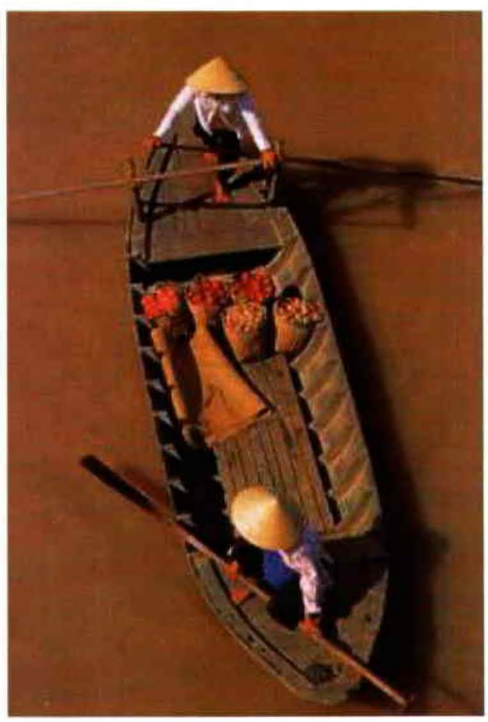
EUROPEAN COMMISSION
Contract 99/362 – B7/6200

Environmental sustainability of brackishwater aquaculture in the Mekong delta – Vietnam

GAMBAS

Volume 1 – Summary report



June 2004

Ifremer

Institute of Oceanography Nha Trang

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Volume 1 – Summary report

June 2004

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GAMBAS Partnership

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Institut Français de Recherche pour l'Exploitation de la Mer	*Institute of Oceanography of Nha Trang, Vietnam*	*Institut de Recherche pour le Développement*	*Université de Bretagne Occidentale, CEDEM (Centre de Droit et d'Economie de la Mer)*	*Université Paul Sabatier, LET (Laboratoire d'Ecologie Terrestre)*	*Research in Aquaculture Nb2 (RIA2 – Ho Chi Minh City)*	*Institute of Fisheries Economics and Planning (IFEP – Hanoi)*

Preface

Jacques Populus, Coordinator

This Gambas report contains two parts. The summary report (Volume 1) gives an account of the project intervention from May 2000 to December 2003, and a digest of the project's results and deliverables. The comprehensive report (Volume 2) contains the details of the scientific research and the technical results brought about by the project. Besides, a CD/ROM containing all the technical reports, publications and maps generated in the frame of Gambas is available from the coordinator.

Many people have contributed to this work. We did our best to mention their names where they contributed to the work and report, at the head of each chapter. We wish to thank all the people who gave their time and energy to the Gambas project.

We wish to give special thanks to Dr. Jacques Fuchs from Ifremer and Dr. Nguyen Tac An, Director of the Nha Trang Institute of Oceanography, for their constant and warm support to the project team, which ensured its success.

Finally, there were many people from the Provinces, Fisheries Officers from Ca Mau and Tra Vinh mostly, without whom our work would have been impossible. They've permanently eased our trips in the field and we wish Gambas will be of some help to them in the future.

Key words

Coastal environment, shrimp farming, sustainability, mangrove, water ecology, zootechnics, ecological confinement.

Disclaimer

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Introduction

Asia plays a leading role in farmed shrimp with almost 80% of world shrimp culture production. In the 1990's several Asian countries suffered from drastic collapses. The mostly traditional farmers in Vietnam's Mekong Delta experienced declining yields over several years. This was probably the result of a situation which was slowly degrading under a conjunction of factors. Aquaculture is so dependent on the health of the environment that it cannot succeed in unsuitable or degraded sites. This dependence has been overlooked until now. After many worldwide debates about intensive aquaculture (e.g. the ban in India in the 90's), it should be considered that ecologically farmed shrimp are commercially worth 20% more than those farmed intensively. Aquaculture may even become a guarantor of environmental quality, if suitable counter-measures to current malpractice or carelessness are implemented.

In Vietnam, the fast increase in shrimp culture surface area and the lack of detailed surveys has imperilled the efficiency of land-use planning and farmers' operations and investments. However, previous studies have indicated that there was very little space left for further expansion of shrimp farming, so yield improvement can only be achieved by careful planning and design, using high quality hatchery-reared post larvae, water quality monitoring, appropriate shrimp feeding. Also, some efforts to reduce the stocking density in some areas and to offer training to the farmers based on local commercial size experimentation seemed to provide good results.

The first thing to do was to define the ecological capacity with respect to shrimp farming development, keeping in mind the very nature of an ecosystem such as the Mekong Delta, which is basically adverse to aquaculture. It was the ambition of this project to examine a) how to reach stable yields under the present ecological conditions, b) whether these conditions could allow some degree of intensification and where, and c) whether this is a viable option for farmers from both economic and social points of view.

The methodology applied here relied heavily on i) hydro-ecological and land ecological assessments on a broad spatial scale, covering two sites well apart in the delta, and ii) analyses of rearing practice, farm structures and farm socio-economics.. The first step was devoted to gaining deep insight into the ecological functioning and to defining some indicators through ecological zonation. The second step investigated the rates of performance (both technical and economic) and tried to explain them in each zone compared to zootechnical and socio-economical data. Some policy, social and industrial aspects were also investigated. The third step examined how to disseminate the right messages to the stakeholders, from the farmers to the ministries.

This summary report first presents the Gambas intervention, i.e. the practical means of implementation of all project's tasks and actions, along with the full list of deliverables. The subsequent chapters give the key project's results.

Chapter 1 : Gambas Intervention

1.1 Project objectives and expected results

1.1.1 Overall objective

To make shrimp brackishwater aquaculture, an essential economic activity in the Mekong delta, sustainable in order to increase households' revenues and reduce rural depopulation, while protecting the ecosystem.

1.1.2 Detailed objectives

1) Confirm, on a significant sample of sites, the reliability of quantifiable relationships between shrimp production and ecological indicators
2) Analyse farming practices and social behaviour on the same sites in order to determine those allowing the lowest environmental and economic costs
3) Carry out mapping of mangrove vegetation, soil and salt intrusions and land use over the two sub-areas. To implement and feed a database focused on farms, as the starting point of future monitoring.
4) Increase capacity building of scientists, local fisheries authorities and farmer groups through strong involvement in the programme. Vietnamese partners are expected to collect and process field data under supervision of the EU experts, follow short-term and long-term training courses, organize and participate in a real case study and seminars.
5) Provide the Vietnamese counterparts with the tools and methods which will make them able to devise a follow-up development project extended to the whole of the Mekong delta.

1.1.3 Expected results

Immediate outputs

1) proper (ecological, zootechnical and socio-economic) ***methods and guidelines*** to help Vietnamese authorities better evaluate the real potential of the Mekong delta for brackishwater aquaculture.

2) ***operational tools*** (know-how and software) to collect, handle and keep data up to date with a view to ensuring future monitoring: data bases, mapping, image analysis and statistical processing.

3) ***capacity building and training***
* short-term training courses in Europe: ecology, mapping and GIS, socio- economics, statistics,
* long-term training courses (AIT Bangkok),
* hands-on workshop at mid-project for fisheries officers,
* initial and final workshops to raise awareness of decision-makers about the project's relevance and outputs.

Long-term outputs

It is expected that the Vietnamese counterpart will be more aware of the relevance of a rigorous approach to aquaculture allocation and environment quality monitoring, using the methodologies and operational tools designed by the project. In addition, links will be reinforced between scientists, local partners and decision-making bodies.

1.2 Field trips

1.2.1 Major field trips

The Gambas project was allocated ***5 field trips*** during the first two years of the project, i.e. an exploratory trip followed by two field trips per season (dry season from December to April, rainy season from May to November). These field trips were conducted in Sept. 2000, Jan./March 2001, Oct. 2001 and March 2002. They were key components of the project. These trips concerned all project activities, with different objectives and schedules. This called for meticulous logistics, with several vehicles and boats rented at the same time for each group to be able to cover a vast expanse of territory (e.g. over 500 km^2 in Ca Mau).

The data acquired during the trips were:

- ***hydrobiology***: about 25 parameters measured at 35 stations scattered over the two sites. Some parameters were replicated by the French and the Vietnamese teams as a double-check.
- ***hydrodynamics***: river cross-sections were measured at 31 stations. This task was done once, but took two trips to be completed
- ***land ecology***: soils were analysed at 11 stations with over 30 samples taken at each location, vegetation (biodiversity) and land use were described at 31 stations in order to validate the interpretation of the imagery.
- ***zootechnical and socio-economic*** data were collected during the four trips using a network of farms and questionnaires.

The ***September 2000*** field trip (dry season) was a kick-off trip devoted to testing the logistics of a large multidisciplinary group of scientists, meeting local authorities, selecting suitable vehicles and boats and positioning the project stations at the two sites of TraVinh and Ca Mau based on the following characteristics: i) the stations had to have several shrimp farms in their vicinity, ii) they had to exhibit diverse aquatic features in relation to their water renewal capacity, e.g. distance from seashore, tidal amplitude, type of waterway, as well as parameters like the nature of soils, mangrove, other vegetation, and zootechnics (a priori knowledge on farms).
Only simple hydrobiological data (multi-probe) were gathered during this trip, along with some land ecology and preliminary information on farms.

The ***2001 dry season*** field trip was split between January (hydrobiology) and March (land ecology and socio-economics). Water sampling was fully operational on this trip, by devising the schedule so as to sample water during high tide ± 2 hours, that is to say during the period when pond water is typically renewed. Large amounts of soil, vegetation (biodiversity) and river cross-section data were collected. Training areas for image processing were also located on the imaging done. To determine farm practices and socio-economics, 129 farms (69 in Tra

Vinh and 60 in Ca Mau) and 6 hatcheries/nurseries were sampled through a detailed farm survey. Farming practices (with the support of AIT - Bangkok), access to input, economic performances as well as social impact data were gathered, covering the rainy season 2000 and dry season 2001. This data set was the core of a costs/benefits analysis.
The ***2001 rainy season*** field trip was conducted in October 2001. River cross-section data were completed. Image processing results obtained in the lab in summer 2001 were validated. This field trip was fully satisfactory as the water level was extremely high and the logistics excellent, with speed boat logistics organised by the Fisheries. Besides, a new protocol had been designed for optimal use of primary production measurements. The purchase and handling of liquid nitrogen was also made fully reliable. This trip provided the project with key rainy season data.

The ***2002 dry season*** field trip (March 2002) was also fully operational and it provided the project with key dry season data. It was also devoted to final control of the land use maps, to more observations in terms of mangrove ecology. An additional 6 stations were investigated for soils, bringing the total to 11 stations. A second field trip took place in April, in order to assess social and institutional issues of shrimp culture at the provincial and country levels (OIKOS and IFEP). Besides, a second detailed survey and an extended general survey were implemented by RIA2 at the end of the dry season (July and August 2002). The first one extended the data set on farm economics and practices and increased the number of farms sampled (85 landholdings in Tra Vinh and 75 in Ca Mau). The second assessed the shrimp farming industry's impact and confirmed some results of the detailed farm survey on the scale of the provinces. 350 and 150 farms were sampled in Ca Mau and Tra Vinh, respectively.

1.2.2 Additionial field trips

More focused field trips were conducted by either project members or third parties under contract:

- AIT: March 2001 (shrimp farming practice)
- IRES: February 2002 (calibration of hydrodynamic model)
- Oikos and IFEP: April/May 2002 (socio-anthropology of shrimp farming and policy issues)
- RIA2: August 2002 (zootechnics and farm typology)

1.3 Training and dissemination

Scientific training was a key component of the Gambas project, as it contributed to enhancing the capacity of the Vietnamese counterpart. The initial training plan was adapted as the project was running, and was concluded by the following assignments, detailed in 1.5:

- 2 MSc training schemes launched at AIT
- 2 medium-duration periods in France
- 1 medium-duration period in Vietnam on dissemination
- 5 short duration training courses in France on specific required technical skills
- 6 field training courses in Mekong delta for local district fisheries and extension officers and farmers.

Dissemination of Gambas products to stakeholders was also a key issue of the Gambas project, and not only for the targeted end-users which were included in the partnership. Thus, its implementation tried to enable ownership of the outcomes by associating targeted stakeholders to the various steps of the workplan. A specific consultation on demands and needs from local officers and farmers was performed to complement what has been assessed through the partnership and which constituted the rationale of the project. ***Two "Hands-on workshops"*** organised in March 2002 and July 2003 were important milestones in Gambas dissemination strand. They brought together a panel of people from farmer level to scientist and province level decision-makers, as well as representatives from development organization involved in shrimp farming improvement toward sustainability (for more details, refer to the "Training and dissemination" section in the final report). They were key event in the co-design of the guidelines and dissemination actions.

1.4 Management

It should be mentioned that the project's duration was extended by 7 months to Dec. 31st, 2003, due to the realization in 2002 that a) less than one year's time after the last field trip was hardly enough to fully process the data, and b) dissemination could only become truly effective after completion of the data interpretation.

More particular actions in terms of management, beyond the reporting, were the following:

- convening of ***two scientific workshops***, at kick-off (September 2000) and in the final phase (November 2003), bringing together the project participants, some guest speakers, some local stakeholders or representatives of programs connected with Gambas (e.g. SUMA, UNDP),

- convening of a high-level workshop (November 2003) aimed at raising awareness at Ministry levels as to the expectations of shrimp farming in the Mekong delta and the pathway forward,

- convening of a ***mid-project review*** (November 2001), not initially planned, which provided the project with a critical view of two international aquaculture experts.

1.5 Deliverables

- The present ***final report*** (immediate output 1) is the key scientific output of Gambas. It is organised into "chapters" which reflect the main project's topics, along with an executive summary

- A ***portfolio of maps*** (immediate output 2) summarizing the spatial aspect of the work, which is made available as a CD/ROM on request to Ifremer or IO Nha Trang. An Arcview GIS version of the maps is also available, for further use. This deliverable complies with output 3.

- A ***data base*** in Access format containing all project data, which can be dispatched to a variety of institutions dealing with the environment in the Mekong delta. This set of data represents the first in-depth aquatic environmental knowledge collected in this region. As such, it can provide the basis to guide any subsequent data collection undertakings.

- A set of ***written guidelines*** (immediate outputs 1 and 3). One document concerns the farm level and is designed to help farmers conduct their management in terms of economics, the other one gives indications for sustainability at the Fisheries office level.

- The ***Gambas website*** will remain alive beyond the project, and is hosted by AUF (Association of French-speaking universities) in Hanoi. This will ensure publicity for the project for a few years following completion and raise awareness in support of the guidelines. The ***Gambas News n°3*** issue is published on the website (immediate output 3).

- A set of ***secondary reports*** produced by project participants and contractors, which are listed below:

  * Global Assessment of Mekong Brackishwater Aquaculture of Shrimp (GAMBAS) Activity 2: Shrimp Farming Practices, C. Kwei Lin, AIT, November 2001.
  * Hydraulic computation of river networks in the coastal region of Ca Mau, Vietnam. Fluid mechanics group, Université de Caen, France, June 2002.
  * Shrimp aquaculture in the Mekong delta: development and impact on local economy and society. OIKOS, Brest, June 2002.
  * Profile of the shrimp industry, institutional arrangements of Vietnamese shrimp farming activity, policy and policy formation mechanisms in shrimp farming sector in Vietnam. Institution of Fisheries Economics and Planning (IFEP), Hanoi, June 2002.
  * Application of GIS (Geographical Information System) and RS (Remote Sensing) for mangrove status and its implication in Shrimp culture activity in the Mekong Delta, Phan Minh Thu, Msc Thesis, AIT Bangkok, August 2002.
  * Practices and socio-economics of shrimp farming in Tra Vinh and Ca Mau provinces, Vietnam. RIA2, Saigon, March 2003.

- Increased technical know-how and ***scientific capacity*** (immediate output n°3) obtained through training in:

  * Hydrobiological data analysis (2 assignments)
  * Soil data analysis (1 assignment)
  * Bibliography on mangroves (1 assignment)
  * Statistical data analysis, using multivariate analysis and Spad-n software (1 assignment)
  * GIS manipulation under Arcview and mapping ability (1 assignment)
  * Spot and Radarsat imagery analysis, using IDRISI and GRASS software (1 assignment)
  * Integrated coastal zone management (2 MSc assignments).
  * Dissemination activities for applied knowledge

- ***Implementation of physical assets.*** The following items were acquired to upgrade the capacity of the mapping laboratory at IO Nha Trang:

  * HP Color Designjet 500 Plotter C7770B,
  * Scanner A3 - MicroTek ScanMaker 9600XL Scanner
  * HP Color Designjet 1125C Printer
  * HP LaserJet 1100 PrinterP
  * PC Pentium 4, 1.4 GH - M128/20G , Screen Monitor 21"

* PC Pentium III/800 MH - M128/20G, Screen Monitor 17"
* Software: Idrisi 32 for RS and GIS

- ***Publications***

* Populus J., Martin J.-L., Nguyen Tac An (eds). Shrimp farming sustainability in the Mekong delta Environmental and technical approaches. Proceedings of the Tra Vinh workshop, Vietnam, 5-8 March 2002. Referenced in "Aquatic Science and Fisheries Abstracts" (ASFA).
* Raux P., Bailly D., and Le Thi Thu Ha. "Shrimp Farming and Sustainability in Asia: toward an ecosystemic management". World Aquaculture Society, Aquaculture 2004, March 1-5, 2004, Honolulu, Hawaii, USA.
* Raux P., Bailly D., and Le Thi Thu Ha. "Shrimp Farming and Sustainability in Vietnam: a multidimensional approach to assess risks and failures in the shrimp farming industry". Aquaculture Economics and Management (submitted).
* Raux P., Bailly D., and Le Thi Thu Ha. "Is shrimp farming sustainable? The Vietnamese case study, role and articulation of institutions, technical knowledge and environmental constraints". Marine Policy (in preparation).
* Phan Minh Thu et al. Using GIS and Remote Sensing Tools for Mangrove Forest Management in Tra Vinh, Vietnam. Ocean and coastal management (submitted).
* Martin J.-L., 2003. Relationships between aquaculture and the surrounding coastal environment : application to shrimp aquaculture. In: Conference on shrimp farming research programs in New Caledonia. Koné, 2-3 Juin 2003 (in press).
* Populus J. et al. GIS in support to data analysis for enhanced sustainability of shrimp farming in the Mekong Delta, Vietnam. CoastGIS'03, Genova, Oct. 16-18 2003.
* Tong P.H.S., Auda Y., Populus J., Aispuru M., Blasco F. and Al Habshi A., 2004. Assessment of mangroves evolution in the Mekong delta, in relation with extensive shrimp-farming. Int. Journ. Remote Sensing (in press).

- ***Articles in newspapers / Web site***

* Gambas News, issues of Nov. 2001, Feb. 2003 and Feb. 2004.
* La crevette du Mékong, Dossier Pêche et aquaculture, Sciences au Sud, Le journal de l'IRD, Juillet 2003.
* Fish farming International, "Sustainable farming in the Mekong Delta", October 2003.
* Gambas web site with AUF (Agence Universitaire de la Francophonie, CAI Ha Noi), in three languages (Vietnamese, English, French).
* Articles in Mekong Delta regional vocational newspapers and in Saigon Economic Time Magazine at the occasion of the 2nd Hands-on workshop

Chapter 2 : Overview and context of the Gambas project sites

2.1 General geographic features

The Gambas project sites, namely the coastal areas of the Ca Mau and Tra Vinh provinces, are respectively located in the southern tip and on the East Sea side of the Mekong Delta. They are both strongly affected by the Mekong River's behaviour and by seasonal monsoons. Figure 2.1 is a satellite picture showing the extent of the plume generated by the Mekong discharge. The discharge is distributed by nine mouths (hence the name of Cuu Long in Vietnamese) located in the north-east of the delta that run off into the South China Sea (or East Sea, figure 2.1).

The Mekong River is the 5th largest river in the world in terms of sediment discharge. Between December and April, the dry season north-easterly monsoon carries the water plume from the Mekong mouths to the south-west, as is clearly visible in the satellite picture. The river's instantaneous flow oscillates between 1,700 $m^3.s^{-1}$ and 39,000 $m^3.s^{-1}$. Ninety per cent of the yearly 475.10^3 m^3 discharged to the ocean occurs during the rainy season. Offshore, due to the Coriolis force, the general water drift is directed to the south-west. During the dry season, this mostly marine water has a salinity of 25-28 ppt. During the rainy season, a far higher Mekong discharge occurs, entailing zero salinity at the Hau mouth (Dinh An station T1 on the Tra Vinh site, Figure 2.3). However the drift to the north-east probably prevents this offshore water from going south and entering the Ca Mau system. This is borne out by the salinity at the Bo De mouth (east Ca Mau coast) which remains around 28 ppt.

Figurre 2.1: satellite image showing the extension of the Mekong River plume along the eastern side of the delta

Courtesy NASA – STS075-721-047 Mekong River Delta, Feb. 1996

The Ca Mau peninsula is mainly constructed from detrital deposits brought by the Mekong River. The southernmost tip of the Ca Mau province, namely the Ngoc Hien district exhibits strong silting up, at a pace thought to reach 80 metres per year. Accretion processes have been much more pronounced in the Ca Mau province study area than in that of Tra Vinh province. Some coastal stretches of the southern delta, especially in the Soc Trang and Bac Lieu provinces, are subject to erosion which further increases the amount of particulate matter present in Ca Mau coastal waters. The particulate matter transiting along the coast carries a large amount of adsorbed organic matter from the Mekong River into the Ca Mau river system.

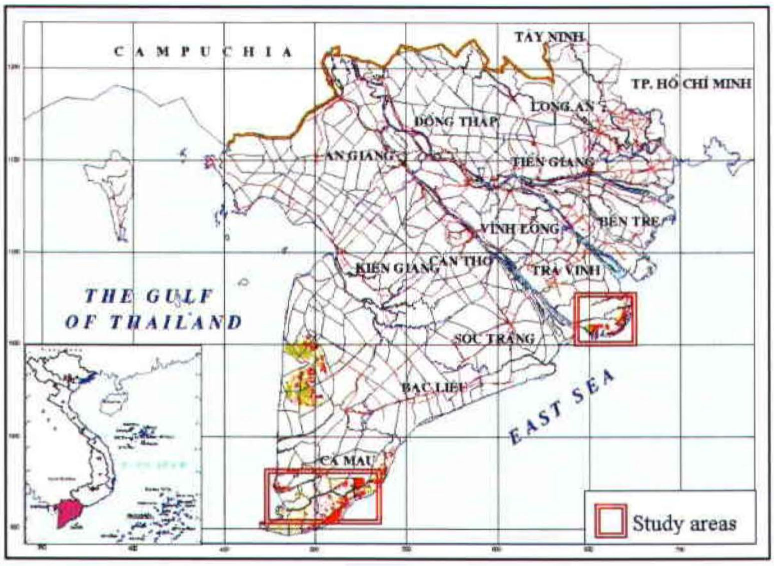


Figure 2.2: Location map of the Gambas study sites of Tra Vinh and Ca Mau

In the Mekong Delta, the population density is very high, with an average of 360 inhabitants per km². All along the river, domestic waste is directly discharged to the waterways. Rivers and dense canal network are important waterways for fluvial transport and one of the most important problems arising from boat circulation consists in bank erosion, leading to an increase in the concentrations of particles in the water. In particular, the Ca Mau headland is a sink for the particles brought by the Mekong River.

2.2 Tides and water dynamics in Tra Vinh and Ca Mau

The Tra Vinh province (figure 2.3) lies between the two major mouths of the Hau and Tien rivers. In spite of good knowledge of tides in the Hau branch (official tidal gauge at Dinh An station, close to station T1), little is known about tides in the Tra Vinh river network system.

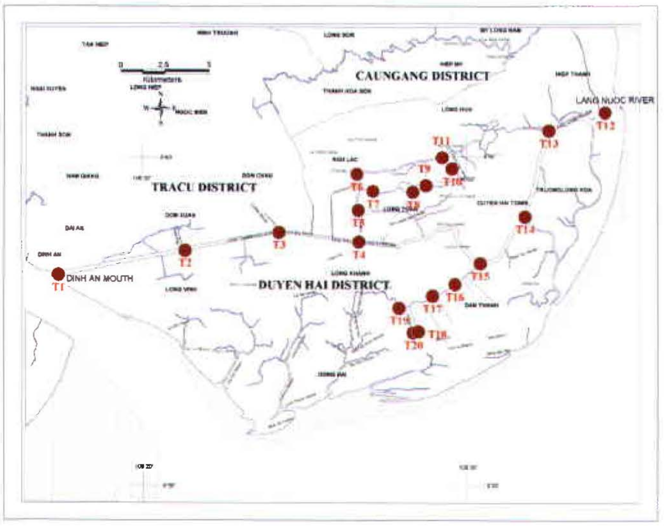


Figure 2.3: Gambas hydrobiological stations in Tra Vinh

The main river (Qua Chanh Bo), running east to west from T12 to T1 with depths between 10 and 20 metres, carries a large amount of water with currents typically reaching 2-3 knots. However, water circulation is drastically reduced in waterways stemming from this main channel, whose depth rapidly decreases. Confinement is expected to be high for stations in the secondary network.

A model was run for both the dry and rainy seasons in the Ca Mau channel network, and validated against in situ measurements. The numerical results and other observations allowed the following conclusions to be drawn:

- The southern Ca Mau peninsula river network is mainly subjected to the tidal regimes of two seas: semi-diurnal and mixed type in the South China Sea and diurnal in the Gulf of Thailand. The tidal range varies on average from 2.5 to 3.0 m in the South China Sea and from 1.0 to 2.0 in the Gulf of Thailand respectively. The influence of upstream discharges from the Mekong Delta is very low.
- The average salinity in the network varies from 22 to 25 $mg.l^{-1}$ in the inland area
- The Cua Lon river (represented by the large blue arrow in figure 2.4) has a considerable transport capacity (94.5-124.5 million $m^3$of water during the month of Feb. 2002). Cua Lon collects water mostly from the east but also from the south through Ong Trang and Ong Nhu channels (smaller arrows), and to a negligible extent from the north. This shows evidence of the overall east-west sediment transit over the area. It is best represented by the residual flow.
- The network's flow regime is not very sensitive to spates in the Mekong Delta, at least during the month of October 2001. Hydrodynamics in Ca Mau remain highly subject to the strong tidal influence. In the flood season, as mentioned above, water residual flows drop by about 40% over the whole network, which is believed to be due to the tidal situation.
- The situation along Doi Cuong channel, which separates Cai Nuoc and Dam Doi districts, is particular. This channel does not receive any outside water and is thus quite confined. In the rainy season, freshwater leaching into the reduced volume of this very shallow waterway (hardly 2 metres deep in the north) entails quite a drop in salinity (down to a few ppt), which remains local and does not affect the downstream system.

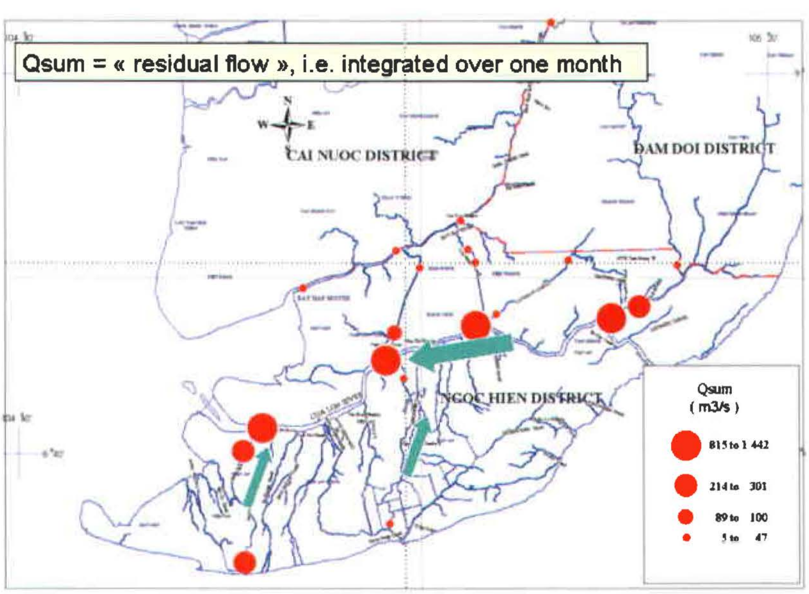


Figure 2.4: Residual flow computed at Ca Mau stations, with blue arrows showing flow directions and related modules

2.3 The shrimp culture activity in the Mekong Delta

The Mekong Delta contributes over 80% of the country's shrimp production. Shrimp farming has quickly developed since the end of 1980, especially improved-extensive and semi-intensive shrimp farming models, gradually replacing some traditional extensive shrimp farming systems. Surface area strongly increased from 249,234 ha in 1997 up to 434,752 ha in 2001.

Several shrimp farming models are commonly used in the Mekong Delta:

- Extensive and improved-extensive shrimp farming models for mangrove forest areas applied in Ca Mau, Bac Lieu, Ben Tre, Tien Giang, Kien Giang provinces,
- Semi-intensive shrimp system applied in Tra Vinh, Soc Trang, Bac Lieu, Ben Tre, Tien Giang provinces,
- Shrimp farming in rotation with rice system applied in Long An, Soc Trang province,
- Shrimp farming with salt field system applied in Soc Trang, Bac Lieu, Tra Vinh provinces,
- Shrimp-Artemia farming system applied in Vinh Chau – Soc Trang provinces,
- Intensive shrimp farming system applied in Soc Trang, Bac Lieu, Tra Vinh, Tien Giang provinces.

Many shrimp crops have been unsuccessful since the development of improved shrimp farming models. Since 1993, epidemic diseases in the Mekong Delta have created very high risks for shrimp farmers and are still currently causing serious losses.

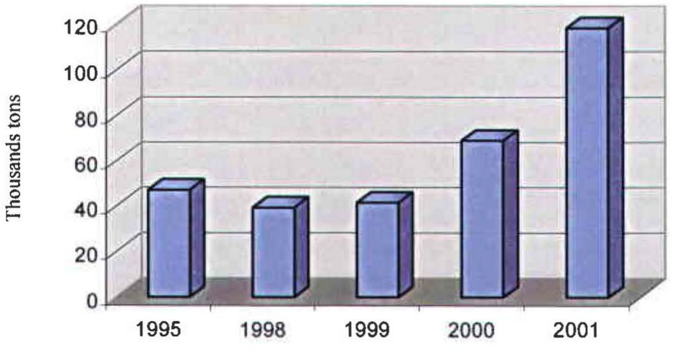


Figure 2.5. Production of shrimp culture in Mekong Delta from 1995 to 2001 (Head Office of Statistics Data, 2002).

According to official statistics, in Tra Vinh the shrimp aquaculture production in 2001 was about 4000 tons. In 2001 there were 13,118 households stocking an estimated 510 million shrimp seeds in 10 500 hectares of ponds. The related average shrimp yield was about 310 kg per hectare. Ca Mau had a total surface area for aquaculture of 202,000 hectares in 2001, with 18,000 ha are for shrimp-mangrove culture, 10,000 ha for shrimp culture in ditches among household vegetable gardens, 147,000 ha for extensive shrimp farming systems, 26,500 ha for shrimp-rice farming systems and 100 ha of semi-intensive and intensive shrimp farming systems. The total aquaculture production in Ca Mau for 2001 was about 87,500 tons of which over 70% was for shrimp production, a 36.3% increase from 2000. According to official statistics, the yield for shrimp culture in Ca Mau province in weight of shrimp harvested per hectare for 2001 was 500 kg/ha in the improved-extensive system, 150-200 kg/ha for the recently changed improved-extensive in rotation with rice crops, 1-1.5 tons/ha for semi-intensive and 3-4 tons/ha for intensive.

Chapter 3: Soils and mangrove vegetation: the current status

In Vietnam, the expansion of shrimp aquaculture over the past 15 years has been extremely rapid. Brackishwater aquaculture increased from 48,700 ha in 1985 to 237,739 ha in 1994. This increase contributed to considerable loss of mangrove forests and environmental degradation in the Mekong Delta. It has been particularly severe in the former Minh Hai province where rates of forest clearance were estimated at up to 5000 ha $year^{-1}$, with less than half the original forest area (<50 000 ha) remaining in 1992. The decline in forest area has led to declines in plankton and shrimp seed densities, saline water intrusion, accelerated coastal erosion, production of pyrites and reduced biodiversity.
A key issue for specialized scientists and decision makers is to know the actual links existing between mangrove ecosystem and shrimp yields in a given site. So far, no simple answer has been given, presumably because we can give as many answers as there are mangrove types and hydrological systems. The main goal of this report is to evaluate the actual impact of shrimp aquaculture on mangrove ecosystems in two provinces of the Mekong Delta, Ca Mau and Tra Vinh, paying special attention to the developing trends by using some sensing data and ecological data collected during field trips or obtained in laboratories.

3.1 Land ecology

3.1.1. Soil assessment

Maintaining water quality and perpetuating the general conditions conducive to rapid higher plants growth and low mortality are of paramount importance. In this respect, mangrove soils frequently suffer from severe limitations. In many parts of the world, the construction of ponds inside mangrove has resulted in serious problems due to the exposure of sediments to air, with formation of acid sulphate soils (ASS). ASS are often observed on disturbed mangrove soils. More than 40 % of mangrove soils in the Mekong Delta (1,6 million hectares of the total area of the delta) are assumed to be acid sulphate. Formed after the oxidation of pyrite-rich sediments, ASS are characterised by low pH and high concentrations of aluminium and iron sulphates.

Table 3.1.1: Relation between pH water and pH in situ. Means et variances are computed for five stations (March 2001)

Station	Number of samples	pH water	pH in-situ	variance pH water	variance pH in situ
CA MAU 10	14	5,2	6,6	2,25	1,40
CA MAU 2	12	5,7	6,5	1,94	1,15
CA MAU 7a	14	4,6	6,5	0,70	0,04
TRA VINH 15	14	6,2	6,9	0,28	0,27
TRA VINH 6	14	5,4	6,5	0,60	0,53

One of the aims of soils assessment in Tra Vinh and Ca was to verify the occurrence of ASS. A total of 116 samples were collected at 5 stations in Tra Vinh (fig. 3.1.1) and 6 stations in Ca

Mau (fig 3.1.2). The distribution of these samples is described in the main report, along with the eleven parameters measured.
We decided to rely only on the pH values measured in situ which are probably more consistent with the actual conditions prevailing in nature between the water and plant roots. Measured pH values oscillated between 5 and 7 (Table 3.1.1), meaning that the average pH of water is slightly acid. Low pH water values, found in sub-stations near the forest cover, were probably due to organic acidity. Salinities in all these samples inside the mangrove or near ponds ranged between 15 and 18 $g.l^{-1}$. As we know, *Rhizophora apiculata* and *Avicennia* sp. normally thrive and have the highest yields when water salinity is between 20 and 30 $g.l^{-1}$. In these "managed areas" where soils have been deeply disturbed (ponds construction) and mangrove forests artificially installed, the differences observed in soil properties from one station to another are logically due to the existing cover vegetation. The primary production of forest and litter should increase the organic matter content and slightly decrease the pH.

3.1.2 Mangrove ecology and zoning

In both sites of Ca Mau and Tra Vinh, at least 60% of the original mangrove forest had been destroyed by herbicides and napalm bombs during the last Indochina war. After 1975, a huge reforestation program was undertaken by the government of Vietnam while at the same time traditional shrimp farming developed. So natural mangroves have suffered everywhere from direct and indirect human disturbance. We have to consider that almost all these mangroves are artificial and less than 30 years old. In addition, for practical reasons, the replanted mangroves are composed basically of only one species, *Rhizophora apiculata.*

The main objectives of mangrove zoning are to: i) explain the zonation and landscapes as observed from satellite mapping, ii) monitor the evolution of land-use in this part of the world, where the government has decided to maintain the acreage of mangroves at its present level, although the extension of shrimp farming will increase significantly, iii) to establish, insofar as possible, links between the extension of mangroves and shrimp farming yields.
A reliable understanding of the present mangrove land-use implied combining the results provided by satellite products and ground truth data collection. During the field trips, the main ecological and floristic conditions as well as main the types of aquaculture and land-use units were collected. The satellite products that were used for mapping purposes in this study were two Spot 4 images which produced colour composites and land use classifications.

The land-use charts were simplified, because human impacts are noticeable everywhere and this permanent disturbance of spontaneous ecosystems and changes in agricultural practices make it difficult to produce a map which could remain valid for several years. The only way to produce a meaningful legend was to consider only broad land-use classes. However, with such a rough classification it was difficult to ascertain the reliability of the map at local levels.

The Tra Vinh site

As an example, the color composite of Tra Vinh given in figure 3.1.1 clearly shows distinct and rather homogeneous areas, corresponding to distinct land-use classes, producing spectral responses which stand out clearly. A full description of these features areas is given in the main report and only summarized here.

Figure 3.1.1: January 22, 2001 Spot 4 image in true colour composite

In Tra vinh, zone I was located outside the mangrove areas, although some mangrove trees can be observed scattered along river banks and some shrimp ponds have been progressively created. This progressive conversion of paddy fields into mixed land uses (i.e. paddy during the rainy season and shrimp culture during the dry season) cannot be detected on satellite images.

In zone II, all red patches on the image belong to mangroves. Here, tidal fluxes move freely in main and secondary canals. All of the 20 hydrobiological stations are located in these zones which are densely populated. All natural mangroves are reduced to degraded remnants along the waterways and very often ponds are deprived of any mangrove trees or brush. The small number of mangrove species could be due to the magnitude of human impacts and to water salinity levels usually under 15 g.l-1. In many cases these mangroves have very little importance for forestry. It is impossible to determine the exact role of these degraded mangroves in shrimp farming. Even along the largest waterways (between stations 13 and 14), where we were expecting beautiful mangrove stands, we found only remnants, in the form of discontinuous dwarf ribbons. There is no scientific explanation to the present distribution of mangrove species in this part of the delta. The past history of anthropogenic disturbances in each part of the delta during the past few decades could help in understanding the present floristic assemblages. So far, it has not been possible to distinguish mangrove species from space. In this land-use system, neither ecological issues nor forestry practices are the main concern of decision makers and mangroves are of minor importance.

Zone III exhibits the so called "mangrove silviculture/shrimp farming" or "mixed shrimp-mangrove forestry farms" mode. Shrimp farming is mainly extensive or improved extensive and is found everywhere. All the mangroves are secondary or artificial (planted). Though the areas under mangroves are quite extensive, it is extremely difficult to observe old trees with girths exceeding 25 cm. The total income from forestry products is probably significant (poles, charcoal, thatching, etc.) but it is not accurately quantified. All propagules used for reforestation purposes are brought from Ca Mau Province. The most conspicuous stand on the image is located near station 16. Here again this is a totally artificial forestry system which includes pure stands of *Rhizophora apiculata* and pure stands of *Nypa fructicans* side by side. All these stands are dense with ground coverage nearing 100% (4-8 m height).

In zone IV, mangroves play important roles for coastal protection. Usually their natural regeneration is extremely dynamic, especially at the highest tidal level. Field surveys often indicate that narrow channels are excavated in these forests where some aquaculture is carried out.

The Ca Mau site

The five main zones distinguished and delineated in the Tra Vinh Province are also found in the Ca Mau Province, although this part of the delta is located away from the main fresh water stream. Even during catastrophic floods, this part of the delta is not affected (ref. 2.2). This means that both influences from the South China Sea and from the Gulf of Thailand are much more important than that of continental waters. Out of the 11 stations studied in Ca Mau Province (Figure 3.1.2) many have mangroves forests within the shrimp ponds. Beside *Rhizophora apiculata,* the flora of the mangroves of Ca Mau is much more diversified.

Zones I and II are changing rapidly. Recently, the dykes were opened in order to permit salty water to enter the fields and convert them into shrimp ponds. The general physiognomy of the landscape may not change drastically, at least on satellite images, even though most of the coconut trees commonly found on dykes are being eliminated due to higher salt contents in soils.

In zone III mangrove forests and shrimp ponds are intermingled (mixed shrimp-mangrove forestry farms) and mangroves cover at least 50% of the land use. Officially it is called either "artificial forest for production purpose" or "artificial forest for protection purpose". Dark red tones are induced by dense mangrove plantations or by vegetated levees separating individual shrimp ponds (5-15 m wide, up to 100 m long or even more). On these levees, under-shrub vegetation may be dense and green even during the dry season, meaning that multidate studies may not make their identification easier. All these plants can be considered as salt resistant weeds. *Nypa fructicans* was conspicuously absent from zone III in Ca Mau Province, although this palm-like species was found everywhere in Tra Vinh Province. This is presumably a strong ecological indicator showing key differences between both provinces.

Finally, zone IV was of special interest for our knowledge about mangroves in this part of the world because some types that are almost climax mangrove can be found in the vicinity of station 9. These regions are reasonably well protected for ecological and security reasons. In the large island of the western mouth (Ong Trang, station 1), in spite of permanent rejuvenation, the forest stands maintain an almost constant acreage.

Most of the finest mangrove stands were recorded North of the Song Dan Doi channel, in the forested area located east-north-east of station 9. These mangroves expanded after 1965 (before the spraying of herbicides), in spite of the destructive effects of typhoons. The most recent, called "Linda" destroyed most dominant trees of the top canopy in 1997.

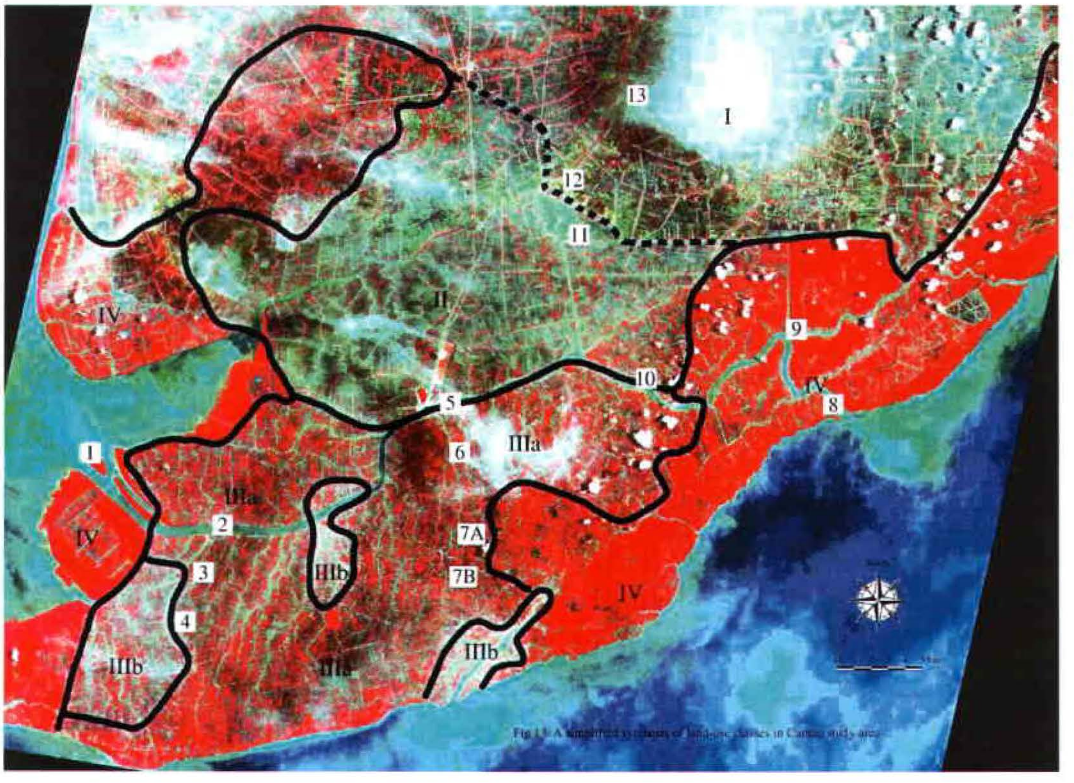


Figure 3.1.2: April 10, 2001 Spot 4 image in true colour composite

Comparing Tra Vinh and Ca Mau sites

Some parameters appear to be identical in both provinces : i) in both cases waters are highly turbid with high concentrations of loamy and clayey particles which are constantly redistributed in suspension by tidal currents and speed boats, ii) nowhere were old mangroves observed, they probably exist in very small areas but are rare, c) human density is quite high almost everywhere. Salinities always higher in Ca Mau (20-30 g.l-1 instead of 10-18 g.l-1 in Tra Vinh) probably explain why the mixed "mangrove forest-shrimp ponds" land use type respectively covers 28,000 ha and 2,500 ha in the two provinces. An interesting ecological indicator is perhaps the relative abundance of mangrove species observed along waterways, which is summarized in Table 3.1.2.

Table 3.1.2: Distribution of main mangrove species along water-ways in Tra Vinh and Ca Mau Provinces

Tra Vinh Province	***Ca Mau Province***
Avicennia and *Sonneratia* >25%	*Rhizophora apiculata* > 80%
Excoecaria agallocha 20%	*Avicennia* (3 species) 5%
Derris trifoliata 15%	*Ceriops* and *Bruguiera* 3-5%
Phoenix paludosa 15%	*Excoecaria agallocha* 3%
Nypa 15 - 20%	*Nypa* and *Sonneratia* 2%
Ceriops, Bruguiera, Xylocarpus < 5%	*Xylocarpus*, *Lumnizera* others <2%

Rhizophora apiculata is the most common planted tree. This species seems to accept various kinds of hydric regimes including the absence of tidal influence. Many plantations located on the levees, inside shrimp ponds, have a disrupted hydric regime, with a flooding frequency which presumably does not exceed 100 days per year, even though some underground water circulation occurs in the root systems, thanks to numerous crab holes. The primary consequence of this situation (resulting from the fact that spoil cleaned from ponds at the end of each cropping cycle is deposited on the levees where mangroves are planted) is that the growth rate and productivity of these mangroves are considerably reduced.

3.1.3 Mangrove change

The most important source of information as regards mangrove change was provided by topographic maps (US Navy maps 1965/1966) and by satellite images (Landsat TM 1995, Spot 4 2001). The surface area of mangrove ecosystems in 1965 was extracted by digitizing the maps. Their extents in 1995 and 2001 was computed using supervised classifications.

Table 3.1.3: Characteristics of mangrove forest distribution in Tra Vinh and Ca Mau.

Year	Factors	Tra Vinh	Ca Mau
1965	**Total**	**21,221**	**90,346**
	Natural mangrove forest		87,097
	Plantation forest		3,249
2001	**Total**	**12,797**	**38,303**
	Low density	8,666	8,677
	Moderate density	2,347	23,860
	High density	1,784	5,766

values in ha

Three main mangrove types were differentiated according to the density of the top canopy: high, moderate and low. In Tra Vinh, mangroves traditionally an essential played an essential role in coastal protection. Mangrove deforestation occurred mainly after 1995. In Ca Mau, as shown in table 3.1.3, about 72% of the total area was covered by mangrove forests in 1965, including 87,100 ha of natural mangrove forests and 3,250 ha of planted mangrove trees which already existed at that time. As deforestation processes were far more extensive than replanting activities in this part of the delta, in 2001 mangrove forests covered only about 38,000 ha (about 30% of the total land area).

The recent expansion of shrimp culture in the region has now substantially reduced the area of mangroves, to the point where the remaining mangrove forest may not meet the projected demand for timber, fuel wood and charcoal. This last point underlines the need of studies on shrimp farming and the environment.

3.2 Mangrove and shrimp farming compatibility

This is a very important issue for which unfortunately no definite or general response can be given at present. Interplaying factors in the yields of forestry and shrimp aquaculture are very diverse and highly changeable over space and time: i) socio-economic conditions, ii) hydrobiological processes, iii) farmers' technical skills, vi) mangrove forestry practices, etc. However, if we focus on mangrove ecosystems and their relationships with shrimp farming, three levels of understanding can be described.

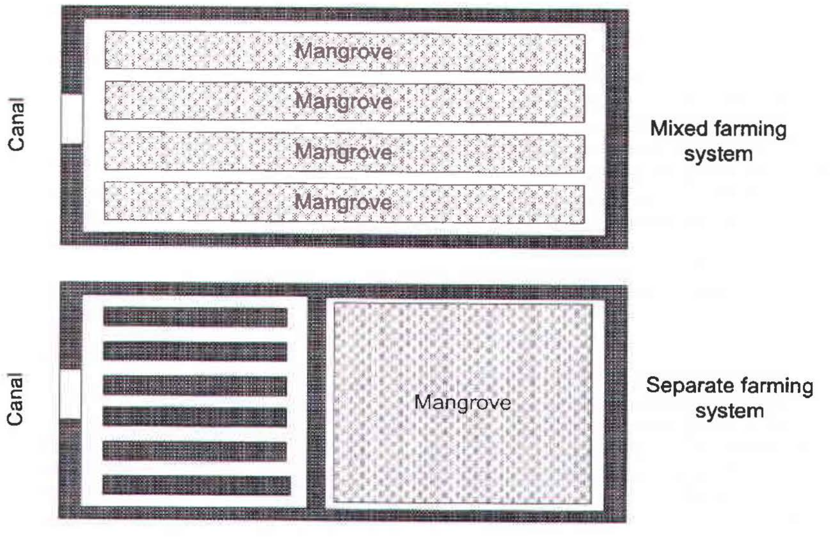


Figure 3.2: Schematic diagram of "mixed" and "separate" farms types (after Clough, 2000)

At the shrimp farm level, mangroves near or inside the pond have some negative effects on shrimp growth, namely: i) excess decaying organic matter in ponds is responsible for important hydrological changes induced by organic acids, tannins, etc. ii) excess tree shade hinders the penetration of sunlight which is necessary for primary productivity, iii) crabs, fish and other predators found in mangroves consume post-larvaes or juveniles. In the "mixed shrimp-mangrove" model (Fig. 3.2) trees are planted on levees located inside the ponds or directly inside the ponds. In the "separate shrimp-mangrove" model, the area exploited by the farmer is split into two zones, one for shrimp culture and one for mangrove replantation. However Gambas yield surveys did not distinguish these two models, so assessing the influence of mangrove location was difficult.

At a more ecosystemic level, post-larval penaeid shrimps mostly migrate to the coastal woodlands to seek shelter and feeding grounds. Regular and important communication between the sea and mangroves is essential for the development of large populations of shrimp. Mangroves thus support coastal fisheries and good correlations have been established between prawns landed and the area of mangroves adjacent to the fishing grounds. Mangrove forest actually substantially contributes to the food chain that supports coastal fisheries. To study the effect of a mangrove on shrimp yield, a comparison between large protected areas and degraded ecosystems is needed. Unfortunately, little information exists on undisturbed mangrove ecosystems in Asia.

In Tra Vinh after 1975, war devastated mangrove areas were first converted to paddy fields. The replanting of mangroves was concomitant with the development of aquaculture. In Ca Mau, particularly in the southernmost part, mangrove devastation was not followed by paddy activity because of too high salinity. The Ca Mau mangrove was replanted and shrimp activity was a compromise between mangrove preservation and shrimp pond construction. The historical consequence is that at province level, mangrove are more extensive in Ca Mau than in Tra Vinh. The policy of mangrove protection and conservation are much more pronounced in Ca Mau than in Tra Vinh. Its geographical position at the extreme Southern part of Vietnam has probably attracted more scientific attention to Ca Mau, and hence more active and efficient mangrove reforestation programmes.

3.3 Conclusions

The main conclusions that can be drawn from this chapter are:

- In Gambas investigations no low soils pH values were encountered. Usually pH varied from 5 to 7, except in station 12 of Tra Vinh where a low value (<4) was recorded. Soils at this station have been greatly disturbed by the construction of new ponds.
- A comparison of the mangrove's extent in 1965 (before the last Vietnam War and the development of shrimp aquaculture) and in 2001 indicates that the current mangrove extent in Ca Mau Province is about 30 to 35% of the initial acreage.

- The results obtained through Spot data analysis provide at first glance the most relevant land-use units with clear-cut boundaries. Practically all mangroves present in the Mekong delta are young, densely planted stands of *Rhizophora apiculata* or *Nypa fruticans*. These plantations have been strongly impacted by high human population density and by the extent of shrimp farming or salt production.

- Ground surveys have provided an array of ancillary data and satellite images have clearly shown that natural mangroves have almost disappeared from the study area. The primary consequence of this fact is that the destruction of these nursery grounds has had a direct negative impact on post-larvae recruitment. This is probably strongly aggravated by the rapid human population growth in the Mekong Delta and dramatic over-fishing activity in almost every waterway.

- One of the main advantages of restoring natural mangroves instead of installing artificial mono-specific mangroves trapped in a very constraining network of dykes and embankments would be to limit rapid water quality fluctuations and to restore reliable wild seed recruitment. Determining locations and extents of these new restored mangroves will require further studies. But this is an approach which is recommended by most mangrove specialists.

Chapter 4 : Mekong Delta brackish water : a suitable asset for shrimp aquaculture ?

4.1 The Gambas hydro-ecological investigation strategy

Very little information is available on the hydrobiological and aquatic ecological characteristics of the brackish part of the Mekong Delta. To our knowledge, the hydrobiological and ecological characteristics of the channels and rivers in the Mekong Delta have never been the object of any structured hydrobiological study.

It has been shown (Guelorget, 1992) that the structure of aquatic ecosystems is based on their water renewal capacity, i.e. their ability to eliminate waste and to supply nutrients for the food web to develop. The water renewal capacity defines the notion of confinement. Confinement, along with the organic matter input will drive the structuring of ecosystems and their characteristics, on which the performances of aquaculture are based.

The aim of this chapter was to determine hoecological and hydrobiological features could explain the differences in shrimp yields between the two ecosystems studied, i.e. Tra Vinh and Ca Mau. This assessment was made on the basis of the principles of ecosystem structure mentioned above. The strategy was to collect and process hydro-ecological data to account for both the seasonal and geographical aspects. The emphasis was put on the dry season, insofar as most of the shrimp production occurs at this time. Subsequently, we tried to correlate the production yields with the most representative environmental parameters in order to highlight the environmental indicators which could show the environment's capacity to accommodate and/or develop shrimp farming there. Lastly, we tried to set up an index (the Confinement Index CI) which would account for the environmental characteristics while avoiding recourse to costly and time-consuming biological and chemical analyses.

In Ca Mau and Tra Vinh ecosystems 15 and 20 stations (see fig. 3.1.1 and 3.1.2) were respectively selected according to two criteria: a) a large potential diversity of ecological and hydrobiological characteristics, b) at least 5 shrimp farms at each station. Two major sampling surveys were conducted (Oct. 2001 and March 2002). In every case, the samples and measurements were done in daytime, at high water ± 2 hours, in a situation of spring tide. The water sampled during this period corresponds to the water introduced into the ponds by tidal flushing. Sample analyses are described in full detail in the main report. Over 20 hydro-ecological parameters were measured and analysed in the laboratory. Besides, on a more fundamental aspect, stress was put on the identification of phytoplankton communities.

4.2 Key results for hydrobiology

4.2.1 Hydrobiological features of the study sites

Four spatial-temporal situations are presented: the two ecosystems of Tra Vinh and Ca Mau for 2 seasons (dry and rainy). Four 4 types of parameters were recorded: i) the most characteristic parameters of estuarine and deltaic environments (total suspended solids, salinity, etc.). ii) parameters more directly linked to the production processes in the environment, particularly primary production, iii) then parameters related to this primary production, which are more specifically linked to the metabolism of organic matter and which may have an effect on the environment's capacity to accommodate aquaculture activity (concentrations of oxygen, dissolved and particulate organic matter, nutrients, etc.), iv) finally, numerous secondary parameters such as temperature or pH for example. For all these parameters, the means, standard deviations and degree of probability concerning the level of significance of the differences are given in various tables for the four spatial-temporal situations. A short description is given below.

For both seasons the mean **salinities** are significantly higher at Ca Mau than at Tra Vinh. In the rainy period, the maximum salinity measured at Tra Vinh was 10.6 g l^{-1}. At Ca Mau, in the rainy season, with the exception of the northern part of the ecosystem (stations 13-14-15, figure 3.1.2), salinities were all above 20 g l-1.

Values for **oxygen** show that in both cases, i.e. both the rainy and dry seasons, the oxygen concentrations observed at Tra Vinh were significantly higher than those measured at Ca Mau, (respectively 5.98 ± 0.64 mg l^{-1} and 4.79 ± 0.68 mg l^{-1}).

The **pH** values were significantly different between the two ecosystems, for the two seasons. The values observed ranged from 7.10 to 8.16.

During the dry season, the mean **total suspended solids** (TSS) concentration observed at Tra Vinh was significantly lower than that at Ca Mau (respectively 104.6 ± 68.2 and 200.4 ± 130.2 g l^{-1}). At Tra Vinh in the dry season, the highest concentrations were recorded in channels with the largest broadth and cross sections (low CI). Opposite this, the lowest concentrations in this ecosystem were observed at stations with the highest CI (stations T18 to T20, and T4 to T11, figure 3.1.1). These TSS concentrations seem to depend mainly on the mineral matter concentrations.

The mean **chlorophyll-a** concentrations were not significantly different between the two ecosystems nor between the seasons in the same ecosystem. When all seasons and stations are taken together, the concentrations ranged from 0.83 to 73.36 µg l^{-1}. It should be noted that the highest chl-a concentrations were found at the stations with the highest CI.

The **primary production** in Ca Mau and Tra Vinh were respectively 48.8 ± 59.0 and 60.1 ± 76.8 mgC.m3.h^{-1}. In the dry season, the highest primary production values were observed at stations with a high Confinement Index (stations 8, 9, 10, 11, 18, 19, 20). The large channels and rivers at Tra Vinh had low primary production values.

The **assimilation number** (AN) values which correspond to the carbon uptake (expressed as mg C.m-3.h-1) per unit of chlorophyll (expressed as µg.l-1) were significantly higher for the dry season at Tra Vinh than at Ca Mau.

Mean concentrations of **heterotrophic bacteria** (HB) were above 3 10^6 HB ml^{-1} in Ca Mau and above 2 10^6 HB ml^{-1} in Tra Vinh. It should be noted that the highest concentrations in this ecosystem were observed at the stations with the highest CI, particularly at stations 8, 9, 18, 19 and 20 at Tra Vin.

The percentages of **DON** (% DON) in all dissolved nitrogen (inorganic + organic) in the samples taken in the dry season was significantly higher (P = 0.0041) in the Ca Mau ecosystem than in that of Tra Vinh (respectively 58.1 ± 13.0 and 41.6 ± 13.6 %). At Tra Vinh, the highest % DON were measured at stations with the highest CI (stations T18, T19, T20). At these stations the %DON reached 83.9 %.

Vibrio analyses were made in the rainy and dry seasons and showed significantly higher values at Ca Mau than at Tra Vinh (respectively 17.6 ± 12.1 and 6.9 ± 4.8 µg l^{-1}).

The **organic matter** concentrations were measured in the dry season. Their mean concentration measured for Ca Mau was significantly higher (P = 5.86 10^{-5}) than the average measured in the Tra Vinh ecosystem (respectively 10.4 ± 3.0 and 6.8 ± 2.0 mg g^{-1}).

The organic carbon and total nitrogen concentrations contained in the sediment are closely correlated to organic matter concentrations. Their measurement made it possible to calculate the **C/N ratio** (mol/mol), which was also significantly higher at Ca Mau than at Tra Vinh.

4.2.2 Hydro-ecological zonation

The ecological zonation was carried out for the dry season, since almost the entire shrimp production takes place there. The zonation aimed to identify zones with homogenous ecological features. This should later allow to analyse the influence of zootechnical practices on shrimp yields, by considering that in the same zone, i.e. under identical ecological conditions, differences in yields will be due to aspects related to zootechnical and social practices.

The normalised principal component analysis applied to dry season hydrobiological parameters show that the two groups of stations, i.e. Ca Mau and Tra Vinh, are the opposite of each other. The ellipse for the Ca Mau stations is characterised by high salinity, and high concentrations of TSS, DON and vibrios. Moreover, the Ca Mau are characterised by high N/P and C/N concentrations in sediment. Most of the Tra Vinh stations are mainly characterised by 3 parameters with high values: O2, P-PO4 and AN. In addition, the Tra Vinh stations have lower N/P ratios and lower vibrio and DON concentrations that in Ca Mau. The hydro-ecological zones are described as follows (Figure 4.2):

Ca Mau
- zone 1 (C1, C2, C8): these are located close to river mouths, under marine influence.
- zone 2 (C3, C4): stations with moderate confinement. No striking feature in terms of TSS or organic matter.
- zone 3 (C5, C6, C7, C9, C10, C11, C12): core Ca Mau zone, exhibiting high salinity, vibrios, organic matter in sediment, TSS.
- zone 4 (C13, C14, C15): upstream stations reclaimed from paddy, confined, with lower salinity.

Tra Vinh
- zone 5 (T1, T2, T3, T4, T5, T6, T7, T12, T13, T14, T15, T16, T17): stations located along the Long Toan channel, typical of Tra Vinh general features, with higher O_2 and $P\text{-}PO_4$, lower N/P ratios and DON concentrations.
- zone 6 (T8, T9, T10, T11) : confinement intermediate, highest Assimilation Number (AN) and lowest TSS.
- zone 7 (T18, T 19, T20): high Confinement Index, with quite high DBO, PP, HB, Chl-a.

In the course of the rainy season, the two ecosystems acted oppositely, Ca Mau featuring higher salinity and Tra Vinh higher concentrations of TSS and DIN. Again, stations T18, T19 and T20 showed characteristics that set them apart from the other Tra Vinh stations.

4.2.3 The seasonal influence

Studying the ecological characteristics linked to the season showed that for both ecosystems, the main difference was related to salinity. For the Tra Vinh ecosystem, we observed that most of the parameters were subject to a seasonal effect. This was not the case for Ca Mau, where drops in salinity seen during the rainy season mainly affected the stations furthest upstream in the hydrographical system (stations C13, C14 and C15, refer to 2.2). In Ca Mau, TSS concentrations did not vary significantly from one season to another. Conversely for Tra Vinh, TSS concentrations measured in the rainy season were significantly higher than those recorded in the dry season. It should be noted that for Ca Mau, in the rainy season, the TSS contained a higher percentage of organic matter than in the dry season. However, in this ecosystem, the chl-a concentrations were higher in the dry season compared to the rainy season. This shows that the Ca Mau ecosystem's enrichment in sestonic organic matter during the rainy season could not be due to a phytoplanktonic type enrichment.

The Tra Vinh ecosystem's characteristics showed great seasonal variations, contrary to those of Ca Mau. The variations indicate a drop in the surrounding environmental quality with regard to shrimp production. In the rainy season the oxygen, chlorophyll and primary production levels were all lower, the latter two directly influencing the food chain's efficiency. The differences in shrimp production at Tra Vinh between the rainy and dry seasons can certainly be explained by this disparity in seasonal characteristics.

4.2.4 The geographic influence (dry season)

It is obvious that the Mekong has a stronger influence on the Tra Vinh ecosystem, in terms of fresh water inputs and certainly in terms of nutrient inputs as well. However an essential difference between the two ecosystems is related to organic matter, which was present in higher concentrations in Ca Mau water and sediment. This may be due to high inputs of organic matter, leaves and detritus from the mangrove. Furthermore, this is where particles carried by the Mekong River are deposited and build up, forming the youngest flat land of the delta. In addition, the C/N ratio values in the sediment which were higher at Ca Mau than at Tra Vinh, indicate that the organic matter is of more detrital nature there. It should be noted that this detrital organic matter is a vital medium for the activity of heterotrophic bacteria consuming oxygen.

A paradoxical difference between the two ecosystems concerns suspended matter (TSS). From a hydrodynamic point of view, we could have assumed that the stronger Mekong influence in the Tra Vinh ecosystem, as attested to by lower salinity in that system, would have consequently favoured high mineral particle concentrations there. The origin of the greater amount of suspended matter in the Ca Mau system may be in great part due to boat traffic, which is much more intense at Ca Mau than at Tra Vinh. In line with this, it was observed that the highest concentrations in TSS were located on the main navigational routes, channels and streams of Ca Mau. The high TSS concentrations may also be due to mangrove deforestation in the Ca Mau ecosystem, leading to increased coastal erosion.

The primary production values measured under strictly identical incubation conditions did not show up any significant difference between the two sites. In fact, the value given in our study corresponds to the primary production potential and not to the primary production which could have been measured *in situ*.

Therefore, it seems that even though the primary production potential was identical in the two ecosystems, the *in situ* primary production in Ca Mau was certainly limited by the effect of suspended particles, and all the more so when TSS concentrations are higher.

Concentrations of heterotrophic bacteria were in keeping with values seen in intensive shrimp farming ponds, i.e., where there was organic matter input due to feed pellets. We can assume, in view of the bacterial abundance measured in channels and rivers, along with the low oxygen concentrations measured overall in both ecosystems, that the Ca Mau and Tra Vinh ecosystems are developing heterotrophically.

> The lower oxygen concentrations at Ca Mau may have been related to higher TSS concentrations, which limit light penetration and therefore the autotrophic activity. In these ecosystems, the oxygen consumption linked to bacterial activity was higher than the oxygen production linked to photosynthesis. It should be noted that the oxygen measurements were taken during the period which was assumed to be optimal for oxygenation of the environment at that time, i.e. in the afternoon.

The silica concentrations measured at Tra Vinh were higher than those measured at Ca Mau. We can assume that they favoured the development of diatom populations there, making one of the most efficient levels, in terms of transferring matter from primary to secondary consumers, in the development of the food web.

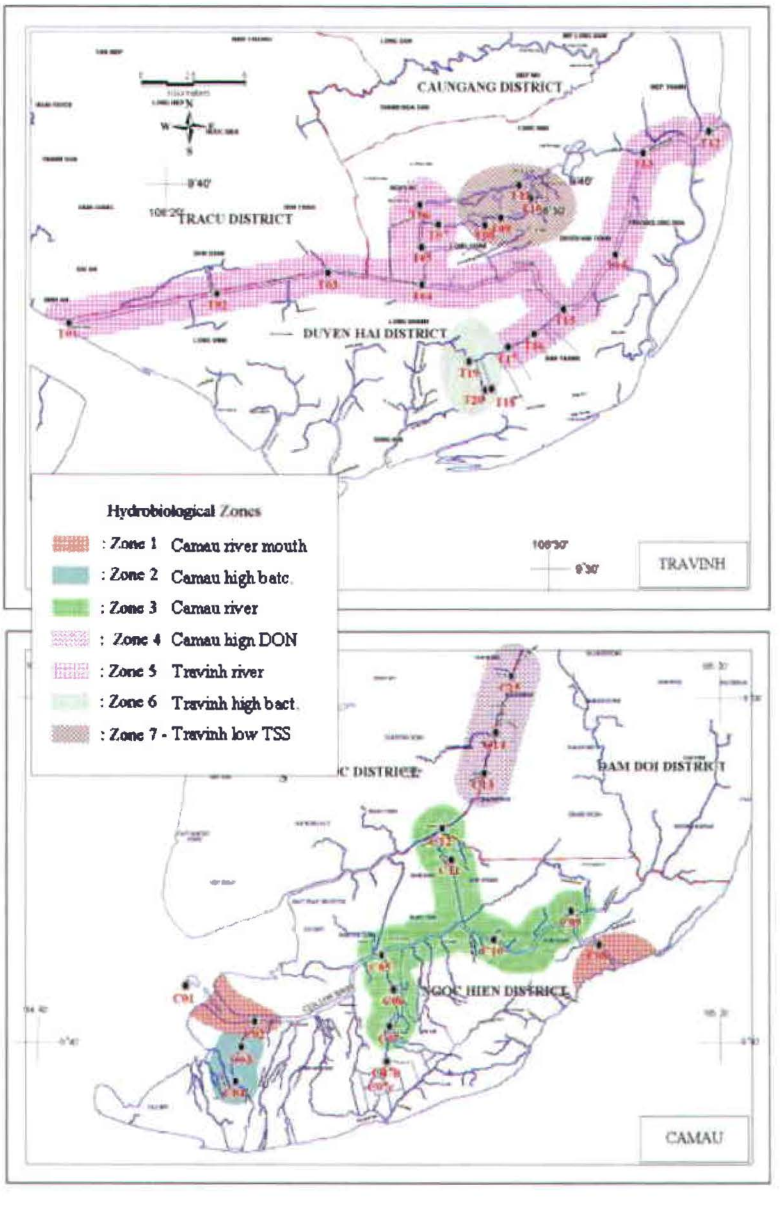


Figure 4.2:Eco-hydrological zones in Tra Vinh and Ca Mau

4.3 The Confinement index: a preliminary ecological descriptor

Studying ecological and hydrobiological characteristics in coastal environments is both a costly and time-consuming activity, all the more so in the Mekong Delta's extremely complex hydrological structures. For shrimp development planning, determining an easily-measured index to represent the ecological and hydrobiological features of the environment was of particular interest. The idea of confinement in the aquatic environment can be expressed as the ability of the water to renew itself at a given location by way of hydrodynamic currents. This capacity involves some physical aspects (water renewal capacity), as well as some ecological aspects (phytoplankton, chlorophyll, O2, heterotrophic bacteria). In fact, the ecological characteristics of an aquatic environment are greatly dependent on its hydrodynamic characteristics. The CI must therefore be checked against these two types of criteria.

Figure 4.2.1. Various Confinement Index conditions, from the highest (pictures a and b), to the lowest (picture d).

4.3.1 The physical aspects of confinement

For shrimp aquaculture, confinement is a drawback when waste elimination, a key aspect in more intensive systems, is required. However, it may be an advantage if it means reduced turbulence and turbidity (hence better light penetration), especially in extensive systems, as is the case here. The confinement index (CI) was tentatively taken here as the ratio of the "hydraulic distance" to the sea to the square root of river cross-section at high tide. In Ca Mau cross-plots of the CI versus both maximum instantaneous discharge values and residual flows computed at 10 stations where hydrodynamic model outputs were also available (see 2.3) denoted a good agreement, especially on secondary channels. These trends provided a result

that tallies with common sense. This was to be enhanced by the correlations in hydrobiology, where the likely effect of reduced turbidity in confined stations followed higher values of primary production (PP). These observations confirmed that the CI could be used as a "proxy" ecological indicator.
In Tra Vinh, no hydrodynamic model outputs were available. The hydraulic conditions there are simpler than in Ca Mau, due to identical tidal conditions on either side of the Tra Vinh peninsula and also a much smaller channel network.

4.3.2 Confinement and environmental parameters

There is a fundamental ecological difference between extensive farming that takes organic matter out of the environment and intensive farming that puts organic matter into the environment (faeces, uneaten pellets). For extensive farming, the environment must, above all, be productive enough to develop a trophic web providing sufficient natural prey in the ponds for the shrimp to feed.

One parameter which appears to be essential for succesful aquaculture is expressed in the notion of confinement. In the case of extensive aquaculture this means supplying the nutrients necessary for the trophic web to function. Figure 4.3.2 shows the relationship between the degree of confinement, the ecosystem features and its capacity to support a given type of aquaculture. The confined areas are those with less energy, and a high capacity for accumulating particles and organic matter. In these dystrophic areas, the development of extensive aquaculture will not be productive, in fact its performances could even be nil, insofar as the trophic web which can develop in this sort of water will be essentially bacterial, and therefore not at all favourable for the development of shrimp's prey. In addition, a bacterial-type development in the environment and then in the ponds, will result in significant lack of oxygen which is harmful for farms.

However, to develop extensive aquaculture, the environment must be sufficiently rich in nutrients and phytoplankon to support the development of the food web. This is why major shellfish producing zones, based on the natural production in the wild, are always located in areas with a double characteristic: i) their location is under river discharge (nutrient supply) and ii) they are located in semi-closed areas (bays) which allow a sufficiently long water retention time to enable the expression of primary production, but also enable sufficient seawater renewal to maintain appropriate salinity and avoid dsytrophic bacterial development in the environment. This pattern is valid for any type of extensive aquaculture.

So developing an extensive type of aquaculture requires the right balance between nutrient and organic matter supply in a given ecosystem and the speed at which the water of the ecosystem is renewed.

This balance appears when looking at the measured parameters. The PCA carried out using all the parameters for the dry season highlighted significant correlations in Tra Vinh between the CI and several parameters (Table 4.3) expressing the metabolism of the organic matter, i.e. primary production, Chl-a, BOD, and heterotrophic bacteria.

The organic fraction in the TSS (% SOM) was also correlated to the CI ($r = 0.8208$; $P < 0.001$). This clearly demonstrates that the mineral fraction decreased as the CI increased. What is more, the positive correlation between the CI and CHl-a ($r = 0.8152$; $P < 0.001$)

shows that the phytoplankton concentration in the sestonic pool rose as the confinement increased.

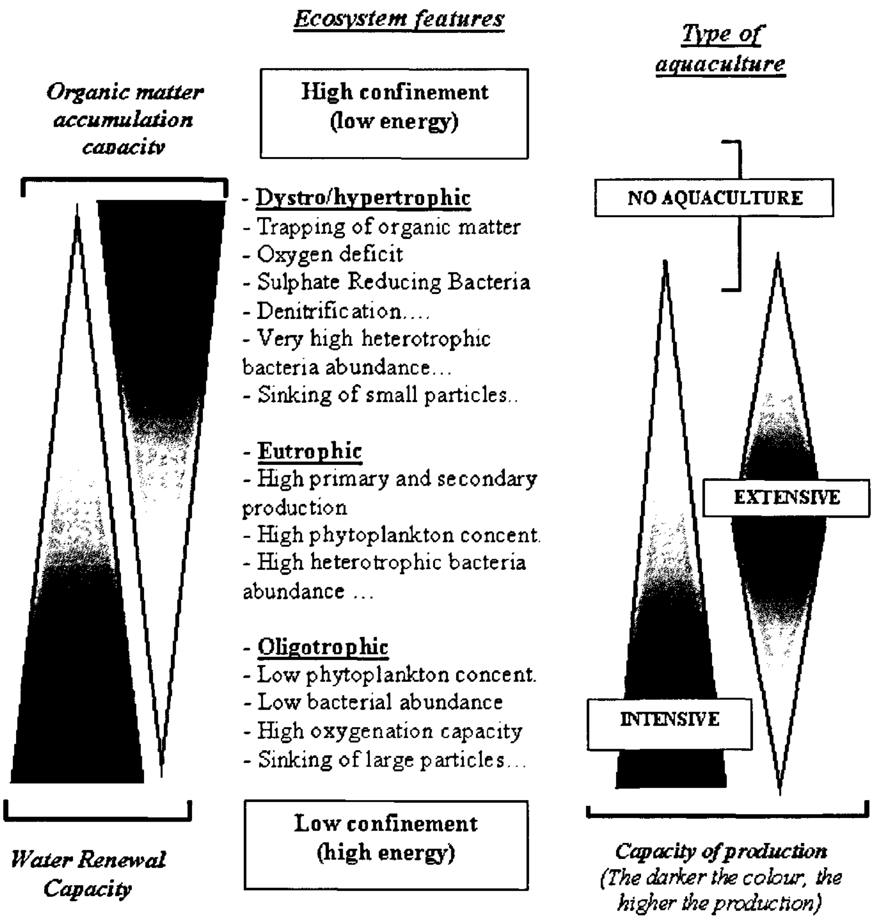
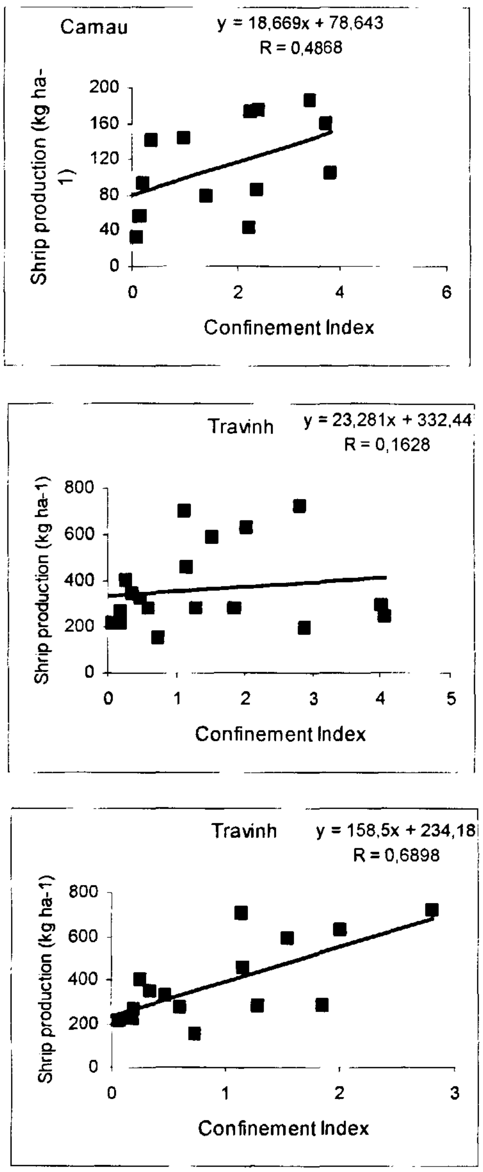


Figure 4.3.2: Positioning of the different types of aquaculture, and their potential performances, according to the trophic characteristics of the environment.

Table 4.3. Correlation coefficients between CI and various parameters for Ca Mau et Travinh ecosystems and both seasons (dry and rainy)

	O2	TSS	%SOM	HB	Chl-a	P.P	BOD	DON	%DON
Travinh Mars 2002 (DS)	-0,7786 P < 0.001	-0,5883 P < 0.01	0,8208 P < 0.001	0,7800 P < 0.001	0,8152 P < 0.001	0,8633 P < 0.001	0,8358 P < 0.001	0,3080 NS	0,5960 P< 0.05
Ca Mau Mars 2002 (DS)	-0,3907 NS	0,3959 NS	-0,2192 NS	0,4191 NS	0,3077 NS	0,3683 NS	0,6515 P < 0.05	0,5663 P < 0.05	0,1316 NS
Travinh Octobre 2001 (RS)	-0,4545 P < 0.05	0,2715 NS	0,0224 NS	NA	0,6122 P < 0.01	0,6022 P < 0.01	0,7087 P < 0.001	NA	NA
Ca Mau Octobre 2001 (RS)	-0,5096 NS	0,8013 P < 0.001	-0,8092 P < 0.001	-0,0122 NS	-0,1990 NS	0,1961 NS	0,6182 P < 0.05	NA	NA

4.3.3 Confinement and shrimp production



The study of the correlations between CI and yields was done for the dry season only. Figure 4.3.3 shows the relations between the confinement index and shrimp production during dry season. For the Ca Mau ecosystem, no correlation was observed ($P > 0.05$). For Tra Vinh, two situations can be examined. Indeed, Figure 4.3.3b at first does not show any significant correlation between the confinement index and production ($P > 0.05$; $r = 0.16$). Stations T18, T19 and T20 feature high CIs, and could be distinguished as a group of stations with particular characteristics in terms of O2 deficit, heterotrophic bacteria concentrations and BOD.

When they are taken out, a significant correlation appears ($r = 0.68$, $P < 0.01$) between the confinement index and shrimp yields (Figure 4.3.3c).

Figure 4.3.3: relationship between CI and shrimp yield during the dry season
(a)in Ca Mau ecosystem
(b)in Travinh (all stations)
(c)in Travinh without stations T18, T19, T20

4.3.4 Discussion

The ecological structure of coastal ecosystems depends on their capacity to renew their seawater and to accumulate and/or eliminate the organic matter and natural or anthropogenic nutrients. These characteristics (water renewal, capacity to accumulate organic matter and nutrients) will determine the environment's trophic status and therefore its ability to sustainably produce living organisms in either extensive or intensive farming. The confinement index was established on the basis of hydrological and geographical criteria and can indicate each station's water renewal capacity. The results obtained for Tra Vinh in the dry season and rainy seasons appear as "ecologically" logical and in agreement with knowledge about the metabolism of organic matter, bacterial activity and primary production. It seems that at Tra Vinh, confinement acted as a « settling » factor for mineral particles, by enabling greater expression of primary production, as seen by the increase in chlorophyll (and therefore phytoplankton) in the water column.

In the Ca Mau ecosystem, the parameters measured in the dry season showed little correlation with the CI. It seems that confinement was not a factor which favoured the settling of mineral particles from the environment. It may be that this ecosystem was disturbed by too high concentrations of suspended matter (particularly induced by heavy boat traffic and bank erosion).

When the Tra Vinh stations with a high CI were left out of the calculation, positive correlations were seen between the shrimp yields and the PP and Chl-a. The significant correlation between primary production and yields leads us to believe that PP could be a determining factor in yield performances. It has been shown that in earthen ponds even on (semi) intensive farms, the higher the natural prey production the higher the shrimp yields. Shrimp feed first on natural food such as the meiofauna and only eat feed pellets when the natural food becomes insufficient. We can effectively assume that too marked confinement can cause the deterioration of the enviromental quality for shrimp farming purposes. So the highly confined stations at Tra Vinh (T18, T19, T20) the environmental conditions are not satisfactory for either extensive or intensive shrimp farms.

The Ca Mau ecosystem, due to its geographical location at the tip of the delta (i.e. a place where mineral and organic particles carried by the Mekong build up) is a special ecosystem which appears to be disrupted by mineral matter pulled away from canal and river banks by boat traffic. These conditions certainly degrade the performance of the (mainly extensive) shrimp farms. It also appears that good performances cannot be obtained by the use of feed pellets which would result in increased organic waste both inside and outside of the ponds and thus nurture heterotrophic development rather than primary production development.

As a conclusion, it appears that the confinement index can be a useful indicator giving a reliable presentation of environmental characteristics, at least for the Tra Vinh ecosystem, where it correlates to the main parameters related to primary production and organic matter metabolism. However, this type of index must be refined and used carefully.

Chapter 5 : Shrimp farming practices and performance

The purpose of this chapter was to analyse shrimp farming practices and economy in the 2 areas in order to (1) quantitatively evaluate the performance of shrimp farming in terms of short and long term economic and social viability under environmental constrains (2) qualitatively assess the relative weight of technical practices and collective action on this performance (3) propose and recommend improvements at the farm and collective levels.
Although socio-economics can indicate dysfunction in shrimp farming (through the costs structure), it often measures the consequences and not the causes of this dysfunction. One of the main reasons remains the unknown ecological characteristics of the shrimp farms' environment. The detailed analysis of farms located on hydrobiological stations can overcome this constraint and assess the different influences of internal and external factors on shrimp farm performance.

The first step was to define suitable farm technical levels due to the high diversity of existing techniques and practices over the Mekong Delta, as well as the gap between official appellations and technical realities. Thus, we saw more of a technical continuum rather than a clearly established technical segmentation all along the study area. A farm typology based on practices was therefore necessary to assess the relative influence of practices on farm performance. For statistics, the multivariate analysis method that was applied could describe the relationship between farm characteristics and their similarities.

Once practices had been identified, farm performance was measured. Both were validated through a wide general survey (500 farms surveyed) to ensure the representativeness of practices and zootechnics (technical systems, yields, farm management, etc.). Farm performance was measured through the economic performance rather than yield which is too simplistic and not indicative of sustainability. Then a cost-benefit analysis was applied and a farms typology with respect to economic performance was drawn up from the analysis. The economic performance was mainly measured through the profit rate and cost structure. All indicators were reported to the Kg of shrimp produced, with values in VND (17,000 VND to the € in 2003).

5.1 Shrimp farming practices

The same way Ca Mau and Tra Vinh appear quite different in terms of hydrobiology, farm typology is also really particular to each site. It shows that technical systems do adapt to the environmental conditions. This highlights significant constraints and adaptation of technical systems to the environment. The environment will naturally set an upper limit for shrimp farming potential, but it also illustrates a local tendency to impose technical feasibility in a fragile and less favourable environment compared to other areas in South-East Asia (surpassing environmental constraints through technical improvements). In the current institutional and socio-economic context, environmental characteristics appear to be the key determining factor for shrimp farming sustainability to orientate techniques and practices.

In the sampled area in Ca Mau, pond water management is often based on water change after one and a half month, whereas adding water is more the rule in Tra Vinh. Water filtration, PL acclimation, pond preparation or stocking juveniles are also far more developed in Tra Vinh than in Ca Mau. The technical choices (mixed systems vs. specialised systems for instance) are also representative of farmers' limited knowledge, their tendency to copy each other and their investment capacities (access to input and capital), outside of topographical constraints which may also be a limitation.

The Tra Vinh province is more homogenous and intensive than Ca Mau in terms of technical systems. The surveyed farms were mainly improved extensive and semi-intensive farms highly specialised in *Penaeus monodon* culture, whereas the farms sampled in Ca Mau ranged from mixed mangrove / shrimp to improved extensive, with some paddy / shrimp farms. Tra Vinh is more intensive on average than Ca Mau and yields are also higher with respective means of 370 Kg/ha and less than 125 Kg/ha (dry season 2002) on the sampled farms. But this is not really seen through the stocking density, which usually is the real indicator of technical choice. SD in Ca Mau is often as high as in Tra Vinh for less intensive systems, the farmers' belief being that "the more you stock the more you will get". This again underlines the lower technical knowledge and efficiency in Ca Mau.
The choice for multiple crops and pond structure also distinguish Ca Mau from Tra Vinh, but it mainly remains based on technical choices driven by the environment and access to inputs in terms of land, capital and knowledge, etc.

In terms of seasonal management, the first detailed survey conducted in 2001 underlined the high risk attached to the rainy season (respectively 280 and 182 Kg/ha/Dry against 220 and 32 Kg/ha/Rainy for Tra Vinh and Ca Mau). The collapse rate and non profitable crops increased greatly, especially in Ca Mau where 85% of the sampled farms were not profitable in the rainy season (Table 5.1). In addition to environmental conditions, the risk of collapse is reinforced by lack of knowledge and inadequate equipment and infrastructures. That leads farmers to a vicious circle, with an incentive to overstock in the dry season and to stock in the risky rainy season to counterbalance dry season losses, instead of giving up shrimp farming in the risky season. The same behaviour is encountered within a given season with favourable and less favourable stocking times.

Table 5.1: seasonal farm profitability

	Dry season		Rainy season	
	Non profitable	Profit > 0	Non profitable	Profit > 0
Tra Vinh	36%	64%	59%	41%
Ca Mau	37%	63%	85%	15%

Gambas detailed survey – 2001

5.2 Farm performance

Based on technical-economic variables, two main results are found:
- there was no linear relationship between economic performance and zootechnical performance; SD and yields were also not always linearly related;
- polyculture or multispecies culture was a key factor at low to intermediate intensification levels in ensuring farms' profitability.

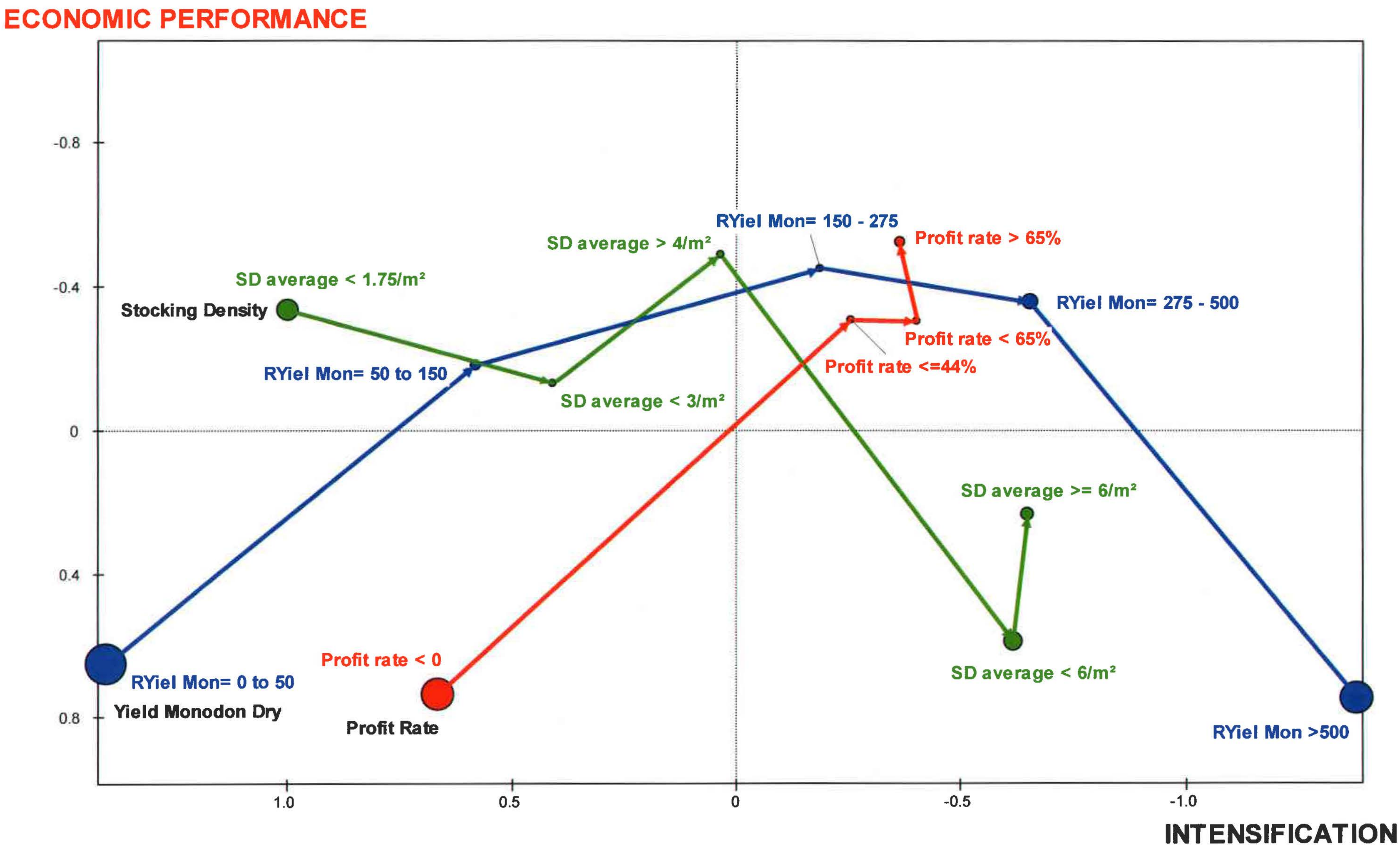


Figure 5.2: Projection of multivariate analysis variables based on zootechnical and economic variables

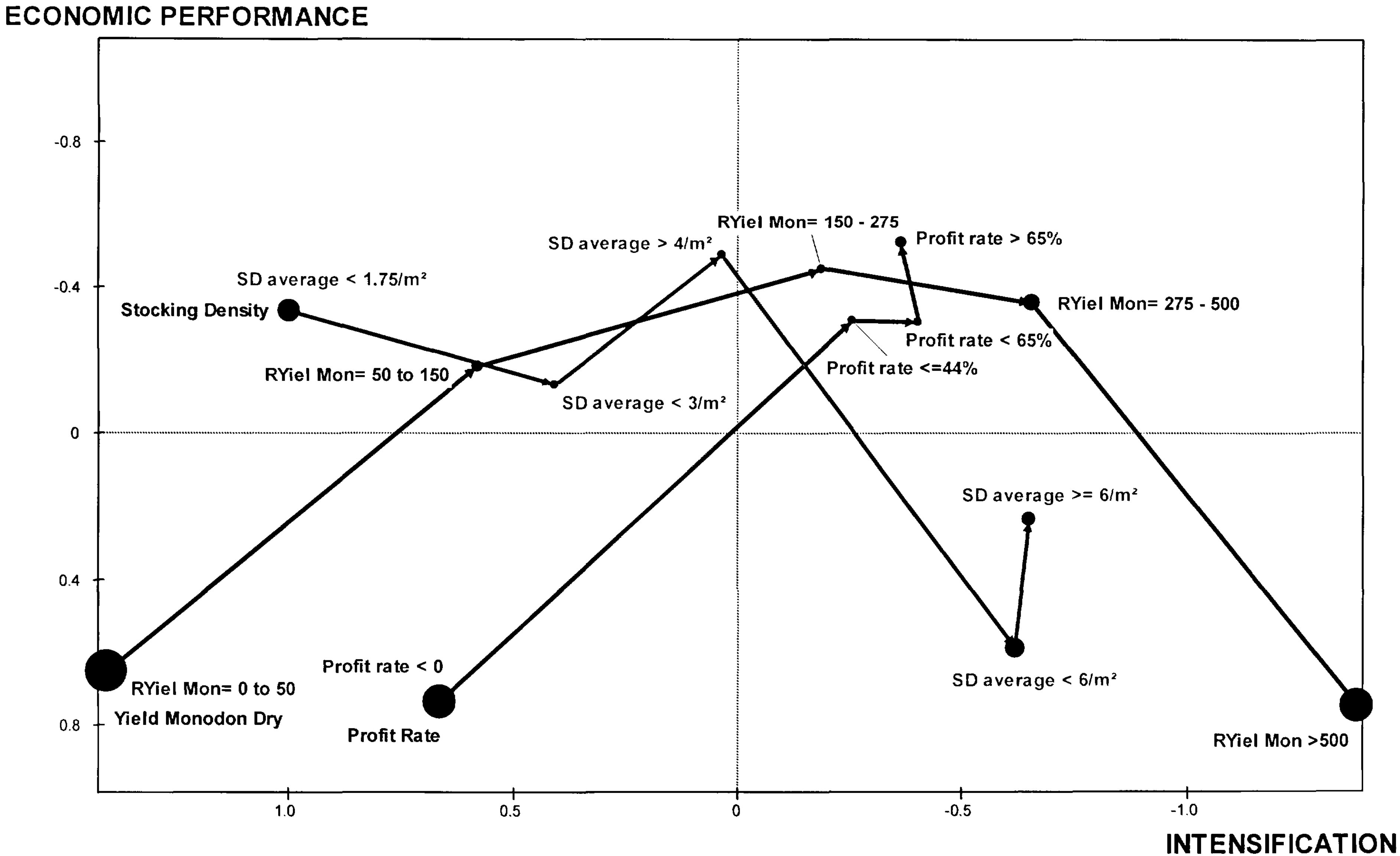


Figure 5.2: Projection of multivariate analysis variables based on zootechnical and economic variables

This is well illustrated by the graphic representation (Figure 5.2) of a multivariate analysis based on zootechnical and economic variables. Factorial methods aim to reduce the data tables' dimensions in order to represent the relationships or associations between individuals and between variables in smaller spaces. This was particularly useful in the present study, where more than 200 variables per farm were gathered.

The left and right sectors of the graph are strongly represented, respectively by the Tra Vinh farms with the highest yield and the Ca Mau ones with the lowest yields. The upper sector is representative of specialised farms in *Penaeus monodon* culture whereas the lower sector features polyculture and multispecies culture. The horizontal axis can be read in terms of intensification direction and the vertical one in terms of economic performance.

Most of the Ca Mau and Tra Vinh farms are well discriminated and contrasted in terms of technical performance and intensification, but a number of them also showed similarities in economic performances. The trajectory of the profit rate (or economic performance, in red), is orthogonal to the trajectory of zootechnical performance variables (in blue). When all data were analysed, this orthogonality was even higher and illustrated the non-colinearity between economic performance and yields, if collapse cases are left out.

These results in terms of economic performance are not paradoxical. While extensive systems can balance out low yields by low operational costs, intensive techniques have to reach high yields to overcome high operational costs. However, these facts are often ignored or under-estimated by the stakeholders who mistake sustainability for technical efficiency. It also highlighted strong variability in production and performances on the same technical level. For a same level of yield a wide spectrum of performances (both technical and economical) can be observed. Lastly, the culture of wild species such as *Penaeus merguiensis* and *Metapeneus spp* remains the basis for profitability for many mixed farms in Ca Mau as illustrated by the zero Break Event Point (BEP, i.e. the profitability limit in terms of minimum yield to be reached) of Monodon species for these farms.

5.3 Farm performance according to technical system

Seven groups of farms were identified, on the basis of their zootechnical and economic performances. These groups were not given the official technical appellations (e.g. extensive, semi-intensive, intensive, etc.), as they sometimes included several techniques. Table 5.3 (in order of SD) and Figure 5.3 (in order of profit rate) sum up the main characteristics in terms of economics and zootechnics. Note that these data refer to one "reference pond" considered by the farmer as the best one on his farm. Table 5.3 and Figure 5.3 illustrate in detail the non-linear relationship either between technical efficiency and economic performance (profit rate) or between yields and economic performance. Within the typology, several groups are of particular interest:

Groups are illustrated on Figure 5.3 by crossing their economic performance (profit rate) and their yields. It brings out the non-linear relationship either between technical efficiency and economic performance (profit rate) or between yields and economic performance. Thus, best technical efficiency farms are not always best economic farms, as well as most intensive farm. On the opposite, low intensive farms can also present very good economic performance.

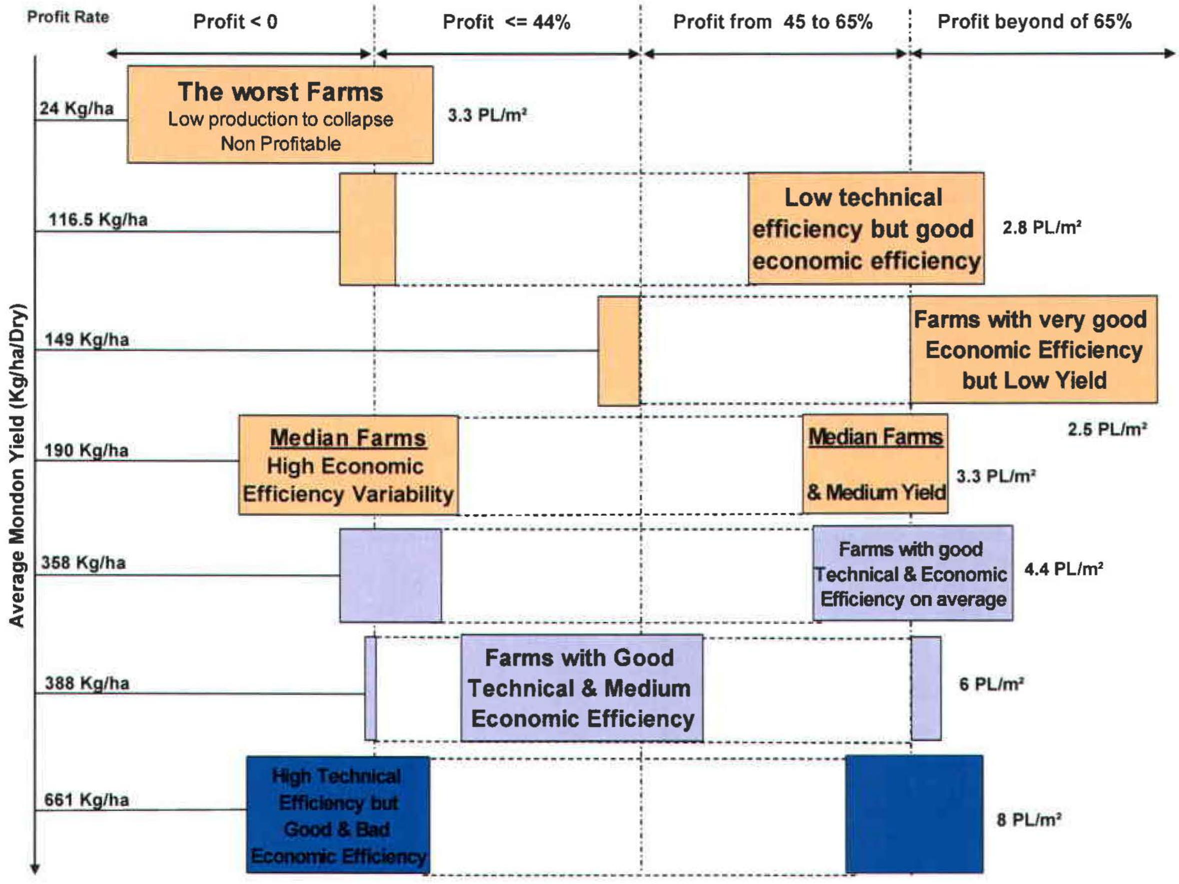


Figure 5.3 Typology of farms' performances based on technical and economic criteria

Within the typology of farm performance typology, several groups are of particular interest:

i) The worst farms were mainly located in Ca Mau and belonged to the mixed shrimp-mangrove system. They underwent strong and generalised collapses. As they did not catch and grow wild shrimp, their economic losses were high. Faced with an unfavourable environment, they also showed lacks of knowledge and poor management for one of the highest stocking density related to this technical system. This, combined with the use of feed, strongly increased their total costs for no apparent gain.

ii) Farms with low technical efficiency but good economic efficiency were also located in Ca Mau and belonged to the mixed shrimp-mangrove system. Although they were characterised by low survival rates, they also had limited pond preparation and sometimes combined culture of wild shrimp with a higher water exchange rate, in order to catch wild juveniles and adults. This, along with very low costs, allowed them to be profitable.

iii) Farms with very good economic efficiency but low yield are the last representatives of the Ca Mau mixed shrimp-mangrove system, located in the same area. Even though the technical efficiency remained low, it was the best of this kind of production system for the lowest stocking density. Use of very little or no feed kept costs very low. Culture of wild species (383 Kg/ha/dry season also showed by the lower income per Kg) strongly increased profitability, since it could ensure the entire farm profitability in case of Monodon collapse (Break Event Point of monodon = 0 Kg/ha/dry season).

iv)Farms with high technical efficiency but good & bad economic efficiency presented the highest yields of the sample and also the highest technical level (more than 661 Kg/ha/dry season and an average of 8 PL/m^2). These farms were located in Tra Vinh. The high variability in profit rate seems to be due to environmental causes as these farms are mainly located in two different ecological environments (zones 5 and 6). In terms of practices, the farms with low economic performance were more intensive, as they had to stock more PL (over 10/m^2 when on the same area other farms stocked 4-5 PL/m^2) and use more inputs than good economic farms to reach the same level of yields. This overuse of inputs strongly affected their operational costs. Marginal cost was then higher than marginal income related to the marginal increase of production.

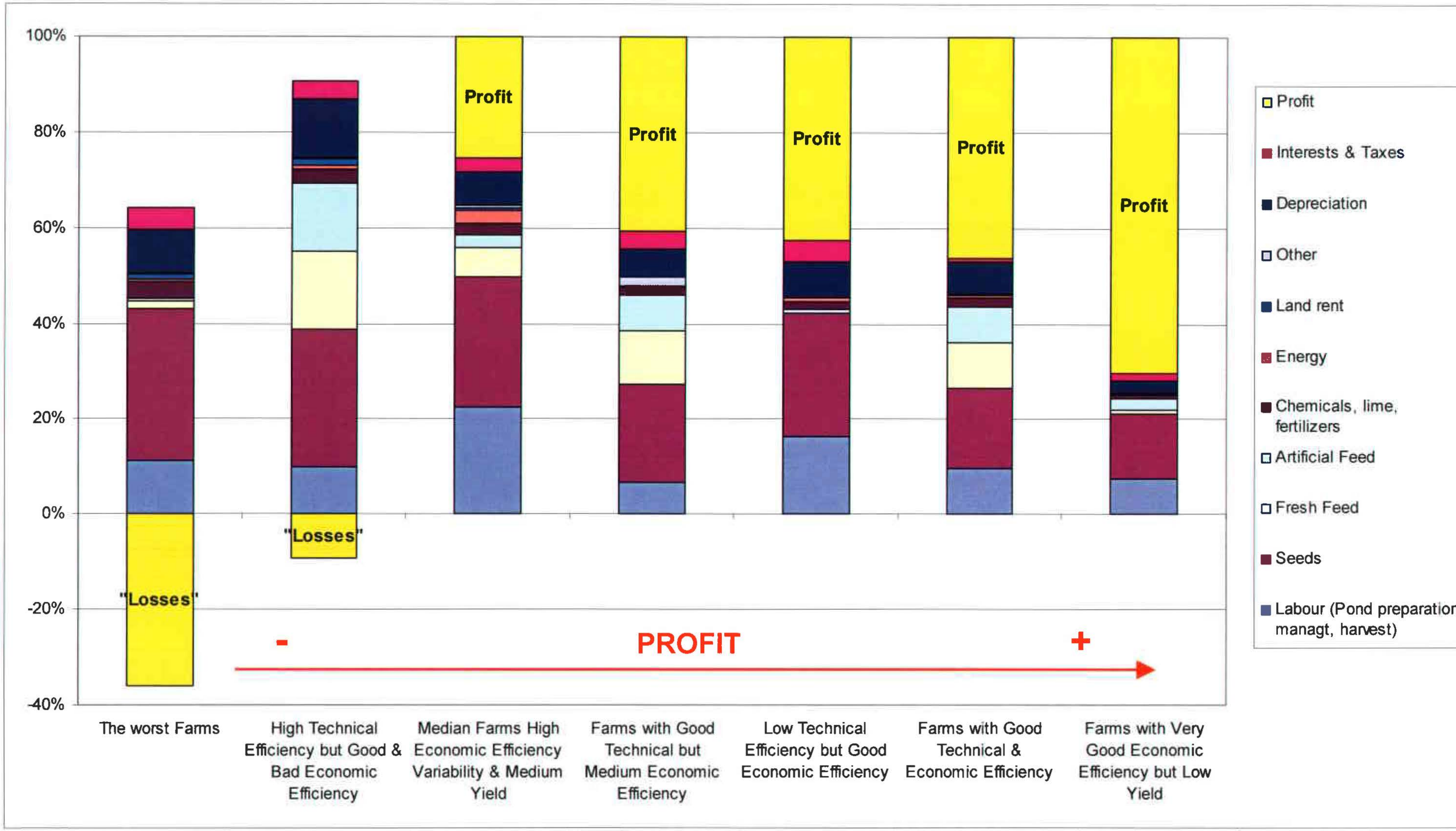
v) "Median Farms" with high economic efficiency variability and medium yield exhibit a broad range of performance. These farms were scattered over Ca Mau and Tra Vinh, with respectively average good and bad economic efficiency. The Ca Mau farms were semi-extensive and mixed shrimp-mangrove systems and the Tra Vinh farms were semi-extensive and semi-intensive systems.

5.4 Farm performance in the light of practices

When both practices and economics are taken into account, the only reliable conclusions will hold for a specific environment. Mixed mangrove-shrimp systems illustrate it with i) the importance of polyculture in the households' income, ii) the inefficiency of feed input and too high SD when compared to low investment capacity and knowledge and iii) less favourable environment for shrimp culture.

The key zootechnical criteria found in the survey were:
- the importance of pond preparation and alternative use or rest during rainy season. Many farmers neglect this preparation step and stock their ponds in very risky conditions;
- overstocking in pond designed and managed for a lower stocking density;
- the way PL or juveniles are acclimated varied greatly and was largely insufficient;
- water management. Topping up water rather than exchanging it seems to get better results but this cannot be implemented by all techniques (water exchange is required to catch wild species, for instance).

The farmers' knowledge in both zootechnics and in economics terms also seemed to be crucial. Among all the farmers sampled, 90% have no idea at all of their production costs and remain price takers with respect to middlemen. Among the 10% who had an idea of "how much it cost to produce 1 Kg of shrimp", less than 2% forecast their production cost with margin error of 20%, all others underestimated it with a factor from 2 to 20.



Mixed Shrimp Mangrove Ca Mau & collapses Tra Vinh	Semi Intensive & Intensive Tra Vinh	Wide diversity of techniques CM/TV in Semi-Ext.	No clear identification overstocking S-E	Mixed Shrimp Mangrove Ca Mau	Improved Extensive Tra Vinh (+CM)	Mixed Shrimp Mangrove Ca Mau

Figure 5.4: Costs and revenue structure of production systems / based on costs per Kg for dry season 2002

Table 5.3: Main technico-economic indicators of production systems

	Farms with Very Good Economic Efficiency but Low Yield	Low Technical Efficiency but Good Economic Efficiency	The worst Farms	Median Farms with High Economic Efficiency Variability & Medium Yield	Farms with Good Technical & Economic Efficiency	Farms with Good Technical but Medium Economic Efficiency	High Technical Efficiency but Good & Bad Economic Efficiency Farms
Farm ponds area(ha)	**2.1**	**1.7**	**1.7**	**1.4**	**1.1**	**2.5**	**0.7**
Reference pond area (ha)	**2.1**	**1.6**	**1.7**	**1.3**	**0.8**	**2.1**	**0.4**
Pond number	**1.0**	**1.1**	**1.1**	**1.3**	**1.8**	**1.1**	**2.0**
Nb of crops in Dry season	**3.8**	**3.6**	**3.3**	**3.0**	**2.5**	**2.4**	**2.0**
Stocking Density (PL/m²)	**2.5**	**2.8**	**3.3**	**3.3**	**4.4**	**5.8**	**7.9**
Average Yield Monodon per crop (Kg/ha/dry season)	**57.3**	**51.4**	**9.0**	**127.2**	**204.5**	**342.2**	**519.4**
Yield Monodon Dry (Kg/ha/dry season)	**149.1**	**116.5**	**24.0**	**189.7**	**358.4**	**387.6**	**661.2**
Yield Wild shrimps dry (Kg/ha/dry season)	**383.1**	**47.0**	**n-r**	**91.3**	**34.2**	**46.0**	**171.3**
Average Technical Efficiency (Kg/1,000 PL)	**3.2**	**1.6**	**0.3**	**4.1**	**4.6**	**5.7**	**8.0**
Average Survival rate	**8.7%**	**4.0%**	**0.9%**	**16.2%**	**17.7%**	**16.4%**	**30.1%**
Profit rate	**62%**	**43%**	**-133%**	**11%**	**38%**	**38%**	**"-66%"**
Profit/Kg (1,000 VND)	**45.5**	**44.4**	**-115.5**	**21.3**	**42.6**	**39.9**	**"-9.9"**
BEP based on Monodon (Kg/ha/dry season)	**-28.2**	**63.7**	**110.4**	**169.4**	**158.1**	**331.7**	**123.0**
BEP based on Wild shrimps (Kg/ha/dry season)	**337.5**	**444.0**	**635.4**	**679.2**	**480.0**	**1530.4**	**260.5**
Ratio Artificial feed cost/total feed cost	**n-r**	**n-r**	**n-r**	**29%**	**40%**	**37%**	**43%**
Shrimp income/kg (1,000 VND/Kg)	**58.5**	**98.3**	**81.6**	**80.6**	**89.7**	**95.8**	**83.5**
Ratio Income fish & crab/Total income	**7.3%**	**4.9%**	**4.7%**	**3.8%**	**3.4%**	**1.8%**	**0.9%**

Beyond environmental factors, it was also quite difficult to isolate trends in best practices, such as pond size or pond depth. In fact, at the same ecological station, 4 farms could be found with the same technical and intensification levels, the same zootechnical performance and close economic performances, but using 4 different practices. Overall, it can be said that in the present situation, the impact of the practices implemented by shrimp farmers was lower than the environmental criteria. But on the other hand, in such an environment, inappropriate practice quickly leads to bad harvests anyway.

From a precautionary point of view in the framework of the two areas studied, the project's socio-economic strand aimed to pinpoint the most economically efficient practices and techniques (inputs management) which were equally efficient, technically speaking, and the most environmental friendly. This led to recommending a mixed shrimp-mangrove system with polyculture and SD not greater than $2PL/m^2$ for the South of Ca Mau and SD lower to present in Tra Vinh's main river channel.

5.5 Farms economics and practices in the local social and institutional context

The purpose is not to take position in favour or against an industrial development versus an small holding development. Both respond to different public choices and raise different technical choices. The purpose is to study different schemes of sustainable development in a particular context, i.e. a deltaic environment, an economy in transition, a specific institutional framework. The impacts and consequences of tropical penaeid shrimp aquaculture are now well known and well documented.

5.5.1 At the local level

Although the farmers are quite hostile to the word "collective", due to past events, there is strong potential for collective action all the same. Farmers often don't wait for central or local government initiatives and there are numerous examples where they have compensated for government's inadequacy. This is a keystone of sustainable development, since shrimp farming is based on a joint resource management. Several problems can be addressed at this level: use conflicts with other activities (paddy, fisheries, water uses, thefts, etc.), access to knowledge and training, access to capital through tontine systems, external expertise, and massive inputs supply for economies of scale etc. Some examples of concerted action zones for shrimp culture exist in Tra Vinh (co-management) and this pilot zone should be studied more in depth and compared to Ca Mau. Currently, the potential for collective action is largely underused.

The farmers always blame failure on external elements: water pollution is always put forward as the main cause of collapses. They are reluctant to accept advice for improvement from extension services. Technical choices for ponds are mainly guided by suppliers who also provide loans. This raises a real issue for public policy:

Should pond management be left under outside influence or should a real policy be developed to disseminate knowledge, thus allowing farmers to run the farms under their own initiative in accordance with public goals (local development and spin-offs, access to knowledge)?

5.5.2 At the regional level

Tra Vinh and Ca Mau present two different development profiles (Tra Vinh is more based on local investors) and different policies. Thus, objectives and goals are different between Tra Vinh, a province presenting a very limited area for new development and wishing to intensify farms to aim at higher production levels, and Ca Mau focussing all attentions due to its large potential area. But both of their strategies share a common vision of decision-makers with respect to shrimp farming: farming is thought of in terms of production volumes and foreign currency revenues rather than in terms of production quality and local consequences (local employment and redistribution of wealth). The former options can be questioned as an important part of inputs, knowledge and investments are imported from other Asian countries. These two options meet two different goals: strong local development versus more centralised management targeting exports.

Compared to other agriculture activities such as rice farming, shrimp culture is far ahead in terms of turnover, but remains quite far behind in terms of redistribution of wealth (general survey 2002).

Concerning the potential areas and their uses, wetlands are often viewed as wastelands. Although the role of mangroves is now fully recognised, there is still a lack of studies and methodologies to assess their real value from direct and non direct uses (problem of non commercial goods).

A final, large problem encountered on both provinces is the planning of shrimp farming. Planning seems to be made with hindsight, since it simply validates the endogenous development. Planning based more on participative policy and involvement of local population would provide stronger approval, a feeling of legitimacy and greater compliance.

5.5.3 At the international level

Local producers and public regional stakeholders have no or really little idea about the shrimp market. The producers act as price takers and their long term activity is not based on or established to match the international market. Local and regional boom-and-bust cycles have maintained the world shrimp farming production between 800,000 to 1,000,000 tons/year, representing 25 to 27% of the world shrimp production. Today shrimp farming has to face several new threats.

The first one is a strong lobbying by environmental NGOs against shrimp culture development and its impacts, as well as public decisions (like the ban on coastal shrimp aquaculture in India by the Supreme Court). An increase in world production, no longer regulated by local collapses, would strongly impact the world price. There is no sign of evidence that local stakeholders are either aware of such a threat or willing to take it into consideration. They do not realize that due to high mobility outside investors can move to another speculative activity, as opposed to insiders who have very little mobility.

Diversification (such as organic aquaculture, as an answer with a higher added value) could be a path for development, especially in the Mekong Delta. Long-term economic development cannot reasonably be based on shrimp culture there. Alternative or complementary activities (like farming species with a lower market value but whose production is less speculative and more reliable) will have to be considered. This holds true for all tropical aquaculture with high value added species (pearls, etc.).

5.6 Discussion

Through the socio-economic study of shrimp farming, the most important issues being currently debated in international fora appear.

The first one is the key problem of the distribution of benefits from shrimp, on which almost all shrimp farming development policies are articulated. Balancing between more shrimp and/or less environmental degradation, most governments support more shrimp culture while believing benefits will contribute to restoration or preservation through BMPs for instance. In Vietnam most of problems are given technical answers without enough consideration to economic and social problems that can balance the technical success. There's an evident lack of global vision by the Vietnamese shrimp industry stakeholders.

The positioning of the rent deduction for the government influences the evolution and the development of shrimp farming as well as its impacts. In Vietnam, like in most countries, this deduction is located at the export level as it is easier to tax at the end of the production process and much easier to control (no VAT at the farm gate). There is then a support to increase the global production but less attention is paid to the way of producing. In spite of public authorities being aware of environmental issues, this distribution system lets the driving forces set up and makes for the maximisation of yields per unit of available area. In this context, such objectives as foreign currencies, poverty alleviation and environmental protection are difficult to combine, in spite of strong will such as the SAPA strategy.

Without anticipating on the global data integration, the ecological environment is not suitable to intensification and not so suitable to shrimp farming regarding to other but less valuable alternative activities on short run. It question the soundness of an economic development based on shrimp farming in the Mekong delta. In a context where investment capacity and access to knowledge remain quite weak, there is an abundant literature underlining that in spite of an economic growth due to shrimp culture, the disruption increases between people and conduct to more poverty due to the distribution system. This distribution system issue, also related to the exclusion of a part of the population from the benefits of the activity, is key for sustainability.

At the local level, property rights and especially land status appear as a key factor to ensure shrimp farming development by restricting access to the activity. Collective action is also stronger at the farm level and is a key issue for public policy success. By palliating and balancing State deficiencies and giving a more important legitimacy to planning, it can also ensure a stronger enforcement of the existing and numerous regulations related to environmental protection. One of the major stakes is then to create a self enforcement in a context of poor means of public capacity to enforce regulation. More down-top decision making process, as well as development of incentives and participative process, would also enforce a better planning. More globally, the study of the governance of the shrimp industry in the Mekong delta needs to be more in depth investigated as it reveals the suitability between the main driving forces and the institutional arrangements.

As many other producing countries in South-East Asia, Vietnamese shrimp industry hits first market problems. This is mainly due to the cross effect of antidumping policy from the United States and the European Union and the strong increase of production with seasonal or punctual over capacity (technical sustainability, switch from *Penaeus monodon* to *Penaeus venamei*, renewal of the Chinese production). The potential for shrimp production remains strong according to the consumption, but not at the same price conditions than today and many stakeholders still neglect this aspect. In a context where the shrimp price will probably decrease to some relatively low levels, the announced objective is to reduce costs.
In terms of the industry implication potential in R&D, most intensive techniques are a priori the most favoured to act on a factor price competitiveness. Extensive farms run under quasi-fixed costs and have then a low potential to reduce them. On the same way, the success of extensive farms characterised by low costs and organic production is also questionable on long run in terms of labelisation at a global level, compared to more intensive farms with stronger investment capacity in R&D. In Mekong delta, from an environmental point of view, the ecosystem is few favourable to intensification and even in case of significant intensification and on short term, it would be difficult in the Vietnamese context to develop a strong investment capacity in R&D to increase productivity and competitiveness.

At last, an important lack of farmers' knowledge and inappropriate practices according to their intensification level are noticed on most surveyed farms. This extension services have the knowledge so basic improvements in farming practices should be easily implemented. But there are difficulties to disseminate suitable and accessible information to farmers. This is partly due to an evident lack of means but also to training courses not ill-adapted to farmers' education level and to lack of on site training. Time scale is also not enough taking into account in pilot projects which are implemented and disseminated without knowing their performances and consequences on long term.
In addition the extension services do not liaise enough with the research sector. Such services should also be developed in or depending on universities and research institutes in order to take into account the different field constraints.

Such a context leads to the question of the industrial organisation and its capacity to face the next stakes and threats related to shrimp farming. This leads to worry about shrimp farming in Mekong delta under such conditions and governance system.

Chapter 6 : Synthesis and recommendations: towards sustainability

6.1 Methodological approach for synthesis

The approach to sustainable development, be it for shrimp farming or any other activity, requires a convergence of social, economic and environmental objectives (Figure 6.1).

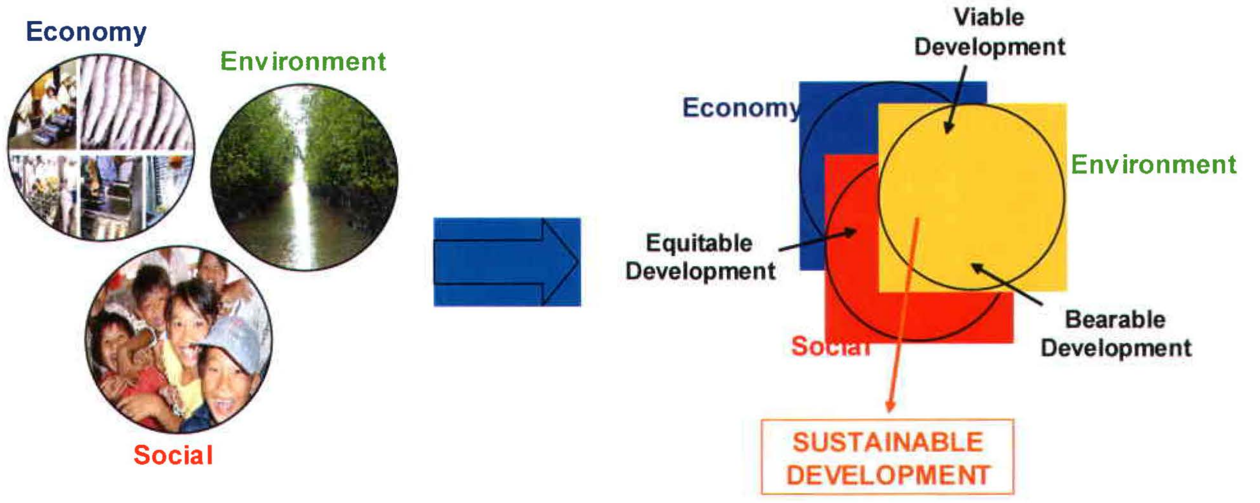


Figure 6.1: requirements for sustainable development

The challenge for Gambas was to succeed in integrating and analysing all the parameters for the time scales and levels of collection which were sometimes quite diverse, from the farm to the ecosystem. However, taking hydrobiological stations as the common basis for different activities made it possible to integrate the data. Multivariate analysis was the statistical method used, enabling both the processing of qualitative variables and establishing relations of proximity between the various parameters.

There were a few restrictions to this approach. The first one was related to the limited number of farms in some hydrobiological areas, which could raise problems of representativeness. A technique-based characterisation was hindered by the wide range of practices within the sample. Therefore, since there were no clear technical boundaries to differentiate the farms, so the typology of practices was based on socio-economic activities. Another limit concerned the high degree of diversity which characterised the two provinces studied, and more generally the Mekong Delta.

6.2 Statements per hydro-ecological area

A multivariate analysis was conducted on each of the areas, pinpointing farm performances and type of management. Two main trends were isolated using this approach.

6.2.1 Zones with no relationship between practises and performance

This was the case for Ca Mau zone 4, and Tra Vinh zones 5 et 7 (see figure 4.2), where farms exhibited a broad variety of practises for either good or bad performance. However slight differences were noted in management modes: i) stocking time in Ca Mau : wait for Têt and avoid stocking after June, ii) pond depth in Tra Vinh's main channel (deeper than 0,70 m), iii) more generally a clear tendency to over-stock. This was shown by the better performance obtained for intermediate stocking levels: below 1,7 PL/m^2 in rice-shrimp in Ca Mau (with no use of feed), 3 PL/m^2 in Tra Vinh main channel (appearing as the less risky option), and 4 to 6 PL/m^2 for Tra Vinh zone 7 (featuring low TSS). On this latter zone, higher stocking density (around 9 PL/m^2) seems to lead to failure.

Conclusions on parameters influencing performance were difficult to reach. For these three zones, although some marginal technical parameters give a few clues, the environmental factors seemed to prevail.

6.2.2 Zones with clear relationship

This was the case for Ca Mau zone 2 and Tra Vinh zone 6 which both feature high bacteria concentrations (figure 4.2). As these zones presented more constraining environmental features, the relationship between performance and practise was likely to stand out more clearly. In Ca Mau, the farms belonged to the mixed shrimp-mangrove system. Practises clearly distinguished good farms from bad ones. The latter only reared Monodon (no wild shrimp), they had very basic or no pond preparation, they stocked juveniles instead of PL. On the contrary, the better farms relied quite a lot on wild shrimp, which ensured farm's profitability. They opted for even lower stocking densities (below 1,5 PL/m^2 in average) and stocked PLs (instead of juveniles), with significant acclimation time. Pond preparation consisted in longer drying time and the use of lime. Far from being innovative, these practises resorted to common sense: the farmers tended to respect the environmental capacity.

In Tra Vinh zone 6 (zone with excess organic matter), there was a very high diversity of practises and the performance was Tra Vinh's worst one. All the farms renewed water through gravity. Here as well, intermediate stocking density figures provided better results (e.g. 2.2 PL/m^2).

Lastly, Ca Mau zone 3 ("Ca Mau core") was difficult to characterise from all standpoints. It exhibited mean values that were close to the overall mean values and consisted in both mixed shrimp-mangrove and shrimp/paddy. The only hint given by the analysis there is that stocking density should be kept low around 2 PL/m^2.

For all zones in Tra Vinh and Ca Mau, water management by "topping up" gave better results than "water exchange" but of course, it could not apply to e.g. the mixed shrimp-mangrove system.

6.3 Overall direct analysis (analysis in fluctuating environment)

Compared to the previous approach, the overall analysis allowed a comparative analysis between hydrobiological zones and/or techniques. It mainly brought out results on Ca Mau mixed shrimp-mangrove farms and on Tra Vinh farms.

6.3.1 Mixed shrimp-mangrove farming

The previous results stood out here in more details. The farms belonged to two hydro-ecological zones and practices seemed to play a major role. These two zones appeared unsuitable as failures already occurred even at low intensification levels. More than practices themselves, the choice to farm wild shrimp was essential to ensure farm profitability. Collapses occurred in the following conditions: highest stocking densities, obvious lack of pond preparation, inadequate structure and insufficient knowledge. Yet the best farms did not reach more than about 149 Kg/ha (dry season), which therefore can be regarded as the upper limit in terms of *Penaeus monodon* yield (Figure 6.3).
The goal for this system is threefold: i) to generalise the idea of low operational costs, ii) to reduce risks by providing additional income based on wild shrimp culture, and iii) to decrease stocking density. Shrimp so produced with almost zero costs could be a candidate to eco-labelling, thanks to their intrinsic quality. However, the issue of the impact on the wild stock of such a kind of aquaculture is raised. In brief, the adverse environmental conditions preclude better efficiency based on technical improvements, however costly they may be.

6.3.2 Tra Vinh semi-extensive and semi-intensive farms

Outside of the particular ecozone with high bacteria (zone 6), performances are more balanced in Tra Vinh: either higher yields (661 Kg/ha/dry season on average) with a very wide range of profitability, or reasonably good yields (from 358 to 388 Kg/ha/dry season on average) with good economic performances.

By combining all the parameters in the analysis, it appeared that the farms located in low TSS and vibrio area (zone 7) were those with best yields and best economic performances at the same time, whereas those located on the main river show lower performances. This cluster of most successful farms on the limited area of zone 7 denotes a likely environmental cause. To reach the same yields, farms by the main river (zone 5) tend to increase their stocking density (10 PL/m^2 and more) and feed trays. The consequence is heavier operational costs for the same income, leading to very bad profitability.

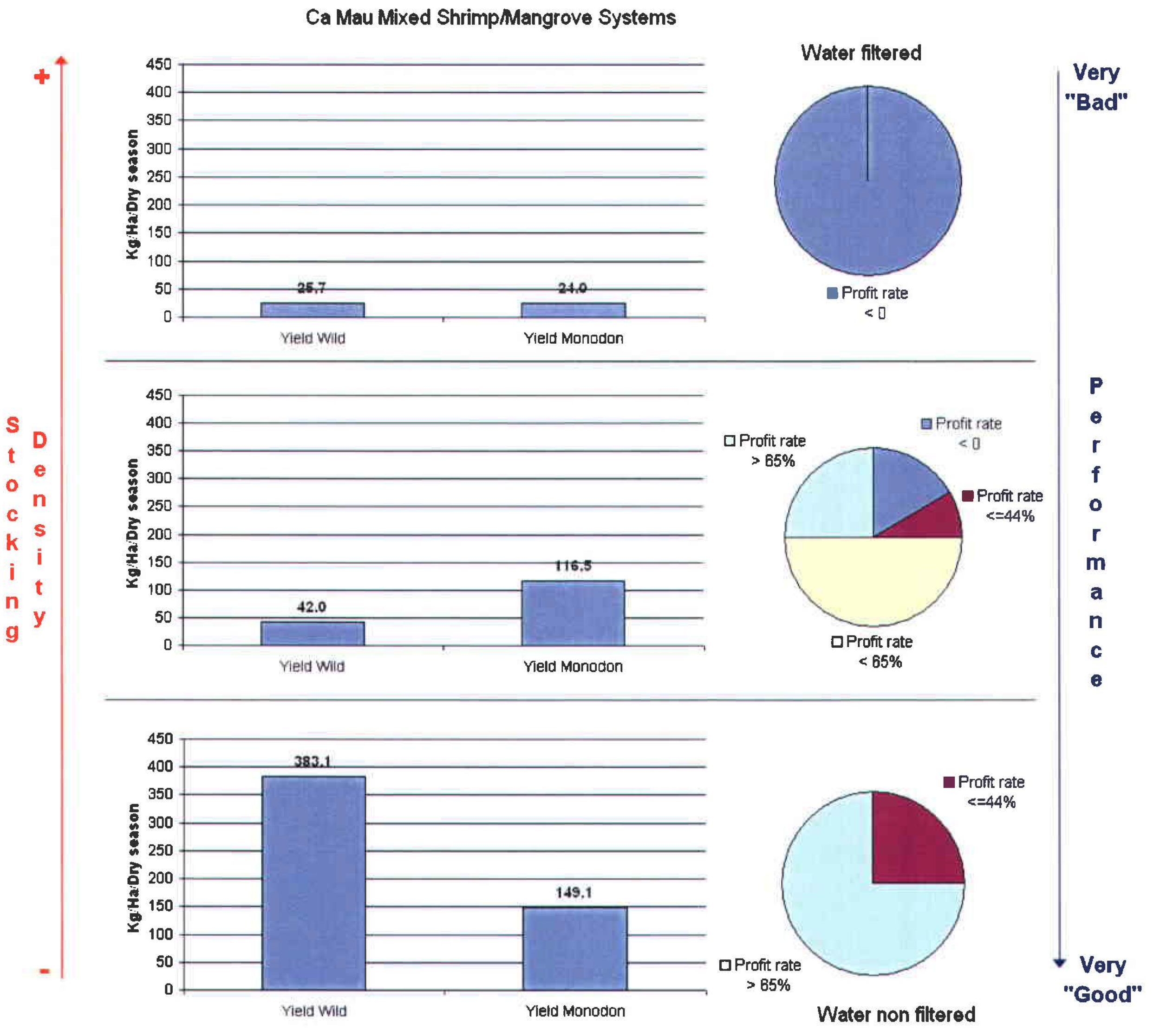


Figure 6.3. Ca Mau mixed mangrove-shrimp systems' performance

While zone 7 farms enjoys an "environmental rent", it is striking to see quite a contrasted situation in zone 5 between i) farms trying to catch up with the latter by overstocking without reaching profit, ii) neighbouring farms with lower yields but higher profitability (below 4 PL/m² on average for an average yield of 358 Kg/ha/dry season).

Nevertheless, zone 7 should not be thought of as suitable location for intensification. It should be recalled that there is no linear relationship between confinement and intensification. The confinement of zone 7, while positive to extensive systems, would rapidly lead to limits in terms of waste elimination if intensification was to be carried out.

Other aspects of practices such as water management, pond structure etc., while they seem to have a local impact (for instance water topping up instead of water exchange), only have a marginal effect on performances. Except for very local specificity, farms' performances seem to be driven by the environment, which sets up the admissible production potential. It is an obvious fact that malpractice will generate bad performance.

6.4 Recommendations for sustainability

How can sustainability of shrimp aquaculture in the Mekong Delta be achieved? In accordance with the project's title, we should first address the question of how to reach shrimp farming sustainability, i.e. how to profitably practice shrimp aquaculture in a long-term perspective without challenging the site's capacity to accommodate an aquaculture activity or its natural, ecological role.

6.4.1 Choosing monitoring environmental indicators

As has appeared in the conclusion of the hydro-ecological study, a set of key indicators can be suggested as follows: CI (confinement index), pH, salinity, TSS, BOD, Vibrio, DO.

These indicators are assumed to provide planners with a suitable "snapshot" of the prevailing conditions for environmental appraisal in case of site selection or suitability assessment. They are also low cost and can be provided by regular certified local laboratories.

Here is a quick description of the specific contribution of each of them:

- the confinement index has been shown to a good proxy for the assessment of the confinement, a factor favourable to extensive aquaculture, but adverse to more semi-intensive activities where waste assimilation is necessary. However, this confinement index ill-functions in a place like Ca Mau where the environment is locally disrupted by external facts (in this case boats traffic).

- salinity, pH and dissolved oxygen are fundamentals in terms of shrimp preferendum

- TSS load has been described as the main drawback to the development of primary production, a key factor in extensive aquaculture which is heavily dependant on the natural food web,

- BOD denotes the intensity of the bacterial activity, which consumes oxygen at the expense of phytoplankton (mostly diatoms).

- the concentration of vibrio reveals disease hazards: their activity is triggered by stress appearing among shrimp stock for a number of reasons: salinity shock, oxygen depletion, lack of meiofauna, etc...

At the shrimp farm level, mangroves near or inside the ponds have some negative effects on shrimp growth. The so-called "separate shrimp-mangrove" model should be fostered, especially where profits are mostly expected from wild shrimp stocking. Even though these artificial mono-specific mangroves are trapped in a rather constraining network of dykes and embankments, they would participate to restoring wild seed recruitment.

6.4.2 Selecting a suitable farming system

For further planning operations and procedures, as well as identifying what kind of farming system should be encouraged in a specific area, an environmental survey and sampling based on these few key parameters should be carried out. The project tested a sampling procedure and trained people to either perform it or to transfer it to operators in other technical organisations. After processing the set of samples, it is possible to position it among the standard environmental types established in the Gambas project.

The methodology is illustrated by figure 6.4. The seven proposed indicators are ranked according to their similarity to the project's samples by way of a statistical test. A computer tool is provided to establish the environmental characteristic of the sampling zone. The 7 ecological indicators are recorded and the software reveals the standard environment identity. This leads to recommending the most suitable farming system for a given zone. This could be useful in further planning operations to help in decision making during planning operations, and local technical adviser in identifying the appropriate advises to provide a farmer already settled. Table 6.4 shows these recommendations, along with practices, profit and risk data.

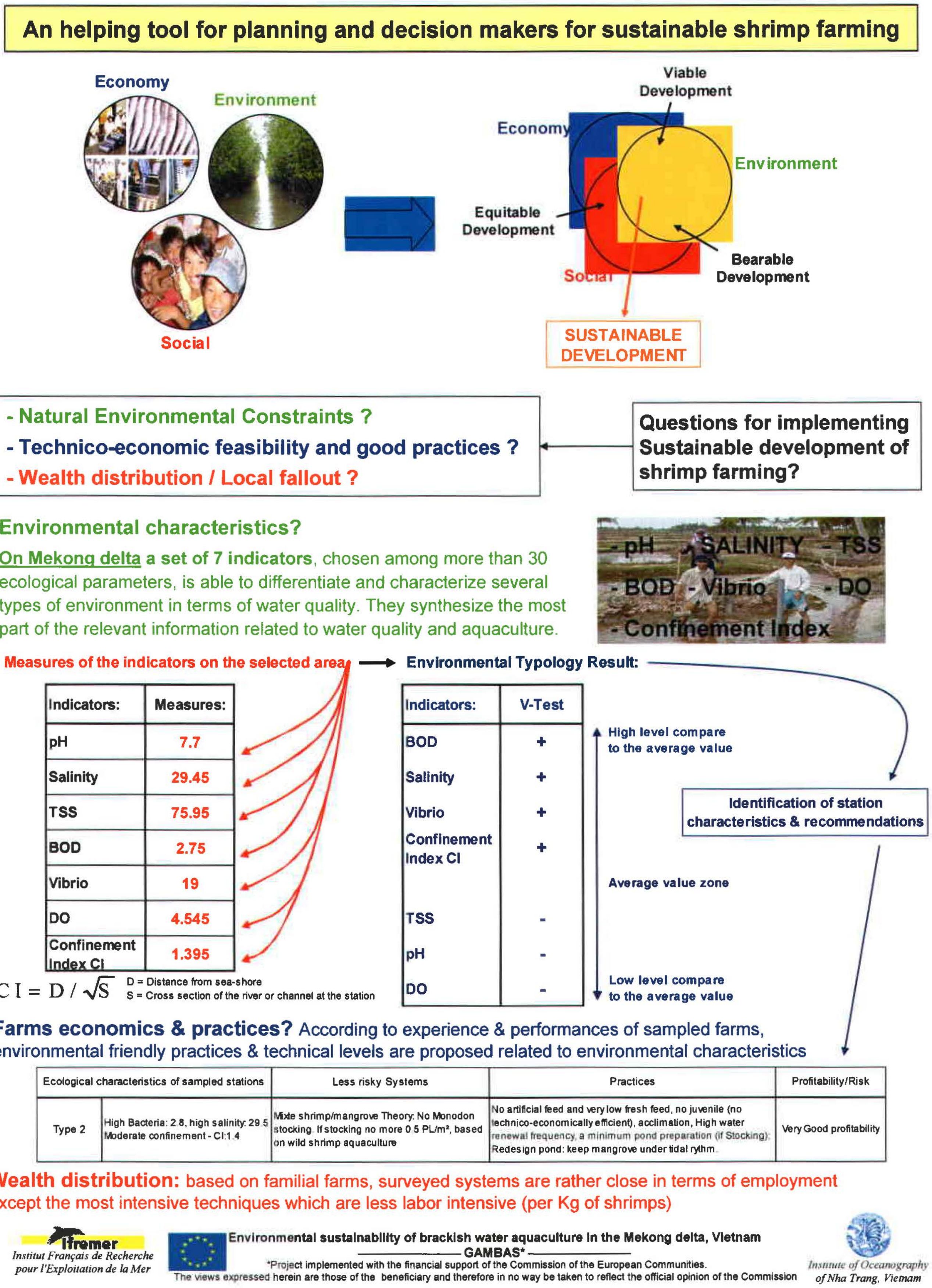


Figure 6.4. Poster representation of the site ecological appraisal procedure

Table 6.4.1. Recommendations for technical systems according to hydro-ecological zone

Ecological characteristics of sampled stations		Less risky systems	Practices	Profitability/ Risk
Type **1**	*Marine like stations* *Low confinement - Low CI: 0,07*	Area thought to be more suitable for more intensive systems		High costs/risky
Type 2	*High Bacteria counts: 2.8* *High salinity: 29.5* *Moderate confinement - CI:1.4*	Mixed shrimp/mangrove Theory: Monodon stocking up to 0.5 PL/m², based on wild shrimp aquaculture	No artificial feed and very little live prey, no juveniles (not technically/economically efficient), acclimation, High water renewal frequency, minimum pond preparation (if stocking); Redesign pond: keep mangrove under tidal rhythm.	Good profitability possible
Type 3	*High TSS: 290, high salinity: 27.7 high Vibrio counts: 18.7, Lower BOD & DO (0.8 & 4.8)*	Theory: no semi-extensive system; Mixed Shrimp/Mangrove	Stocking density kept low, mixed shrimp/mangrove systems: same as type 2 zone but SD = 1 PL/m²; semi-extensive: 2 PL/m².	Good profitability possible
Type 4	*Confined: 3.6, high DON: 436, high salinity in dry season (29) and very low salinity in rainy season, high BOD: 2.4, high Vibrio counts: 21.4*	Shrimp/paddy	Reduce number of harvests (2 to 3), SD <= 2PL/m², no chemicals or artificial feed, no stocking in June	Good profitability
Type 5	*Low DON: 116, low confined:0.5, low salinity: 17.9, low BOD: 0.6, low vibrio counts: 6.4*	Semi-extensive (S-I too risky)	Stocking density <= 4PL/m², also growing wild shrimp, pond depth > 0.70 m	Good profitability
Type 6	*Low TSS: 31, Low salinity: 19.4, low Vibrio counts: 4.5*	S-I	Water supplements throughout the rearing cycle (no water exchange)	Variable profitability
Type 7	*High Bacteria counts: 3.7, confined: 3.2, low salinity: 19.7*	Semi-extensive under restriction	SD< 2.5PL/m², water top-up	Lower profitability

6.4.3 Technical recommendations

It was observed that, within the same environmental unit, the farms which had the worse results (in profitability and yield) were those with high post-larvae stocking densities. Moreover, surveys and data correlations proved that: i) stocking should be avoided from June to August, ii) an acclimation period significantly influences the success of farms.

In farm systems where only the Monodon species was grown, the studies determined that pond water management based on regular supplements had a better impact on profitability than that using large water exchanges.

In mixed shrimp-mangrove systems, mainly in Ca Mau, the recommendations would be:

- remain at low intensification level for *Penaeus monodon*, between 1 and 1,5 PL/m^2 (2 PL/m^2 is the official recommendation but it is rarely applied);
- carry out basic pond preparation;
- let the ponds dry out during the rainy season (with possible catches of wild species once in a while when tides are suitable);
- avoid stocking juveniles (the extra cost, compared to PL, does not bring any extra income);
- avoid artificial feed and reduce fresh feeding; they strongly increase the operational costs with no evidence of better efficiency;
- combine Monodon culture with wild shrimp culture;
- redesign mangrove conservation scheme so that its natural and ecological role is restored, with positive effect on wild stock.
- For all zones in Tra Vinh and Ca Mau, water management by « topping up » gives better results than water exchange but of course it cannot apply to e.g. the mixed shrimp-mangrove system.

6.4.4 Recommendations in terms of farm socio-economics

Since profitability is one of the pillars of sustainable development, it is a key argument in recommendations resulting from the Gambas studies. Economic performance was measured through profit rate, i.e. the proportion of profit to total income (it is neither representative of total production nor of farm income levels).

What is important is to assess the way shrimp are produced rather than the volume of production. This is well illustrated by the following statements: i) in Ca Mau, Mixed shrimp-mangrove farm profitability was guaranteed by wild shrimp. Monodon stocking had a negative impact on profitability, ii) in Tra Vinh yield could not be the only way to guarantee economic profitability.

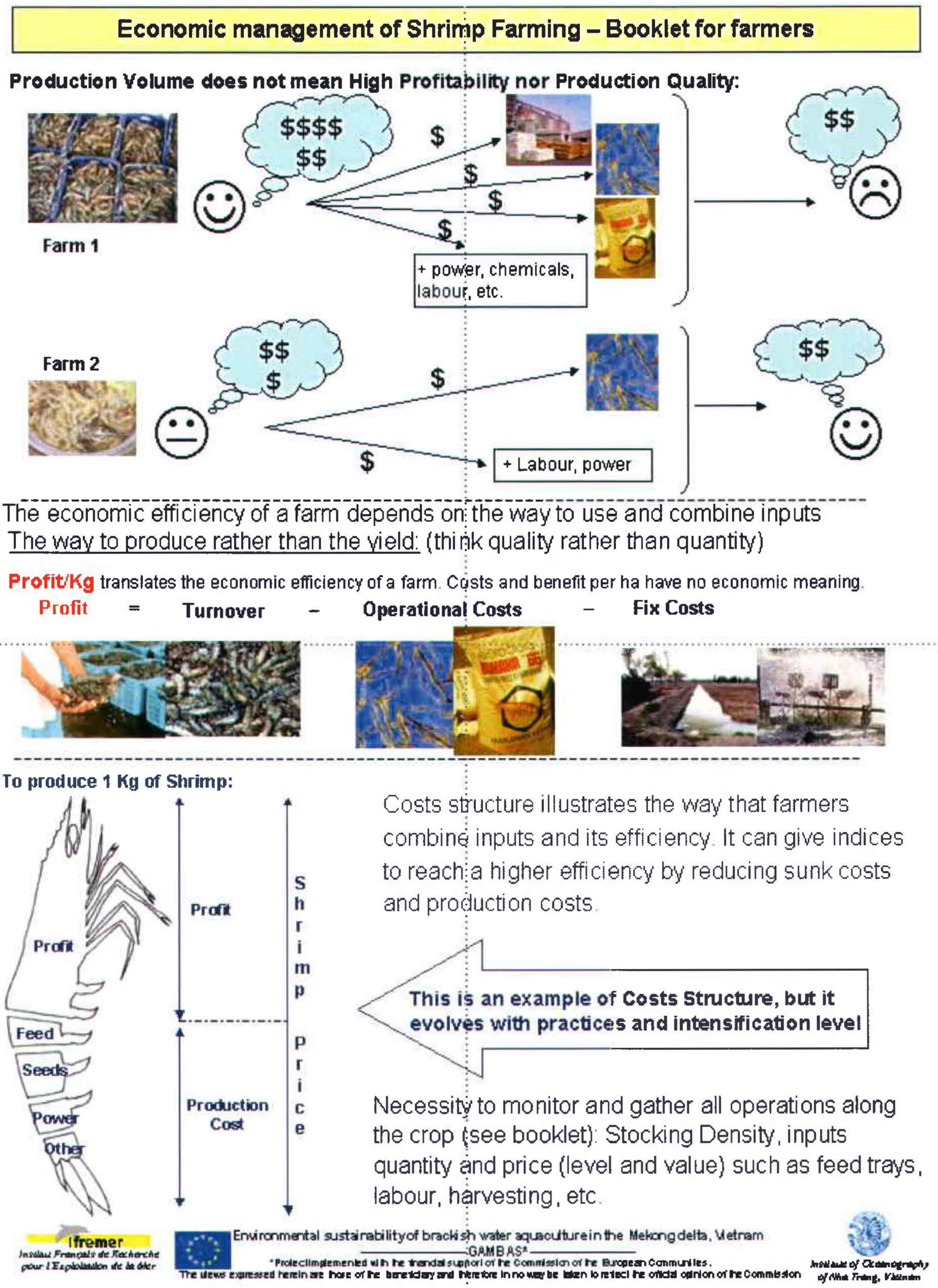


Figure 6.4.4. Poster representation of the booklet for farm economic management

This was the case of semi-intensive farms with high stocking densities. To get a satisfactory household income, production will have to increase in the same proportion as profit.

Gambas has provided a simple combination of basic economic indicators to raise farmers' awareness about economic monitoring of their activities that should lead them to adopt the most sustainable farming system. This means that local knowledge transfers and services rendered by local officers should include both technical advice and economic basics. Of course, this economic monitoring cannot be disseminated and put into use by local farmers overnight. It will be part of a long-term cultural aspect to be included in the training of people working in shrimp production, and in the advice provided by local technicians or fisheries officers. Gambas included a first round of training in the regions of Ca Mau and Tra Vinh, targeting these people and farmers.

In a suitable ecological environment, for public policy-makers who have to foster local development, the choice is between i) high production level per unit area (intensive systems) versus ii) low intensive systems but more important local spin off. To help them out, labour per Kg of shrimp produced and Added Value (what is produced by the farm) are interesting quantitative indicators to measure the social impacts of shrimp culture.

Recommendations expressed above are mainly based on common sense management rules that are currently encountered in rice culture. The transition to village economy based on shrimp culture has often led to a desegregation of collective structures, due to high private benefits arising from shrimp farming. The speculative behaviour ("lottery logic") often observed in endogenous development is associated to an intensification trend that goes beyond farms' usual infrastructures as well as current farmer's knowledge. More active training in environmental issues appears as a corner stone to ensure farms sustainability.

6.4.5 Assessing the socio-economic impact of shrimp farming compared to that of other activities in the same area

Shrimp farms ability to reach profitability is not the only thing to be taken into account during a planning decision-making procedure. Depending on the farming system, the socio-economic impact may not be the most profitable at the level of the community concerned in the area. Some tools were proposed to assess this impact.

In planning procedures, 3 parameters could be used jointly to choose the most sustainable options:
- Break Even Point (BEP = minimum yield to reach profitability)
- Profit Rate (Profit/income)
- Labour multiplier (assessing system performance with respect to social impact).

Profitability, socio-economic and environmental impact should be assessed in comparison with traditional activities or others possible in the environment (rice, fruits, vegetables, woods, fauna). Besides, a mono-specific farming activity presents higher risks than a diversified system. A farm should have a second type of crop to make it less economically vulnerable to seasonal events and market variations.

6.4.6 Improving human resources, knowledge and skills

Many shrimp farmers are new to the activity. They are former rice or other land-crop farmers, who used to apply common sense rules in their everyday practise. Switching rapidly to high instant profitability shrimp activity made them loose this sense. Very few have had access to any training or can self-train from technical publications. They often obtain knowledge empirically, from their neighbours or suppliers. The latter are likely to provide advice more in line with their own business interests. Thus it has been observed that the farming techniques employed by numerous farmers are not based on rational farming system procedures that take into account the environmental characteristics. Local technical officers are needed to give advice for technical improvements and economic bases to meet a true public policy objective of enabling sustainability. Several past and on-going training and dissemination projects have been observed to date.

> Sharing of experience and better coordination could provide high added value and impact in the field. Training appears as a fundamental issue for sustainability. To provide training effective application of planning choices, many more extension officers are required. Too few farmers can benefit from such service or too rarely. This creates a situation where middlemen and suppliers can promote the farming systems which are most favourable for their own business, especially for manufactured feed.

In some areas, by encouraging vocational cooperation between farms, increased farming efficiency has been enabled by economies of scale for supplies, shared knowledge, logistics and protecting stocks from theft and from disease or risks of mutual contamination.

Developing semi-intensive, semi extensive or extensive farming systems, in a framework of sustainable development and ecological protection of mangroves in the Mekong Delta environment holds eco-label potential for the shrimp produced there. Nevertheless, the assessment should take into account the necessary costs of a rigorous control framework to create market confidence in this Eco value, as well as the pollution development threatening the Mekong River.

Conclusion

On the basis of the Gambas project's results and participants' feedback, several conclusions could be drawn. They were related to the environmental characteristics of the ecosystem, to current farming practices and to socio-economic issues.

For each standard ecosystemic area defined in the project, a set of technical systems based on environmental and economic concerns was proposed. A precautionary approach was applied by proposing lower-risk and more economically efficient systems. For instance, in confined areas where high bacteria levels are found, shrimp aquaculture was recognized not suitable. The only truly profitable farms mainly reared wild shrimp. Semi-intensive farming seemed to be efficient when vibrio and total suspended matter remained low, provided limited levels of stocking density were maintained (6 PL/m^2). However, unless proper and often costly measures were applied, these low TSS levels would not remain so if the number of such farms was to grow. For other areas, the semi-intensive technique showed much lower economic efficiency, in spite of high yield levels in some cases.
PL quality, water management, pond preparation and stocking times were other key criteria in reaching technical sustainability. These are reported elsewhere and should be respected altogether.

The dataset collected in the frame of the Gambas project has shown that the Mekong Delta has little ecological carrying capacity for shrimp aquaculture and also strong technical and socio-economic constraints. An alternative development is recommended based on:

i) Careful planning using ecological indicators
ii) Control of farmers' settlements
iii) Limited yield per surface unit in medium-size enterprises, favouring limited but stable income and local added value,
iv) Conservation/restoration of natural bio-diverse mangrove conditions in the vicinity of the ponds,
v) The respect of simple management rules,
vi) Along with the active support of the authorities in terms of training and access to knowledge,
vii) Maintaining rice culture for food security.

With surface areas becoming scarcer, the choice of large-scale shrimp farming intensification in the Mekong Delta is risky. The ecosystems there cannot support such intensification in the long run. Farm practices show an overall trend towards overstocking of ponds that were designed and built for low levels of intensification. Farmers' lack of knowledge concerning these techniques further reinforces the technical and economic risks. At higher stocking densities, the marginal income cannot cover the marginal costs.

If there was strong public will to develop shrimp farming in such an area, then the shrimp-mangrove systems should be redesigned to recover mangrove's natural role and favour wild shrimp aquaculture.Very low stocking density (from 0.5 to 1 PL/m^2, depending on the environment) of *Penaeus Monodon* could complete the system with no feed input and therefore, limited economic losses in case of collapse. Such low density systems have been showed by the project as economically viable in the long term, ensuring local added-value. They could be associated with the promotion of an "organic shrimp" label.

Social and policy recommendations focus on participatory and collective action to manage natural resources at the local level, as a way of more efficiently managing shrimp farming development. The threat of a drop in shrimp prices on the international market appears to be a major preoccupation. This has been due to seasonal and local overproduction, and is a significant threat for the future of shrimp farming, especially for the most intensive techniques that rely on a high selling price in order to cover higher operational costs. Greater technical sustainability would mitigate this phenomenon by smoothing the boom and bust cycles in world shrimp farming.

The practical output of Gambas has consisted in two guidelines booklets, one for farm economic management, the other one for planning procedures, also printed in the form of posters for display in the province and district Fisheries offices. These tools were tested in the field during six events, adressing farmers and fisheries extension officers, where these materials were distributed and dispatched. Besides, a 15 minute TV program was also designed with the content of the Gambas project. This program will be broadcast in the Mekong Delta provinces in the framework of the Fisheries extension programme.

However broader dissemination remains to be performed beyond the scope of Gambas, according to training opportunities that may be offered by on-going initiatives such as SUMA (Support of Marine Aquculture) or UNDP projects for instance. Training farmers in farm economic management should be simple as no technical costs are involved and this could be applied anywhere in Vietnam. Demonstrating the planning procedure should best be applied to another region of the Mekong Delta (e.g. Soc Trang), provided the technical tools for sampling and analysis are made available.