individual pumps; they may sometimes pay to hire a pump but this situation is becoming rare.

Those who do not have direct access to canal water must either excavate tertiary ditches to supply water to the inner fields (they need to buy land, sometimes collectively if a few plots can benefit from the ditch), or irrigate their field by gravity from one field to the other (plot-to-plot). In some case an exchange of land is done to allow access to water to all farmers (generally kinship links are needed to facilitate such a transaction).

Other solutions are collective. Only two cases, however, have been observed. The first one was a group of 11 farmers who joined another farmer already equipped with a 13 cv pump. The second was an attempt by the State to establish a collective pumping unit under a cooperative scheme. Instead of individual pumping, an area of 41 ha can be supplied by a single pump which raises the water level in the canals (allowing gravity inflow to the plots). In case drainage is needed, the pump is reversed and the drainage of plots to the canal system is also expected to be achieved by gravity. This proved an optimist assumption and most farmers have to use their own pump to speed up this operation. This solution also requires a good timing of operations, which is perceived as a constraint by farmers, who therefore prefer the individual option.

6.2 Access to equipment

Tractors and threshers have been used since the beginning of the 1990s or before. In the past, tractor owners were coming from others Provinces like Can Tho or Soc Trang to propose their services. Now more farmers have their own tractor and threshers are rented from other farmers. In one village (in the three crops area) more than 50 tractors can be found since 1995.

Land preparation and post harvest are not a constraint for the cropping calendar even if the need for equipment increases every year. Moreover, the number of tractors significantly increased in the last two years and the price for land preparation is now decreasing year by year (from 50,000 vnd/congA (for ploughing and levelling) in 1998, to 30,000 vnd/congA in 2000).

Access to equipment is necessary to intensify rice cropping, but in the present case this condition did not stand out as a critical constraint.

6.3 Access to land

The land market has undergone drastic changes with the intensification of agriculture. In the last three years, transactions on land have been more and more common. This phenomenon is the result of losses in rice farming. The increasing use of inputs for rice leads farmers to making loans. In case of crop failure (mostly for the third crop), farmers may have to sell their land to pay back their debts (for example in one hamlet in the three crop area, 10 farmers became landless farmers for such reasons).

With intensification, the price of land has increased from 1 million vnd/cong in 1990, to 2 million in 1996, to 4 - 4.5 million/ cong in present times.

Renting land is not a common phenomenon, but it appeared a few years ago with the fresh water. We can observe two cases of renting:

- renting a land for one crop, mostly the *He Tu* crop (100 000 vnd/cong), that concerns mostly farmers who have more than 2 ha. They rent out land in order to finance their inputs.

- renting the land for three years (2.5 to 3 million vnd/cong). This case is similar to a mortgage. Farmers have to pay back the money after 3 years. This case is apparently more and more present in the three crops area because the mortgage is used to pay back the loan from the moneylender or the bank. We can make a link with this kind of mortgage and the fact that some farmers have to sell land to pay back their loans. This form of money lending has long been practised in Vietnam and is now reappearing (Fontenelle ; pers. com.)

Through these mechanisms, some farmers can have access to a larger area of rice land and some farmers can have more than the official maximum of 3 ha.

More than 90% of the farmers have their land certificate and pay a land tax, while the remaining 10% also pay the land tax in most instances. The land tax has not changed with the increase in cropping intensity, but the land classes are to be adjusted soon (according to Ninh Quoi People's Committee). Village’s People's Committee are waiting for the agreement of the Department of Agriculture and Rural Department of Bac Lieu Province.

6.4 Access to credit

With the land certificate, farmers can have access to credit from the bank to finance the crops. Farmers can make loan from three different sources:

i) The Vietnamese Bank for Agriculture (State bank): "group loan"

At the beginning, in 1993, farmers could apply for loans of 1 million vnd per hectare with an interest rate of 1.25% per month. In 2000, the limit was increased to 1.5 million per ha with a lower rate (1% per month). Farmers have to form a group, composed by 10 to 20 farmers of the same hamlet, under the direction of a leader. This form of loan is now common for most rice farmers who use this credit to finance inputs.

ii) Private loan (Bank)

Private loans (with the bank) are not very common; the amount is higher (2 million vnd/ha, rate 1%/month). This kind of loan needs the authorisation of the People Committee, and is generally used to buy equipment like a tractor or a rice thresher.

iii) Private loan from a private person

Private loans are commonly found; most of the time the input salesman supplies his products with a rate of interest which ranges from 5 to 10% per month. But this kind of loan decreased since 1995, with the formation of farmers groups.

To conclude this section, we can say that the access to means of production for rice cultivation did not appear as a crucial constraint for farmers. Even if the change from one to three crops is a very big change, which demands the acquisition of new techniques and the improvement of the rice production chain, no significant constraint was identified. The fact that a part of the district already used short time varieties and grew 2 crops per year made the change easier. In addition Hong Dan district is close to Can Tho and Soc Trang provinces, where rice cultivation has already been improved to 3 rice crops per year. All this facilitates the flow of equipment and inputs to Hong Dan. But in some cases, the change in rice cultivation was constrained by the neighbourhood. The change in cropping calendar in one area can only be effective if all the farmers change their rice cultivation at the same time. Sometimes, the change of rice cultivation is delayed because some farmers cannot make the necessary investments to grow high yielding varieties.

7 Evolution of shrimp farming

As mentioned earlier, shrimp farming in Hong Dan district has developed in the area since the beginning of the 1990s. With shrimp farming, farmers found a way to use low lands and very acid soils. With the construction of new sluice gates, fresh water is now entering the shrimp area. What has been the evolution of shrimp farming in Hong Dan district and how can it adapt to the new water conditions?

Shrimp farming appeared in Hong Dan district in 1986, in the southern part of the district (Phong Thanh Nam village) with the capture of natural shrimps. Natural shrimps were to be found in this village in the past but have now disappeared with the closure of the area. Then new techniques came from Ca Mau province, Gia Rai district or even from Nha Trang, and shrimp farmers began to raise *Tiger monodon,* a high value shrimp.

With the introduction of *Tiger monodon* in Phong Than Nam village, the shrimp area expanded to other villages, year by year, from the south west to the north east. It took 3 to 4 years to convert all the fallow land and the pineapple area of the district into shrimp ponds. Fallow land and pineapple fields were converted into shrimp ponds. Rice farmers could not convert their fields in shrimp ponds (because of the provincial land use planning), despite the willingness of some of them. That is the reason why some rice farmers buy some shrimp land. With the construction of new secondary canals, new land was available for shrimp farming, as most of the new canals cut across low land and acid soils.

Since the beginning, farmers have been raising shrimps in an extensive way; the shrimp pond area is over 1 ha and shrimp density is between 0.7 to 1.4/m^2. Shrimps are fed only with natural food, such as plankton. The only inputs are for land preparation, farmers use fertilisers (N.P.K or D.A.P) to improve the growth of phytoplankton, and lime to improve pH. Until the beginning of the project, farmers were able to do 3 to 4 crops per year.

With the new fresh water supply, shrimp farmers had to change their cropping pattern or to modify their techniques. Tiger shrimp need high salinity (20 to 35 ‰) at the beginning of their growth cycle. At the adult stage, the salinity rate can be reduced to 2 to 5 ‰. Problems of mortality of the young shrimps and lower growth rate are the most common manifestation of the decrease in salinity. Farmers cannot reach the same yield as before and cases of total losses are getting more common.

With the new water quality, farmers devise different strategies, according to their background, quality of soil and land possession.

- Some rice farmers abandoned their shrimp pond, some of them sold it to other farmers after the loss of the harvest;

- Shrimp farmers located in the eastern part of the district tried to diversify their activity raising ducks, pigs or engaging in forestry;

- Shrimp farmers on deep acid sulphate soil in two hamlets have changed their cropping pattern from 3 to 4 shrimp crops to 1 or 2 shrimp crops followed by one traditional rice. As mentioned earlier this system can be done only on deep acid soils. Even if this system is less profitable than year-round shrimp farming, it allows the cleaning of the pond and a renewal of water. This system may be more sustainable regarding shrimp production (from a technical point of view) but also from a food security point of view, because rice cultivation is less risky than shrimp farming.

- Most shrimp farmers raise carps (*Cyprinus carpio*) together with shrimps. Farmers on shallow acid sulphate soil are not able to grow rice and they prefer to combine shrimps and fishes, but shrimps are raised with a lower density in order to limit investments. Only a few of them try to intensify their cropping systems, with higher density and special food for the shrimps. This is common in the whole shrimp area, even in those areas where the salinity rate is lower and the duration of salinity period is shorter.

With this adaptation in cropping patterns, farmers have developed new techniques to avoid fresh water or to adapt shrimps to the new water conditions.

- First, since the fresh water came into the shrimp area, shrimp fries producers started to sell shrimps acclimated to fresh water. The young shrimps are slowly acclimated to fresh water and farmers have less mortality in the ponds. Now, these techniques are commonly used and some farmers inside the area diversify their activities, doing acclimation of shrimp fries.

- Some farmers who raise young acclimated shrimps rent boats to procure saline water in the saline area of Ca Mau, in order to improve the salinity rate in their hatchery.

- With the fresh water, farmers drilled deep wells to get saline groundwater (40 meters deep), but this activity is not allowed by the authorities and some farmers got into trouble.

- During the dry season, when salinity gradually penetrates into primary canals, farmers build dams at the extremities of secondary canals, pump out the fresh water (from the secondary canal to a primary canal, at the extremity where there is no saline water) and let enter the saline water into the secondary canals.

As we can see shrimp farmers find many ways to avoid fresh water and to continue raising shrimps. For them, shrimps are tantamount to high income and better life. This strong willingness to raise shrimps, even if it is more and more difficult and if the yield is lower, can be explained by the increasing price of Tiger shrimps. Since 1998, the price increased from 75,000 vnd to 160,000 vnd per kg (30 units).

The dramatic change in livelihood and economic opportunities brought about by shrimp farming cannot be overemphasised. In the past, the residents of the area were engaged in fishing in the canals and would lead the buffaloes of fellow rice farmers to graze on fallow land. During the dry-season they used to go to Ca Mau Province to work in construction or as fishermen in Ganh Hao or Rach Gia ports. At harvest time they would provide the bulk of the labour force. After the development of shrimp farming, the same peasants have now their houses made of bricks instead of nipa palms and they hire outsiders as wage labourers for canal or pond dredging.

Evidence of shrimp farmers resistance to fresh water appeared this year in the neighbouring province (Ca Mau) and the government choose to let enter the saline water for farmers to raise shrimps, instead of continuing the closure of the area. Another argument for a new sluice gate management is that fresh water from the Bassac River is not enough to irrigate the whole Ca Mau peninsula. Vietnamese authorities have requested rice farmers to grow only two rice crops par year instead of three in order to reduce fresh water consumption during the dry season.

From an economic point of view, we can compare the gross margins of rice and shrimp farming. As we can see in Table 2, the gross margin of shrimp farming (with salinity like in 1994) was 22 times higher than triple rice cropping. This is very similar to the current situation found in the Chao Phraya Delta, Thailand (Szuster *et al.*, 2002) Under the present conditions, shrimp farming is still almost six times more profitable than rice triple cropping.

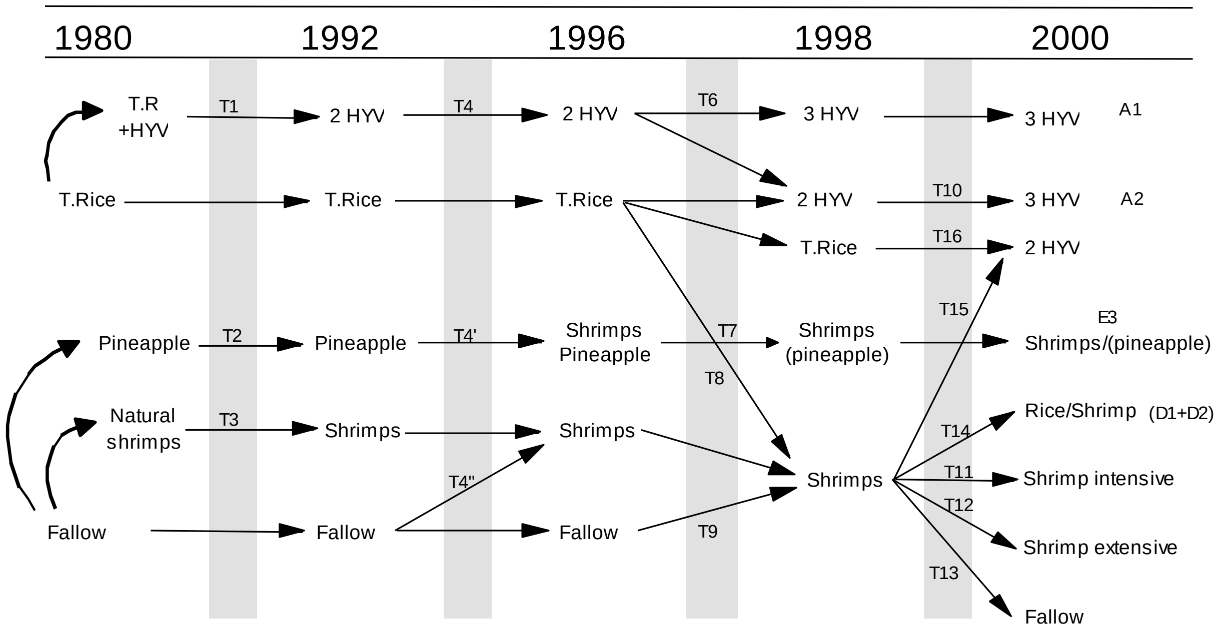
TABLE 2 : ESTIMATION OF THE GROSS MARGIN FOR RICE AND SHRIMP FARMING

	3 rice crops	Shrimp (1994)	Shrimp (2000)
Gross margin (million vnd/ha)	3.85	85	22

8 Summary of land use change

Figure 4 recapitulates the changes in land use that have occurred in the area. The different phases identified are then specified and the different constraints and enabling factors are recalled. What is striking in this picture of change is how rather undifferentiated farming systems have evolve, in a short period, towards a complex set of cropping patterns closely shaped by local conditions in land and water.

FIGURE 4. SEQUENCE OF LAND USE CHANGE IN THE STUDY AREA



Phase 1980-1992

- *Transformation T1: Traditional rice to 2 rice crop*

Enabling factors: Topography (high land), alluvial or deep acid soil, digging of tertiary canals, importation of technique from other provinces, lixiviation of the acid soils of the eastern fringe (use of fertilisers and washing out of residual acidity at the beginning of the cycle in may)

Constraining factors: Topography (low land), acid soil, salinity intrusion (early December for the western part of the district), no capacity to invest, lack of techniques, interdependence, dike around the field

- *Transformation T2: fallow to pineapple*

Enabling factors: extension and provincial local planning; adequate technique for making raised beds in acid soils

Constraining factors: too acid for rice; declining price of pineapple, capacity to invest in raised bed

- *Transformation T3: fallow to shrimps*

Enabling factors: existence of natural shrimps capture technique; importation of technique from south; development of export markets and post-harvest facilities by the state; colonisation allowed by secondary canal excavation (canals 2,4, 6 and 8), important land size.

Constraining factors: access to information,

Constraining factors in other areas with no transformation:

Salinity; acidity, no canal, no capacity to invest

Phase 1992-1996

- *Transformation T4: expansion of double cropping*

Enabling factors: same as above with more effort of extension and provincial planning, access to loan

Constraining factors: same as above

- *Transformation T4': Pineapple to pineapple and shrimp*

Enabling factors : importation of technique from south; development of export markets and state post-harvest facilities, high value of shrimp

Constraining factors: access to information, capacity to invest

- *Transformation T4'' : Fallow to shrimp*

Same as T3 and capacity to invest

Phase 1996-1998

- *Transformation T5: transformation of traditional rice to rainfed double cropping*

Enabling factors: no more salinity; on-farm development; more farmers with capital; development of tertiary canal network (access to water)

Constraining factors: Access to loan, interdependence,

- *Transformation T6: development of triple cropping*

Enabling factors: no more salinity; on-farm development; more farmers with capital; Constraining factors: Cost of inputs, interdependence

- *Transformation T7: Pineapple to shrimp (and pineapple)*

Same as T4' (transformation is increase by the low price of pineapple)

- *Transformation T8: Traditional rice to shrimp*

Enabling factor: access to technique and information, high price of shrimp

Constraining factor : instability of yield, provincial authority does not allowed the use of rice land for shrimp farming

- *Transformation T9: Fallow to shrimp*

Same as T4''

Phase 1998-2000

- *Transformation T10: expansion of triple cropping*

Enabling factors: reduction of salinity, easy access to equipment, less cost for equipment

Constraining factors: lack of water (future), rice price

- *Transformation T11: shrimp to intensified shrimp*

Enabling factors: reduction of salinity, smaller plot (increase of population), access to information (other province),

Constraining factors: lack of investment, risk of shrimp farming

- *Transformation T12: shrimp to low extensive shrimp*

Enabling factors: reduction of salinity, lack of investment

- *Transformation T13: shrimp to fallow*

Enabling factors: reduction of salinity

- *Transformation T14: shrimp to 2shrimp/rice rotation*

Enabling factors: moderate acidity; extension service

Constraining factors: strong acidity, interdependence

- *Transformation T15: shrimp to double rice cropping*

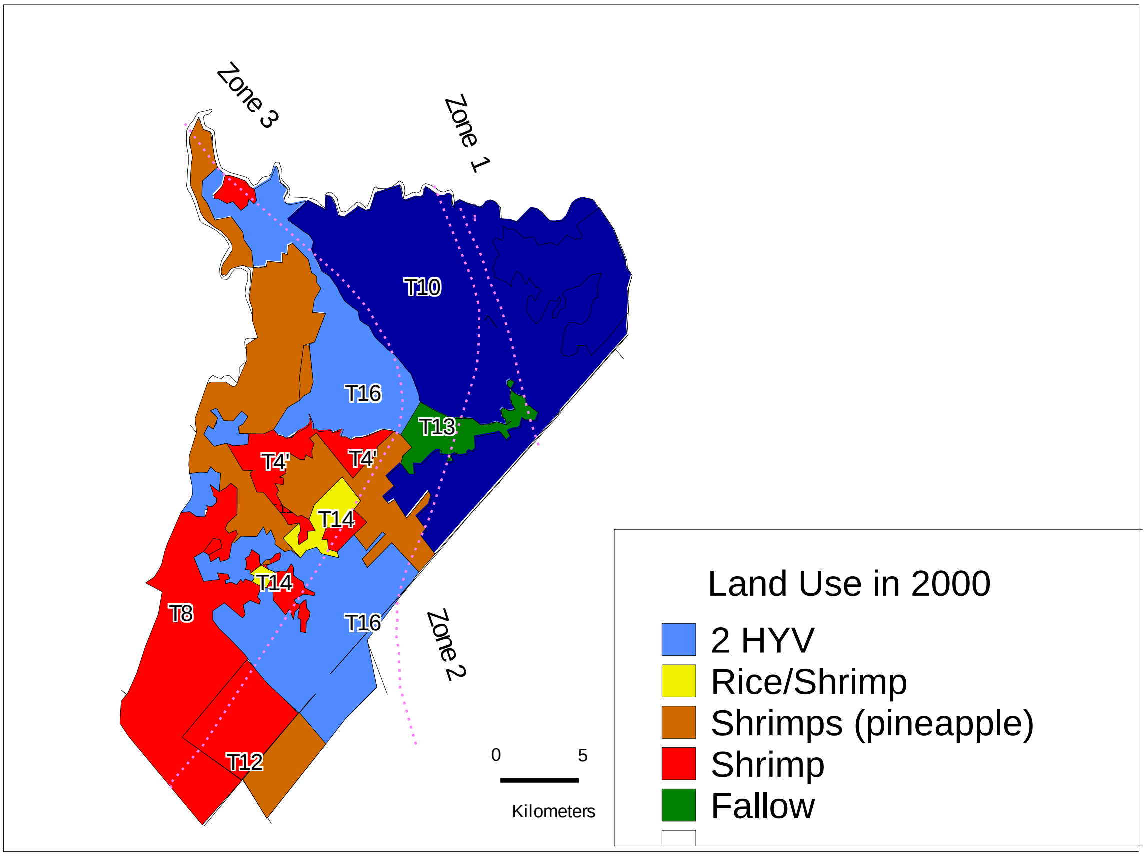
Enabling factors: lack of salinity, moderate acidity, provincial local planning, interdependence.

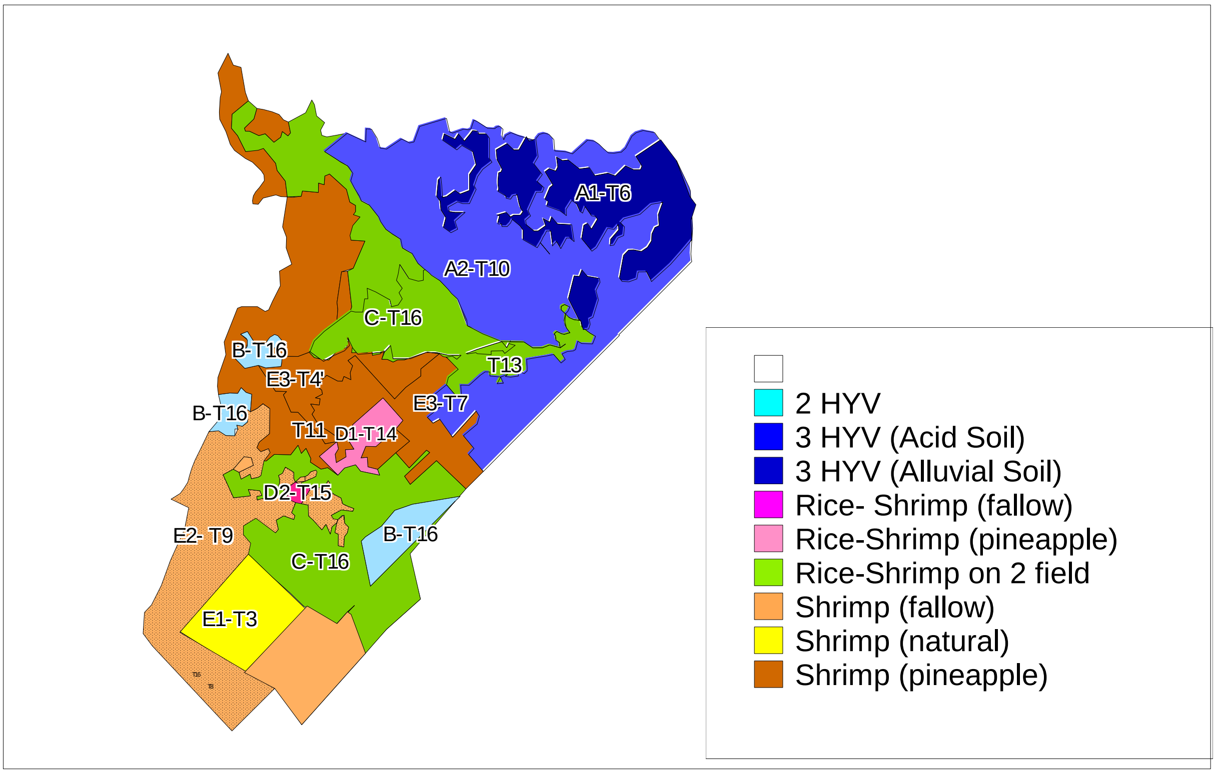
- *Transformation T15 : traditional rice to double rice cropping*

Enabling factors: no more salinity; on-farm development; more farmers with capital; development of tertiary canal network (access to water)

All these transformations have eventually given way to the land use pattern shown in the following figures. The figures indicate where the transformations specified above have taken place.

FIGURE 5. LAND USE IN THE STUDY AREA (2000) AND INDICATIONS OF TRANSFORMATION CODES





9 Prospective and options for water management

All this elements suggest two different options for a new water management which can allow both shrimp and rice farming in the same area.

Scenario n°1 :

The last sluice gate Chac Bang need not be built, so as to allow saline intrusion in the western part of the district by the Ong Doc river and Chac Bang Canal. At the same time sluices gates from Chu Chi to Bac Nguu should be opened during the dry season at high tide after the harvest of the second rice crop (middle of February to April) (see Figure 6). In such a way saline intrusion would remain at the level of 1998. Most of the rice area will be protected and shrimp farming will be allowed to continue. This suggestion does not incur new costs, but a new sluice gate management, and co-operation and communication are need for setting a stricter irrigation calendar. A large part of the district will not be able to cultivate the third rice crop. But this consequence is in line with the Bac Lieu Province recommendations, which dictates that only two rice crops can be cultivated. Only the eastern part of the district will be able to cultivate three rice crops per year. Shrimp farming could continue on shallow acid soil, maybe in a more intensive way, and rice – shrimp system may extend on deep acid soils.

Scenario n°2 :

This proposal came from the Bac Lieu Department of Agriculture and Rural Development. It considers not building the last sluice gates (see Figure 7). This, will allow limited saline water intrusion in the western part of the district (by primary canal located before the Chac Bang sluice gate). Shrimp farming may continue with lower yields and more problems, but rice farming will not be affected by saline water.

FIGURE 6: SCENARIO 1

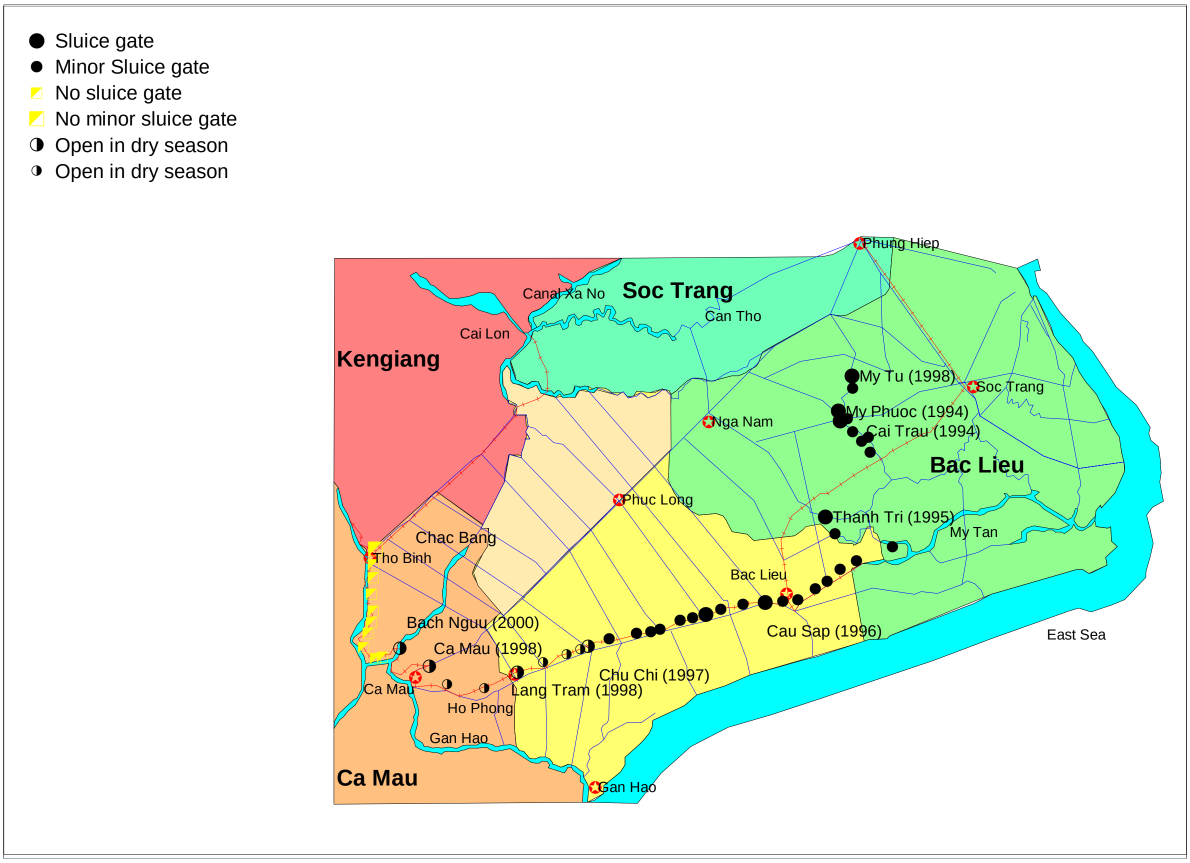
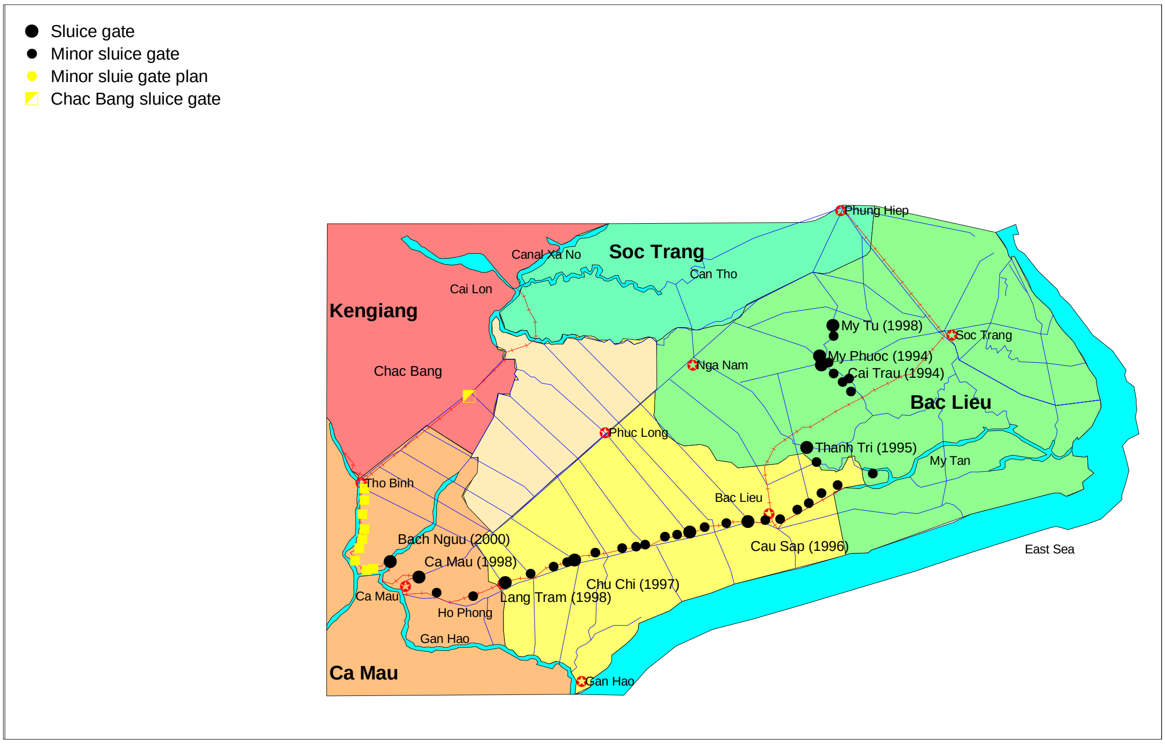


FIGURE 7: SCENARIO 2

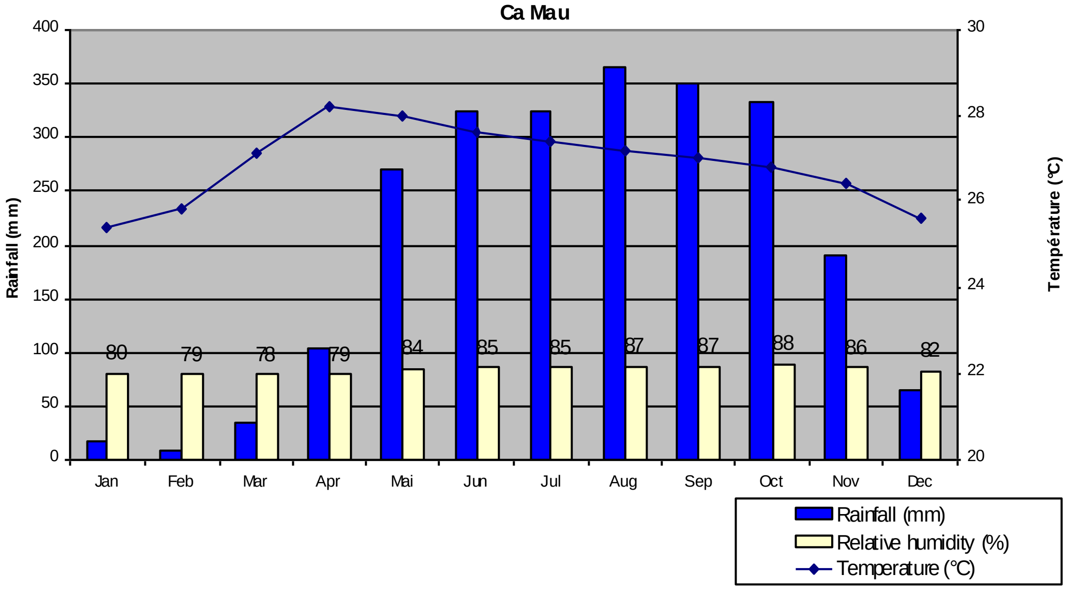


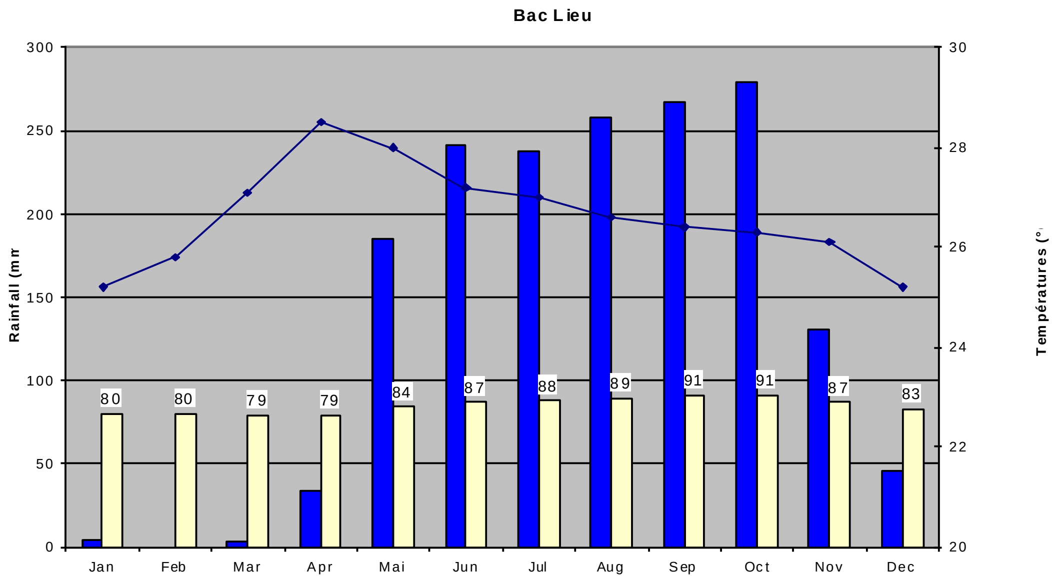
10 Conclusion

Two major dynamics have been observed is the study area. The change from one rice to three rice crops is not significantly constrained by a possible insufficient access to means of production and this intensification led to a diversification in farmers' activities. The change in water quality, from saline to fresh water, stopped the expansion of the shrimp area and led to the adaptation of this production system to the new conditions instead of its disappearance.

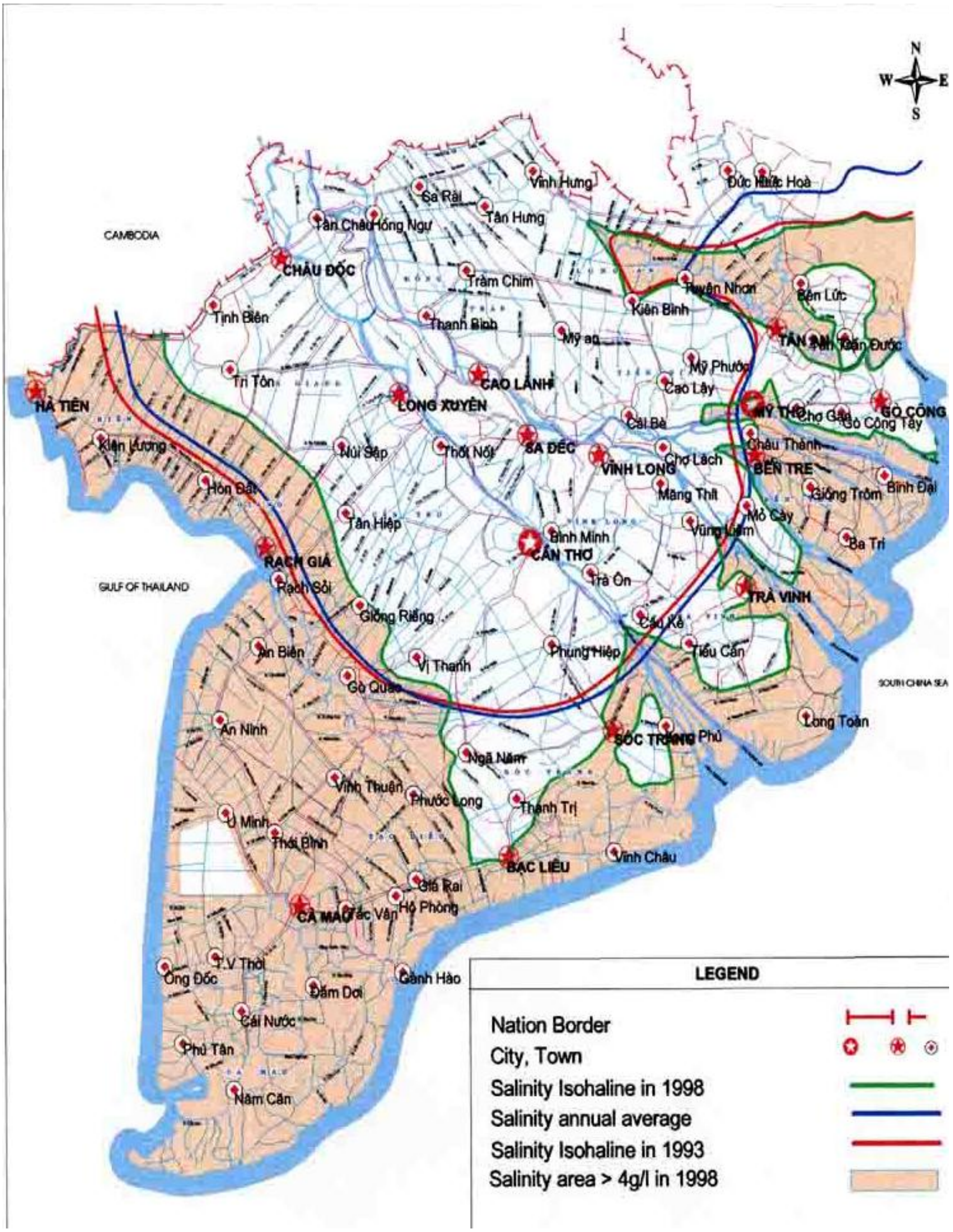
The study of land use change brought about by infrastructure development shows us that the Vietnamese government may have inadequately given emphasis on development options centred on rice intensification, and rice self-sufficiency. In this area, however, we could evidence a wide range of endogenous farmers' responses to varied and changing ecological situations. It is striking to see how these adaptations have been both quick and varied. Economic calculations and the recent unrest of farmers opposing the construction of sluice gates show that shrimp farming is a preferred option and that, consequently, water management and land development plans should take this point into consideration.

ANNEX 1 : Rainfall, relative humidity and temperature of Quan Lo Phung Hiep area.





ANNEX 2 : Salinity Intrusion at 4 p.p.m. in the Mekong Delta



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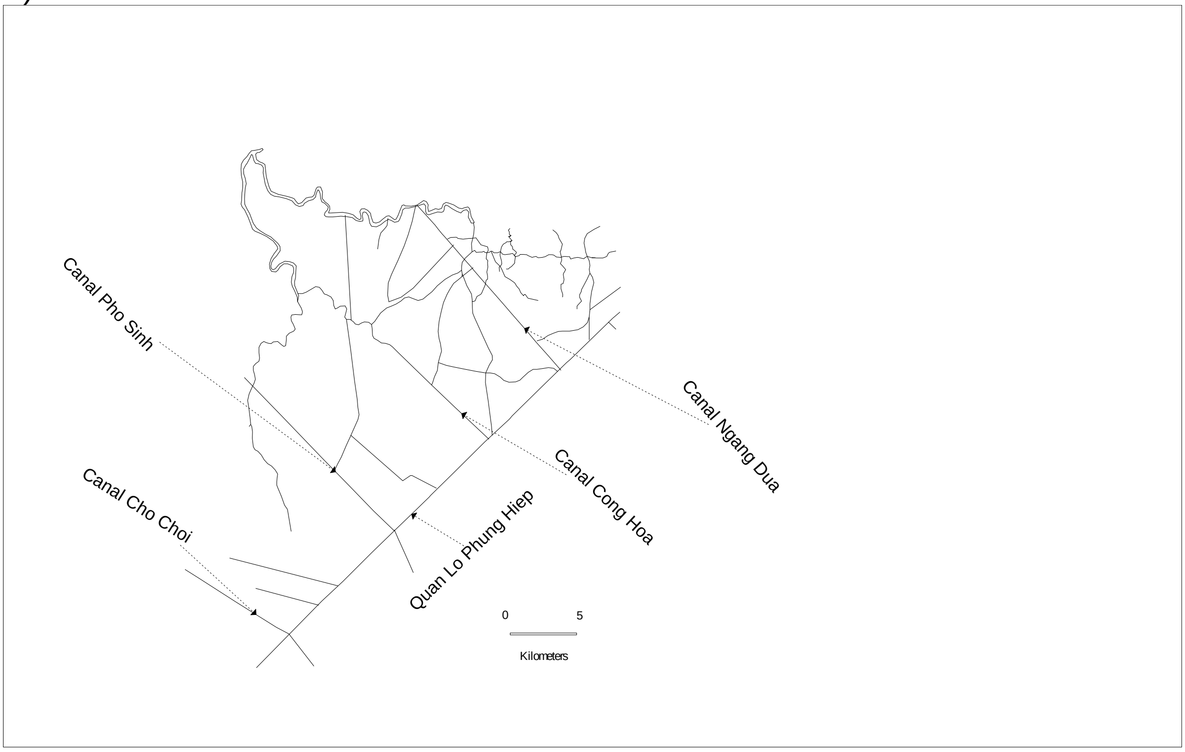
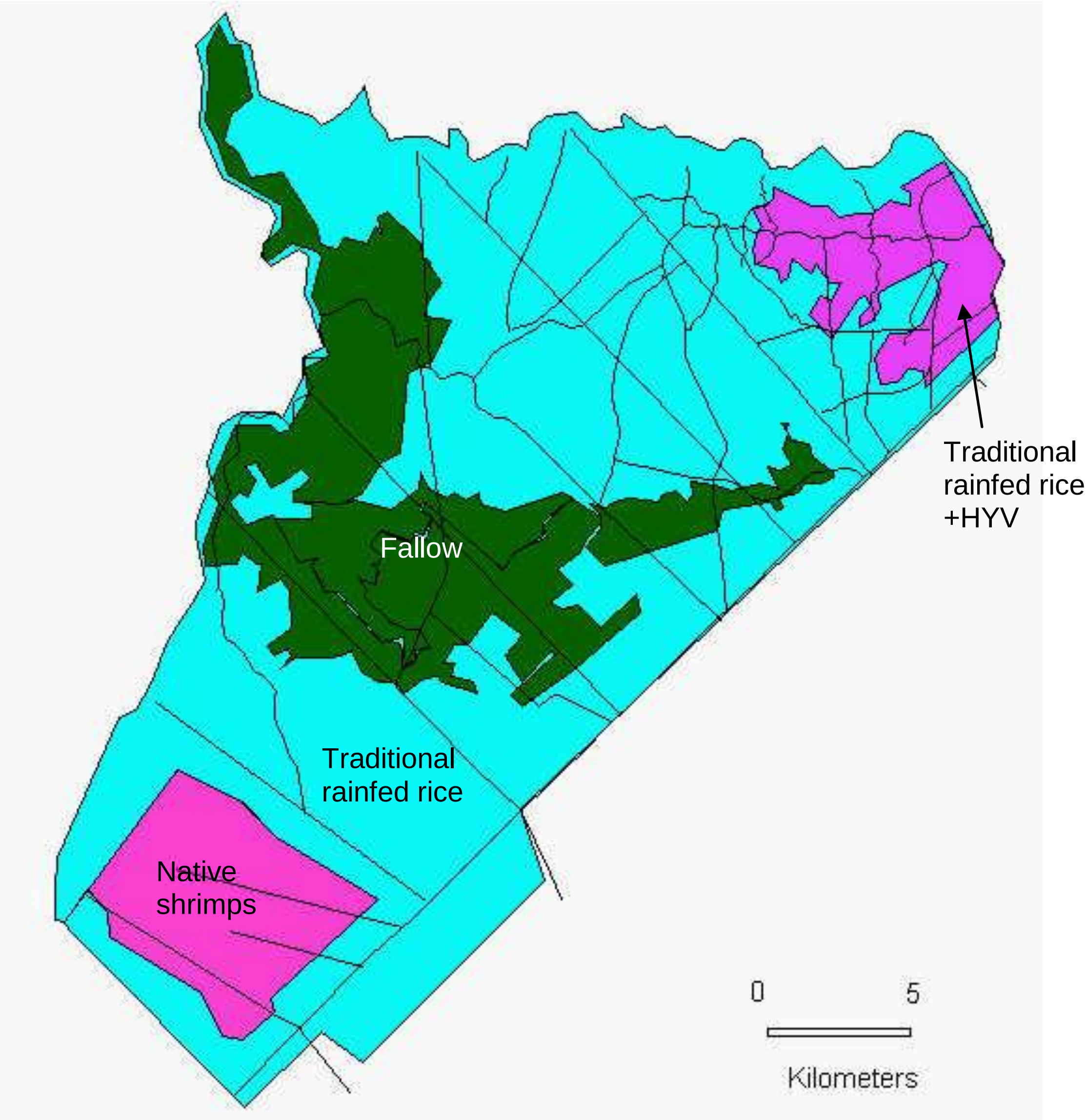
Annex 3 : Canal network development of Hong Dan district

A)Before 1975



B) In 1985

Land use in 1985



Part III

Local dynamics in land and water use : a case study in An Giang Province

Pascal Lienhard

François Molle

Nguyen Hieu Trung

1 Introduction

The land use shift from floating rice to irrigated rice is often regarded as one of the main feature of agrarian systems changes in the Mekong Delta (Farming System Center, 1998; Vandome *et al.*, 1993; Bruzeau *et al.*, 1994).

The Mekong Delta (MD) is a place of permanent confrontations between several flows: the water level in the MD depends on the Mekong river level but also on tidal effects coming both from the Eastern Sea and the Gulf of Thailand (FSC, 1998).

During the rainy season (from May to mid-November) big floods[3] occur frequently, generated by rainfall and high river flows (40,000 cms at that period). Seven provinces of the MD are affected every year by floods that can last two to five months in the lower lands (DANIDA, 1994).

Unlike the Red River in North Vietnam, water levels in the Mekong River increases quite slowly because of the role of the *Tonle Sap* lake (in Cambodia) as an upstream buffer. A progressive rise in water level allows the cultivation of rice varieties which stems can elongate with water (not above 10 cm a day) (Molle *et al.*, 1999).

Thus, floating rice varieties has been widely used in these flooded areas since the beginning of the 20th century (Brocheux, 1995; FSC, 1998). This crop is often presented as well adapted to flood and low labour force availability, conditions that could be found in the lowest areas of the MD flooded provinces (DANIDA, 1994; Brocheux, 1995). The low input level required for cropping (see frame 1 below) explains why these varieties have been widely adopted.

Frame 1: **Floating Rice based Cropping Systems**

At the beginning of the rainy season about one month before flood to occur, the soil is ploughed and rice is sown at a 120-150kg/ha density. One month is indeed necessary to allow rice roots to develop enough. Soil is then scratched to prevent rice to be eaten by predators (birds, rats, snails). A weeding can be made before water reaches 50-80 cm high but is not systematic. Neither fertilizers nor chemical treatments are usually applied during the cropping cycle (7 to 8 months). Rice flowering occurs while water level is decreasing. Rice is harvested into 0,8 to 1m of water and barks are used to collect the rice. More than 1m of rice straws then remain on the field after harvest. This biomass is either burned to give back minerals to the soil or kept to keep soil humidity. Anyway, field crops, such as maize, sesame or vegetable are then usually grown.

(synthesis of: Vandome et al. 1994. Bruzeau et al. 1994. Brocheux. 1995. FSC. 1998. Hauswirth et al. 2000)

In An Giang province (located at the Cambodian border) where this study was conducted, floating rice production has undergone a decrease of about 115,000 ha between 1976 and 1994 (from about 150,000 ha in 1976 to less than 35,000 ha in 1994). During the same

[3] Flood can reach 3 m in height. The year 2000 is once again a good example of such exceptional floods.

period, irrigated rice areas rose from less than 35,000 to 175,000 ha, that is to say an increase of more than 140,000 ha (DANIDA, 1994).

This chapter aims at a better understanding of these changes in land and water use. This study was conducted between April and October 1999 in Chau Phu district (see map 1), in three villages belonging to the same cross section: Vinh Thanh Trung, Thanh My Tay and Dao Huu Canh, hereafter referred to as V1, V2, V3 respectively, in order to facilitate reading.

1.1 From floating to irrigated rice: the different periods of land use changes

At the beginning of the 20th century, population in our cross section was concentrated in the upper part of V1 (created in 1804), as close to the Bassac River banks as possible. Beyond canal 1 or 2 only forests and swamps[4] could be found. The main activity along the cross section was fishing and field crops cultivation on the upper lands.

Floating rice cultivation appears closely linked with historical settlements and land reclamation. It might have been in use close to the Bassac river since 1920-1930 (not clearly defined) but did not appear in V2 and V3 before the first migration wave (1945-1947). This settlement followed the excavation works done during the French time[5].

Except for isolated cases such as the one described in frame 2 (below), the shift from floating to irrigated rice did not start before the country reunification (1975). Thus we will focus in this chapter on the last 25 years period and will not address here the political changes (Diem and Thieu reforms), and the evolution of farming systems (cropping systems intensification and diversification) that occurred before 1975.

Frame 2: **Example of individual shifting from floating to irrigated rice before 1975**
(*from Hauswirth et al, 2000*)

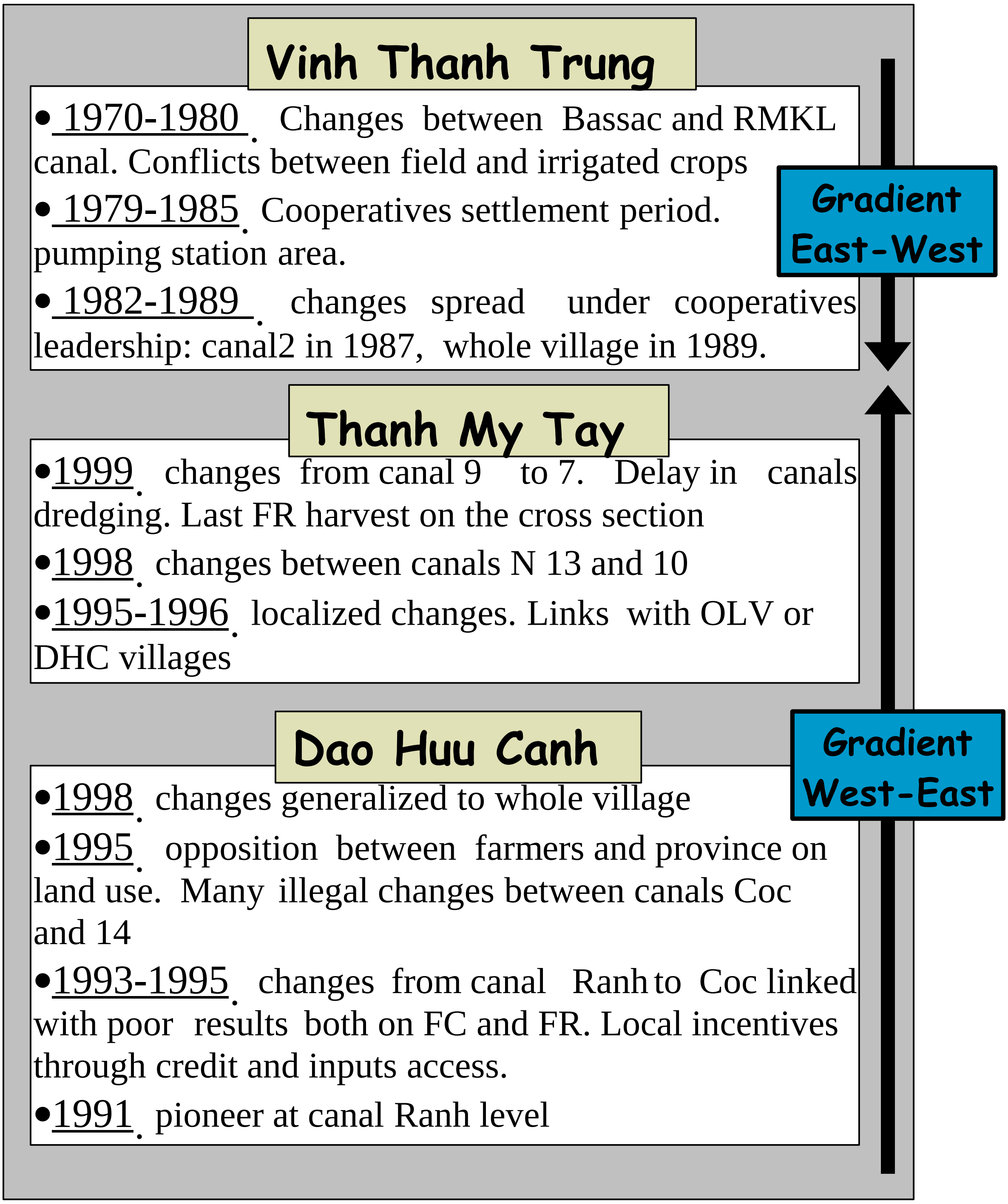
Mr K., farmer located close to Bassac river (V1) bought his first tractor in 1948 for personal use. In 1968, agricultural services at district level (in relation with US agricultural extension program) proposed him to experience two rice crop cropping system. He received seeds and fertilizers as subsidies. After 3 failures (3 crops), he went to a nearby village, where two rice crops were already grown for few years, to learn the techniques. After his return, some neighbours started to imitate him.

Figure 8 (left) synthesises the different phases of change along the studied cross section.

[4] The former name of V2 was “Lang Linh” that means “the holly swamp” (MDMP, annex 10, 1994)

[5] Between 1938 and 1945, the primary canal Vinh Tre–Tri Ton (see map 1) was excavated. Several secondary canals (MKL, No 7, Nb13, Coc and Ranh) were also dug during that period. Settlements have always been related to hydraulic works: digging, rehabilitation and nowadays diking policies.

FIGURE 8. FROM FLOATING TO IRRIGATED RICE: A PERIODISATION OF CHANGE ALONG THE CROSS SECTION



1.2 Phase I: 1975 - 1989

1.2.1 1976-1982: transitional period from a free market based economy to a planned economy

After the reunification, the northern policy was supposed to be extended to South Vietnam. Concerning agriculture, the main expected changes were:

- Planning of agricultural production

- Collectivisation of production and nationalisation of marketing channels

What has actually been done between 1976 and 1982 is the establishment of a new institutional and economical framework allowing planned economy. The following changes have to be considered in order to understand linkages with changes in cropping systems.

- The present administrative system (province/district/commune) is created after the reunification: the People's Committees are established at the different levels under the Communist Party's authority. In 1976, formally named village V1 was split in V1 and V2. Canal 7, already existing since the colonial period, is used for administrative (but also agricultural –see below) delimitation.

- In 1976, a plan dealing with the "agricultural production level to be reached for the year 2000" is defined at the provincial level. This plan divides our cross section into two areas with two different production goals for the year 2000:

  * From the Bassac River to Canal 7: objective of 2-rice crop/year for 2000

  * From Canal 7 to Canal Ranh: objective of 1 floating rice + 1 field crop for 2000.

- The hydraulic network is developed mainly from 1977 to 1980[6] in order to achieve the newly defined agricultural objectives. Network design and workplans are established at the province and district level (Planning Department) while the civil population contributes its work through a "compulsory collective work service" created in 1977. An electric pumping station covering 350 ha is also constructed in V1 in 1978.

- From 1976 to 1979, land requisition/re-distribution is aimed at preparing cooperative settlements. The 'Groups of production' set up from 1978 to 1982 (at least in V1) are another step towards cooperatives. They consist in small groups (3 to 5 persons) working together (at least for irrigation) on small areas (5 to 10 ha) (Hauswirth, 2000).

Changes in cropping systems mostly occurred in the upper part of V1: close to the Bassac River (see Mr. K's experience in frame 2) and also inside the area served by the new pumping station, where everyone had to follow the 2 rice crop (RC) calendar for irrigation. Some farmers from the Bassac River to Canal 1 also shifted to 2 RC/year, organising irrigation by themselves or resorting to private services. Such cases, however, remained limited but some conflicts already appeared between field crops and irrigated rice farmers.

1.2.2 1982-1989: the cooperatives period

The process of creation of cooperative units began in 1982 for the three villages. In V1, shifting from floating to irrigated rice was achieved under cooperative leadership. Indeed, equipment management was centralised (pumps and tractors) and co-operation was based on collective land preparation and water management for irrigated rice cultivation.

[6] All present canals on the cross section have been dug (or widen for the one already existing) during this period.

‘Digging and dredging’ services still remained compulsory for all villages but works were concentrated in V1 to fit the plan. Thus, the upper reach of Tri Ton primary canal was renovated in 1985. Secondary canals number 1, 2 and 7 (all belonging to V1) were also dredged between 1985 and 1989.

Therefore, a main gradient of change could be observed from the Bassac River down to Canal 7: in 1985, the upper part of V1 till Canal 1 had shifted to irrigated rice. This change expanded to Canal 2 in 1987. In 1989, the whole village had changed to 2 RC/year.

Anywhere else along the cross section, cropping systems based on floating rice and field crops succession were still the rule. “Cooperativisation” was also put in practice. Land preparation was carried out by the cooperatives; chemicals and seeds are centralised. But this process seems to have been of lesser significance in V2 and V3 compared with V1.

1.3 Phase II: 1991 - 1996

In 1992 and 1993, works for canal capacity improvement were concentrated in V2 and in the upper part of V3[7]. These works were officially carried out in order to boost the adoption of new corn varieties in the floating rice/field crops area. Indeed, the People's Committee at the provincial level has signed a contract with a Thai company (AFIEX) for corn exportation.

But in the western part of the cross section, field crops experienced bad results (especially watermelon) due to soil acidity problems. In 1991, a farmer located on Ranh Canal started 2 RC/year. He became head of a co-producer group created in 1993 to develop 2 RC cropping systems on 60 ha of farmland. Indeed, in 1992, an exception to the provincial production goals was endorsed at the district level. Farmers were therefore allowed (and even encouraged through credit access conditions) by the People's Committees at village level to perform 2 RC/year between Ranh and Coc[8] canals.

In 1994 and 1995, poor harvest both on floating rice (inundation) and field crops (pest outbreaks), associated with conflicts on field crops sale price (contracts for maize), stirred discussions and criticism on the profitability of the floating rice/field crops cropping system. Moreover, irrigated rice yields increased since 1994, when IR rice varieties, resistant to brown plant hopper (one main limiting factor for rice production) replaced former OM[9] varieties. The shift from floating rice to irrigated rice occurred in V3’s middle and V2’s lower parts without the consent of the People's Committees. Under farmers’ pressure (as it was presented by the district agricultural services), a new production plan was officially defined at the provincial level in 1996:

(i) From Bassac to C 7: objective of 3 crops/year;

(ii) From Canal 7 to Ranh Canal: objective of 2 RC/year.

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[7] Canals number 8, 9, 11, 14 and 15 were dredged in 1992/1993.

[8] Coc Canal with its habitations and trees appeared as an ideal natural limit.

[9] IR for IRRI varieties. OM for O Mon, district in the Mekong delta where new rice varieties are developed.

It is notable that after a North East/South West gradient of change (progressive shift to 2 RC cropping system from the Bassac River to Canal 7), an opposite gradient can now be observed (from Canal Ranh to Canal 13 and then up to Canal 7, see below).

1.4 Phase III: 1997 - 1999

To match the new production goals, important hydraulic works have been conducted since 1997. Both primary canals were dredged. Secondary canals are also gradually improved from Ranh Canal (V3's western part) to Canal 7 (V2's eastern part).

Following these works, the change in cropping system expanded in 1998 to the whole of V3 and up to Canal 10 in V2. The shift between Canal 9 and 7 occurred in 1999.

1.5 General remarks concerning these changes

- There is no more floating rice on the cross section since 1999.
- Chronological changes coincide with village changes (see Figure 8). Indeed shifts occurred between 1976 and 1989 for V1, between 1991 and 1998 for V3, between 1996 and 1999 for V2.
- Three different paces of transition for three different periods of change. The following factors contribute to explaining this differential: existing infrastructures before the change occur, the type of infrastructure constructed, the technical context and also the experience accumulated by predecessors in irrigated rice cropping.
- Collective change. Except for pioneer experiences and localised individual changes in 1994-1995, the shift from floating rice to irrigate rice occured by 'bulk' , that is by entire hydraulic unit, corresponding to cooperative units for V1, and large blocks including several secondary canals in the case of V2 and V3.
- Uniform changes. A very low diversity can be found into the 2-crops/year schemes. Everyone is conducting a 2-rice crop cropping system. Moreover, the varieties used, the crop cycle duration, the crop establishment techniques, and fertilisation practices are quite homogenous along the cross section.

2 Factors explaining land use changes

2.1 HYR/rice: a more profitable cropping system?

2.1.1 Comparison of financial performance

An example of cropping system associating floating rice and field crops and a rough economical analysis of this system are presented in frames 3 and 4. Watermelon is taken as an example for field crops since it appears to be the most profitable crop cultivated in the past and the one farmers are most missing.

It must be noted that watermelon is not cultivated continuously. After two years, others field crops (such as beans, corn) are then cultivated for at least a 5-years period, in order to avoid pest pressure. Moreover, watermelon is sensitive to acidity and cannot be grown everywhere (see chapter 3.2).

<u>Frame 3</u>: **Floating Rice – Watermelon Cropping System (an example)**

At the beginning of the rainy season about one month before flood to occur, the soil is ploughed and rice is sown at a 120-150kg/ha density. Soil is then scratched to prevent rice to be eaten by predators. A weeding can be made before water reaches 50-80 cm high but is not systematic. Neither fertilizers nor chemical treatments are usually applied during the cropping cycle (7 to 8 months). Harvest (1,5-2,5 T/ha) is realized in January into 0,8 to 1m of water.

Watermelon seeds are sown 15 days after harvest directly into rice straws' mulch. Small pumps can be used to drain remaining water out of the plot. Holes are made with sowing sticks or by hand and 2-3 seeds are put down into each pod. Sowing density is about 10000 to 12000 seeds/ha, ie about 40 measures of a tin (unit used). Seeds are pre-germinated (12H into water and then 24H of incubation). Crop cycle length is about 70 days and crop has to be irrigated every 3-4 days. Weeds pressure depends on mulch thickness and a manual weeding can be necessary. About 400kg/ha of urea are added. Chemical treatments depend on pest pressure. Production is sold per surface and prices are discussed according an rough evaluation of fruit number and weight and according to price on the market (high inter-annual variability).

<u>Frame 4</u>: **Rough economical analysis of FR-Watermelon cropping system**

<u>COSTS</u>

Floating rice:
- Ploughing: 220.000d/ha
- Seeds: 250.000d/ha (7 bags of 20kg/ha, 1 bag = 35.000d)
- Soil scratching: 80.000d/ha
- Extra labor force for harvest: 550.000d/ha (15 rice bags/ha)

Watermelon:
- Seeds: 40 tins/ha, 4.800.000d/ha (120.000d/tin)
- Fertilisation: 720.000d/ha (90.000d/50 kg urea)

<u>PRODUCTS</u>

Floating rice: 3.500.000d/ha (average of 2T/ha)
Watermelon: 30 to 40 millions/ha

<u>GROSS RESULT</u>: 30-35 millions of VND/ha (1 USD = 14.000d)

Frame 4 shows that the gross product of watermelon is about 30 millions VND/ha (figures given by farmers are approximately the same: 3 to 5 millions/old cong[10]). This result is mainly due to the selling price of watermelon (30-40 millions/ha) and a relatively low level of

[10] Old cong = 1300 m2

production costs (the main cash input is watermelon seeds, with a price of about 5 millions/ha).

This result must however be considered with caution. Field crop weeding costs and irrigation requirements were not considered. Irrigation depends on the quantity of mulch left after the harvest of floating rice, that is to say partly relies on the success of floating rice, which is quite variable over the years. Watermelon market prices must also be considered in the long run, since fluctuations are said to be important (from 20 to 65 millions/ha according to farmers). 1998 and 1999 appear as good years both for production and selling price in V2, and this may have contributed to over-estimating the selling price (and farmers' enthusiasm too!).

The presentation and the economic analysis of the 2 RC cropping system are given in frames 5 and 6 for comparison. This system (if not seen in a dynamic perspective) appears less interesting economically than the former one. Indeed, the gross product is only about 13 millions/ha. The value of production is lower (about 18 millions VND/ha) and production costs are higher (land preparation, about 2 millions/ha; inputs, about 1,4 millions including purchased products and extra labour force; and pumping service, about 0,6 millions/ha).

Again, the gap between the two systems may be over-estimated but in 1998, the Farming System Center also showed for the same area (An Giang province) that floating rice associated with corn was more profitable than 2 RC/year.

Frame 5: **An example of 2 RC cropping system**

When flood-level has fallen to 80cm (usually in December), a manual weeding is achieved. No land preparation is realized before sowing. When water level dropped (naturally trough side effects or artificially by pumping) to 10cm, pre-germinated seeds (24H into water followed by 36H of incubation) are broadcasted. Sowing density is about 300kg/ha. Rice density heterogeneity can be reduced 2 days (seeds transfer inside the plot) or 20 days (transplantation when rice puts out suckers) after sowing date (ASD). Extra labor force can be hired according to the work to be done. One herbicide is sprayed 7 to 15 days ASD. Fertilizers (about 400kg/ha: 250kg urea, 150kg of 16-16-8) are applied at 3 different periods: germination, suckering, blooming. Insecticides are sprayed 2 times to prevent from brown plant hopper. Pumping service costs about 300kg of rice/ha/cycle (equivalent prices for first and second cycle). Rice crop cycle lasts 90-95 days. Harvest is manual and occurs in February/March according to former flood-level drop. Yield for winter-spring rice is about 6T/ha. Rice is transported to houses where it is dried before storage. Rice straws are then burned and a plough is realized. According to plots, land planning can be necessary. Plot is then watered and a new planning is then realized to prepare sowing. Rain during summer-autumn rice cycle leads to a higher pest pressure, extra costs for harvest and problems for rice drying. Rice is conducted almost the same than during the former cycle but yields are lower (4 to 5,5 T/ha).

Frame 6: **Rough economical analysis of 2 RC cropping system**

COSTS

Winter-Spring rice crop:

- First weeding: farm labor force
- Sowing: seeds price: 530.000d/ha
- Rice transplanting: extra labor force hired for a day: 20.000d
- Fertilizers: 810.000d/ha (450.000d for urea, 360.000d for 16-16-8)
- Herbicide and insecticide: 110.000d/ha (products and extra labor force)
- Pumping service: 530.000d/ha
- Extra labor force for harvest: 400.000d/ha (230 kg rice/ha)
- Threshing cost: 260.000d/ha (150 kg/ha)
- Transport: 140.000d/ha (80 kg/ha)

Summer-Autumn rice crop: identic costs with the following ones to be added

- Land preparation: plough (240.000d/ha), first planning (1,4 millions d/ha), second planning (80.000d/ha)
- Herbicide and insecticide: 40.000d/ha added
- Harvest: 150.000d/ha extra labor force added (rice laying down)

TOTAL COSTS: 2,8 + 4,7 = 7,5 Millions/ha

PRODUCTS

Winter-Spring rice crop: 12 millions d/ha
Summer-Autumn rice crop: 9 millions d/ha

GROSS RESULT: about 14 millions VND/ha

One conclusion of the study is that (at least in V2, where watermelon production was concentrated), while farmers do not regret floating rice because of its uncertainty (severe loss in some years), they would nevertheless have liked to continue with field crops production (that are still cultivated in some remote and specific areas).

2.1.2 Added costs required to shift to irrigated rice

Several investments have to be made as to allow the cultivation of 2 RC/year, since water needs and water use are radically changed. The following table summarises the main investments to be made.

Kind of investment	Description	Cost
Individual	land levelling (first year(s))	1,5 millions VND/ha
Individual	Purchase of irrigation pipes	1 million VND/2 pipes
Collective (then individual)	Canal dredging, dike building	0,7 million/ha

Because of these costs, some farmers (especially small ones) emphasise that it is more interesting to keep on producing only field crops (when possible) than shifting to irrigated rice.

2.2 A less risky cropping system?

If the 2RC cropping system appears to be less profitable in the short term, rice production is however less risky. Indeed:

- There are fewer variations in rice price along the years than in field crops prices, due to governmental policy that defines a minimum price for rice every year. Rice is an economically and politically sensitive issue and must be protected from drastic economic failures;

- Agronomic results are more regular with irrigated rice. Pest pressure is better known and controlled (genetic material resistant to plant hoppers, IPM program, chemicals etc…).

- Floating rice production is too dependent on the flood regime. In 1994 and 1996 big floods destroyed rice crops. In 1998, even if the overall flood depth was low, water levels increased too fast to allow rice to grow without damage.

Most landless farmers who rent land thus prefer to grow 2 RC/year: “The risk with field crops is too high” explained one of them.

2.3 Irrigated rice cultivation: more (compulsive) co-operation required?

“ **Everybody is doing it, I have to do it…”**

is one of the most frequent answer obtained from farmers.

Does irrigated rice cultivation entail the necessity of cooperation among neighbours?

2.3.1 Interdependence regarding crop choice

Field crops and irrigated rice present several incompatibilities as listed below.

- Different resistance to water excess. Even in the best case where plots have their own irrigation and drainage canals, are provided with small plot dikes and, thus, are theoretically independent regarding water management, water is still flowing down from the highest to the lowest areas. Consequently, it is difficult for a farmer in the low lands to grow field crops if surrounding neighbours with a higher topographical position are growing 2 RC/year.

- Product incompatibility for crop chemical protection. Herbicides sprayed on rice can damage field crops cultivated sometimes quite far away. Farmers from canals 7-9 report losses that occurred on squash and watermelon crops when farmers from canals 11-13[11], who had already shifted to irrigated rice, were spraying herbicide.

- Different harvesting periods that increase pest pressure on crops.

2.3.2 Technical interdependence in the 2 RC cropping pattern

The low diversity observed inside 2 RC cropping system can be explained by the following factors:

- *Production periods and pest pressure*. Inside a specific water unit, sowing dates and crop cycle duration are quite homogenous. Any time-lag between plots for rice harvest results in a higher pest pressure (and especially rat pressure) on the isolated plots. A farmer who has been experiencing a 3 RC cropping system alone was confronted with high rat damages (30 to 50%). A similar problem affect perfumed rice varieties (only 5-10% of the cross section area is concerned with perfumed rice production). Their cycles are longer (100-110 days instead of 90-95) and flowers have a stronger smell (attracting insects).

- *Dependence regarding cropping calendars*. The principle of 2RC relies on the possibility to achieve the 2 rice crops between two successive flood seasons. Flood calendars limit the flexibility of this rice cropping system. Some farmers would like to experiment with 85-day rice varieties to diffuse the risk of an early flooding, but fear that the corresponding decrease in yield may be too high.

- *Interdependence regarding "irrigation and drainage" calendar*. Water management sometimes have to be planned collectively (especially in V1). Farmers then have to schedule their field work operations according to the agreement existing for water pumping.

BUT crop irrigation does not automatically mean compulsory cooperation for water management!

- Collective agreements for water pumping in V2 and V3 are less numerous and concern small groups of farmers (3 to 8 ha in 60% of the cases, according to V2's Tax Department, i.e. 2 to 8 farmers on average).

- Pioneer farmers succeeded in starting 2 RC/year alone, as in the case of the villager who shifted to irrigated rice in 1995-1996 without the agreement of the People's Committee.

- Some field crops producers can still be observed in the "irrigated area".

In all cases, it is important to consider the plot situation regarding micro-topography and access to water.

[11] winds on the cross-section are west-east oriented, coming from Thailand gulf (MDMP, annex 3, 1994)

2.4 The impact of provincial objectives upon the process of change

« Why did you change for 2 RC/year? …because People's Committee wanted to»

People's Committees are governmental institutions represented at three different levels: provincial, district and communal. The functioning and the interactions between these institutions are not easy to establish (see Hauswirth, 2000). However, if the generic term of People's Committee generally means the communal level to farmers, the policy-making and decision-making processes are concentrated at the provincial level.

2.4.1 Plans for 'agricultural production level to be reached'

The 1976 and 1996 production plans are the main factors explaining the changes described above. Hydraulic plans and financial incentives such as access to credit were directly related to these plans. If the 1976 plan was the result of a typical top-down decision making process (which can be explained by the political context of the reunification), the plan elaborated in 1996 was much more controversial and debated. Indeed, according to the district level Planning Department, the 1976 plan was forced to revision in 1996 because of the farmers' demand to shift to 2 RC/year. Meetings at the hamlet level were organized (according to the district) in order to discuss the benefits of this change but many farmers were not informed (and still do not understand why they had to give up field crops) and those who participated described these meetings not as discussions aimed at a collective decision making but as a presentation of the expected benefits of a decision already taken.

2.4.2 Impact of the hydraulic network improvement plan

Four main periods can be highlighted concerning hydraulic improvements in the last 25 years:

- **1977-1979**: important excavation works were carried out mainly to reclaim vast swamps areas, release soil acidity, develop agriculture and allow population settlements. A state pumping station was established in V1 to initiate 2 RC cropping systems.

- **1985-1989**: secondary canals were dredged in V1, but many tertiary canals and sluice gates we also constructed under the leadership of cooperatives. Canals 12 and 13 (V2) were also rehabilitated but with the aim of easing transport from the north to the south of the province.

- **1992-1993**: secondary canals in V2 and in the upper part of V3 were dredged to boost the development of corn production.

- **1997-1999**: the capacity of secondary canals was progressively improved from the western part of V3 to the eastern part of V2, while pipes (both for irrigation and drainage) were installed in the dikes. During the same time, higher dikes were constructed in the upper part of V1 to allow 3 RC/year. A new electric pumping station was installed in V1.

2.4.3 Indirect impact of access to credit

The Vietnamese Bank for Agriculture (VBA) and the Vietnamese Bank for the Poor (VBP) were established in 1990 and 1995 respectively. To benefit from loans, farmers must be members of a "credit group" organized by the Farmers Union[12] (for VBA) or by village representatives for poor people (for VBP). Until now, credit attribution requires the approval of the hamlet head and from the village Farmers Union's head. Credit groups have to be focused on a particular activity (i.e. they also have to be a production group in the case of VBA) and because of the Farmers Union's approval precondition, the production chosen has to be in line with provincial goals.

2.4.4 Risk of penalties in case of non-respect of provincial plans

The following list summarises penalties experienced or reported by farmers:

- Convocations to People's Committee (village level) (interview).
- Financial penalties up to 500,000 VND (40 USD, interview).
- Seizure of pumping equipment (interview).
- Land confiscation to the benefit of landless farmers (case mentioned, but not met).
- Possibility of being arrested and sent to jail (case mentioned, a person named but not met).

These penalties concerned mainly V3 during the 1994-1996 transitional period. V2 seems to have been less affected (rumours, threats but no real cases met) and V1 not at all (?).

3 What are the perspectives for the future?

Electric pumping station development: impact on farmers' management flexibility?

In 1997, Chau Phu district a total of 15 fixed pumping stations covering 2,020 ha were recorded. The plans for 2010 are to reach 20,000 ha, that is ten times more. Electric pumping stations are technically possible since the whole cross section has electricity since 1996 (along Tri Ton primary canal).

The reduction of pumping costs is the main official benefit of such stations but this benefit remains to be demonstrated since the fee collected by the present state-run pumping station is higher than that proposed by some private operators using mobile pumps and gasoline.

Electric pumping stations imply a change in the size of water units (one pump of a fixed station allows the irrigation of 100 ha, while the area of water units served by a mobile pump ranges from 5 to 20 ha). Many farmers fear to lose flexibility in irrigation and drainage scheduling, as expressed by one of them: "we will not control irrigation calendars any longer (…), pumping service will be less flexible."

[12] This organisation is linked with People's Committees since Farmers Union's heads and vice-heads receive salary from the People's Committee.

Keep on intensifying (and organisational consequences)

To shift from 2 to 3 crops/year requires higher dikes to lengthen the potential cultivation period but also a better planning of field works. Indeed, 3 rice crops were scheduled for the 1998-1999 season in the upper part of V1 but a slow decrease of the water level and the resulting delay in land preparation resulted in the postponement of the experience to the 1999-2000 season.

To avoid a new failure, a guide book indicating the timing of field works has been approved by the different People's Committee concerned and will be applied in the 1999-2000 season. One way to make sure that farmers are on time is to control irrigation calendars.

A trend towards agricultural diversification?

Fish ponds are increasingly encroaching on paddy fields, most particularly near the houses. Duck and pork breeding is also increasing. Farmers also remain interested in field crops.

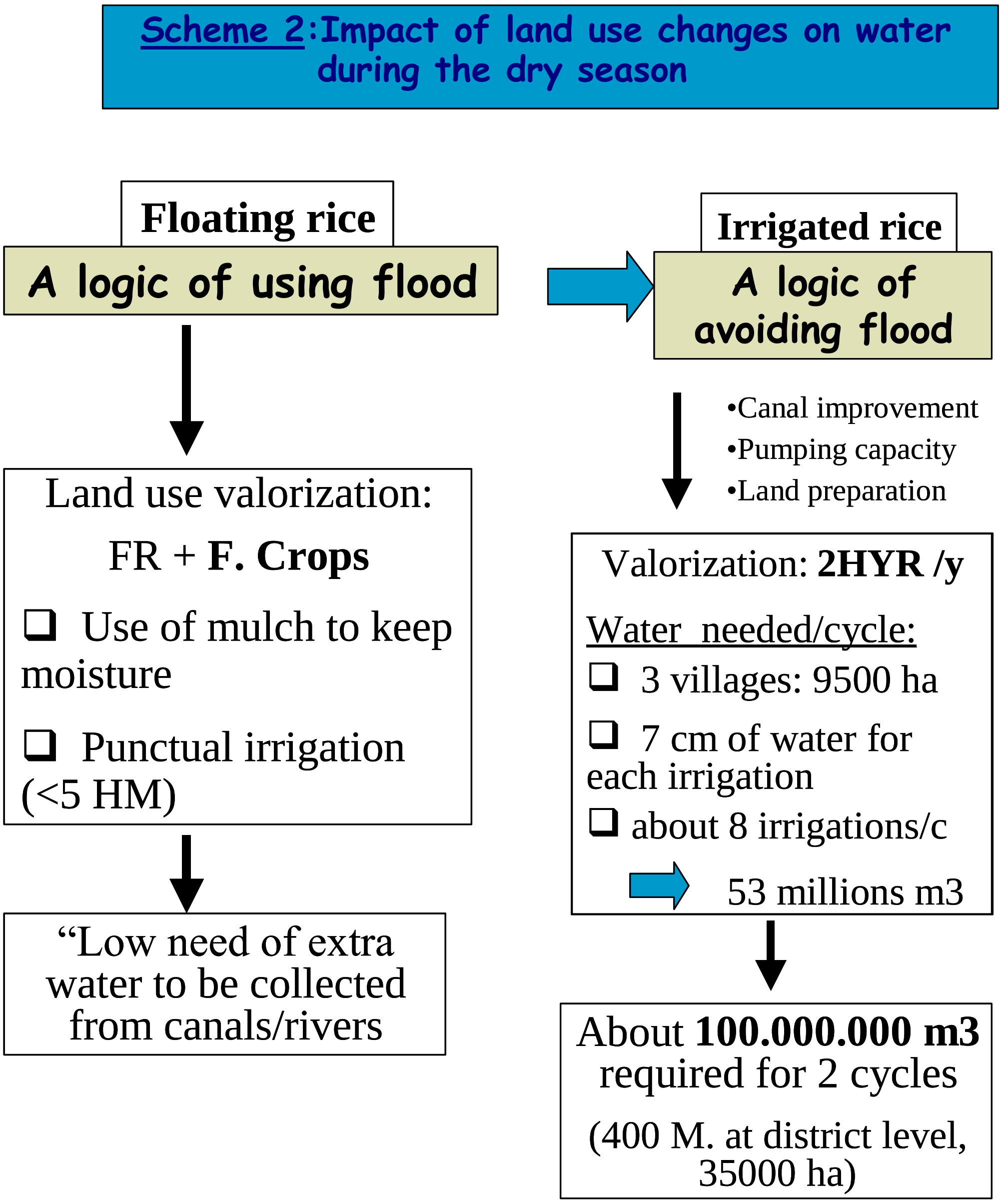
The completion of the road along Tri Ton Canal should also bring about many changes: religious tourism (Hoa Hao religion, proximity to the mountainous area), restaurants, new trades, etc…

4 Impact of land use changes on water use

Floating rice is based on a logic of flood water use while 2RC cropping system reflects the wish to get rid of the flood variability. However, such a change in land use results in the dramatic increase of water demand during the dry season. A basic simulation of the water required locally to grow irrigated rice crops is shown on Figure 9.

Water requirements are about 100 million m^3 for the 3 villages interviewed and about 400 millions m^3 for the whole district. This crude estimate raises the question of how dry-season water demand at a broader scale (the whole Mekong Delta) will be met in the future, especially if we consider that Cambodia is also shifting from floating rice based cropping systems to irrigated ones. This question will be addressed in the next chapter.

FIGURE 9. IMPACT OF LAND USE CHANGES ON WATER USE IN THE DRY-SEASON



Part IV

Macro-level perspective on water use in the dry season

5

Nguyen Nang Hung

Lam Van Thinh

Nguyen Hieu Trung

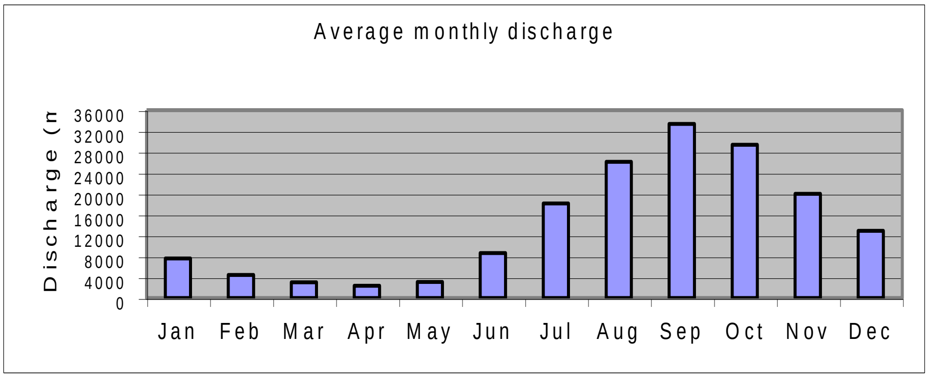
1 Introduction

The Mekong Delta is the part of the catchment downstream of Kratie, Cambodia, and covers an area of 49,520 km2. The Vietnamese part of the Delta covers 39,000 km2 or 74% of the entire Delta. At Phnom Penh, Cambodia, the Mekong splits in a Hau (Mekong) and a Tien (Bassac) branch. From the same point leads the Tonlesap branch to the Great Lake, which acts as a buffer, receiving and releasing water depending on the levels in the Mekong. The length of the main river in Vietnam part is 230 km.

The constraints in water resources in the Mekong Delta are function of: the flood in wet season; acid production flushing from acid sulphate soil; and fresh water shortage in dry season causing saline water intrusion.

The flow pattern of the Hau and the Tien branches is closely related to the rainfall in the Lower Mekong basin. Some 80-90 % of this rainfall occurs during the wet South-West monsoon in the period May-October, causing discharges at the border with Cambodia of some 40,000 m3/s**.** These large discharges result in flooding of some 30 to 40% of the Vietnamese part of the Delta, with maximum flood depth up to 3 metres**.**

FIGURE 1. THE AVERAGE MONTHLY DISCHARGE OF THE MKD



During the dry season (from December to May), the discharge at Phnom Penh varies between 2,000 and 6,000 m^3/s. Salinity intrusion occurs in very large areas in the downstream part of the Delta, especially in the dry season when the upstream discharge is limited and no rainfall occurs. The Ca Mau Peninsula is entirely affected, while the coastal areas of Long An, Tien Giang, Ben Tre, Tra Vinh and Soc Trang are partly affected. In recent years, after the construction of the Quan Lo-Phung Hiep, South Mang Thit salinity control projects, and of a system of embankments with water gates along the East and West Sea, the salinity effected areas were reduced. However, due to the benefit from aquaculture production being very high, especially for shrimp, farmers in some parts of the salinity protected areas had spontaneously brought the saline water into they land for aquaculture cultivation (see Part 2). From 2001 up to now, the government have struggled to establish a rearrangement plan for these areas. In this plan, aquaculture areas will be extended into the salinity protected are. The government encourages the farmers in those areas to apply the shrimp-rice model (rice in rainy season and shrimp in dry season).

According to Sam (1996), in the main streams (Hau and Tien branches) in the dry season, the isohyetal line of 0.5 - 1 $^{o}/_{oo}$ can come up to 90 -100 km from the sea. Obviously, dry season irrigation is seriously constrained in areas with saline water.

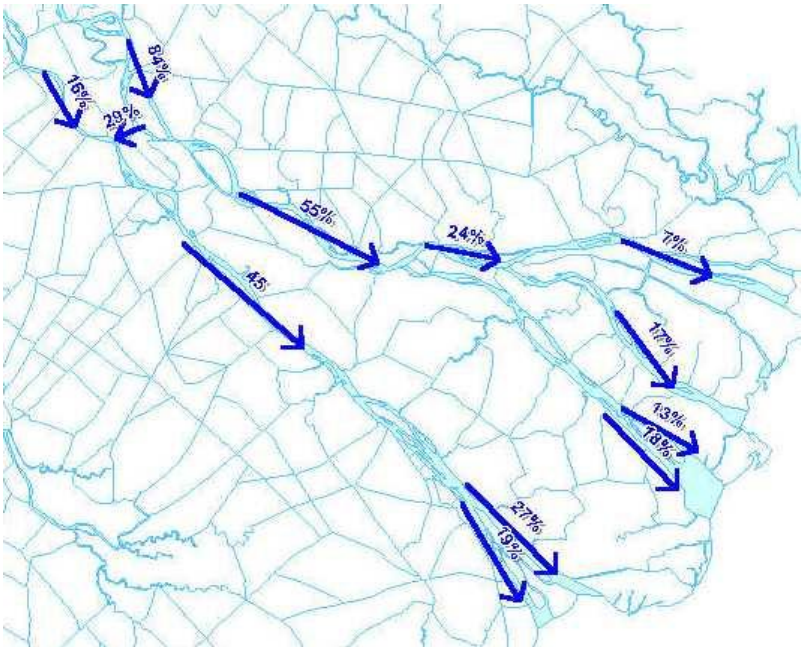
There are two types of tides affect the Mekong Delta: from the East Sea, semidiurnal, but sometimes-diurnal tide (in peak flood) with amplitudes to 3 m; from the West Sea, a diurnal tidal movement prevails with amplitudes of up to 0.8 m**.** Because of the large rivers and the thousands of kilometres of open canals in the delta, a complex water motion occurs, in which different tidal movements meet under varying upstream discharges. This spectrum is further complicated by monsoon wind effects in the South China Sea that may raise or lower the mean sea water level by several decimetres. An illustration of the effect of the tide of the South China sea is the change of flow direction at Tan Chau and Chau Doc, 200 km from the river mouths.

The average percentages of flow in the dry season is about 84-87% at Tan Chau in the Tien branch and 13-16% at Chau Doc in Hau branch. Down stream, about 29% of the discharge of the Tien branch flows to the Hau branch through Vam Nao branch and distribute to river mouths as seen in Figure 1. In April, when the discharge is its lowest with only some 2,000 m3/s, the minimum is about 1633 m3/s in April 1988 (Sam,1996).

Water abstraction in dry season

During the low flow period, fresh water abstractions for irrigation cause intrusion of saline water. Apart from posing constraints to crop growths and yields, saline water affects drinking water supply and would induce changes in the ecosystem. Therefore, *the expansion of the area under double cropping, and of the area under perennials or triple cropping, which draw even more heavily on the low flow, should be carefully planned*. The *critical period*, for studying sea intrusion in Mekong Delta, is from the second decade of March to the first of May, about 60 days

FIGURE 10. DRY SEASON DISCHARGE DISTRIBUTION IN THE MEKONG AND BASSAC BRANCHES



2 Objectives

The objective of this chapter is to study the effect of water management projects on the saline intrusion in the MKD, and to simulate the intrusion of saline water in the main branches (Hau and Tien) in an extreme unfavourable case.

3 Methodology

The following scenarios will be taken into account:

- <u>scenario a:</u> study the saline intrusion with the situation before constructing the Quan Lo-Phung Hiep project (with specific year 1990)

- <u>scenario b:</u> the effect of the Quan Lo-Phung Hiep project and the new canals in the Plain of Reeds (with specific year 1996)

- <u>scenario c:</u> the effect of the Flood Control Project in the Long Xuyen Quadrant with the several sluices along the West Sea (with specific year 2000).

- <u>scenario d:</u> the intrusion of saline water in the main branches (Hau and Tien) in the extreme unfavourable case, with the assumptions that:

  - Maximum water abstraction in the dry season (He-Thu –Summer_Autum- rice crop is cultivated whole of the Mekong delta)

  - The whole Mekong is embanked except the main streams (Hau and Tien branches)

- The discharge of water from the upstream at Tan Chau and Chau Doc is minimum (April 1988), and no rain occurs.

- Closing of Cai Lon river.

The aim of the first 3 scenarios is to simulate the salinity instruction in the Mekong delta in past and current time. The aim of scenario **d** is to predict the salinity intrusion in the Mekong delta under extreme utilisation of water for rice cropping.

This study will use the following models: the Rainbow (to analyse the frequency of rainfall); the ET_0 (to calculate the evapotranspiration); the BIRIZ (to calculate of water requirement) and Sal99 model (simulate of salinity intrusion in dry/wet season of Mekong delta). MapInfo is used for presenting of the results.

3.1 Simulate the past and the present salinity intrusion (scenarios a, b, c)

The following steps were conducted:

3.1.1 Generating of the water level boundary for Sal99 model

- 13 coastal hydro-stations in the MKD are used for the water boundary condition (see Figure 3)

- Developing of the tidal predicting model

  + Using the harmonic function method for the predicting tidal model

  The basic values H, g and Z_0 of 23 mono waves of 13 coastal hydro-stations in the MKD

  + The model was constructed in Excel worksheet (Figure.4)

- Establishing of construction data: the major sluices constructed from year 1990 to 2000 (Figure 5)

FIGURE 3. HYDROLOGICAL STATIONS IN THE MEKONG DELTA

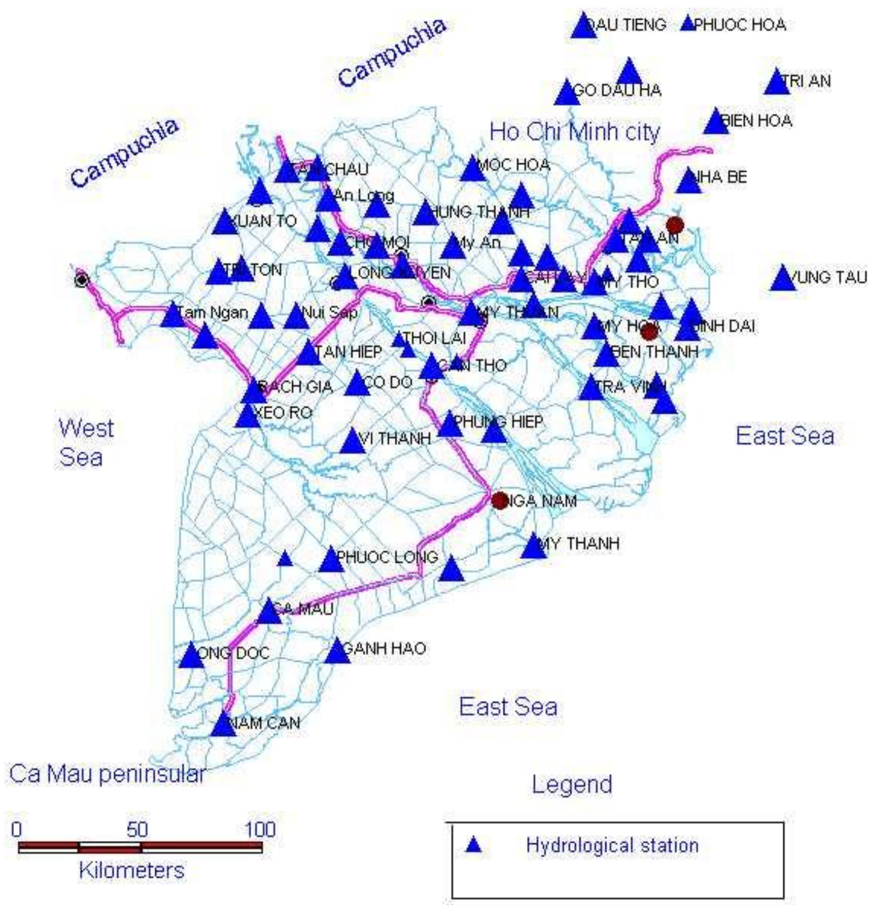


FIGURE 4. THE TIDAL PREDICTING MODEL IN EXCEL WORKSHEET

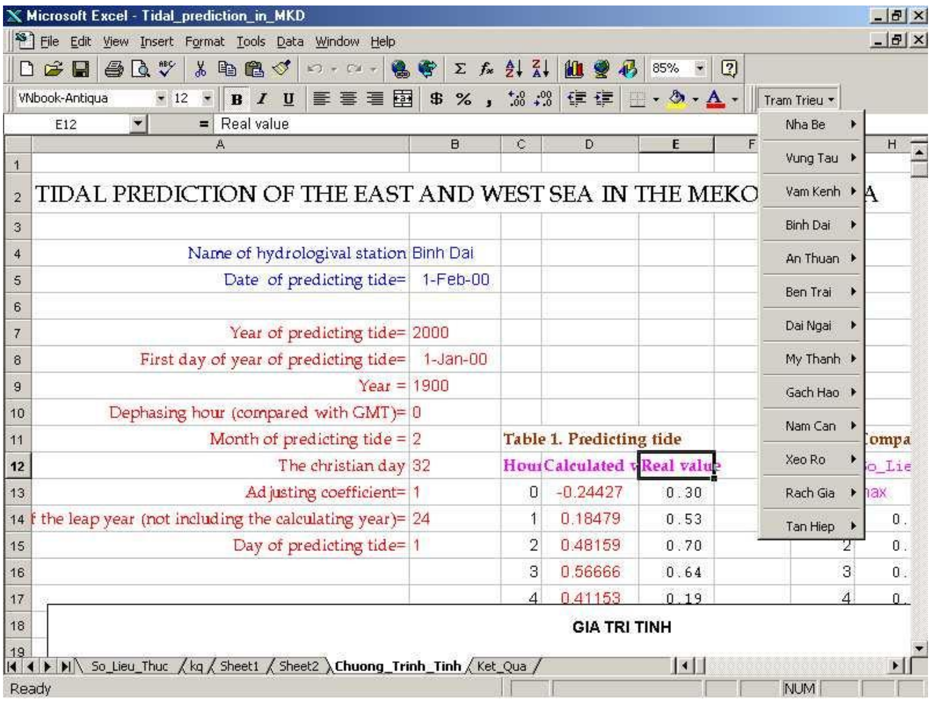
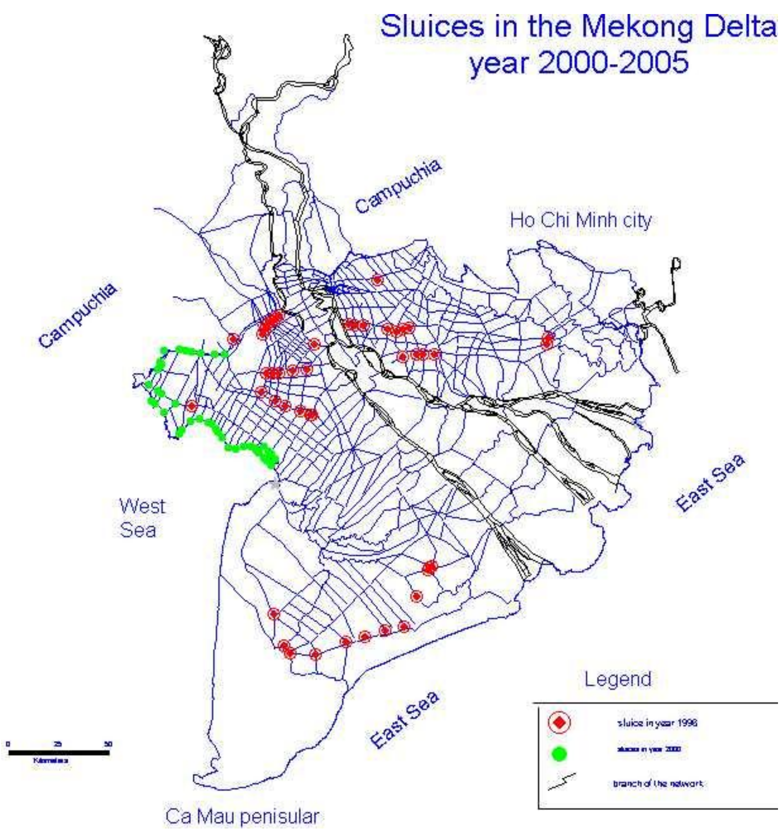


FIGURE 5. MAJOR SLUICES IN THE MEKONG DELTA YEAR 2000-2005



3.1.2 Input data for running SAL99 model

The model includes many fragments (figure 7), the discharge boundary data are presented in the map as the dark red points, the salinity and water level boundary data are the blue triangles. Sluice gates are in light red (constructed from 1990-1996) and blue (constructed from 1999 to 2000) points.

3.1.3 Calculation of water abstraction value of the canals in the model (results of BIRIZ) and run the Sal99 models.

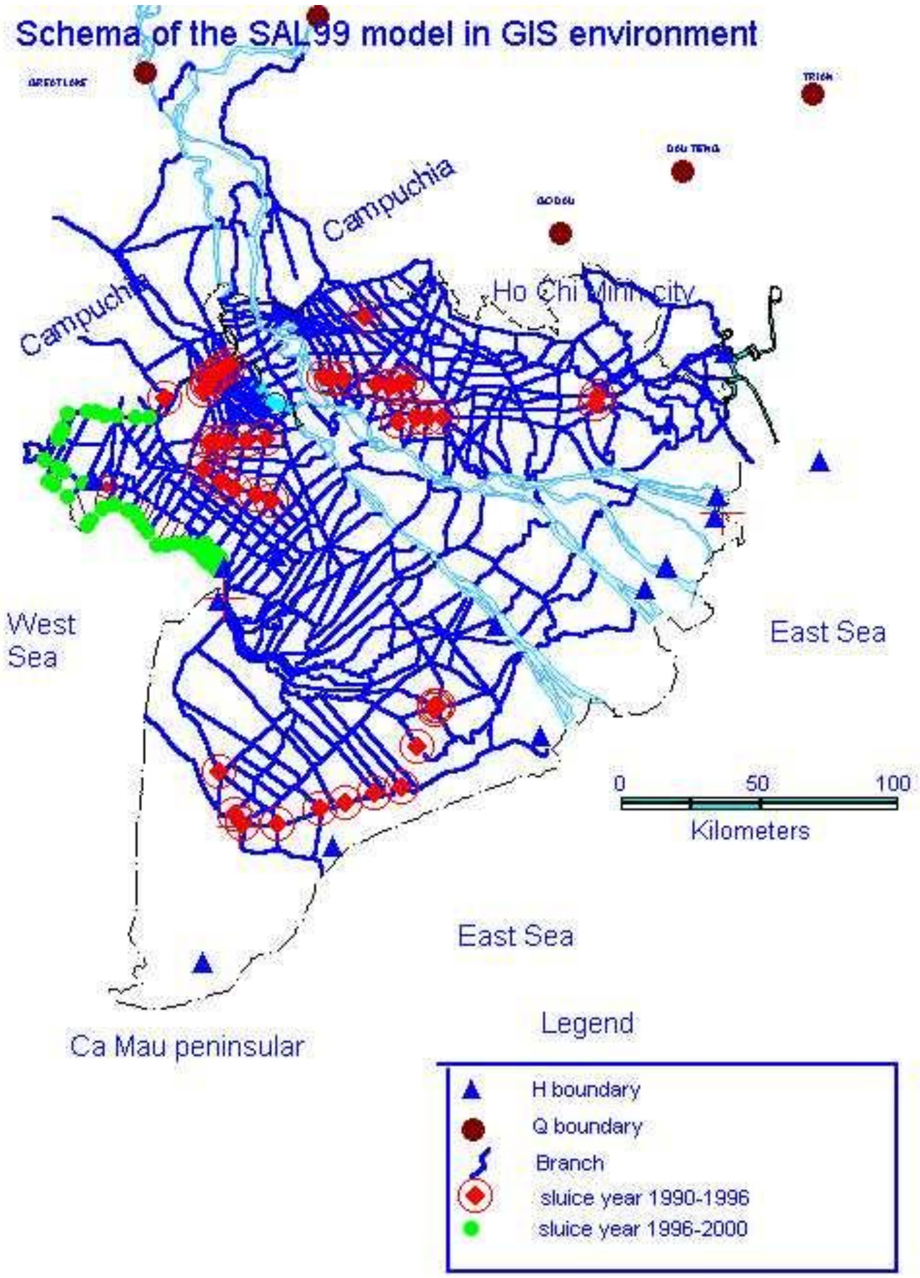
The BIRIZ model was used to generate the water abstraction for each fragments of the model. After inputting all of the data, the SAL99 was used to simulate the scenarios a, b and c.

3.2 Predict the salinity intrusion in the main streams Hau and Tien branches (scenario d).

For the scenarios d, the procedures are as following:

- Establish the model
- Setting up of boundary data for the model
- Estimation of the water abstraction for each fragment in the system

FIGURE 7. SCHEMA OF THE SAL 99 MODEL FOR SCENARIOS A, B, AND C

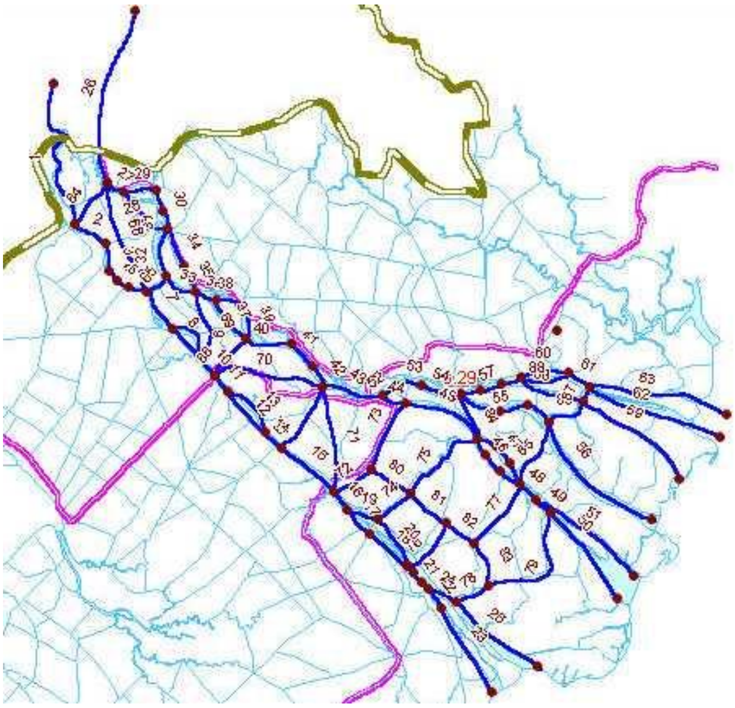


- Calibrating the model and run the model for an extremely unfavourable case of salinity intrusion.

3.2.1 Establish of the model

Under the assumption that embankments and sluice gates protect the whole delta except the main branches, the schematic of the model can be simplified as the figure 2 below:

FIGURE 8. SCHEMA OF THE MODEL FOR SIMULATING OF THE SALINITY INTRUSION TO THE MAIN STREAM IN THE EXTREME UNFAVOURABLE CONDITION



The model includes 88 fragments of Hau and Tien branches, in each fragment, there are at least 2 cross sections.

3.2.2 Setting up of boundary data for the model:

Two discharge boundaries are used at upper stream of Chau Doc and Tan Chau, for this extreme unfavourable case of salinity intrusion, we use the minimum discharge in April of 1988. At the river mouths, 8 water level and salinity boundaries are set.

3.2.3 Estimation of the water abstraction for each fragment in the system

The Mekong delta can be divided into 8 regions based on 8 weather-stations: Chau Doc, Cao Lanh, Rach Gia, Can Tho, My Tho, Cang Long, Soc Trang and Ca Mau (figure 3). The crop calendars of the He-Thu rice crop (Summer-Autumn rice crop) are different for each regions. In this study, we used the data from the book “Water Management in the Mekong Delta” compiled by Prof. Le Sam (1996)

- Region 1: In the high land of this region, the He-Thu rice is start from April to July. The highest irrigation requirement is about 1.02 l/s/ha at the second 10 days of April. In the depressed and acid sulphate soil areas the irrigation requirement is about 1.24 l/s/ha at the third 10 days of May, and start from May to August.

- Region 2: In the high land of this region, the He-Thu rice is start from April to July. The highest irrigation requirement is 1.33 l/s/ha in the last 10 days of April. In the depressed and slightly acid sulphate soil areas the irrigation requirement is about 1.10 l/s/ha at the second 10 days of April, and also start from April to July.

- Region 3: In the depressed and acid sulphate soil areas, the He-Thu rice is start from May to August. The highest irrigation requirement is 0.9 l/s/ha in the second 10 days of May.

- Region 4: In the high land of this region, the He-Thu rice is start from April to July. The highest irrigation requirement is 1.15 l/s/ha in the first 10 days of May. In the depressed and slightly acid sulphate soil areas, the highest irrigation requirement is 1.05 l/s/ha in the last 10 days of April, and also start from April to July.

- Region 5: In the high land of this region, the He-Thu rice is start from April to July. The highest irrigation requirement is 1.14 l/s/ha in the second 10 days of April. In the depressed and slightly acid sulphate soil areas, the highest irrigation requirement is 1.07 l/s/ha in the first 10 days of April, and also start from April to July.

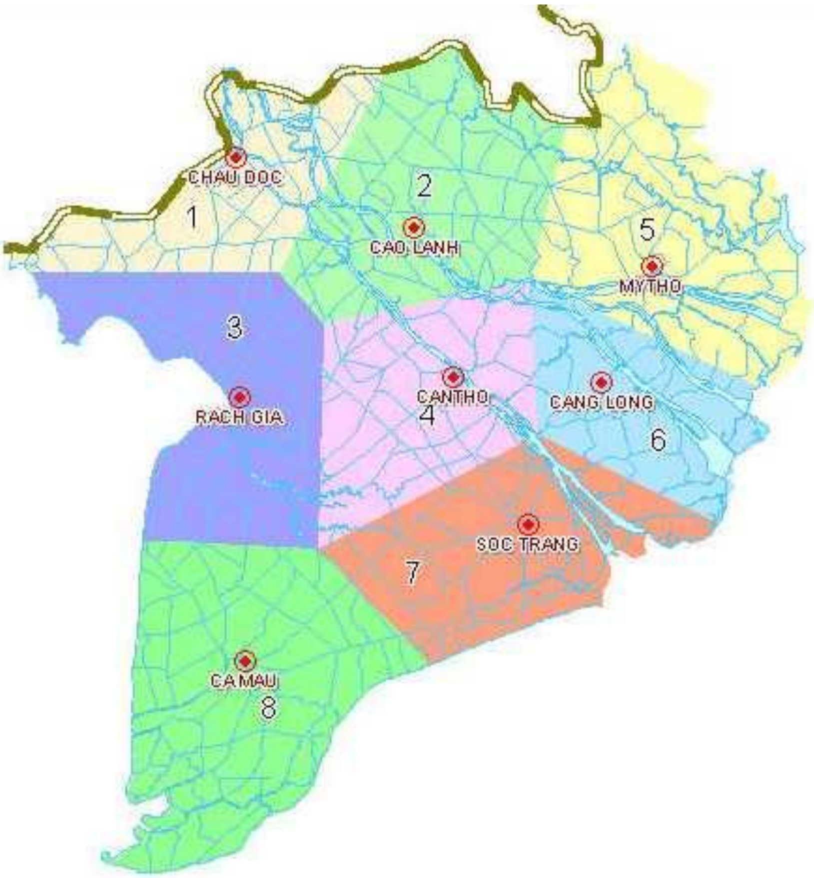
- Region 6: In the high land of this region, the He-Thu rice is start from April to July. The highest irrigation requirement is 1.11 l/s/ha in the second 10 days of May. In the depressed and slightly acid sulphate soil areas, the highest irrigation requirement is 1.10 l/s/ha in the first 10 days of May, and also start from April to July

- Region 7: In the depressed and slightly acid sulphate soil areas, the He-Thu rice is start from April to July. The highest irrigation requirement is 1.34 l/s/ha in the last 10 days of May.

- Region 8: In the depressed and slightly acid sulphate soil areas, the He-Thu rice is start from May to August. The highest irrigation requirement is 0.62 l/s/ha in the first 10 days of May.

The water abstraction of each regions was calculated based on the irrigation requirement of the evaporation regions (Figure 9). The model was run with the period of 30 days of April with the minimum water discharge at Tan Chau and Chau Doc.

FIGURE 9. WEATHER-STATIONS AND EVAPORATION REGIONS IN THE MEKONG DELTA



4 Results

4.1 Simulation of the past and present salinity intrusion

4.1.1 <u>scenario a</u> study the saline intrusion with the situation before constructing the Quan Lo-Phung Hiep project (with specific year 1990)

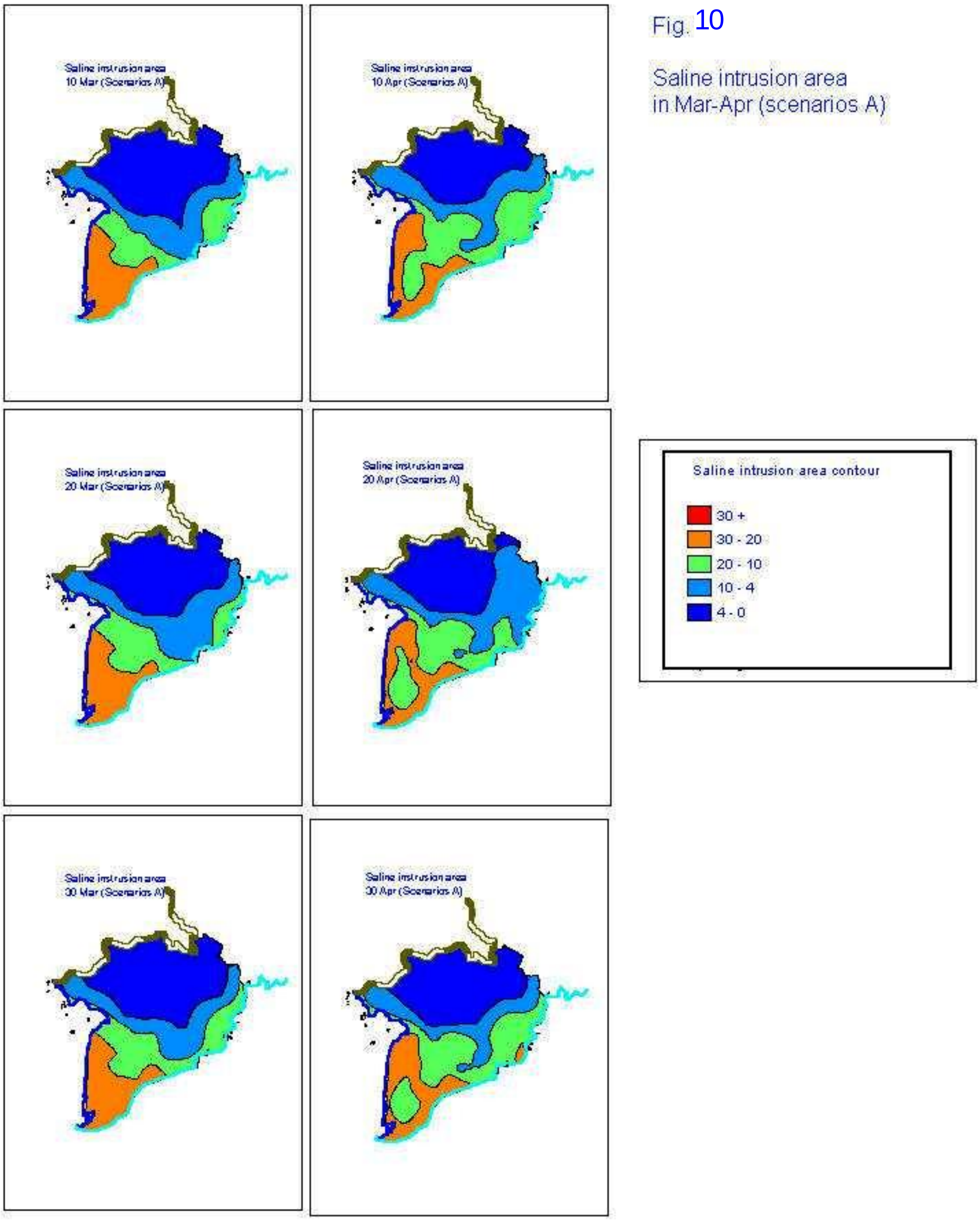


Fig. 10 Saline intrusion area in Mar-Apr (scenarios A)

The results show that the saline water intruded from the beginning of January to the end of April and went very far inland, especially for the whole of Camau peninsula.

4.1.2 <u>scenario b</u> the effect of the Quan Lo-Phung Hiep project and the new canals in the Plain of Reeds (with specific year 1996)

+ Results of scenarios B, with the effect of the Quan Lo-Phung Hiep project and the new canals in the Plain of Reeds

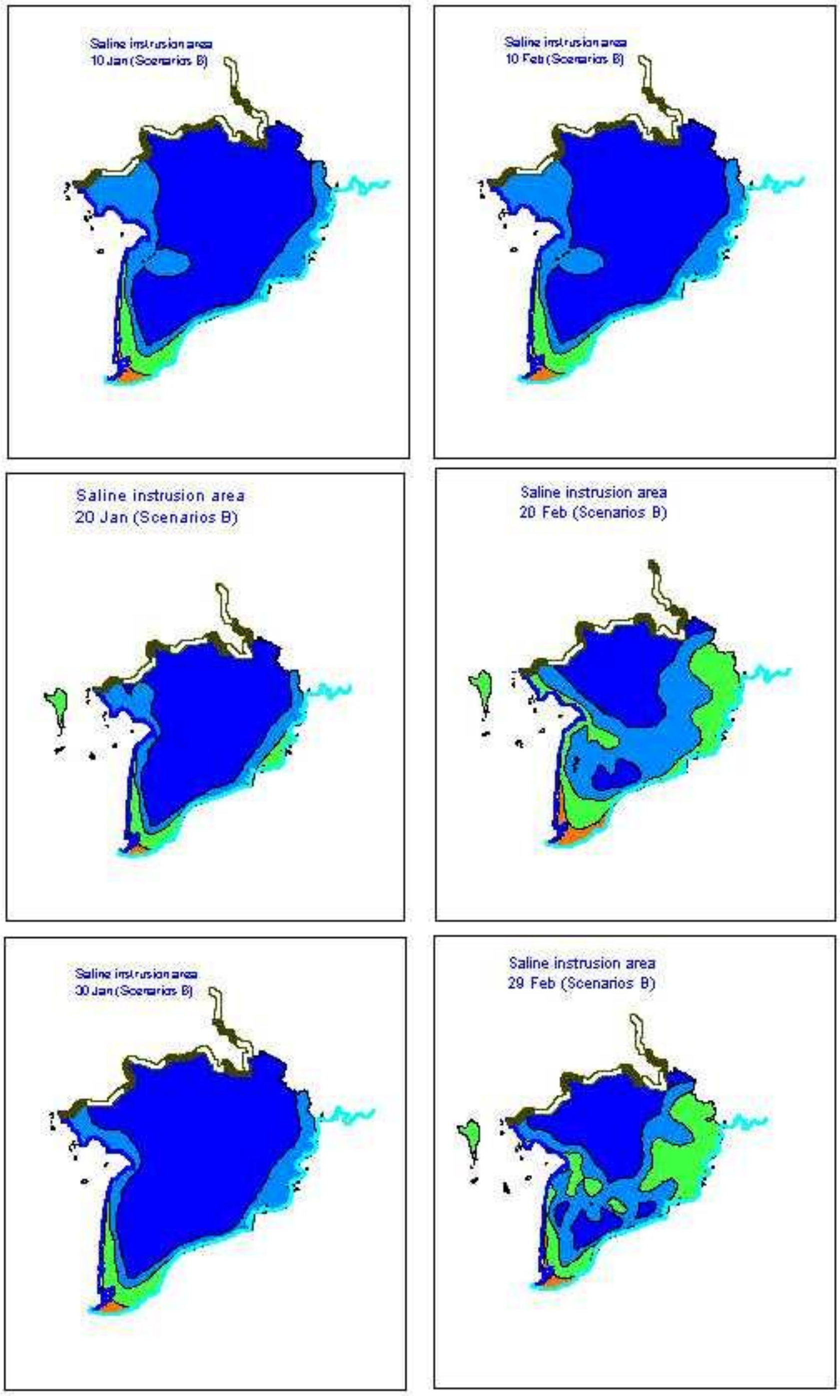
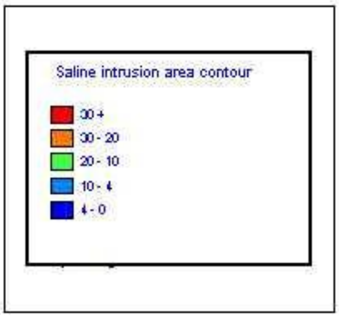


Fig. 11

Saline intrusion area in Jan-Feb (scenarios B)



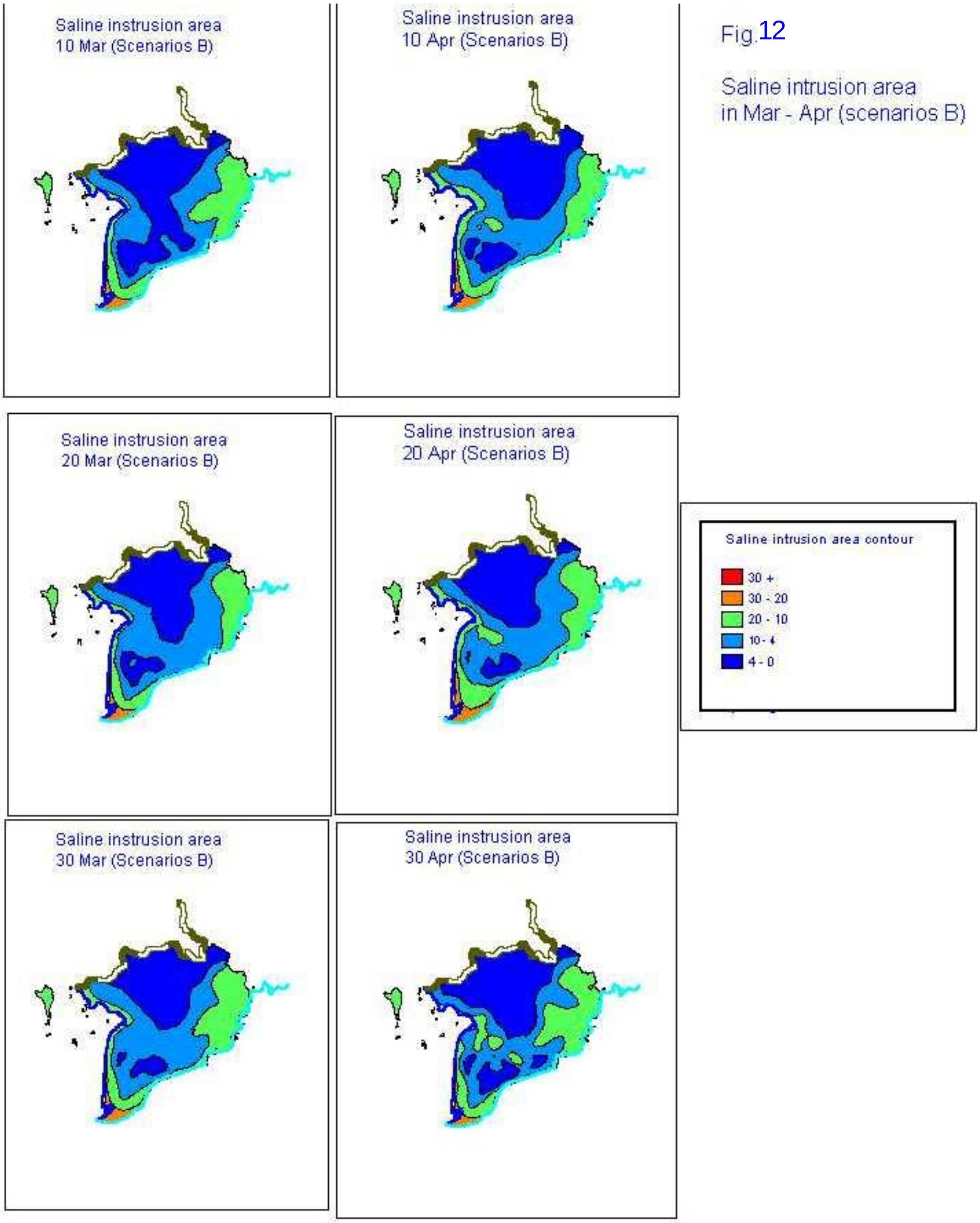


Fig.12

Saline intrusion area in Mar - Apr (scenarios B)

With the Quang Lo-Phung Hiep project, the situation was better, the salinity of 4 g/l only occurred near the coastal and penetrated deeper from the periods of 20 of February, through the river mouths including from the Cai Lon river (west sea) and then extended to the Camau peninsula areas. However, at the end of April, there were still some fresh water areas inside the Quang Lo –Phung Hiep project areas.

4.1.3 <u>scenario c</u> the effect of the Flood Control Project in the Long Xuyen Quadrant with the several sluices along the West Sea (with specific year 2000).

+ Results of scenarios C, the effect of the Flood Control Project in Long Xuyen Quadrant with the serial sluices along the West sea (with specific year 2000)

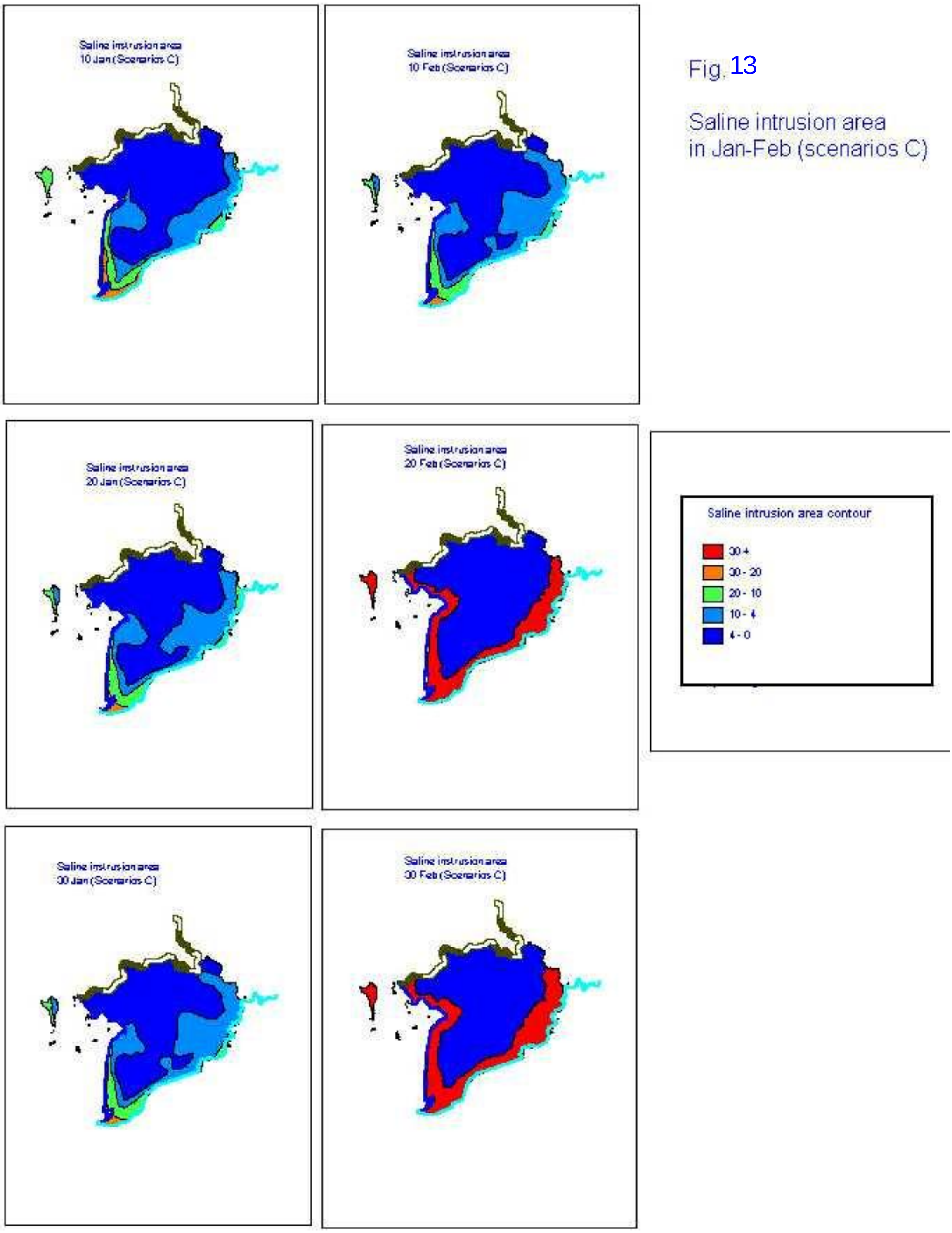


Fig. 13

Saline intrusion area in Jan-Feb (scenarios C)

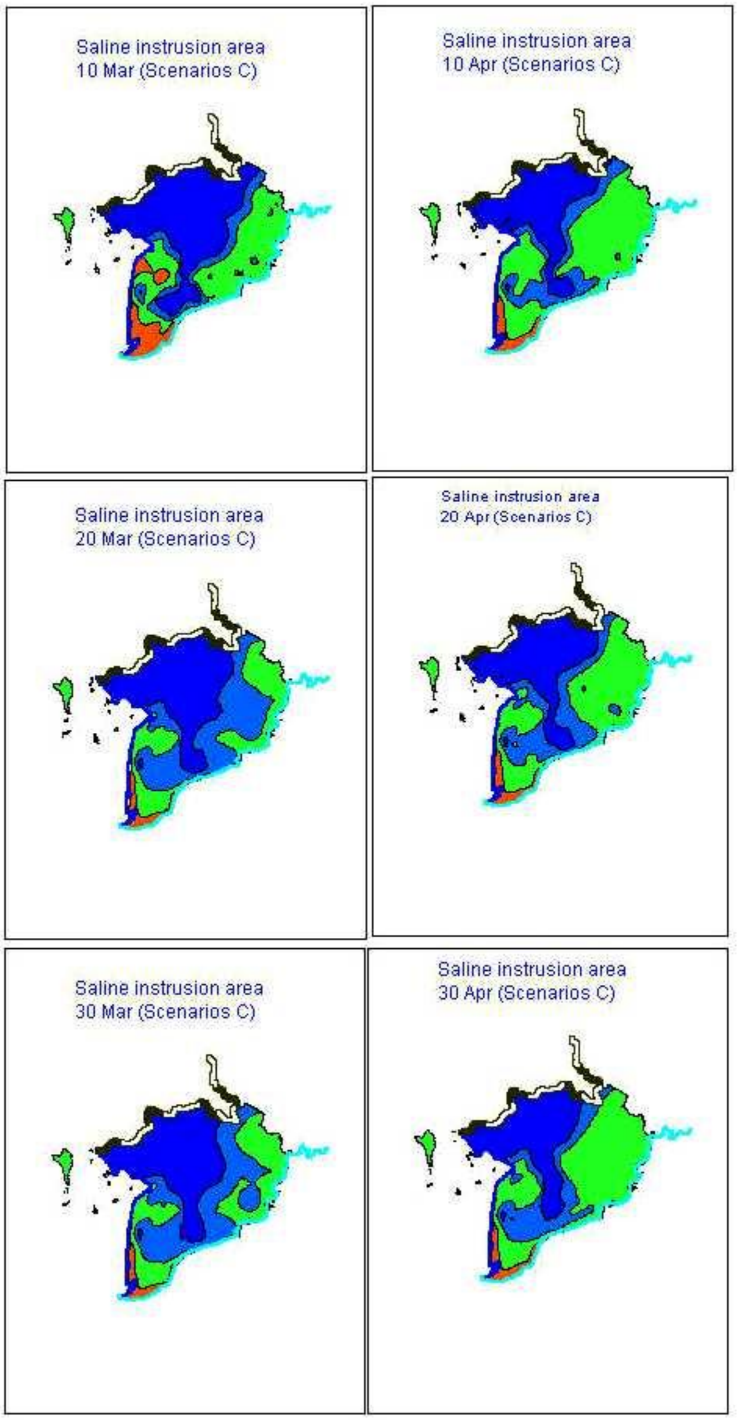
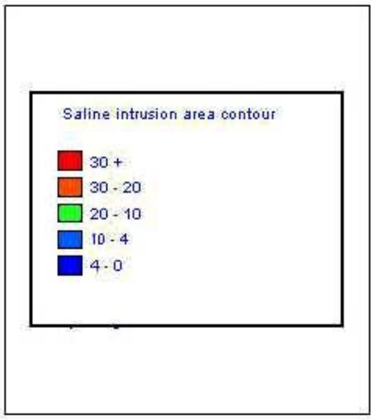


Fig. 14

Saline intrusion area
in Mar-Apr (scenarios C)



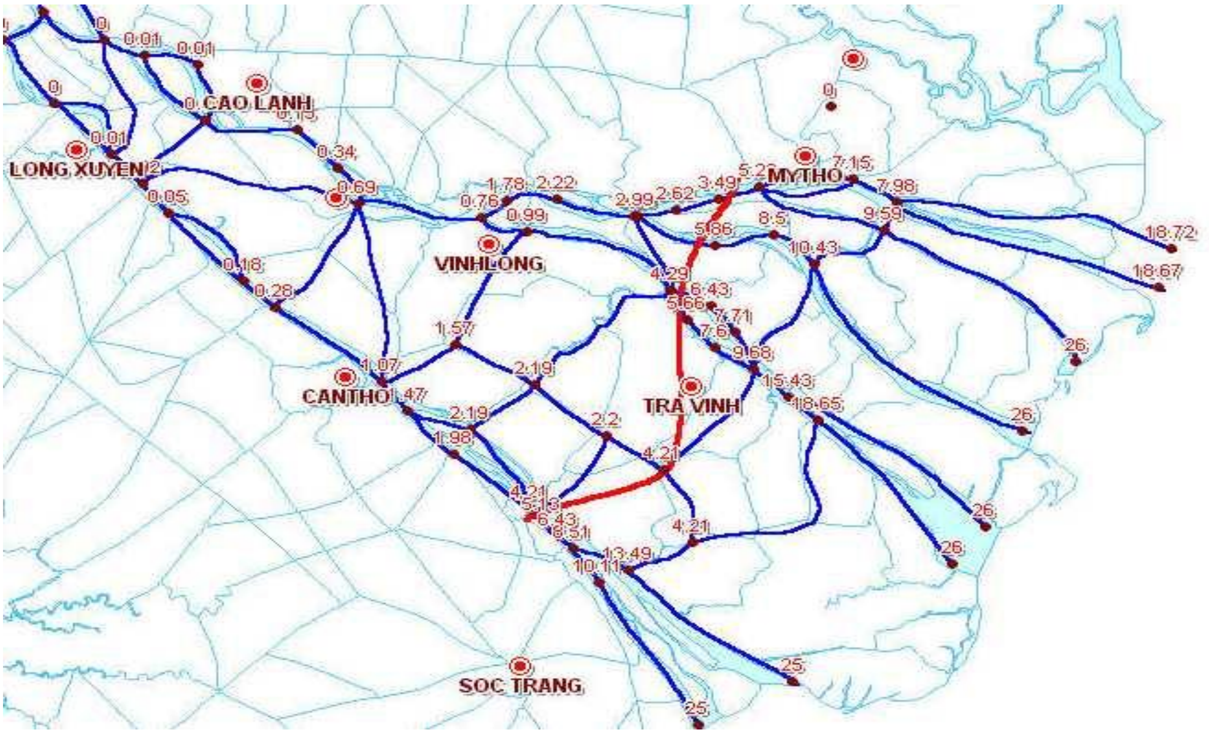
The results of this scenario illustrate that even with the Quang Lo-Phung Hiep project completed, and with the salinity protection system built, but if the Cai Lon river (connect to the West sea) and the Hau and Tien river mouths are not closed, the saline water still can intrude into the delta through those river mouths and expand to some part of the delta.

4.2 The intrusion of saline water in the main branches (Hau and Tien) in the extreme unfavourable case

In scenarios d, the assumption was that the water extraction from the Hau and Tien branches was maximum, the Isohyetal line of 4 g/l comes very high, especially in the Tien branch, about 11 km above My Tho city (or about 60km from the sea) where the discharge distribution is low (figure 2). In Hau branch, the isohyetal line of 4 g/l is about 14 km above Dai Ngay (or 46 km from sea). The salinity in water at Cantho and Vinh Long is about 1 g/l. The isohyetal line of 4 g/l is very close to the Man Thit River (the water source for the South Man Thit irrigation project).

These results indicate that with the on-going trend towards generalised dry-season cropping and the closure of the delta, the region will be extremely sensitive to dry years, where salinity will intrude into the main branches of the Mekong and into the lateral waterways that are not gated.

FIGURE 15. SALINITY INTRUSION IN THE HAU AND TIEN BRANCHES WITH THE MAXIMUM WATER USE



5 Conclusion

- The scenarios a, b, c showed how the fresh water areas increased after the Quang Lo-Phung Hiep project and the coastal embankments were completed. However, as the side of river mouths (including the Cai Lon river) are too large to be closed, saline water can still intrude into the Camau peninsula during the period of March-April.

- The scenario (d) simulates the salinity intrusion into the Hau and Tien river with the extreme use of water when the whole of the Mekong delta is closed. The results of this scenario are very useful for the water resource planers and managers in the Mekong delta to decide where to construct the canal check gates along the Hau and Tien rivers.

- The hydrological regime in the Mekong delta is very complex due to the density of canals, the complex tidal movement, and the variety of water abstraction schedules for each type of land. The model cannot give an accurate picture of the salinity intrusion in the Mekong Delta. The model should be calibrated with more up to date data.

- More scenarios should be studied, considering several scenarios of development along the upper reaches of the Mekong river.

Part V

Macro-Micro level perspectives: conclusions

The Mekong Delta first strikes the visitor by the might of its flow. No dams, weir or structure (not even bridges!) have ever been constructed on the main branches of the river. Yet, in the dry season, its discharge may not be sufficient to properly control salinity intrusion into coastal areas and in the lower reaches of the river.

In some dry years, saline water may penetrate inland and damage crops, in particular fruit trees. It is apparent that the regulation of the Mekong River discharge in the dry season is becoming an issue of paramount importance. What are the actual and planned means to achieve such a regulation? The construction of several dams across the Mekong is planned but all these dams are located further upstream in the basin, in Cambodia, Laos or China, therefore not under the direct control of Vietnamese authorities. Whether these dams will have a beneficial impact on the dry season flow is still a controversial question. While some fear that flows will be retained and will therefore compound the situation, others emphasise that the generation of energy will on the contrary result in more releases during the low flow period.

In any case, regardless of what supply will be, this report has placed emphasis on the growth of water use in the dry season in the delta. Two case studies carried out in different environments have detailed the dynamics of intensification and expansion of cultivation into the dry season. In the flood-prone area, improvements in the canal network and dike system have allowed the cultivation of two HYVs between two consecutive flood periods. In the coastal area, the closure of the delta has allowed farmers to control salinity and to benefit from the fresh water coming from upstream areas to grow rice in the dry season. This transformation has required significant excavation work, especially at the secondary and tertiary levels, but led to a rapid expansion of double and triple cropping.

In both cases, it is apparent that possible bottlenecks in terms of soil quality, labour force and machinery, credit or marketing, have not significantly hindered these transformations. Rather, the dynamism of farmers shows that a rapid expansion of cultivation can be expected in all the areas of the delta, as they get protected from salinity or flood (partially).

The case study on Bac Lieu Province demonstrated that full closure may not be the best option. Shrimp cultivation yields much higher benefits than rice cultivation and reverted the logic according to which fresh water (and rice) is better than brackish water. The study pointed to a balance management that would allow salinity to come in only part of the year, and shrimp farming to coexist with rice cultivation.

Another phenomenon which must also be factored in the analysis is the growth of dry-season cropping in Cambodia, particularly between Phnom Pen and the Vietnamese frontier. This growth has been largely fuelled by Vietnamese pump service providers who cross the frontier and support the development of rice cropping patterns on the model of those adopted in the upper (Vietnamese) part of the delta.

The question of the overall availability of water thus comes to the fore with more intensity. What will be the combined resulting impact of all these scattered evolutions towards more dry-season cropping? How will all these increased withdrawals of water impact on the overall hydrologic regimen of the river system? What will, in particular, happen in years of extremely low flow into the delta?

It is clear that, at the moment, development is mostly driven by the *local* initiatives taken by the difference provinces to improve agriculture within their respective boundaries. They sometimes benefit from development project initiated at the national level, often with the aid of some donors (notably the World Bank). These initiatives translate into more water demand and canals are widened and deepened in order to allow the required flow to be channelled from the river network.

Modelling allowed us to show that salinity would intrude into the main branches of the Mekong, and laterally into the ungated waterways, endangering agriculture, notably fruit cultivation. It becomes evident that the on-going largely un-coordinated provincial development plans will have, sooner or later, and the next extremely dry year might well give the opportunity, to be considered within a more macro framework. It can be expected that, in the future, a fine tuning of cropping calendars will be necessary, triple cropping might have to be partly banned, and planting decisions might have to be reasoned based on the expected water inflow into the delta. Here, again, the evolution of the hydrograph of the Mekong River at its entrance point in Vietnam, as a result of coming dam development in upper reaches of the river, will be paramount in defining what is possible to achieve and what is not.

References

Brocheux (1995) Mekong Delta, Chapter 5, Monoculture of rice

Bruseau Isabelle et Khiem Dang Hoang (1994) rapport ENSA-CNEARC Approche de la réalité agraire d'une petite région du delta du Mékong, province de Can Tho

Chu Thai, Hoanh (1996) Development of a Computerized Aid to Integrated Land Use Planning (CAILUP) at regional level in irrigated areas. A case study for the Quan Lo Phung Hiep Region in the Mekong Delta Vietnam. ITC ed. 297p.

DANIDA (1996) flood forecasting and damage reduction study in the Mekong delta of Vietnam

Environmental and Social Systems Analyst LTd (ESSA) (1992) Water control project for the Quan Lo Phung Hiep Area Mekong Delta; Vietnam. A Pre-feasibility Study. 293p.

ESSA (1992) Water Control Project for the Quang Lo/Phung Hiep Area Mekong Delta, Vietnam. A Pre-Feasibility Study. International Environmental Management Inc. Thailand

General statistical office, 1999. Statistical yearbook 1998. Statistical publishing house, Vietnam.

General statistical office, 2000. Statistical yearbook 1999. Statistical publishing house, Vietnam.

Hauswirth, D. (2000) Libéralisation économique encadrée par l'Etat : stratégies d'acteurs dans une arène villageoise du delta du Mékong. CNEARC, France.

Hauswirth, D. ; Lienhard, P. (2000) Elements communs: Histoire agraire le long d'une toposequence. 52 p.

Huynh Tran Quoc, Vandome Laurent (1993) Etude d'une région agricole du Nord Ouest du Delta du Mékong, rapport CNEARC-INA.

JIRCAS, CTU, CLLRI (1998) collective publication conducted by the Farming System Centre, Development of Farming System s in the Mekong Delta, 70p.

Joffre, Olivier (2000) Transformation agraire dans le delta du Mékong: l'exemple du projet Quan Lo-Phung Hiep. Mémoire CNEARC, 130p.

Le Sam (1996) Thuy Nong Dong Bang Song Cuu Long, Nha xuat ban Nong Nghiep, TP. Ho Chi Minh

Lienhard, P. (2000) L'innovation en milieu rural. Le passage du riz flottant au riz irrigue le long d'une toposequence. Etude de cas dans le district de Chau Phu, province d'An Giang, delta du Mekong. Memoire de Master of Science, CNEARC. 94p + annexes

Mekong Delta Master Plan (1991) Mekong delta Master Plan (Vie/87/031), Working paper No.4 Agriculture . The Netherlands Engineering Consultants.

Mekong Delta Master Plan (1993) Master Plan for the Mekong delta in Vietnam, A perspective for sustainable development of land and water resources. The Nethelands Engineering Consultants.

Mekong Delta Master Plan (1993) Mekong delta Master Plan (Vie/87/031), Thematic study on management of water resources. T1: Optinal use of water resources . The Nethelands Engineering Consultants

Ministry of Water Resources (1994) Secondary canal development project Ba The Tri Ton, feasibility study (annexes, 1,2,4,5,10,11.)

Molle, Francois; S. Durongdej; C. Chompadist; A. Joannon and Y. Limsawad (1999) Improvement of rice cultivation and water management in the flooded area of the Central Plain of Thailand : a zoning of rice varieties by using remote sensing imagery Kasetsart University, DORAS Center, Research Report n°5, submitted to NRCT, Bangkok, 155 p.

Robequain, C. (1939) L'évolution économique de l'Indochine française. Edition Centre d'Etude de Politique Etrangère, 397p.

Sanh et al. 1998. History and Future of Farming Systems in the Mekong Delta in "Development of Farming Systems in the Mekong Delta of Vietnam", Ho Chi Minh City Publishing House.

Szuster, Brian W.; Molle, F.; Flaherty, Mark S. and Thippawal Srijantr, forthcoming. Socio-economic and environmental implications of inland shrimp farming in the Chao Phraya Delta. In *Thailand's rice bowl: Perspectives on Social and Agricultural Change in the Chao Phraya Delta,* edited by F. Molle and Thippawal Srijantr, Bangkok.

The Netherland Delta Development Team (1974) Recommendations Concerning Agricultural Development with improved water control in the MekongDelta, Irrigation and Drainage. Committee For The Coordinations of the Lower Mekong Basin.

Tuong T.P, Hoanh C.T and Kiehm N.T. (1989) Report of experiment E-61. Agrohydrological factor as land qualities in land evaluation for rice cropping pattern in the Mekong Delta. University of CanTho, Vietnam; The Wageningen Agricultural University, Netherland.

Vo-Tong-Xuan and Shigeo Matsui (1998) Development of farming systems in the Mekong Delta. JIRCAS, CTU, CLRRI, Vietnam.