Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives

International Conference
Phnom Penh, 6-8 February, 2006

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ROYAL ACADEMY OF OVERSEAS SCIENCES

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Mekong River Commission (MRC)

2006

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FOREWORD

The main objective of the Royal Academy of Overseas Sciences of Belgium is to promote scientific knowledge of overseas regions. One of the means is to create meeting opportunities at an international level in order to stimulate collaboration and exchange of scientists in a partnership perspective.

The Academy has in the past co-organized two seminars in La Paz with the Bolivian Academy of Sciences. This year we have had the privilege of holding an international scientific event in Cambodia. We are grateful to the Royal Academy of Cambodia for its participation.

This conference aimed at bringing together scientists of Southeast Asia and reinforcing research networks at an international level. The theme *Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives* is of particular importance for the region, where deltas are zones of high population density and economic concentrations which are communication hubs for maritime and river transport. The approach was multidisciplinary involving economic issues, transport, agriculture, aquaculture, environment, public health and cultural aspects. The major perspective was orientated towards regional development and integration.

The conference was attended by more than a hundred participants coming from various countries. The majority of speakers originated from Asia: Cambodia, Vietnam, Indonesia, Malaysia, Singapore, Hongkong, India, Laos, Thailand, the Philippines.

Fruitful discussions and scientific exchange between researchers took place. As a result of this conference the statements delivered during the final session are included in the recommendations at the end of this volume. Abstracts, power point presentations and posters are gathered in the attached CD-Rom.

On behalf of the Royal Academy of Overseas Sciences of Belgium we would like to acknowledge the financial support of the Ministry for Development Cooperation, the Directorate General for Development Cooperation, the Asian Development Bank and the logistic support of the Belgian Technical Cooperation and the Mekong River Commission.

We warmly thank the members of the Academy involved for all their help.

Prof. em. Dr Yola VERHASSELT
Honorary Permanent Secretary
of the Royal Academy of
Overseas Sciences of Belgium

Opening Session

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p. 13.

Welcome

by

PRUM MOAL*

Samdech,
Excellencies,
Ladies and Gentlemen,

On behalf of Dr Sorn Samnang, President of the Royal Academy of Cambodia, who has a mission abroad, and in the name of the committee that organizes the international conference on "Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives" starting today, I would like to welcome and deeply thank the national guests and distinguished guests who are present at this conference.

I feel that this conference is very useful for the cooperation between the Royal Academy of Cambodia and the Royal Academy of Overseas Sciences of Belgium, and also it is very important for Cambodia and the countries in the region.

I would like to thank the Royal Academy of Overseas Sciences of Belgium, that provides the honour for the Royal Academy of Cambodia to be the partner in organizing this international conference.

And last, I would like to wish the distinguished guests a nice stay in Cambodia.

* Member of the Royal Academy of Cambodia, P. O. Box 2070, Phnom Penh 3 (Cambodia).

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Introduction

by

Jean MARCHAL*

On behalf of the Royal Academy of Overseas Sciences of Belgium I have the pleasure and honour to welcome all of you at this opening session of the International Conference "Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives".

Our Academy has been very pleased to organize this conference with the collaboration of the Royal Academy of Cambodia.

It is a great honour to welcome his Excellency Mr Sun Chantol, Minister of Public Works and Transport of Cambodia.

The Royal Academy of Overseas Sciences of Belgium and his president want to warmly thank his Excellency Mr De Decker, Belgian Minister for Development Cooperation, for his essential contribution to the realization of this conference.

It is also a great honour to benefit of the presence of his Excellency Mr Matthysen, Ambassador of Belgium, and an important Belgian official delegation composed of Mr P. Vaesen, Director of the Strategic Unit of the Ministry for Development Cooperation; Mrs M. Van Dooren, Director General of the Directorate General for Development Cooperation; and Mr C. Michiels, Director of the Belgian Technical Cooperation.

I would also like to thank the Mekong River Commission, and its chief officer Mr O. Cogels, for its cooperation.

The proceedings of the conference will be published by the Academy with the support of the Asian Development Bank.

* President of the Royal Academy of Overseas Sciences of Belgium, rue Defacqz 1/3, B-1000 Brussels (Belgium).

All the previously mentioned organizations are sponsoring the present conference and I would like to express the gratitude of the Academy.

Last but not least, I want to insist on the extremely important work realized by professor Yola Verhasselt, Honorary Permanent Secretary of our Academy, who, with Cambodian and Belgian collaborators, has been organizing the present international event for quite a long time: many thanks!

Thanks all of you for participating in this conference.

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Opening Statement

by

Olivier COGELS*

Excellency Mr Sun Chanthol, Minister of Public Works and Transport of Cambodia,
Excellency Mr Armand De Decker, Minister of Development Cooperation of Belgium,
Mr Jean Marchal, President of the Royal Academy of Overseas Sciences of Belgium,
Mr Prum Moal, member of the Royal Academy of Cambodia,

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

I am deeply honored and privileged to be here at the International Conference on Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives.

At this special event, allow me on behalf of the Mekong River Commission to extend a warm welcome to all participants at this conference. Such a wide attendance is a good indication of the strong partnerships between Asian scientists and scientists from other regions for such important topics as transport, regional integration, cultural exchanges and environmental matters in the wider context of sustainable development of Southeast Asia.

I am also pleased to see that this conference has been organized in a regional economic integration perspective. This is indeed the key to the future of this region. Regional economic integration is thus one of the key principles

* Chief Executive Officer of the Mekong River Commission, P. O. Box 6101, Vientiane (Lao PDR).

outlined in the new Strategic Plan of the Mekong River Commission, towards its objective towards poverty alleviation in the region.

Before touching upon navigation activities in this perspective I would like to share with you some thoughts on the MRC integrated approach for sustainable development. The MRC is a river basin organization which has been built on a foundation of nearly 50 years of knowledge and experience in the region. In 1995, the governments of Cambodia, Lao PDR, Thailand and Vietnam signed the Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin and agreed on joint management of their shared water resources and development of the economic potential of the river. The Agreement formed the Mekong River Commission. Since then, the MRC has made every effort to apply the principles of Integrated Water Resources Management for the Mekong people's well being.

Today, the MRC is promoting the Mekong Programme, a basinwide cooperation programme for the sustainable development of water and related resources. In this context, the MRC is seeking to promote balanced and well-coordinated activities in all water resources sectors, ranging from Irrigation and Drought to Hydropower, Flood Management, Fisheries, Watershed Management, Environment Management, and to Tourism and Navigation.

The subjects considered at this Conference, harbours and ports, are therefore on our daily agenda at the Mekong River Commission.

In this context, I am pleased to inform you that in Cambodia the MRC Navigation Programme has had a quick start. The Design of the Master Plan for Mekong Navigation in Cambodia, a bilateral project funded by Belgium, is closely coordinated with our navigation programme within the framework of regional transport planning. This project has, besides integrated planning, produced detailed navigation maps, and mapped out in detail where to mark the channel between Phnom Penh and the Cambodia-Vietnam border. The Mekong River Commission will follow-up on this initiative and design, manufacture and install the buoys and beacons to guide the ships captains safely to the port of Phnom Penh. Moreover, MRC will cooperate with the Cambodia-Belgium Consultancy Fund to develop a management Information System for the port of Phnom Penh. This system will be linked with the Electronic Data Exchange system, to be put in place in Cambodia by the World Bank.

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

Of course navigation improvement in Cambodia cannot be regarded in isolation. In particular, strong ties with Vietnam are essential to make cross-border navigation possible. Now with the generous support of the Government of Belgium to the MRC Navigation Programme, we have all the instruments to facilitate this initiative between the two countries and relevant navigation activities in other MRC member states. Based on a strong foundation and developed through thorough investigations, such a transport agreement will be of huge benefit for both Cambodia and Vietnam. It will serve many generations to come in the Mekong Spirit and reaffirm the *raison d'être* of the MRC in putting the Mekong Spirit of cooperation to work.

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

In closing, allow me to take this opportunity extend my sincere thanks to his Excellency Mr Armand De Decker for his presence here today and for the generous support provided by the Government of Belgium to the Mekong River Commission for the implementation of its Navigation Programme. I am looking forward to the fruitful discussions we will have here today and I am glad that they can feed into our programme to focus its implementation.

Finally, I would like to express my sincere gratitude to the Royal Academy of Overseas Sciences for organizing this Conference in cooperation with the MRC and to the Royal Academy in Cambodia for its effective support, which will undoubtedly contribute to making the meeting a success.

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Discours d'inauguration

par

S. E. M. Armand De Decker*

Monsieur le Ministre,
Monsieur le Président de l'Académie Royale du Cambodge,
Monsieur le Président de l'Académie Royale des Sciences d'Outre-Mer de Belgique,
Monsieur le Directeur exécutif,
Mesdames et Messieurs,

Il y a des noms de pays comme des noms de villes, de montagnes ou de fleuves qui marquent une vie avant même le temps des voyages. Ainsi mon enfance fut elle bercée des noms de Vladivostok et d'Anchorage, de Pondichéry et de Valparaiso, de ceux de l'Everest et du Kilimanjaro, de ceux plus puissants encore dans leur évocation magique du Gange, du Nil et du Mékong. Il suffit d'ailleurs de prononcer ce nom, pour entendre toute la force de l'eau qui se déverse des montagnes du Tibet, puis de voir les gorges profondes du Yunnan lui donner cette majesté, cette force faussement tranquille, comme le serpentement d'un dragon bénéfique traversant le Laos, la Thaïlande, le Cambodge et le Vietnam qui aboutit à la mer de Chine et la féconde des plus riches limons des terres d'histoire et de culture qu'il abreuve tout au long de son parcours.

Je suis plus qu'heureux d'être à Phnom Penh aujourd'hui, car les villes que traversent les fleuves ont aussi quelque chose de spécial, comme si elles n'étaient pas seulement une accumulation de commerces et d'habitations, mais voulaient surtout se définir par leurs quais bordant l'eau de la rivière, par leurs ponts la traversant, par les grues actives ou au repos, par les petits

* Ministre de la Coopération au Développement de Belgique.

bateaux amarrés le long de l'eau. C'est un peu comme si la ville était elle-même un navire prêt à larguer ses amarres, était plutôt une partie du fleuve, prête à prendre le fil du courant et à se laisser transporter vers la mer.

Je suis donc plus qu'heureux d'être à Phnom Penh aujourd'hui pour célébrer avec vous ce grand fleuve de la terre, à l'occasion de cette conférence internationale consacrée aux aspects multidisciplinaires et aux perspectives interculturelles des ports et des deltas d'Asie du Sud Est. Notre conférence évoquera à côté des défis économiques et écologiques de la gestion des ports et des deltas l'histoire des liens commerciaux entre l'Europe du Nord et l'Asie du Sud-Est, mais aussi, pour revenir à nos villes fluviales symboles du voyage, l'histoire des langues et des cultures des ports de la région, l'histoire et le destin des hommes et des femmes qui ont fait leurs richesses et ont porté leurs espoirs.

J'ai décidé que la Coopération Internationale belge, par le biais de la Direction générale de la Coopération au développement et celui de l'agence de la Coopération technique belge aient apporté leurs soutiens à l'Académie Royale des Sciences d'Outre Mer de Belgique pour mettre sur pied cette rencontre internationale en collaboration avec la Mekong River Commission.

L'Académie Royale des Sciences d'Outre-Mer de Belgique, qui organise des colloques et des symposiums réunissant des représentants d'institutions scientifiques belges et étrangères a dès lors réuni ici à Phnom Penh une conférence qui s'inscrit dans une perspective régionale de développement afin de renforcer les liens existant entre la Belgique et les pays de l'Asie du Sud Est.

Nous essaierons, au cours des deux prochains jours d'intensifier nos relations scientifiques avec nos partenaires du Cambodge, de l'Inde, de Malaisie, des Philippines, de Singapour et du Vietnam en tentant de démontrer, par une approche multidisciplinaire touchant aux sciences appliquées, aux sciences humaines, aux sciences médicales et naturelles, les vertus et les potentialités des régions deltaïques.

Comme vous le savez, ces régions deltaïques présentent des avantages certains, puisqu'elles sont caractérisées par une forte densité de population et par une concentration économique en pleine expansion, et parce qu'elles constituent souvent des nœuds de communication (hubs) pour le transport maritime et fluvial.

Ces grands avantages des deltas que l'on retrouve dans toute l'Asie du Sud-Est, présentent néanmoins une série de défis communs, de problèmes environnementaux spécifiques, des problèmes de santé publique également, liés à la concentration des populations qui doivent être abordés et résolus dans la perspective d'un développement durable et d'une gestion rationnelle des ressources.

Le partenaire idéal pour cette réflexion sur l'avenir des régions deltaïques ne pouvait être que la «Mekong River Commision», avec laquelle la Belgique coopère avec d'autres partenaires européens, l'Australie, la Banque Mondiale et la Banque asiatique de développement depuis plus de dix ans. La Mekong River Commission a été crée en effet en 1995 par un «Accord de Coopération sur le Développement durable du Bassin du Fleuve Mekong», regroupant à côté des états et des institutions partenaires déjà citées les pays riverains du fleuve Mekong, le Cambodge, le Laos, la Thailande et le Vietnam, auxquels s'associent également la Chine et le Myanmar.

Je suis très heureux de saluer aujourd'hui le Directeur Exécutif de la Mekong River Commission, mon compatriote Monsieur Olivier Cogels, qui en plus de la qualité d'être Belge est originaire de la ville et du port d'Anvers, dont les liens avec les ports d'Asie du Sud-Est sont aussi nombreux qu'anciens.

L'Académie Royale des Sciences d'Outre Mer de Belgique ne pouvait pas trouver meilleur partenaire que la Mekong River Commission pour cette conférence, puisque les objectifs de la Commission rejoignent complètement les buts de cette conférence. Concrètement la Commission du Mekong est active en matière de navigation, de contrôle des inondations, de pêcherie et d'agriculture, d'hydro-électricité et d'environnement. Son plus grand défi sans doute est de concilier les exigences environnementales, dont l'importance est d'ordre planétaire, aux développements des aspects économiques, dont les gouvernements concernés et les populations riveraines voient d'abord les avantages concrets.

Le fleuve Mekong est en effet un des rares fleuve de notre planète qui offre encore un grand potentiel de développement économique régional. Plus de 400 milliards de mètres cubes d'eau traversent chaque année le delta pour se déverser dans la mer, mais malheureusement avec un débit trop petit en saison sèche et trop grand en saison des pluies. Des ouvrages de régulation seront donc nécessaires pour faciliter la navigation et développer davantage l'agriculture. Cela pourra se faire grâce à la remarquable coopération internationale qui existe entre les pays membres de la commission du Mékong. Ces pays viennent d'adopter lors de leur dernier conseil des Ministres à Chiang Rai en décembre dernier une nouvelle stratégie commune pour les cinq prochaines années, conciliant d'une part les importants besoins en investissement et d'autre part une gestion responsable de l'environnement et de l'équilibre écologique.

Je voudrais, avant d'aborder les thèmes de la conférence, m'attarder un instant sur les relations qui existent entre le Cambodge et la Belgique dans ces domaines fluviaux et maritimes, et dire l'intérêt de mon pays et de la Commission européenne dont les financements peuvent intervenir en la matière,

pour l'établissement d'un partenariat entre la Cambodia Maritime Training Center et l'Antwerpse Zeevaartschool, l'école de Navigation maritime d'Anvers, qui forme tous nos officiers au long cours et de nombreux marins étrangers. De même la Belgique serait certainement intéressée à une coopération avec le Cambodge pour la rédaction d'un nouveau code de droit maritime cambodgien, et je voudrais rappeler aussi le rôle que nos pourrions jouer en facilitant la signature de protocoles de coopération maritime et fluviale entre le Cambodge et le Vietnam, un peu à l'image des accords existant entre la Belgique et les Pays Bas sur la navigation de l'Escaut et l'accès des navires à la mer. L'expérience belgo-néerlandaise dans ce domaine pourrait être plus qu'utile à d'autres pays co-riverains de fleuves maritimes. Le très récent accord d'amitié signé entre la région flamande de Belgique et le Cambodge pourrait à mon sens intervenir pour faciliter la mise en œuvre de ces projets.

J'évoque ces projets qui touchent à l'avenir, mais il y en a bien sûr déjà d'autres qui sont en voie de réalisation, tel le Master Plan for Navigation on the Mekong River System auquel nous contribuons via la Mekong River Commission, ou le financement des projets «Aid to Navigation» et «Managment system for the port of Phnom Penh, financés grâce au Cambodian-Belgian Consultancy Fund.

Mr Minister,
Ladies and Gentlemen,

Peering through the program of this conference, one realises the symmetry of approaches between the Mekong River Commission and the Royal Academy of Overseas Sciences of Belgium. We shall indeed discuss themes related to the economy, to navigation, to agriculture and fisheries, to environment and public health, without forgetting subjects like history, linguistics and culture.

We will indeed listen to presentations related to the development of fluvial and maritime container transport, discuss the merit of natural sand dams compared with artificial embankments, question the tracing of transport, the management of fresh water, the feeding of ducks, the enrichment of soils for the culture of rice, aquaculture and fisheries in the deltas, the role of the mangrove. We shall also look at the incidence of HIV/AIDS in Cambodia, study the performance of prawns farms in Vietnam, analyse the scientific results of soils studies in Thailand, revisit the history of the Belgian maritime transport towards Asia.

All the facets indeed of human activities are reflected in the waters of the Mekong.

Earlier on I evoked the mythical strength of the river Mekong. We think of its power, and of its destructive strength as strong and impressive as its benevolent virtues. We think of its history that passed through times of bloodshed and misery, before regaining its peaceful course.

My country, as you know, attaches a special attention to the respect of human rights and freedom of speech. In this Southeast Asia, that it rebuilt itself in peace, after so many years of wars and violence, those values are more important than ever. I wish that in Cambodia, as elsewhere, they could flourish freely.

It is impossible to speak about the Mekong without being carried away by the vital flux of the stream. We are indeed today on its shores, and water streams in front of us, maybe to better underline our own stillness. But one should only close one's eyes, be ready and think of the delta open on the sea, listen to the rumbling of the water, feel the freshness of the wind blowing on the banks, to embark on a skiff, on a boat, on a ship and sail to the delta, to the open sea, to the adventure of a travel and of life.

This is the wish that I wish for your all, the wish of a lively crossing on the waters of the Mekong, the wish of a fruitful and enriching conference.

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Opening Statement

by

H. E. Mr Sun Chanthol*

Your Excellency Mr Armand De Decker, Belgian Minister for Development Cooperation,
Mr Jean Marchal, President of the Royal Academy of Overseas Sciences of Belgium,
Mr Prum Moal, member of the Royal Academy of Cambodia,
Dr Olivier Cogels, Chief Executive Officer of the Mekong River Commission Secretariat,
Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

It is a great pleasure for me being here today on the International Conference on Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural perspectives. On behalf of the Ministry of Public Works and Transport as well as on my own behalf, I would like to extend my sincere and warmest welcome to all participants and speakers from Australia, Canada, Europe, India, Malaysia, Philippines, Singapore, Thailand, Vietnam and Cambodia to attend this International Conference.

The range of themes of the Conference is quite broad, dealing with transport, cultural and linguistic issues, agriculture and aquaculture, and environment. A wide array of aspects which I am sure will be discussed by the different discipline speakers over the next three days. Please allow me to focus on the first theme of the Conference, namely on regional economic integration related to harbour development and multimodal transport links. This session

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will help the participants from different parts of the world to learn from the lessons of what happened in their country, be it good or detrimental. These lessons will help us to find the measures to use the potentials or to avoid or mitigate the devastating impact related to trade and development.

The economic growth in Southeast Asia resulted in the expansion of international trade. And as you are well aware there is no trade without transport — or transport without trade. Consequently, the amount of cargo being moved between the countries has increased rapidly, and therefore the sea and river ports are important transport nodes — or hubs — to make this all happen. The quality of the port facilities and the condition of the nautical accessibility have to be in line with the demand for trade. As you are well aware, the level of development in the Southeast Asian countries is not the same. The infrastructure in countries such as Cambodia and the Lao PDR lags behind that of its neighbours. I hope that this difference, and how to cope with this, will be discussed in this Conference.

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

The extension of port facilities makes a significant contribution to economic development and the growth of maritime transport, it may also create adverse impacts on the surrounding environment. Port development and operation should therefore be planned with careful consideration of their environment impacts for the sustainable development of natural resources. Planning is indeed crucial and all projects have to be seriously prepared, in an integrated way. I would like to take this opportunity to demonstrate the need for careful planning.

Cambodia has two international ports: Phnom Penh Port on the Mekong River, and Sihanoukville Port as our deep sea port. It is expected that in 2010, the cargo throughput in Sihanoukville Port will be more than 4 million ton. Phnom Penh port can be reached by sea-going ships of up to 5,000 tonnes, is smaller than Sihanoukville port but has its own distinctive advantage. Distribution of cargo share between, and consequently level of development of these ports has to be studied properly. Until now, no such plans have been available. Moreover, other aspects of maritime and river transport have so far been addressed on an *ad hoc* basis: training, formulation of rules and regulations, waterway design, small port engineering, oil spill contingency plans and environmental protection of the wetlands, etc.

I would hereby like to take the opportunity of thanking the Minister for Development Cooperation of Belgium, the Directorate-General for Development Cooperation (DGDC), and the Belgian Technical Cooperation (BTC) for their financial and technical support to the project "Design the Master Plan for Waterborne Transportation on the Mekong River System in Cambodia", which is now formulating the integrated action plan and investment programme. As Minister of Public Works and Transport, I give my fullest commitment to ensure that waterborne transportation in Cambodia will follow this plan. I hereby sincerely hope that the two Governments of Cambodia and Belgium will once again sit together and elaborate on how best, and perhaps jointly, implement the Master Plan.

However, improvement of hubs, such as Phnom Penh Port, will only be possible if a good legal and operation *regional* framework is attained. Indeed, the river is only accessible through the territory of Vietnam. We would hereby rely on the only related regional instrument that belongs to the four lower Mekong countries, the Mekong River Commission. As we all know, the Mekong Spirit among the countries is there, but it has to be linked through proper agreements to guarantee smooth operational and sustainable development. In this respect, on behalf of one of the member states of the Commission, I would also like to thank the Belgian Government for their support to the MRC Navigation Programme. This regional programme has all the ingredients to remove the physical and non-physical obstacles for freedom of navigation.

Excellencies,
Distinguished Guests,
Ladies and Gentlemen,

My sincere thanks goes to the Royal Academy of Overseas Sciences for choosing Cambodia as a place for their international conference. I am convinced that the multidisciplinary collaboration will reinforce research networks in developing countries and will also help the Royal Academy in Cambodia to set up the contacts between researchers of the region with their colleagues of other research institutes. We all know that scientific research plays a fundamental part in the sustainable development of our countries. I sincerely wish that the objective of the conference to intensify the contacts between researchers in the region who may not always have the opportunities to exchange their experience will be met.

In closing, allow me once again, on behalf of the personnel, employees of the Ministry of Public Works and Transport to express my sincere appreciation

to the Royal Academy of Overseas Sciences for organizing this event, to the Directorate-General for Development Cooperation (DGDC), Belgian Technical Cooperation (BTC) and to the Mekong River Commission Secretariat for their valuable financial support to this conference.

I also would like to take this opportunity to express my best wishes to your Excellency Mr Armand De Decker, Belgian Minister of Development Cooperation, Ladies and Gentlemen, and all distinguished guests who are here today, a very Happy New Year, happiness and prosperity for the year 2006.

I wish the conference success and hereby declare the conference open.

Hubs, Harbours and Deltas and Regional Economic Integration

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The Expansion of Regional Ports in Southeast Asia: Prospects and Challenges

by

IDRIS HANIZAH*

Introduction

In 1980s and early 1990s Malaysia was one of the ASEAN countries that had achieved high economic growth, an average of gross domestic production (GDP) 8 per cent annually. As the economics of ASEAN countries grew over the years, the regional ports of Southeast Asia also developed to reflect the changes in the economy. New ports were established and the older ones acquired new facilities and expansion plans. Therefore the aim of this paper is to examine the rapid development and expansion of major ports in the region namely Port Klang, and Port of Tanjung Pelepas (PTP) in Malaysia, Port of Singapore, Singapore, Port of Tanjung Priok in Indonesia, Laem Chabang Port in Thailand and the Manila Port in the Philippines (IDRIS 2002). Apart from the economic factor, the evolution of containerization, the changes in shipping trends including global port development and shipping technology have great impact on the future expansion of Southeast Asian regional ports. Latest economic indicators show that recovery measures taken by most Southeast Asian countries including Malaysia since the Financial Economic Crisis 1997/98 have yielded positive results. For example, real GDP for Malaysia recovered to an average growth of 7.2 per cent during the 1999-2000 periods from negative 7.5 per cent in 1998 (Economics Report 2003/2004).

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In line with the tendency of using larger vessels, transshipment activity in the region is expected to grow. The forecast volume by Drewry Shipping Consultant indicated that Southeast Asia represents 34 per cent of world total transshipment volume that require greater port and shipping facilities in the future. At the regional level, port competition is expected to be stiff. The Port of Singapore will remain the leading port in the region in view of its long establishment and reputation for excellent services. However, with the establishment of new regional hubs namely the Port of Tanjung Pelepas in Malaysia, Laem Chabang Port in Thailand and Tanjung Perak in Indonesia, its dominance will continue to decline. These ports are undertaking serious measures in planning for future development and expansion in order to maintain steady growth in cargo throughput and regional market shares.

Developing Malaysian Ports into Regional Hubs

Catalyst for port development in Malaysia and other ASEAN countries has been closely related to industrialization and the growth in containerised trade. The recovery of the Asian economies has witnessed the strong growth in the export sector of 15.1 per cent per annum in 1998. Table 1 demonstrates the ASEAN seaborne traffic by country including Malaysia. Table 2 demonstrates the structural changes of Malaysian economy led to increasing volumes of manufactured exports from 11.9 per cent in 1979 to 85.2 percent in 2000. Both the strong growth in the external trade sector and the increased volume of manufactured goods have therefore generated rising demand for port facilities and infrastructures.

In 1970s, Port Klang and other Asian regional ports had witnessed the arrival of containers. Together with the strong growth in the external trade and manufactured goods have therefore generated rising demand for port facilities, particularly container cargo facilities. Malaysia has been at the forefront of port privatisation with nine port operators namely Kelang Multi Terminal Sdn.Bhd (KMT), Northport (Malaysia) Berhad, Bintulu Port Sdn Bhd, Johor Port Berhad, Penang Port Sdn Bhd, Kemaman Port Port Sdn. Bhd, Tanjung Pelepas Sdn Bhd and Kuantan Consortium Sdn Berhad. These private operators have contributed in managing and developing the ports and provides a conducive place for trade and shipping activities.

Since 1993, The Ministry of Transport and other related agencies in their public statements had made clear that their main objectives are to make Port Klang as the national load centre and regional transshipment hub. This

Table 1
ASEAN seaborne traffic by country

Country	Foreign trade		Domestic trade	
	1996	2000	1996	2000
Brunei Darussalam	2,379	2,074	n.a.	n.a.
Cambodia	860**	1,859	n.a.	n.a.
Indonesia	328,439	364,000	170,133	180,229
Malaysia	161,956*	174,078	21,689*	16,091
Myanmar	1,373	1,975	100	153
Philippines**	67,516	72,181	71,956	77,655
Singapore	314,164	325,591	–	–
Thailand	106,400	126,591	24,661	21,970
Vietnam	38,468*	52,128	7,261*	21,119
ASEAN	1,021,555	1,120,052	295,800	317,217

*1997 figure.
**PPA ports only.
n.a.: not available.

Source: PUSPANATHAN 2005.

Table 2
Malaysia: structure of exports, 1970-2000 (%)

	1970	1975	1980	1985	1990	1995	1998	2000
Rubber	33.4	21.9	16.4	7.6	3.8	2.2	1.6	0.7
Tin	19.6	13.1	8.9	4.3	1.1	0.3	0.3	0.1
Logs & timber	16.5	12.1	14.1	9.9	5.1	1.3	1.0	1.5
Palm oil	5.1	14.3	9.2	10.4	5.5	5.6	9.5	2.7
Petroleum	3.9	9.2	23.8	22.9	13.3	3.6	4.4	3.8
LNG					3.3	1.6	3.7	3.0
Manufactures	11.9	21.4	21.7	34.9	55.4	76.1	79.1	85.2
Others	9.6	8.0	5.9	10.0	12.5	8.4	0.4	3.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Malaysia Financial Reports (various issues).

followed by the Seventh Malaysia Plan (1996-2000), indicated that all other Malaysian ports acting as feeder ports, and would be consolidated where possible through Port Klang. Port Klang since then has grown to be one of the premier ports in the region, ranking from number 27th position in the league of world container ports in 1995, to 11th position last year. With an investment of RM2.7 billion made during the 7th Malaysia Plan and coupled

with concerted efforts by the three privatised terminal operators namely Klang Container Terminal Berhad (KCT), Klang Port Management Sdn Bhd. (KPM) and Klang Multi Terminal Sdn Bhd. to enhance the quality of service, the port has capable of handling about 3 million twenty equivalent units (TEU) of container volume. At present the port is served by 15-berth container handling facilities that draws 3.7 km and capable of handling 3.8 million TEU per annum. Soon, the expansion plans of the container handling facilities at the port was expected to expand the container handling capacity at Port Klang to 5.2 million TEU.

Its position however appears to be challenged with the establishment of PTP at the beginning of the new millennium. However, instead of becoming rivals, a complementary relationship could be established if a well defined policy is pursued by the government and other related agencies. Load centring strategies as outlined in the Seventh Malaysia Plan (1996-2000) includes:

— Establishment of close linkages with regional ports, as well as other ports in Sabah and Sarawak through provision of feeder services at competitive rates;
— Supply efficient facilities and providing free commercial zones at Port Klang;
— Restructuring of rebates and other incentives;
— Maximum back-up facilities including simplification of custom procedures.

Before the establishment of new Port of Tanjung Pelepas, other major ports particularly, Penang Port, Johor Port, Kuantan Port, and Bintulu Port respectively have contributed to the success of load centring at Port Klang. Penang Port in particular serves as an important feeder port and gateway for the northern region, so as the Johor Port for the southern region, and Bintulu Port serves as an important gateway for East Malaysia. The establishment of the new Port of Tanjung Pelepas must be seen as the viable alternative to Singapore. According to the PTP Chief Executive Officer, PTP was established with two primary objectives:

— To develop a regional transshipment hub;
— To stop leakage of local cargo being exported via Singapore through feedering or trucking across the causeway.

Located at the southern tip of the Peninsula, PTP has positioned itself well within the network by the growing ASEAN market to capture cargo particularly, transshipment cargo in the region. Already, the ports ability to offer tariff rates 30 per cent less than the Port of Singapore and its success

in persuading Danish Shipping Line, Maersk Sealand and Taiwan's Evergreen Marine Corp, to shift its transshipment hub from Singapore to PTP indicated its potential of becoming a major regional transshipment hub in the near future. The current world berth productivity record of 340 gross moves per hour that was achieved during operation on the vessel AP Moller this year was testament to the level of skill of professionalism of the ports operations (*Star Maritime*, 27 December 2004). Over 4,000 containers were handled over a period of less than 13 hours with peak production reaching 480 moves per hour.

The port currently offers six berths of 360 metres each in length thereby offering 2.16 km of linear wharf length (Malaysian Business 2003, p. 52). This year, PTP continued with its expansion plans and two new berths were completed, adding an estimated 1.5 million TEU to existing annual handling capacity. Today, PTP's aggressive expansion had put it in the unique position of being the only container terminal in Asia to offer additional capacity to shipping lines. Nevertheless, Port Klang is still a leading port in the region with ability in handling cargo particular, transshipment containers more than 3 million TEU annually, that are provided by neighbouring ports. Port Klang currently operates with its two major terminal operators namely Klang Multi Terminal Bhd. that operates Westport and Northport (Malaysia) Sdn. Bhd that operates Northport. Table 3 demonstrates Total Container by Major Ports in Malaysia.

As seen in table 3, Port Klang is still maintaining its position as a leading port in Malaysia with a steady increased in total of container handled by the port from 1993 to 2003. In 2004, Port Klang's two terminals, Northport and Westport, have successfully handled 2.7 million TEU and 2.6 million TEU respectively. While other ports, and particularly the Port of Tanjung Pelepas, have shown tremendous achievement in container handling, from less than 1 million TEU in the year 2000 to 3.4 million TEU in the year 2003. The present scenario implies that Port Klang and PTP are well positioned in the system of port networks of the region with Port Klang catering for local trade flows and PTP concentrating on the regional transshipment trade. At this point in time, each port could well cater for niche markets, concentrating on specific regions to serve. For example, PTP has its own advantage, being located at the strategic location on four busy international sea-lanes, *i.e.* Intra-Asia, Trans-Pacific, Europe-Far-East and Southeast Asia-Australia can well serve both the regional transshipment trade and the international trade.

Therefore, with a properly coordinated and sound strategy, Malaysian ports specifically the Port Klang and the Port of Tanjung Pelepas can be complementary ports, each with a niche role to play, and also to become a regional transshipment centre, ready to compete with other regional ports in the region,

Table 3
Total container by major ports in Malaysia, 1993-2003 (TEU)

Year	Port Klang	Port Pinang	Johor	Kuantan	Bintulu	PTP	Total
1993	771,901	330,922	168,315	9,681	17,298	–	1,298,117
1994	943,846	386,000	238,008	12,192	21,521	–	1,601,567
1995	1,133,811	433,474	302,898	22,591	24,511	–	1,917,285
1996	1,409,594	454,765	377,890	40,821	28,331	–	2,311,401
1997	1,684,508	506,863	429,448	54,855	32,571	–	2,708,245
1998	1,820,007	510,307	439,661	50,989	29,536	–	3,767,358
1999	2,550,419	566,409	558,056	56,056	36,418	–	3,767,358
2000	3,206,753	635,780	659,181	60,376	47,609	418,218	4,609,699
2001	3,759,512	604,294	638,718	76,339	66,139	2,049,487	7,194,489
2002	4,533,212	634,042	683,816	91,524	104,081	2,668,512	8,715,187
2003	4,841,235	688,171	750,466	208,108	145,300	3,486,786	10,120,066

Source: The Ministry of Transport (various issues).

i.e. the Port of Singapore, the Port of Tanjung Priok in Indonesia, Laem Chabang Port in Thailand and the Port of Manila in the Philippines. According to HA DONG-WOO (2002, p. 33) it is estimated that Malaysian port international container throughput will increase at an annual average rate of 12 per cent from 3.8 million TEU in 1999 to 14.6 million TEU in 2011, of which transshipment will account for 7.9 million TEU or 55 per cent.

The Development of Other Regional Ports in Southeast Asia

As Malaysian ports particularly the Port of Tanjung Pelepas, moving towards becoming a new hub in the region, other ports namely Port of Singapore is trying to maintain its position as the main transshipment hub in the region. The Port of Singapore, which was established more than a century ago, has proved itself to be the premier port in the region by attracting regional transshipment cargo. But the emergence of new port namely PTP in Malaysia and Laem Chabang in Thailand has proved that any ports will have the chance to develop and becoming new hubs in the region.

"Both Tanjung Priok and Laem Chabang are among the top 30 container ports in the world and are looking to expand their position as transshipment hubs. This means mounting pressure and competition for PSA and PTP" (*The New Straits Times* 23rd August 2004).

Therefore, at the regional level, port competition is expected to be stiff. It is expected that Malaysian ports along with other ports in the region will compete for regional supply of transshipment cargo that is expected to exceed 26 million TEU. Other regional ports namely Tanjung Priok, Tanjung Perak, Laem Chabang and Manila Port respectively are undertaking serious measures to make themselves competitive in order to maintain steady growth in cargo throughput that requires new infrastructure and facilities. Figure 1 demonstrates ASEAN transport corridor including regional ports in Southeast Asia. According to the map, twenty-three priority routes for the upgrading and development of trans-ASEAN highway system have been identified including the trunk seaways, feeder seaways and ASEAN highway that interconnected with each other. It is therefore important to promote integration of all transport links, and co-operation between ports supply chain players is absolutely necessary.

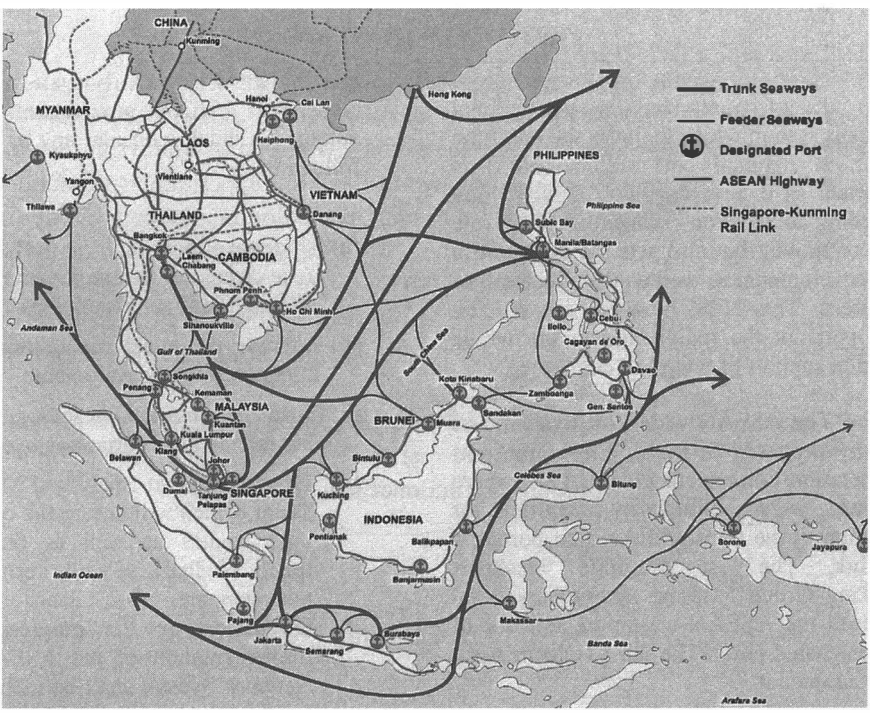

Fig. 1. — ASEAN transport corridors (*source*: PUSPANATHAN 2005).

Port of Singapore

Port of Singapore (PSA) is a major port of call for about 250 shipping lines from 600 ports worldwide (http://www.psa.com.sg/container/container.html). PSA comprises six terminals including the latest new generation port, Pasir Panjang Terminal, that has been in operation since October 1997. The dedicated terminal has been equipped with the latest facilities and applying state-of-the-art technology, such as the use of remote control bridge cranes, to meet their customer's growth in the next century. The new terminal, once fully completed in 2009, will raise Singapore's annual container handling capacity by 18 million TEU.

PSA's Singapore terminals handled a record 20.6 million for 2004 achieving an unprecedented growth of 2.5 million TEU over the previous year. The volumes represent a 14 per cent rise against 18.1 million handled in 2003. The higher increase in percentage has been buoyed by a rebounding regional economy led by China's rise as a manufacturing base. Containerized cargo accounts for about 51 per cent of total cargo tonnage and represents the port's primary business. Last year, Singapore handled 23.2 million TEU to be the world's biggest cargo port followed by Hong Kong with 22.4 million TEU and Shanghai with 18.1 million TEU.

The government owned terminal operator also attributed the strong show to measures implemented to sharpen the competitive edge. These enabled PSA to retain lines since losing Maersk and Evergreen to Malaysian neighbour Port of Tanjung Pelepas. Despite increasing competition from neighbouring ports, Singapore is trying to remain as the dominant shipping hub in Southeast Asia region. In doing so, the port has also begun to play a role in Singapore's long-term plans to develop its own multinational companies. PSA itself is trying to become a global player by exploiting its expertise in port management and development to provide infrastructure to developing countries. On the regulation side, The Maritime and Port Authority (MPA) was established in 1996 replacing PSA as port regulatory body with its mission to protect Singapore's strategic maritime interests and promote Singapore as a world-class port and international maritime centre.

Laem Chabang Port

The establishment of Port of Laem Chabang (LCP) in 1991 is to overcome the port congestion in the Port of Bangkok, due to the rapid increase in the volume of containerised cargo. Located at the eastern shore of the upper Gulf of Thailand, the port is managed and operated by both public-private

partnerships. Today, LCP operates 11 terminals to accommodate various types of vessels particularly container ships of various sizes. There are five container terminals namely B1-B5, another three are the Coastal Terminal (A1), the Bulk Terminal (A4) and the General Cargo Terminal (A5). Others are still under construction. The Port of Thailand Authority (PTA) is the regulatory body responsible for trying to facilitate LCP becoming a hub port for services between Southeast Asia and North America.

Like other port authority in the region, PAT also plans a privatisation programme, where the operation of the port will be handled by a private operator. This has been practised in Malaysia where Port Klang has been successfully privatised in 1986, which later followed by other major ports in the country. As the port of the millennium, LCP has been equipped with the latest technology to accommodate various types of cargos that arrived at the port including general cargo, containerised cargo, and bulk cargo and passenger liners. Like other emerging ports in the region, LCP has set out a master plan including phase 2 and phase 3 development of the port to meet cargo demands until the year 2018.

The Port of Manila

The Philippines and Indonesia have similar unique geographical configuration. In the case of the Philippines, it owns more than 7,000 islands where sea transport is more crucial than the land transport. About 98 per cent of the products imported and exported via ports. In order to be globally competitive, under the Philippines Port Authority (PPA) the port of Manila has been put under major development in infrastructure. The port of Manila is the largest port for the country, handling the country's most domestic and international trade. It also serves as the country's national load centre and consists of three terminals, the North Harbour, the South Harbour and the Manila International Container Terminal for international containerised cargo.

In the early 1970's, there were already 591 national and municipal ports plus 200 private ports scattered all over the country necessitating the need for long-range planning and rationalization of port development. In the next 25 years, PPA will work towards the development of selected major ports to serve as service centers or hub ports. They will offer a comprehensive transport package to include storage, distribution, and information support. The smaller ports will not loose their relevance but will be developed as multipurpose terminals capable of handling both break bulk and container cargo. The coming age of multimodalism and intermodalism will push ports to provide the major interface between land and sea. Thus, future investments of the PPA

will be geared at situating port facilities in locations where they complement and integrate smoothly with other transport modes such as land and air.

The Port of Tanjung Priok

To establish itself as a regional hub, the port of Tanjung Priok has always been part of Indonesian government vigorous attempt to improve their ports facilities. To be able to compete with other ports in the region, Tanjung Priok has taken several port developments, under the public-private partnership scheme, Koja Container Terminal. The port has been equipped with the latest state of the art facilities including latest technology to improve efficiency levels in berthing services. Today the port of Tanjung Priok is capable in handling container vessels with capacity of 5,000 TEU. Other facilities such as a Vessel Traffic Information System (VTIS) for monitoring traffic flow have been put in place. In terms of inter-modal transportation, shippers can either use the highway or the railway for transporting containerised cargo. Table 4 demonstrates summary of the development and expansion of regional ports in Southeast Asia.

Table 4
Regional port development and expansion

The Port of Singapore
— Plans to add three new berths as part of an expansion plan over the next five to seven years;
— Will increase capacity from 11million TEU to 31million TEU.
The Port of Tanjung Pelepas
— Phase I development includes 24 super post-panamax quay crane on 2.16 km of linear wharf, one of the region's largest container yards.
— Phase II will comprise of an additional 2.8 km of linear wharf and two berths. Upon completion PTP will have an annual capacity of 6 million TEU.
The Port of Laem Chabang
— Evergreen, MOL-NYK, Maersk and P&O invested/entered JV to operate container terminal;
— Phase 2 will add 5 million TEU by 2008.
The Port of Tanjung Priok
— Hutchison invested US$243 million for 51 % stake;
— Plans to raise additional 2.7 million capacity.
The Port of Tanjung Perak
— P&O has taken 51 % stake;
— Plans to promote as a transshipment hub.

Source: various sources.

Prospects and Challenges. An Analysis for Future Plans in the Port Industry

Progress in Containerization

According to Faust (2002, p. 22) progress in containerization has been decisively based on the exploitation of economics of scale, on improvements in transport organization and on systematic in application of information and communication technologies. Increasing vessel size is not new in container shipping and has taken place throughout the history of containerization. Since the 1960's, numerous other container sizes have emerged. This progress has been most visible in dramatically increased vessels sizes. Today, ships of 8,000 TEU are in service and shipyards have already drawn up plan for construction of even larger ships.

Since the containerships introduction, larger and more efficient ships have been introduced with regularity. Increased ship size has placed pressure on ports to adapt (Turnipseed 2001). For ports to attract the largest ships and remain competitive, capital-intensive investments are necessary. According to Robinson (1989, p. 138) containerization was, and continues to be, the stimulus for change, the basis of new port morphologies, and the mechanism for achieving fundamental changes in port efficiency in the primate ports of ASEAN countries. Further more, port channel must be dredged to 52 feet to handle the largest post-Panamax ships and must be equipped with gantry cranes capable of spanning these giant containerships.

The implications of increases in ship size will be an even greater focus on hub and spoken system, in which the biggest ship will call at only a limited number of very efficient ports on the main trunk routes, with other ports being linked by extended feeder networks. Through this approach, carriers will maximize the utilization of vessel capacity and reduce port/transit time (Ha Dong-Woo 2002). This encourages the use of even larger vessels on highly streamlined routes between key hub ports, and the domination of the key trade routes will be even greater. Under this "big ships" scenario, around 870 vessels with a capacity of more than 3,500 TEU will be in service by 2011, including 127 ships of around 9,000-13,000 TEU capacity (Ha Dong-Woo 2002).

Mergers, Takeovers and Acquisitions

With mergers and alliances, each main line's volumes will get bigger. Growth through mergers and takeovers has enabled lines to address some of

the issues that alliances could not resolve. Previously, 100,000 TEU at a port was big for any mainline. Soon it will be more than 2 million TEU per port. What are the implications of these mergers, consolidation and slot sharing efforts on the development of ports worldwide including regional ports in Southeast Asia, as such, ports need to build the capacity to attract such big volumes as the Port of Tanjung Pelepas, and other regional ports like Laem Chabang Port and Manila Port did to attract more than 1 million TEU with giant shipping lines. In the case of Malaysia, to stay ahead at the global front, we have formed alliances with two of the four main world-class players. Hutchison Port Holdings and Maersk from Denmark have 30 per cent equity in Westport, Port Klang and Port of Tanjung Pelepas respectively.

The "China Effect"

The rise of China as a manufacturing powerhouse has created boom times for shipping company that will benefit Southeast Asian Ports. Boosted by soaring trade from China's economic boom, global container volumes hit 5.43 million TEU in January and February of 2005 compared with 4.84 million in the corresponding period last year (*The Star Maritime* 21st March 2005). As for Malaysian ports, it continues to benefit from the expansion of shipping services on account of the burgeoning global trade brought about by the "China effect". Global shipping lines, which have been deploying more ships, mounting new services and expanding existing ones, are linking the expanded services to Malaysia, notably Northport of Port Klang.

In response to the dramatic rise in demand for container shipping services in China brought about by the export boom to Europe and the US, several lines have increased their capacity, including Hapag-Lloyd Container Lines, Malaysia International Shipping Corp, Nippon Yusen Kaisha, Orient Overseas Container Line and P&O Nedlloyd (Logistics, *The New Straits Times*, 27th June 2005). These lines have increased their vessels capacities by deploying mega-sized carriers and introduced new strings or services. In the case of Malaysia, Grand Alliance, the biggest shipping group that serves China and Malaysia, offers regular sailings to Yantian, Hong Kong, Xiamen, Shanghai and Ningbo, connecting the Asian region with the US. Outside the Grand Alliance, China's forth-largest liner operator and one of the fast growing China line, Shandong Yantai International Marine Shipping Co (SYMS), just inaugurated a new weekly service linking Northport of Port Klang, Malaysia to Chinese ports.

As the Chinese and the world economy continue to grow and new markets are opened via trade agreements, global maritime trade will increase

and exert its impact on port development. Therefore, ports are expected to play an immense role amidst the challenging scenario. The future development of Southeast Asian ports will be marked by an increasing need to adequately support greater cargo volume and cater to ships with bigger capacity and better technology. They are expected to be more involved in logistics services, undertaken either alone or via strategic alliances with logistics operators. It is likely that the pursuit to accommodate greater trade with China will exert influence on the role of ports in the region and the way it will be developed.

Conclusion

There is no doubt that regional ports in Southeast Asia will continue to expand and improve their port's facilities for the next decade. Already the government of Southeast Asia countries including Malaysia, Singapore, Thailand, Philippines and Indonesia have developed their own plans to increase their ports capacities by installing a state-of-art-facilities and infrastructures. But the question arrises as to what extend these regional ports will continue to expand is yet to be further discussed which becoming one of the great challenges facing by the regional ports in Southeast Asia today. Therefore, challenges are abound for port planners in the Southeast Asia region to not only focus on the physical development of the port but also improved on value added logistics and ancillary services to attract growing regional transshipment cargo in the future.

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Sihanoukville Wind Turbine Project

Funded by the EU Asia Pro Eco Program and Flanders Government

by

Lou KIM CHHUN*, Luc DEWILDE**,
Yves CABOOTER** & Jacques DEZEURE***

Introduction

The introduction of renewable energy sources in the power mix of stand alone grids in remote industrial areas is of great importance. This fact is justified because those isolated grids are autonomous and are mainly fed by diesel generators that increase dramatically the energy production cost. Although the wind potential in these areas is not always very high and the grid quality is often limited, the introduction of wind energy can lower the cost of energy and make it less sensitive to future increases of diesel price. The implementation of a hybrid wind-diesel system with an appropriate control strategy in the harbor of Sihanoukville is considered to be an effective solution to reduce the cost of energy and the environmental impact.

In 2001 the Minister Vice-President of Flanders and Flemish Minister for Mobility, Public Works and Energy visited the port of Sihanoukville. Following the experience in the port Zeebrugge at the Belgian coastline the minister proposed to help the port of Sihanoukville with renewable energy exploration.

A contract was signed to start with a feasibility study in Sihanoukville for a pilot project consisting of building one or more wind turbines in the port of Sihanoukville.

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On the slide* the map of Cambodia and the location of the port of Sihanoukville is shown. This picture at the left hand side shows the port of Sihanoukville the only deep sea port of Cambodia.

The port was in a dire need for a new container berth equipped with gantry cranes and a container yard. The first phase of the works are now completed.

This slide shows also the port statistics.

Where general cargo knows a sharp decline, container transport volume is rising very quickly and reached in 2005 a total of 211,141 TEU. 686 ships called the port in 2005 from which 63 % container vessels, whereas in 2003 this figure was 878 from which 55 % container vessels.

The location of Sihanoukville has some advantages for the development of the project. First there is the cooperation agreement between Flanders and Cambodia. The port has sufficient qualified people needed for the operation and maintenance of this type of technology. The energy is currently generated with expensive dieseloil and there are regular power cuts. The harbor is in full expansion and more diesel will be needed. In addition there is support available for the measurement of data.

Existing Power Supply

The power supply system of the harbor of Sihanoukville is independent from the main grid. The power is delivered by two diesel groups each consisting of two dieselgenerators. One of the groups is used for daytime operation; the other one for night time operation. The groups have a power rating of 2×255 kVA for the nighttime units and 2×350 kVA for the daytime units.

In order to carry out a feasibility study for a wind power project in the port of Sihanoukville, the following items are needed:

— Measurement of wind speed and analysis of the wind resources;
— Measurement of existing load patterns and scenario's for further expansion;
— Specification of turbine characteristics and energy yield calculation;
— Grid connection possibilities;
— Financial analysis and ecological benefits.

* Cf. power point presentation on CD-ROM.

Existing Information on Wind Resources in Cambodia

A wind atlas of SE Asia has been calculated by the American Company True Wind solutions. These calculations are based on available long term data from the National Center for Atmospheric Research (NCAR)and the following input:

— Topographic details of the terrain;
— Digital elevation model;
— Long term wind data from NCAR.

A Meso scale Model for the calculations is used.

The Wind Atlas has to be considered as a first estimation due to the uncertainties of the calculation models and the lack of good quality long term wind data. Therefore it was decided to start additional quality measurements for at least one year on site, and preferably as close as possible to the future turbine.

The wind atlas was calculated by the American Company True Wind solutions for Southeast Asia. It shows the wind availability for the period of the year (December-February). Vietnam mainland (*i.e.* the mountains west of the country between Vietnam and Laos) and the coastal zones of the Mekong Delta seem to be most wind prone zones in SE Asia. Thailand and Cambodia are generally poor in wind resources during this period of the year.

On Site Wind Measurements

In order to have reliable information on the actual wind resources, a professional wind measurement campaign was carried out. The first step was the preparation of a tall tower with a height of 30 m. This mast was constructed by the port technical staff and Mr Jacques Dezeure, Technical representative for Environment and Infrastructure in SE Asia. The mast was equipped with the following instruments:

— Height: 30 m;
— Measuring levels: 31.2 m & 19.4 m;
— Professional equipment from Weatherpack;
— Every 10 minutes a record of the averages;
— Two wind Speeds and wind Directions;
— Barometric pressure, humidity and temperature.

The measurements started in February 2005 and have been stopped last month for reasons of maintenance and eventual recalibration.

Wind resources are commonly assessed by a distribution curve. There are 52,560 measurements per year (every 10 minutes) and these data are brought in a distribution curve which is called 'Weibull Distribution'. This wind speed distribution gives the frequency of occurrence of a certain wind speed.

The wind speed Weibull Distribution curve for the given location is shown in the slide.

The graph shows the Weibull distribution from the two measuring heights. 30.20 m and 19.4 m. From this graph we can conclude that wind speeds between 4 and 5 m/s have the highest frequency of occurrence. The mean wind speed at 30.20 m height was 4.21 m/s and at 19.4 m only 3.72 m/s.

The other parameters that influence the power output are temperature, pressure, and humidity. From these parameters the air density is determined (the thickness of the air).

The prevailing or dominant wind direction is West (coming from over the sea). Based on the measured wind climate at the topography of the site a resource map has been calculated for the entire neighborhood around the mast. The yellow spots are the best locations regarding wind resource. These spots are the surrounding small hills around the town, the Peek Casino hill (which is not shown on this map*), the water purification plant and the hill with the TV antenna's. Therefore additional measurements have been done on an existing tower on the hill of the water treatment plant.

Electrical Load Measurements

In order to measure the load pattern of the power demand in the harbor two power meters were installed on Oct 2004 on the two diesel groups.

They measured during one year the following items:

— Active power in function of the time;
— Reactive power;
— Load factor;
— Current/Voltage;
— Frequency.

* Cf. power point presentation on CD-ROM.

The main conclusions are:

— There is more active power consumption during night than day;
— The most frequent Power demand: ± 150 kW;
— The max Power demand: 300 kW;
— The minimum diesel generator load: ± 10 %.

Wind Turbine Requirements

From the wind speed measurements and the load measurements we can draw the following conclusions:

— A Low start up speed wind turbine is needed to match with the low wind resources;
— A Variable speed wind turbine is needed to match the weak diesel grid in all conditions;
— A Synchronous generator is advised since the control characteristics of such a generator are in favor of operations with a diesel generator;
— A Minimum hub height of 50 m is required to have sufficient wind speed;
— A IEC class III (International Electro-technical Committee) certification is required as minimum criterion for safety and reliability.

Grid Connection

Wind energy is a variable energy resource. In order to guarantee 'security of supply' A wind turbine is often connected to 'another supply system' to deliver or absorb power in case of shortage or abundant energy.

In this case the wind turbine is connected to a relative weak grid (PAS DIESEL GRID).

Therefore, the output power of the wind turbine will have to be controlled as a function of the power demand and the wind speed.

Conclusion: a well designed and advanced control system is needed.

Power System Simulations

Power system simulations have been carried out based on:

— The measured wind regime at the two masts;
— Measured electrical load of the grid of PAS;

— Diesel price 0.6 $/l and rapidly increasing;
— Investment costs of existing diesel power system and cost for operation and maintenance;
— Preliminary estimation of investment cost of wind turbine and auxiliary, including its operation and maintenance cost.

First, the existing power system consisting of the two diesel units, daytime and night-time, have been simulated. It is found that the actual average cost of energy equals 0.290 $/kWh.

The current annual energy production equals almost 1,200 MWh/yr. Therefore, over 500,000 liter of diesel fuel is needed.

These calculation results have been checked with the actual fuel consumption and good correlation was found. The actual total CO_2 emissions equal 1,350 ton per year.

For the simulations with the integration of a wind turbine, a wind turbine of 300 kW nominal power at a hub height of 50 m was chosen, after detailed analysis of the measured electrical load patterns.

The layout scheme shows the different components that make up the grid now:

— A 300 kW wind turbine;
— The existing diesel generators (generator 1 is the daytime generator of 350 kVA, generator 2 and 3 are nighttime generators of 255 kVA each);
— Further, we foresee a battery bank, which is connected to the grid via a converter.

The primary load represents the grid of PAS with the characteristics as measured during the electrical load pattern measurement campaign.

Again, the simulations are based on a diesel price of 0.6 $/liter. The project life time is 20 years.

Investment cost of wind turbine and control system and other auxiliary was estimated at 520,000 $.

The battery bank was estimated at a cost of 180 $/kWh. Maintenance costs for the wind turbine are estimated at yearly 2 % of the initial investment cost. Cost for transport and crane facilities are not taken into account so far. These will be known after tendering.

The cost of energy has come down from 0.290 $/kWh now to 0.277 $/kWh, which represents a decrease of 4.5 %. This cost of energy could be reduced more with optimizing the existing day-night schedule of the generators. In this case, cost could decrease to 0.265 $/kWh, or 8.6 % cheaper than the current system.

The wind turbine could deliver 333 MWh/yr, good for 28 % of the actual power consumption on the grid of PAS.

Almost 120,000 l of fuel and 313 ton CO_2 could be saved. The additional income for this CO_2 saving is estimated between 1,565 and 3,130 $ when CO_2 emissions are valued between 5 and 10 $/ton.

This graph shows the evolution of the cost of energy as function of the diesel price for the existing power system with the diesel generators and for the new system with one wind turbine of 300 kW integrated in the system. The difference between the two becomes more important with increasing diesel price.

Asia Pro Eco Program

The objective of the project is to demonstrate that renewable energy can deliver a substantial part of the energy needs of a port in order to develop economic activities.

The total budget is 1,197,000 €. The Government of Flanders, who has initiated the pilot project, contributes with 25 % of the total cost. Another 25 % of the total cost is granted by the EU Asia Pro Eco Program as a demonstration project.

Finally, the port of Sihanoukville, being the recipient of the project contributes with 40 % PAS, whilst 10 % is coming from other partners, mainly in kind.

Project partners are:

— PAS (Port Authority of Sihanoukville);
— MIME (Ministry of Industry, Mines and Energy);
— The Lead Contractor is Flanders International Technical Agency;
— GERES, an NGO of France with a long tradition of working in Cambodia.

The program started officially on 17/03/05 with an implementation duration of 3 years, from which the last year will mainly be monitoring.

Installation is foreseen by the end 2006 whilst a one year monitoring program is integrated in the project activities. The project looks also at alternative fuel sources for Dieseloil, for example Bio Diesel from vegetable oil.

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The Added Value of Intermodal Transport for the Logistical Organization of Enterprises. A Study on the Opportunities and Bottlenecks

by

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Introduction

Freight transport makes a vital contribution to the economy and to society, and is at the heart of globalization. The dramatic growth of freight transport in the road sector is rapidly taking away its benefits, through impacts such as congestion, noise, pollution and infrastructure damage. Innovative policies and technologies can reduce these impacts by promoting an integrated transport chain for door-to-door services. Today, intermodal freight transport is used as promoted and improved transport technologies for modern logistics to balance the economic, social and environmental interests of the enterprises and the society. It is identified by the European Commission as a policy measure for the sustainable economic growth in EU zones. Recently, the intermodal share of the total freight transport market grows steadily by an average rate of 10% per year. In certain corridors, this growth reaches a share of more than 30%.

In order to face the strong competition of globalization and internationalization modern enterprises require high quality logistic services for their economic interests, production requisites and market changes to enhance

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their competitive positions. In accordance with sustainable socio-economic developments, enterprises should comply with the social rules and regulations that aim at reducing society costs such as congestion, pollution, and environmental protection.

Intermodal transportation is an attractive solution for modern enterprises by offering economic, environmental friendly and door-to-door transport means that can easily be integrated into modern logistic chains. Making full use of the intermodal transport has become a strategic measure for many enterprises in their logistical organization, with many successful stories.

However, the tendency towards implementing intermodal transport has not been well recognized by certain enterprises. Some barriers and bottlenecks block the proper integration and organization of intermodal logistical chains, which are indispensable for the logistics of enterprises. In order to optimize the structure of transport systems and to help enterprises implement modern and innovative technologies a study was carried out in Belgium, with the representative characteristics of Western Europe, to identify the potential of utilizing intermodal transport and to search for the bottlenecks that break the logistical chains. This study supplies decision makers and enterprises with useful suggestions to improve intermodal transport services and intermodal traffic. This paper will introduce the main concepts and methods of this important study.

Modern Logistical Services

Logistics as a term is experiencing a constant evolution. Currently, the logistics concept is far from that in the time when Napoleon organized the supply-chain for his troops, distinguishing itself as an important industrial sector that offers new services.

From another perspective, modern society imposes strict constraints on the transport sector and logistical services. Security, pollution control, transport cost, and reliability are all important criteria to shape this sectors' development. With the changing market and the pressures of globalization, enterprises require high quality logistical services that can be easily integrated into the production/consumption procedures. Many new logistical concepts have appeared, imposing certain criteria on service activities. The latest concepts can be summarized as:

Just-in-Time logistics (JIT): This requires the logistical service to deliver merchandise within precise time slots. It synchronizes the logistical services into the production procedures with the minimal level of the stocks.

Quick Response logistics (QR): This is an extended JIT logistics concept that requires close cooperation by different partners in the production/consumption chain with an effective information exchange, which provides the basic conditions (time intervals) for prevision, optimization, and marketing.

Efficient Consumer Response (ECR): This is a strategy to satisfy the consumer's needs through a close and efficient cooperation between the partners so as to have high quality products with lower prices delivered at the right time.

The keys to achieve the success of logistical services in an enterprise are:

— Good planning and synchronization of different tasks in the logistical chains and the production processes;
— Good information exchange and cooperation between different partners;
— Profound understanding of the market and high precision of prevision.

In addition to these concepts modern logistical services require the integration of *value-added activities* into logistical chains. In many cases, the value-added activities (packages, intermediate stock, clearing, repairing, etc.) constitute a crucial factor influencing the potential utilization of intermodal transportation. The advantages of the value-added activities make up an important attractiveness for large categories of enterprises to redistribute their production/consumption activities so as to optimize service structures.

The economic activities in modern enterprises require modern transport and logistical services. Concretely, these requirements can simply be expressed as: to deliver the products /materials

— to the *Right place*;
— at the *Right time*;
— in the *Right state*;
— at the *Right prices*.

Intermodal Transport System

The intermodal transport system should not simply be considered as the accumulation of classical unique-mode transport systems (roads, rails, and waterways). Actually, intermodal transport system includes the subsystems of:

Intermodal Network: Transport infrastructure constitutes the basic component in the transport system. In addition to the single modes infrastructure network, *intermodal platforms* (bi-modal or tri-modal) are the crucial links

to interconnect different transport modes, guaranteeing the possibility of cargo trans-shipments between different modes. Creation of a European intermodal transport network is a high-priority objective of the European Union under the TEN programme (Trans-Europe Network) and the construction of highly efficient intermodal terminals is considered as the prerequisite to set up such a network.

Intermodal Equipments & Technologies: Trans-shipment facilities and handling equipment are the key technologies for smooth and efficient cargo transfers. The technical conformity of intermodal loading units/vehicles, with respect to their technical standards (dimensions, fixes, etc.), and to the transport vehicles of different modes are the determinants of the possibility of transferring unitized cargo from one transport mode to the other. A specific indicator to explain the operational possibility of the transfers is *interoperability*.

Intermodal Information Services: Intermodal transport operations require an establishment of a seamless information chain. A wide variety of communication flows already exist between intermodal operators and their clients, and many of them adopt such modern technologies. Nowadays information services are integrated as a part of e-logistic systems and transport telematics systems to link transport operators, shippers, forwarding agencies, and administrators together sharing transparent and foreseeable information concerning the cargo, vehicles, and the traffic.

Intermodal Organization/Operations: Due to the participation of different market players in intermodal operations, its operational origination evokes great interest among the system administrators, intermodal operators and shippers with the aim to optimizing the processes, increasing safety/reliability, and improving the service quality. Except that of the operational efficiency within intermodal terminals, many studies have discovered that the economic potential lies in optimal cargo groupage/bundling. (Groupage refers to "the process of transporting cargo with different origins and/or destinations in common transport units and/or load units during shared parts of their routes", and the bundling concept refers to "the collection of goods to fill a transport unit".)

Value-added transport services: Inserted at the moment when the loading/unloading operations happen, the value-added services (repairs, clearing, storage, tests, quality control, etc.) are appreciated by the many enterprises as a means to complete their production/consumption procedures. Due to its characteristics of arrangement in the transport process, the procedures can be optimized to save time and money.

Intermodal Market Framework: Market and policies framework in favour of intermodal transportation should be set up to remove the man-made

obstacles. It is especially vital for international transport, where intermodal transport takes on a very important share. International standards, coherent rules and regulations, harmonized activities, and fare competition conditions are the core part of the framework.

Harmonized functions of these sub-systems provide user-friendly interfaces and high-quality services for enterprises, as well as for the whole society.

Intermodal Logistics Advantages

The advantages of intermodal transport attract more and more enterprises to integrate it into their logistical strategies. As a result, intermodal traffic continues to grow. Seizing the opportunities of developing intermodal logistics, enterprises are in a position to optimize their supply chain structure to benefit both from the transport logistics services and from the improved performance of economic activities as a whole. Generally, intermodal logistics will benefit the enterprises on the following aspects:

Door-to-door transport is a most attractive objective for enterprises in their logistical organization and it is marked as one of the core characteristics of intermodal transport. The enterprises do not necessarily care about what modes are used during the transport processes. Limited only to the doors of origin and destination, the procedures for logistical chain integration is dramatically simplified.

Lowering transport cost is the desired objective of the enterprises. With the integration of waterways and rail transport, intermodal transport in freight corridors (medium or long distance) has lower transport costs than road transport, giving privileges to be integrated into an enterprise's supply-chain.

Lower environmental impacts are the requirements imposed on the transport and logistical service sector to reduce the cost to society (external cost). Hence, intermodal transport is a solution to shift traffic from the heavily loaded road network to the environmentally friendly modes (rail, waterways) without losing the convenience to users. The costs incurred by congestion, pollution, including noise, can be dramatically reduced through the implementation of intermodal logistics, which allows both enterprises and society to benefit.

Safety and reliability are the two important requirements of modern logistical services and they were translated as JIT logistics. Unified standards and coordinated operations will increase reliability, avoiding the unbearable delays due to congestion. Transportation of dangerous cargo by waterways

or railways might dramatically increase transport safety, both for enterprises and for society.

Value-added services are appreciated by enterprises facilitating the integration of production/consumption procedures through optimal logistical chain management. These services might easily be realized in the intermodal hubs (ports, terminals, or platforms) by using the opportunities of modal transfer breaks of intermodal transport processes. The value-added services will create strategic, financial, and organizational advantages for enterprises.

Integrated Information Services provide enterprises with modern means to organize its logistics and integrate intermodal transport into their supply chain management. At present the information services for intermodal transport have already been integrated into the 'Intelligent Transport System', which is a part of the support system of the 'information society'. Through integrated information systems enterprises can easily book transport services and get information about the status of their loading units directly via internet. The operational parameters can easily be exchanged between systems of different transport modes at the convenience of the intermodal operators to optimally organize their transportation.

Bottlenecks and Their Elimination

Recently intermodal transport has been promoted and improved as a means of transport for sustainable development, benefiting the transport sector and socio-economic development in general. However, the system is not yet in a perfected status. There are barriers that hinder the full usage of intermodal transport capacity and the full exploration of its potential. In order to identify what the barriers are, a method called *'Modal Scan'* has been introduced in the study.

'Modal Scan' is a method of analyzing the modal choices of an enterprise's logistical processes, discovering the modal shift barriers and quantifying intermodal potentials. It comprises the following steps:

— Analyzation of logistics operations;
— Selection of freight flows;
— Analyzation of alternatives;
— Recommendations of optimal solutions;
— Implementation.

After surveying a considerable number of enterprises in the study the bottlenecks were identified. They are mainly related to the infrastructure network

(especially intermodal platform, operational efficiency (main focus on transfer operations, line frequency), pre and post haulage, market (policy) framework, and information exchange, etc.).

To encourage the utilization and integration of intermodal transport into enterprises' logistics, strategic measures have been elaborated. They include:

Removing the barriers and reducing the costs: The identification of impediments to interoperability in the transport system and the evaluation of costs and benefits of changes led to the following recommendations for a generic approach:

- Stimulate the increased usage of telematics and modern transport equipment.
- Promote strategic co-operation between transport operators and improved inter-connectivity and inter-operability of transport networks.
- Standardize intermodal loading units, safety and other technical equipment and procedures.
- Harmonize organizational/institutional structures and regulatory frameworks.
- Harmonize fiscal conditions for transport across Europe.
- Use pricing measures to make operators take account of the real costs of different modes, including external costs. This could lead to increasing fuel tax generally, introducing on-board measuring and debiting for emissions, and enabling the trading of emissions permits.
- Introducing an "eco-label" for companies that achieve best practice in their logistic operations.

Exploiting information and communication: New information and communication technologies (ICT) will lead to major improvements in the vital flow of information along the intermodal transport chain, enhancing the quality, efficiency and safety of the services provided. For example, by sharing information on vehicles and consignments between terminal operators, shippers, carriers and responsible authorities, efficiency savings can be made in the planning and delivery of intermodal services and the management of infrastructure.

Facilitating efficient operations: Promoting co-operation between infrastructure planners and decision-makers on a cross-modal basis is a vital policy measure in order to provide a coherent and efficient infrastructure of networks and terminals and facilitating integration between modes through standardized and harmonized activities.

The requirements for efficient trans-shipment call for the new generation of intermodal terminals (optimized terminal layouts, better operational

procedures, and the use of advanced terminal management systems; GPS-based identification, location and positioning systems; automated freight handling; technical and organizational improvements of intermodal terminals; etc.).

Conclusions

1. Intermodal transport is an attractive solution to be integrated into the logistical strategies of enterprises. Making full use of intermodal transport will benefit not only the enterprises but also society as a whole. Considering the sustainable socio-economic benefits, development of intermodal transport can be regarded as a strategic measure to optimize existing transport systems.
2. Evolution of modern logistics introduces new concepts (such as JIT, QR, ECR, and value-added services), which require the adapted transport system to support themselves. The characteristics of intermodal transport can meet these needs, fundamentally soldering intermodal logistics. The advantages (door-to-door, transport cost, environmental impacts, reliability and safety, value-added services, advanced information services, etc.) of intermodal transport offer enterprises the opportunities to build up an efficient, economic, and reliable logistical system to respond to the challenges of globalization and internationalization.
3. Intermodal transport is realized through the co-operations of partners and it consists of different sub-systems (infrastructures, operations, information, policies, organizations, etc.). Integration of intermodal logistical chains require collective efforts from the participating partners to guarantee high quality services.
4. 'Modal Scan' is an effective approach in analyzing the traffic potentials for intermodal transport. It can help to identify the obstacles, bottlenecks, and shifting potentials, and to elaborate optimal logistical strategies for enterprises.
5. Currently, the bottlenecks in Europe are mainly on the transport infrastructure (intermodal platforms), operational efficiency, and information exchanges. The on-going measures concentrate on:

   — Removing bottlenecks and reducing costs;
   — Exploring information and communication;
   — Facilitating efficient operations.

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An In-depth Analysis of Why our Maritime World needs the First Feasible International Container Transshipment Hub in Vietnam

by

LE ANH TUAN*

The further study of the following key points will help to establish what is required in order to evaluate the viability of a transhipment port in Van Phong:

— Why the first International transshipment HUB needed in Vietnam?
— Geographical and maritime information on Van Phong.
— Where will the cargo come from — *i.e.* which countries could benefit from transhipping cargo in Van Phong?
— Development of each of the selected countries — and for the South East Asia region as a whole (trade and economy).
— Competitors — other transshipment ports in the region.
— Deviation (cost and distance).
— Carriers' route planning.
— Development of transshipment cargo and gateway cargo in the South East Asia region and outlining the possible markets/destinations which Van Phong could serve.

Why is the First International Transshipment Hub needed in Vietnam?

Shipping companies utilize transshipment to service a wide range of ports in a cost-effective manner. Mainline vessels call at hub ports to discharge

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and load containers from regional ports, referred to as spoke ports. Cargo is transported between hub ports and spoke ports on feeder vessels. In this way shipping lines can benefit from the economies of scale provided by the deployment of larger vessels on the mainline routes, offer a high service frequency and maintain commercially viable transit times.

Geographical and Maritime Conditions

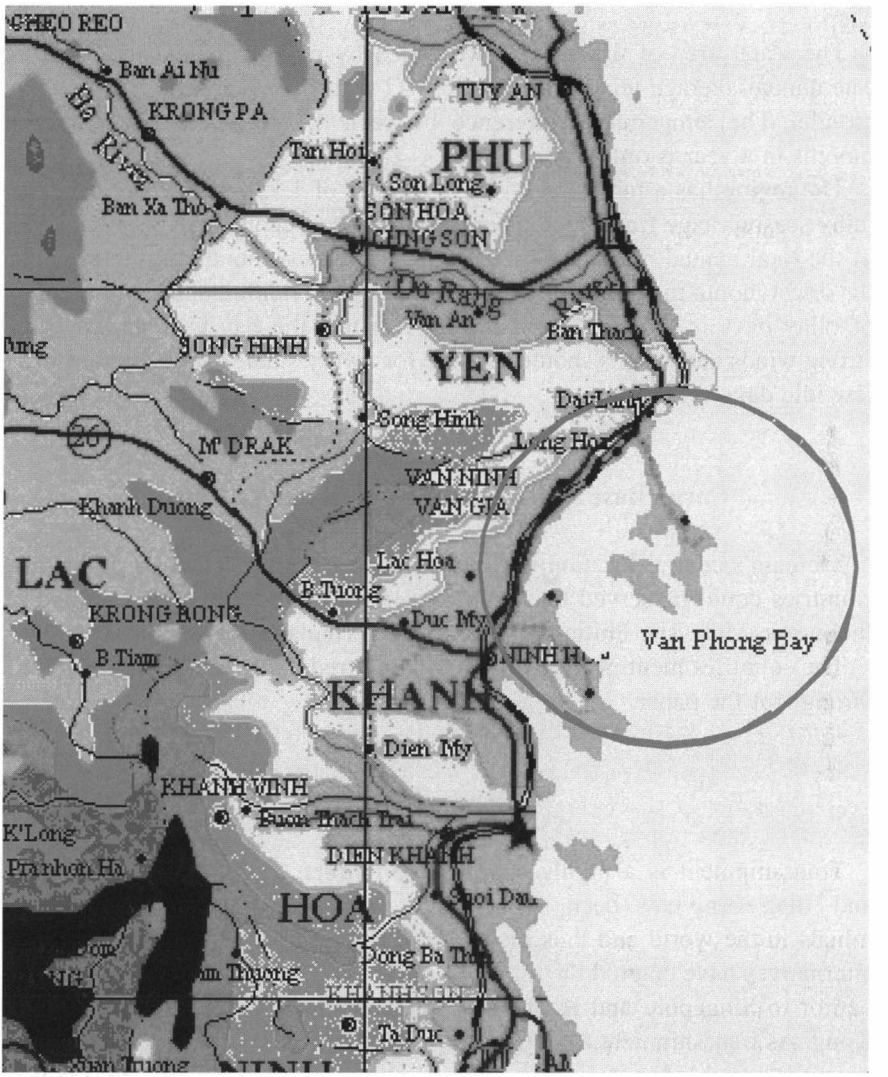
Van Phong Bay is located at 12°28'N – 12°47'N and 109°11'E – 109°28'E, which is the most eastern point of the Indochinese Peninsular. The water surface, under the coverage of this study, is 43,544 ha, land area is 13,800 ha on Hon Gom Peninsular and Hon Lon Island (fig. 1), and the shore length possible for berth construction is 30.7 km.

The bay is located in Van Ninh district of Khanh Hoa province which is the southern part of the Central Vietnam. 35 km north of Van Phong Bay is the provincial town of Phu Yen and 80 km south lies Nha Trang city. Hon Gom Peninsular on the north of the Bay stretches more than 28 kilometers from north to south. From the middle of Hon Gom Peninsular to the national highway no. 1 and the national railway is about 20 kilometers. Van Phong bay is located very near the most important international maritime routes (The Pacific trade, Europe/Far East, Intra Asia).

Van Phong Bay is sheltered from waves and winds by the Hon Gom Peninsula which act as a natural dike or breakwater. As winds in the South China Sea normally blow from Northeast or East and the storms run in anti-clockwise direction, Van Phong Bay is rarely affected by the changing weather conditions in the area. Usually, waves in the bay never reach a height of more than 0.4 mm and thus the bay is an ideal place for ship anchoring and cargo handling.

The depth of Van Phong Bay as well as the depth of the access channel to the proposed terminal area can accommodate the largest container vessels of today and should be able to do so for the next generation of vessels too — with none or very little dredging required. Generally the depth is about 20-22 meters with the minimum depth of 15 meters and maximum depth of 38 meters.

There are 2 channels leading to the proposed terminal area (the Co Co area). The first is Cua Lon (Big Channel) which is 950 m at the narrowest point and 18 meters deep while the other access channel, Cua Be (Small Channel), has the width of 700 m at the narrowest point and is 25-38 meters



Source: Vinamarine.

Fig. 1. — Location of Van Phong Bay.

deep. Both channels are protected from winds and waves and are easy to navigate through. In comparison, the channels of Singapore, Hong Kong or Tanjung Pelepas are all only 300 meters wide and a maximum of 16 meters deep.

The water area of the bay is surrounded by mountains and sand dunes. The annual average temperature is 26.4 °C with little variation between the months. The temperature difference between the coldest and the hottest months in a year is only 6 °C.

The region has a fairly low average rainfall of 1,358.9 mm per year. The rainy season range from September to December, accounting for about 76 % of the total annual rainfall. November is the wettest month and February is the driest month in the year. The rather low annual rainfall and small number of rainy days in a year along with the fact that the bay is protected from strong winds and storms should provide for a very stable port operation with few idle days.

Cargo Base seen from a Location Point of View

Vietnam's central location in South East Asia suggests that the following countries could be served by a hub port in Van Phong: Brunei, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Laos, Vietnam.

The countries mentioned above will be referred to as "the forecast region" throughout the paper.

Competition

Transshipment is a highly competitive market. Traditionally, Singapore and Hong Kong have been — and still are — the largest transshipment terminals in the world and thus in Asia too. However, in recent years various alternatives have entered the market with Tanjung Pelepas as a serious competitor to Singapore and Kaohsiung and Shanghai as competitors to Hong Kong. As transshipment terminals rely mainly on volumes from other countries it is possible for carriers to change hub ports with relatively short notice as long as the economics, transit times, etc. live up to their requirements.

In 2002 it was estimated that almost 95 % of transshipment moves in South East Asia were undertaken at the three main hubs of Singapore, PTP (Tanjung Pelepas) and Port Kelang (tab. 1). A new hub at Van Phong would be better located than any of these main hubs to handle traffic for both the

Central and North-east sub-markets. However, the existing ports must be considered as having "critical mass" — *i.e.* a well-established mainline and feeder network handling high volumes with the associated cost advantages.

Feasibility of Van Phong

If Van Phong transshipment terminal is realised, it must be able to compete on equal terms with the terminals mentioned in table 1. Various important components must be examined in order to establish the feasibility of a transshipment terminal in Van Phong seen from a market point of view. Those are: deviation, route planning, total cost compared to Singapore and Hong Kong (feeder cost, tariffs, handling cost, etc.).

The deviation to Manila from the Singapore-Hong Kong direct route is 535 miles, whereas Vung Tau is a deviation of some 115 miles, while Van Phong would appear to be only a minimal diversion of 50 miles at most (depending on shipping line, to/from, etc.).

Deviation imposes additional marginal costs on a vessel operator in the form of fuel, time and port expenses. Crucially, time has two elements in this equation — first as the direct extra charge for the additional vessel time added to a round voyage by the deviation, but second as a determinant of vessel scheduling. Unless an existing service is scheduled with considerable contingency time (which would be highly unusual), any deviation and/or introduction of an additional port call will almost certainly necessitate some corresponding reduction of time/port calls elsewhere on the voyage, in order to maintain the fixed day weekly call pattern. This means that while a new port call may offer a reduction in direct costs to a carrier this will usually not be enough on its own to produce a change in policy, as the call will actually have to compete with other possible scheduling options and offer greater overall benefits than those when not just costs, but also cargo generation possibilities, are taken into consideration. However, with most major carriers having multiple strings passing by Vietnam on Europe-Asia, Transpacific, intra-Asia and pendulum routings it might be thought that rearrangement of port calls on individual services and/or the introduction of new strings would go a long way to overcome this problem in the case of Van Phong.

On average, and assuming that the full volume of 1,650 TEU per call could be attracted, this would mean that savings of $20 per TEU would be needed to break-even on the direct marginal costs, and conceivably up to $50 per TEU to yield the necessary inducement to carriers (to be achieved

Table 1
Development of transshipment container trade at major SE Asian hub ports, 1980-2002 (million TEU)

	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
(a) Transshipment throughput															
Singapore	550	1,104	3,656	4,511	5,443	6,604	7,696	8,884	9,837	10,884	11,715	12,915	13,926	12,644	13,608
Port Kelang	6	12	40	55	68	77	94	113	176	227	460	964	1,212	1,421	1,813
Tanjung Pelepas													382	1,968	2,588
Other ports	41	77	198	225	268	302	355	400	448	509	543	626	791	892	972
(b) Transshipment incidence (% total port throughput)															
Singapore	60.0%	65.0%	70.0%	71.0%	72.0%	73.0%	74.0%	75.0%	76.0%	77.0%	77.4%	81.0%	81.5%	81.2%	81.0%
Port Kelang	5.0%	5.0%	8.0%	9.0%	10.0%	10.0%	10.0%	10.0%	12.5%	13.5%	25.3%	37.8%	37.8%	37.8%	40.0%
Tanjung Pelepas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.4%	96.0%	97.0%
(c) Share of SE Asian transshipment market															
Singapore	92.0%	92.6%	93.9%	94.2%	94.2%	94.6%	94.5%	94.5%	94.0%	93.7%	92.1%	89.0%	85.4%	74.7%	71.7%
Port Kelang	1.1%	1.0%	1.0%	1.1%	1.2%	1.1%	1.2%	1.2%	1.7%	2.0%	3.6%	6.6%	7.4%	8.4%	9.6%
Tanjung Pelepas	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%	11.6%	13.6%
Other ports	6.9%	6.4%	5.1%	4.7%	4.6%	4.3%	4.4%	4.3%	4.3%	4.4%	4.3%	4.3%	4.8%	5.3%	5.1%

Note: Some data are estimated.

through a combination of lower transshipment costs at Van Phong relative to other hubs, and/or lower feeder costs).

Realistically it can be assumed that the cargo base will come from the forecast region as mentioned previously in the paper. Thus, a transshipment terminal in Van Phong must be able to attract cargo from these countries in order to prove feasible.

A key element in determining Van Phong's transshipment reach is its distance from the main regional ports, relative to the distance from other regional transshipment points. Distance is not the only determinant of feeder cost, but together with vessel size it plays a large part in the level of feeder slot rates. While Van Phong is not to be found in any marine distance tables, the estimated distances to/from major regional outports, and comparisons with existing hubs, are recorded in table 2.

Comparing Van Phong's distance from each of the selected outports, it is possible to arrive at a few preliminary conclusions:

Bangkok — Van Phong and Singapore are equidistant, and transshipment via Van Phong should be highly competitive on transit times for transpacific cargo and any Thailand-N/E Asia traffic moving by transshipment.

Manila — Van Phong should be a lower cost transshipment option than Singapore, but would need to have distinctly lower handling costs than Hong Kong to compensate for the additional feeder in feedering distance.

Table 2
Estimated mileages — regional hubs and main outports

	Van Phong	Singapore*	Hong Kong
Bangkok	895	831	1,489
Manila	745	1,341	632
Jakarta	1,170	525	1,789
Kuching	665	443	1,352
Kota Kinabalu	575	795	1,059
Sandakan	700	1,040	1,115
Muara	575	711	1,120
Sihanoukville	620	630	1,200
Da Nang	300	1,031	520
Ho Chi Minh City	250	646	927
Haiphong	610	1,322	637

* PTP distances almost identical.

Jakarta — No obvious advantages for Van Phong, but might be competitive with Singapore for Transpacific traffic.

Kuching — Van Phong would have a transit time advantage over Singapore for transpacific cargo, and should be a lower cost option than Hong Kong (unless the main-line vessel had to extend to Van Phong)

Kota Kinabalu — Van Phong would be competitive on transit times against Hong Kong for transpacific cargo, and may be able to offer a lower cost solution than Singapore for Europe/Med/Mid East-Asia traffic at the expense of a slower transit time.

Sandakan — Van Phong would be competitive on transit times against Hong Kong for transpacific cargo, and may be able to offer a lower cost solution than Singapore for Europe/Med/Mid East-Asia traffic at the expense of a slower transit time.

Muara — Van Phong would be competitive on transit times against Hong Kong for transpacific cargo, and may be able to offer a lower cost solution than Singapore for Europe/Med/Mid East-Asia traffic at the expense of a slower transit time.

Sihanoukville — Van Phong and Singapore are equidistant, and transshipment via Van Phong should be highly competitive on transit times for transpacific cargo and any Cambodia-N/E Asia traffic moving by transshipment.

Da Nang — Van Phong should be the optimum transshipment option for costs and transits.

Ho Chi Minh City — Van Phong should be the optimum transshipment option for costs and transits.

Haiphong — Van Phong should be the optimum transshipment option for costs and transits.

It would thus appear that Van Phong should be able to offer competitive costs and/or service against the mega-hubs of Singapore and Hong Kong for at least a part of the traffic of each of these ports, and in some cases the new port would appear to be the optimum hub solution.

The next stage in the analysis is to quantify the likely cost advantage or disadvantage for Van Phong for each of these target markets mentioned above bearing in mind the deviation cost. As Van Phong is not operational at this point following facts and assumptions have been included in the further calculations:

— **Deep water**, minimum 15-17 m over substantial tidal windows.
— Plentiful, modern **handling equipment** for both yard and quayside operations.

— Specialist **computer systems** for yard management and ship planning.
— **Productivity** and **performance** - rapid handling rates on a consistent, reliable basis
— **Uncongested** facilities allowing vessels to berth on arrival.
— **Economic, social and political stability** to give carriers confidence in using the port.
— Good quality **management**.
— Skilled, low cost **labour** with a flexible working approach and an absence of militancy or excessive union control.
— **Tariffs** must be highly competitive, both against other hubs, and against direct call alternatives.
— Acceptable levels of **vessel related costs** such as port dues, towage and pilotage charges.
— **Non-extreme** weather conditions.
— Low levels of **bureaucracy**, government and customs interference in the transshipment process.
— Realistic **environmental** standards.

For each of the selected outports the typical, current feeder/intra-regional vessel size and performance is indicated in table 3, and this has been used as the base for service cost purposes. In the case of Van Phong, however, further analysis has been undertaken to establish the possible variation in service slot cost if smaller ships have to be operated at the outset of operations, as this will result in higher feeder costs for Van Phong compared to the existing hubs. Consequently, in the slot cost analysis, the Van Phong-based feeder services have also been assessed on the basis of vessels of (i) 75 % and (ii) 50 % of the capacity of the currently operated ship size.

Table 3
SE Asian feeder trades — typical vessel sizes and specifications

Market	**Current Vessel Size** (nominal TEU)	**Speed** (knots)	**Consumption at service speed** (t/day)	**T/C rate/$ per day** (4q 2003)
Bangkok	800	16.5	26	7,500
Manila	1,200	18.5	47	11,000
Jakarta	2,450	21.5	86	22,000
Kuching, Muara, Kota Kinabalu and Sandakan	300	14.0	15	4,250
Sihanoukville	500	14.5	18	5,000
Ho Chi Minh City	700	16.0	22	6,550
Da Nang & Haiphong	600	16.5	25	6,250

Where Van Phong is the second best feeder option (again, before main line diversion and transshipment handling costs) it could be anticipated that it might secure a portion of the available transshipment traffic for the outports dependent upon the trade route. Where the lowest cost option is Singapore, then on transit grounds alone, Van Phong might be able to secure some cargo arriving from or departing to the east (*i.e.* transpacific and north/east Asia, and possibly WCSA), whereas when Hong Kong is the lowest cost hub, then Van Phong's opportunity would be more oriented towards cargo moving to or from western markets (Europe, the Med and Mid East in particular). However, in each of these cases Van Phong could not logically expect to capture traffic against the lowest cost hub when that also has a geographical (and hence transit time) edge.

In cases where Van Phong might be competing against existing hubs for traffic but with a disadvantage on the size of feeder vessel which can be supported, the potential cost premium naturally varies from route to route, largely dependent upon the size of ship that is currently deployed. If Van Phong services have to be maintained by ships 25 % smaller than those operating out of Singapore or Hong Kong, then the premium per TEU for feeder costs alone is estimated at between $3 and $17, whereas with vessels only 50 % the size of those operating from the existing hubs, the cost disadvantage rises to between $6 and $27 per TEU. Interestingly, however, even the 50 % disadvantage in vessel size does not alter the assessment that Van Phong would never be the highest cost option for any of the identified markets. Clearly there could be substantial additional costs relative to the ideal scenario where equal size vessels could be deployed on Van Phong feeder services, but nevertheless, there could still be sufficient advantage over the highest cost option to secure a part of the transshipment traffic.

It can be seen from tables 4 and 5 that the competitive position of Van Phong relative to Singapore and/or Hong Kong is not substantially changed by movements in charter rates. In none of the cases examined does the change in rates affect the ranking of Van Phong as first or second choice.

Obviously , the Van Phong tariff is not known at this stage, but by reference to reported rates at Singapore and Hong Kong it is possible, when these are combined with the assessments in tables 4 and 5, to obtain some indication of the maximum transshipment charges which might be levied without affecting the port's relative competitive position.

There are often considerable discrepancies in reported terminal charges, dependent upon source, and leaving aside deliberate misinformation these can be attributed to a variety of possible causes, confusions or imprecisions:

Table 4
SE Asian feeder trades — variable service costs* by hub, low charter rates
(US$ per TEU per one way leg at 75% utilisation of nominal capacity)

Service Itinerary	Charter Rate ($/day)	Vessel Size (TEU)	Hub Port		
			Van Phong	Singapore	Hong Kong
			Current Vessel Size		
Bangkok	5,700	800	39.2	38.7	68.0
Manila	8,360	1,200	31.3	56.6	30.1
Jakarta	16,720	2,450	38.9	19.5	61.4
Kuching & Muara	3,230	300	61.6	59.2	113.0
Kota Kinabalu & Sandakan	3,230	300	60.5	84.1	100.0
Sihanoukville	3,800	500	34.2	37.2	68.9
Ho Chi Minh City	4,978	700	12.8	31.7	45.7
Da Nang & Haiphong	4,750	600	32.3	70.1	43.1
			Current Vessel Size less 25%		
Bangkok	4,750	600	46.3	–	–
Manila	6,308	900	33.4	–	–
Jakarta	12,578	1,837	41.9	–	–
Kuching & Muara	2,888	225	65.6	–	–
Kota Kinabalu & Sandakan	2,888	225	64.4	–	–
Sihanoukville	3,572	375	39.3	–	–
Ho Chi Minh City	3,914	525	15.1	–	–
Da Nang & Haiphong	3,762	450	36.2	–	–
			Current Vessel Size less 50%		
Bangkok	3,648	400	53.1	–	–
Manila	4,750	600	38.9	–	–
Jakarta	8,379	1,225	47.2	–	–
Kuching & Muara	2,090	150	89.3	–	–
Kota Kinabalu & Sandakan	2,090	150	87.7	–	–
Sihanoukville	3,040	250	53.6	–	–
Ho Chi Minh City	3,458	350	18.0	–	–
Da Nang & Haiphong	3,230	300	48.1	–	–

* Fuel, time charter costs for time at sea, and hub port costs only. All other elements assumed to be constant between options, though overhead and out-port costs may be slightly higher on a per teu basis for the smaller ship sizes. Fuel price assumed is $ 160/t.

Table 5
SE Asian feeder trades — variable service costs* by hub, high charter rates
(US$ per TEU per one way leg at 75% utilisation of nominal capacity)

Service Itinerary	Charter Rate ($/day)	Vessel Size (TEU)	Hub Port		
			Van Phong	Singapore	Hong Kong
			Current Vessel Size		
Bangkok	9,300	800	52.8	51.2	90.6
Manila	13,640	1,200	41.1	74.3	38.5
Jakarta	27,280	2,450	51.9	25.3	81.3
Kuching & Muara	5,270	300	82.9	78.7	151.0
Kota Kinabalu & Sandakan	5,270	300	81.4	112.6	133.2
Sihanoukville	6,200	500	45.6	48.8	91.0
Ho Chi Minh City	8,122	700	16.7	41.8	60.2
Da Nang & Haiphong	7,750	600	42.5	92.5	55.4
			Current Vessel Size less 25%		
Bangkok	7,750	600	61.4	–	–
Manila	10,292	900	44.5	–	–
Jakarta	20,522	1,837	55.6	–	–
Kuching & Muara	4,712	225	92.9	–	–
Kota Kinabalu & Sandakan	4,712	225	91.2	–	–
Sihanoukville	5,828	375	53.1	–	–
Ho Chi Minh City	6,386	525	19.6	–	–
Da Nang & Haiphong	6,138	450	48.6	–	–
			Current Vessel Size less 50%		
Bangkok	5,952	400	72.9	–	–
Manila	7,750	600	51.5	–	–
Jakarta	13,671	1,225	62.4	–	–
Kuching & Muara	3,410	150	122.9	–	–
Kota Kinabalu & Sandakan	3,410	150	120.6	–	–
Sihanoukville	4,960	250	73.1	–	–
Ho Chi Minh City	5,642	350	23.8	–	–
Da Nang & Haiphong	5,270	300	64.6	–	–

* Fuel, time charter costs for time at sea, and hub port costs only. All other elements assumed to be constant between options, though overhead and out-port costs may be slightly higher on a per teu basis for the smaller ship sizes. Fuel price assumed is $160/t.

1. Whether rates have been quoted per box or per TEU;
2. Whether rates have been quoted as base tariffs or are actual average costs inclusive *e.g.* ancillary charges incurred;
3. Whether transshipment rates are reported per cycle or per move;
4. Whether rates are quoted before or after volume discounts;
5. Whether there are differences in import and export charges;
6. Whether some charges are paid by the cargo interests and not the shipping line;
7. Whether the rate includes the full stack-gate move for gateway cargo;
8. Whether there are discounts for empty containers.

With these issues in mind, available information on regional handling costs for transshipment *containers* indicates the considerable disparities which exist, firstly between Hong Kong and the other ports, and secondly between Singapore and its South East Asian competitors. This should add considerably to the potential for Van Phong to establish itself as a competitive option for transshipment in preference to its more northerly Asian rival. One would certainly expect the operating costs in Vietnam to be substantially below those in Hong Kong, and consequently, as long as the actual construction/development/concession costs are in line with industry standards, there should be no reason why Van Phong could not enjoy a further competitive edge over and above the advantages it might command on feeder costs.

Total Cost

Because Van Phong represents an additional port call compared to any existing itineraries operated by carriers there are marginal main-line costs associated with its use. However, in practice, a Van Phong call may be made as a substitute for another port, rather than as an addition, and so the true actual extent to which carriers would experience these costs is not certain. Moreover, in such a case the Van Phong call could represent a reduction in overall service distance/cost, and might also result in additional net cargo contribution, dependent upon the size of the relative port markets.

Thus it is by no means clear how much, if any, of the marginal main-line vessel deviation costs should be assessed against the Van Phong option, and consequently the table 6 summarizes the situation both with and without the marginal deviation cost ($ 32,993 per call). It is pertinent to note, moreover, that the deviation cost per TEU is dependent upon the volume of containers

Table 6
SE Asia hub port total variable cost* comparison for main outport markets — equal sized feeders at Van Phong (US$ per TEU)

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Singapore					
Bangkok	44.9	103	–	147.9	–	–
Manila	65.5	103	–	168.5	–	–
Jakarta	22.4	103	–	125.4	–	–
Kuching & Muara	69.0	103	–	172.0	–	–
Kota Kinabalu & Sandakan	98.4	103	–	201.4	–	–
Sihanoukville	43.0	103	–	146.0	–	–
Ho Chi Minh City	36.7	103	–	139.7	–	–
Da Nang & Haiphong	81.3	103	–	184.3	–	–
	Hong Kong					
Bangkok	79.3	137	–	216.3	–	–
Manila	34.3	137	–	171.3	–	–
Jakarta	71.4	137	–	208.4	–	–
Kuching & Muara	132.0	137	–	269.0	–	–
Kota Kinabalu & Sandakan	116.6	137	–	253.6	–	–
Sihanoukville	80.0	137	–	217.0	–	–
Ho Chi Minh City	53.0	137	–	190.0	–	–
Da Nang & Haiphong	49.2	137	–	186.2	–	–
	Van Phong — With Marginal Deviation Costs					
Bangkok	46.0	N/a	20.0	66.0	**81.9**	**150.3**
Manila	36.2	N/a	20.0	56.2	**112.3**	**115.1**
Jakarta	45.4	N/a	20.0	65.4	**60.0**	**143.0**
Kuching & Muara	72.3	N/a	20.0	92.3	**79.7**	**176.7**
Kota Kinabalu & Sandakan	70.9	N/a	20.0	90.9	**110.5**	**162.7**
Sihanoukville	39.9	N/a	20.0	59.9	**86.1**	**157.1**
Ho Chi Minh City	14.7	N/a	20.0	34.7	**105.0**	**155.3**
Da Nang & Haiphong	37.4	N/a	20.0	57.4	**126.9**	**128.8**

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Van Phong — without Marginal Deviation Costs					
Bangkok	46.0	N/a	0	46.0	**101.9**	**170.3**
Manila	36.2	N/a	0	36.2	**132.3**	**135.1**
Jakarta	45.4	N/a	0	45.4	**80.0**	**163.0**
Kuching & Muara	72.3	N/a	0	72.3	**99.7**	**196.7**
Kota Kinabalu & Sandakan	70.9	N/a	0	70.9	**130.5**	**182.7**
Sihanoukville	39.9	N/a	0	39.9	**106.1**	**177.1**
Ho Chi Minh City	14.7	N/a	0	14.7	**125.0**	**175.3**
Da Nang & Haiphong	37.4	N/a	0	37.4	**146.9**	**148.8**

* Fuel, time charter costs for time at sea, hub port costs and transshipment handling only.

carried on the main-line vessel, and so this would inevitably be subject to variation in practice. The assessment of $20 per TEU incorporated in this analysis is thought to be a reasonable estimate, being based on an exchange representing some 13.75% of vessel capacity based on a vessel both loading and discharging. Under more favorable assumptions one might reassess this at, say, 25% (3,000 TEU) which would equate to an equal share of activity across four Asian loading/discharging ports, and this would reduce the cost per TEU from $20 to an estimated $14.7.

If it is assumed that an average of the Malaysian/Indonesian transshipment charges quoted in table 6 (*i.e.* $65.50) would constitute a reasonable benchmark for potential Van Phong costs, then — with equal sized feeders — the new port could be competitive against Hong Kong on all the identified routes, even with incorporation of the main-line deviation cost, and would actually produce a saving of at least $49.6 per TEU. The advantage of Van Phong over Singapore is less extreme, but even so there would appear scope to be competitive for all destinations except Jakarta. When the main-line vessel deviation costs are excluded, Van Phong could be expected to be able to compete on price for all the selected outports.

Table 7 presents a similar analysis but assumes that the lower traffic volumes at Van Phong would mean that feeder ships of 25% lesser capacity

Table 7
SE Asia hub port total variable cost* comparison for main outport markets — 25% smaller feeders at Van Phong (US$ per teu per one way leg)

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Singapore					
Bangkok	44.9	103	–	147.9	–	–
Manila	65.5	103	–	168.5	–	–
Jakarta	22.4	103	–	125.4	–	–
Kuching & Muara	69.0	103	–	172.0	–	–
Kota Kinabalu & Sandakan	98.4	103	–	201.4	–	–
Sihanoukville	43.0	103	–	146.0	–	–
Ho Chi Minh City	36.7	103	–	139.7	–	–
Da Nang & Haiphong	81.3	103	–	184.3	–	–
	Hong Kong					
Bangkok	79.3	137	–	216.3	–	–
Manila	34.3	137	–	171.3	–	–
Jakarta	71.4	137	–	208.4	–	–
Kuching & Muara	132.0	137	–	269.0	–	–
Kota Kinabalu & Sandakan	116.6	137	–	253.6	–	–
Sihanoukville	80.0	137	–	217.0	–	–
Ho Chi Minh City	53.0	137	–	190.0	–	–
Da Nang & Haiphong	49.2	137	–	186.2	–	–
	Van Phong — With Marginal Deviation Costs					
Bangkok	53.8	N/a	20.0	73.8	**74.1**	**142.5**
Manila	38.9	N/a	20.0	58.9	**109.6**	**112.4**
Jakarta	48.8	N/a	20.0	68.8	**56.6**	**139.6**
Kuching & Muara	79.3	N/a	20.0	99.3	**72.7**	**169.7**
Kota Kinabalu & Sandakan	77.8	N/a	20.0	97.8	**103.6**	**155.8**
Sihanoukville	46.2	N/a	20.0	66.2	**79.8**	**150.8**
Ho Chi Minh City	17.4	N/a	20.0	37.4	**102.3**	**152.6**
Da Nang & Haiphong	42.4	N/a	20.0	62.4	**121.9**	**123.8**

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Van Phong — without Marginal Deviation Costs					
Bangkok	53.8	N/a	0	53.8	**94.1**	**162.5**
Manila	38.9	N/a	0	38.9	**129.6**	**132.4**
Jakarta	48.8	N/a	0	48.8	**76.6**	**159.6**
Kuching & Muara	79.3	N/a	0	79.3	**92.7**	**189.7**
Kota Kinabalu & Sandakan	77.8	N/a	0	77.8	**123.6**	**175.8**
Sihanoukville	46.2	N/a	0	46.2	**99.8**	**170.8**
Ho Chi Minh City	17.4	N/a	0	17.4	**122.3**	**172.6**
Da Nang & Haiphong	42.4	N/a	0	42.4	**141.9**	**143.8**

* Fuel, time charter costs for time at sea, hub port costs and transshipment handling only.

would have to be operated, while table 8 then presents the results with Van Phong being served by feeders of 50 % less capacity. Naturally, the additional feeder cost per TEU changes the relative competitive position of Van Phong under these less advantageous circumstances.

With both 25 % and 50 % smaller feeders operating from Van Phong, the break-even transshipment charge needed to undercut the Hong Kong option remains well in excess of $ 100 per TEU in each case, and so the ability of Van Phong to be competitive against Hong Kong appears to be robust even under unfavorable assumptions.

Singapore is a greater threat, although under the 25 % smaller feeder ship option, Van Phong seemingly remains competitive for all outports except Jakarta, although Bangkok, Kuching/Muara and Sihanoukville become more marginal. Under the 50 % smaller feeder ship option, these markets become still more difficult for Van Phong, though it is noticeable that the greatest effect is in the smaller volume markets of Eastern Malaysia and Cambodia where the feeder unit costs rise steeply with the deployment of very small vessels, whereas for Bangkok the reduction in feeder ship size has much less impact due to the higher capacity base position.

The actual potential saving that these unit values might represent to any carrier per sailing or per year would be determined by the volume of traffic to/from each outport and the current distribution pattern (*e.g.* most outports will be served from more than one hub dependent upon trade route/service

Table 8

SE Asia hub port total variable cost* comparison for main outport markets — 50% smaller feeders at Van Phong (US$ per teu per one way leg)

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Singapore					
Bangkok	44.9	103	–	147.9	–	–
Manila	65.5	103	–	168.5	–	–
Jakarta	22.4	103	–	125.4	–	–
Kuching & Muara	69.0	103	–	172.0	–	–
Kota Kinabalu & Sandakan	98.4	103	–	201.4	–	–
Sihanoukville	43.0	103	–	146.0	–	–
Ho Chi Minh City	36.7	103	–	139.7	–	–
Da Nang & Haiphong	81.3	103	–	184.3	–	–
	Hong Kong					
Bangkok	79.3	137	–	216.3	–	–
Manila	34.3	137	–	171.3	–	–
Jakarta	71.4	137	–	208.4	–	–
Kuching & Muara	132.0	137	–	269.0	–	–
Kota Kinabalu & Sandakan	116.6	137	–	253.6	–	–
Sihanoukville	80.0	137	–	217.0	–	–
Ho Chi Minh City	53.0	137	–	190.0	–	–
Da Nang & Haiphong	49.2	137	–	186.2	–	–
	Van Phong — With Marginal Deviation Costs					
Bangkok	63.0	N/a	20.0	83.0	**64.9**	**133.3**
Manila	45.2	N/a	20.0	65.2	**103.3**	**106.1**
Jakarta	54.8	N/a	20.0	74.8	**50.6**	**133.6**
Kuching & Muara	106.1	N/a	20.0	126.1	**45.9**	**142.9**
Kota Kinabalu & Sandakan	104.1	N/a	20.0	124.1	**77.3**	**129.5**
Sihanoukville	63.4	N/a	20.0	83.4	**62.6**	**133.6**
Ho Chi Minh City	20.9	N/a	20.0	40.9	**98.8**	**149.1**
Da Nang & Haiphong	56.3	N/a	20.0	76.3	**108.0**	**109.9**

Service Itinerary	Feeder Costs	Trans-shipment Handling	Mainline Vessel Deviation	Total	Maximum Van Phong Transshipment Charge	
					To Equate with Singapore	To Equate with Hong Kong
	Van Phong — without Marginal Deviation Costs					
Bangkok	63.0	N/a	0	63.0	**84.9**	**153.3**
Manila	45.2	N/a	0	45.2	**123.3**	**126.1**
Jakarta	54.8	N/a	0	54.8	**70.6**	**153.6**
Kuching & Muara	106.1	N/a	0	106.1	**65.9**	**162.9**
Kota Kinabalu & Sandakan	104.1	N/a	0	104.1	**97.3**	**149.5**
Sihanoukville	63.4	N/a	0	63.4	**82.6**	**153.6**
Ho Chi Minh City	20.9	N/a	0	20.9	**118.8**	**169.1**
Da Nang & Haiphong	56.3	N/a	0	56.3	**128.0**	**129.9**

* Fuel, time charter costs for time at sea, hub port costs and transshipment handling only.

string, while a proportion of cargo will move direct). These factors will obviously vary from carrier to carrier, and so it is very difficult to arrive at any meaningful assessment. However, the figures in table 9 do provide some flavor of the scale of the possible savings.

Table 9
Estimated gateway volumes at selected outports, 2002

Market	Saving via Van Phong* (US$ per TEU)	
	Singapore	Hong Kong
Bangkok (incl. Laem Chabang)	8.6	77.0
Manila	44.1	46.9
Jakarta	(8.9)	74.1
Kuching	7.2	104.2
Muara	7.2	104.2
Kota Kinabalu	38.1	90.3
Sandakan	38.1	90.3
Sihanoukville	14.3	85.3
Ho Chi Minh City	36.8	87.1
Da Nang	56.4	58.3
Haiphong	56.4	58.3

* Assuming transshipment charge of $65.5 per TEU at Van Phong, and deployment of same size feeders at Van Phong.

Potential Development of New Services

The foregoing analysis has centered upon the operation of a feeder network to support calls from 6,000 TEU main line vessels operating on transpacific or Europe-Asia trade routings, as this is the most obvious way in which Van Phong might be incorporated into carrier schedules. However, it is not the only way, and a couple of other options suggest themselves:

Four primary possibilities suggest themselves:

1. Diversion of a north-south intra-Asia service into Van Phong between Port Kelang/Singapore and Manila or Hong Kong.
2. Addition of a Van Phong call to a N/E Asia-Vietnam/Thailand intra Asia service.
3. Substituting a Van Phong call for a Laem Chabang call on a transpacific and/or Europe-Asia service.
4. Extending a transpacific service beyond Hong Kong to Van Phong.

As far as options one and two are concerned, the current structure of intra-Asian services is clearly important (tab. 10). There is a large potential market of main-line intra-Asia sailings — probably around 50 per week — passing very closely to Van Phong. These services are being operated by vessels of between 1-2,000 TEU capacity (NE Asia) and 600-2,000 TEU (E Asia). This is not including the approximately equal number of weekly main-line services — Europe-Asia (27), Asia-Mid East (14) and Transpacific (10 plus 2 diverting via Laem Chabang) — which are also plying the main route between Singapore and Hong Kong without currently making any intermediate calls.

Any of these services could divert into Van Phong with a relatively low deviation cost. Compared with the estimated $32,993 per call assessed for a 6,000 TEU vessel the costs for a vessel of, say, 1,200 TEU might be estimated at only around $8,900 — assuming a lower port time of 8 hours, which might permit an exchange of around 420 TEU (7 hours net x × 20 moves/hr × average 2 cranes × 1.5 TEU per box), so that the basic diversion cost might amount to some $21 per TEU.

The ability to divert into Van Phong with an existing string would demand either that vessels were sailing with considerable vacant space, or that the service would be upsized to cater for the additional volumes.

Turning now to deep-sea possibilities, it is the Thai market which would seem to hold out the greatest potential for the development of new scheduling possibilities based on Van Phong.

Table 10
Port call patterns of intra-Asian liner services*, to/from SE Asia (calls per week)

	North East and East Asia	East Asia only
Singapore	26.2	8.0
Port Kelang	16.0	9.0
Pasir Gudang	7.0	2.0
Jakarta	11.8	5.0
Surabaya	5.8	3.0
Semarang	1.8	1.0
HCMC	10.0	7.0
PTP	2.0	0.0
Bangkok/Laem Chabang	18.5	7.0
Manila	14.0	12.0
None of the above	1.25	2.7
Total services	56.0	29.7

* Excludes pure feeder services.

Bangkok/Laem Chabang is a major deviation for vessels sailing between Singapore and Hong Kong, but a number of deep sea services are scheduled in this way (tab. 11). This is a comparatively recent development, as when Laem Chabang was first incorporated into deep sea schedules it was invariably on transpacific strings which were extended from Hong Kong and then turned in Laem Chabang. One of the deep sea services now calling Laem Chabang actually makes this deviation twice with calls both north and southbound during the ship's Asian coastal transit (on a pendulum rotation between the USWC and the USEC via Asia).

The deviation to Laem Chabang (compared to Singapore-Hong Kong direct) is some 860 miles, which under study assumptions for large ships (24 knots on 195 tpd; $ 30,000/day for ship's time) is 1.5 days sea time and at least 0.5 days in port. So total deviation is 2 days per call, and with port costs speculatively estimated at $ 12,500 this would produce an all up cost of some $ 120,000 — considerably in excess of the cost to deviate to Van Phong. Of course, the net difference between the two diversions ($ 87,338 per call) would have to pay for the transshipment of the Thai cargo which would otherwise be loaded direct, and the cost to handle this traffic by feeder over Van Phong would be in excess of the variable cost earlier assessed, as in this case the full feeder cost would need to be included for comparison purposes.

Table 11
Direct calls in Laem Chabang — main-line vessels
(Calls per week)

Operator	String	Type	Trade(s)	Avg Vessel Size (TEU)	Port Rotation
Grand Alliance	SCX	End to End	T'pac	5,654	KHH, HKG, SIN, **LCH**, HKG, KHH
Grand Alliance	AEX/ PNX	Pendulum	T'pac, Med/ECNA	4,267	KHH, HKG, **LCH**, SIN ... SIN, **LCH**, YTN, HKG, KHH.
Maersk Sealand	TP5	Pendulum	T'Pac, ME/ISC	4,678	PTP, **LCH**, HKG, YTN .... KWY, SHA, NBO, HKG, YTN, SIN, PTP
New World Alliance	SAX	End to End	T'Pac	5,762	KHH, HKG, CWN, **LCH**, SIN
CSCL/Norasia	AAT/ MAP	Pendulum	T'Pac, Med	2,559	PKG, **LCH**, HKG, YTN, NBO, SHA, PUS ..... DAL, XGG, QIN, SHA, NBO, XMN, HKG, CWN, PKG

* Excludes pure feeder services.

One further possibility is that carriers might be induced to extend transpacific services which presently turn around at Hong Kong or one of the Shenzhen ports to Van Phong. Such a course of action would require that the additional costs of the voyage extension should result in reduced transshipment costs for cargo to Thailand and to other Vietnam destinations, as well as increased volumes of national traffic by virtue of the direct call in Vietnam.

Volumes for Van Phong

As mentioned previously the transshipment market in the region (Asia) is very competitive and it is difficult to arrive at a final result with the information available. However, in the information above it is clearly shown that Van Phong could be competitive on both distance and prices for various spoke ports in the forecast region. Table 12 summarizes the scenarios where Van Phong would have advantages compared to the mega hubs of Hong Kong and Singapore.

A transshipment terminal in Van Phong would clearly not be able to attract cargo from all places where an advantage exists and it is thus not possible to arrive at an exact and meaningful figure (as mentioned above). Table 13 details the potentially available traffic under a range of market share scenarios (5 % to 50 %) for each of the sub-markets if indeed the terminal had been operational in 2002.

Funding

The paper will not dwell a lot on the funding of the two projects. However, it is an important component and will thus be discussed briefly below.

The Van Phong project will require substantial and continuous investments throughout a number of years in order to reach a size where it will be able to compete with the mega hubs of Hong Kong and Singapore.

As previously mentioned, the transshipment market is very competitive. It would therefore make sense to attract private investors and thus professional port operators to achieve the highest level of operation and thereby maintain a sound level of competitiveness. Traditionally, ODA funding has assisted to develop a number of infrastructure projects in Vietnam and also in this case it should be considered to aim at attracting some ODA funds.

In this respect it is imperative that the Government of Vietnam makes an effort to make the investment possibilities as attractive and transparent as possible by supplying the geographical area with the necessary infrastructure and give the investor(s) the best possible investment incentives. Furthermore, it might make sense to allocate a certain amount on the local budget for developing parts of the project to make clear to the outside world the commitment of the Vietnamese Government in Van Phong.

Conclusion

Although being a very ambitious and long term project requiring a great deal of commitment it seems that Van Phong have favourable conditions for the construction and development of an international transshipment hub.

In the part of the paper dealing with the Van Phong project a number of issues were analysed and discussed. The results of the analysis are mentioned below:

— Volumes will have to come from the forecast region and potentially southern China.

Table 12
Summary of regional gateway market by port, 2002 (' 000 TEU)

Country	Port	Gateway teu	Gateway market share	Van Phong advantage over:	
				Singapore	Hong Kong
Brunei	all ports	75	0.4%	YES	YES
Cambodia	all ports	54	0.3%	YES	YES
Indonesia	Tanjung Perak	1,315	6.1%	NO	YES
Indonesia	Tanjung Priok	2,504	11.7%	NO	YES
Indonesia	other ports	854	4.0%	NO	YES
Indonesia	all ports	4,673	21.8%		
Malaysia	Johor	634	3.0%	NO	YES
Malaysia	Tanjung Pelapas	80	0.4%	NO	YES
Malaysia	Penang	588	2.7%	NO	YES
Malaysia	Port Kelang	2,720	12.7%	NO	YES
Malaysia	other ports	488	2.3%	SOME	YES
Malaysia	all ports	4,510	21.1%		
Philippines	Manila	2,729	12.8%	YES	NO
Philippines	other ports	1,119	5.2%	YES	SOME
Philippines	all ports	3,848	18.0%		
Singapore	Singapore	3,192	14.9%	NO	YES
Thailand	Bangkok	1,063	5.0%	NO	YES
Thailand	Laem Chabang	2,550	11.9%	NO	YES
Thailand	other ports	5	0.0%	NO	YES
Thailand	all ports	3,618	16.9%		
Vietnam	Ho Chi Minh	1,018	4.8%	YES	YES
Vietnam	other ports	407	1.9%	YES	YES
Vietnam	all ports	1,425	6.7%		
TOTAL		**21,394**	**100.0%**		

Table 13
Summary of Van Phong regional transshipment moves
under different market share scenarios for each sub-market, 2002 (' 000 TEU)

Sub-market	Van Phong gains a market share of:									
	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Central Asia	117	234	351	468	586	703	820	937	1,054	1,171
North-east Asia	160	319	479	639	798	958	1,118	1,277	1,437	1,597
Southern Asia	793	1,586	2,379	3,172	3,965	4,758	5,550	6,343	7,136	7,929
% share of regional transshipment market										
Central Asia	0.5%	1.1%	1.6%	2.2%	2.7%	3.3%	3.8%	4.4%	4.9%	5.5%
North-east Asia	0.7%	1.5%	2.2%	3.0%	3.7%	4.5%	5.2%	6.0%	6.7%	7.5%
Southern Asia	3.7%	7.4%	11.1%	14.8%	18.5%	22.2%	25.9%	29.7%	33.4%	37.1%

— Trade patterns and economic development of the forecast region seem to be in favour of a potential transshipment terminal in Van Phong.
— Van Phong is at most a 50 NM deviation from the main shipping routes.
— The theoretical cost for a 6,000 TEU vessel, based on additional fuel and port costs, as well as time spent steaming and in port, amounts to an estimated USD 32,993 per call.
— There is already a high number of services on Europe — Far East, Trans-pacific, intra-Asia, and pendulum routings.
— In order to introduce a call at Van Phong route planning of the carriers must change if and thus another port call must be shortened or dropped. It is furthermore important that the services and prices offered in a Van Phong terminal encourage the carriers to change their routing.
— The Government of Vietnam must do its best to make the investment in Van Phong as attractive as possible to private investors. Moreover, it could be a possibility to allocate a certain amount on the local budget for developing parts of the project to illustrate towards private investors the strong commitment of the Vietnamese Government with regards to developing a transshipment hub in Van Phong.
— As the funds needed to realise the Van Phong project are of a substantial size investment should be sought from all possible sources (foreign and local) in all possible shapes (BOT, BT, BT+O, JV).

The Van Phong transshipment terminal project is indeed an interesting and very ambitious project. Being a development of such long term it is naturally difficult to predict the exact developments in the regional and global markets. Having said that, Maersk would like to officially support the initiative and it is the hope that Maersk will be taken into consideration when the investor(s) and/or operator(s) are going to be nominated. In addition, the realisation of the Van Phong transshipment terminal is subject to further investigation due to its long term nature and intensive investment requirements.

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The Evolution of Cargo Concentration Patterns in the East Asian Container Port System

by

Theo NOTTEBOOM*

1. Introduction

Seaports function as important nodes in container service networks on the seaside as well as the landside. Much literature addresses the spatial development of seaport systems in relation to maritime and hinterland networks. The model of TAAFFE *et al.* (1963) suggests an increasing level of port concentration as certain hinterland routes develop to a greater extent than others in association with the increased importance of particular urban centres. The geographical system would evolve from an initial pattern of scattered, poorly connected ports along the coastline to a main network consisting of corridors between gateway ports and major hinterland centres. The models of BARKE (1986) and HAYUTH (1981) are quite similar, though they have introduced a process of port system deconcentration. In the meantime, some authors have introduced modifications to the above models in order to reflect the uniqueness of some port regions (see *e.g.* WANG 1998). More recently, NOTTEBOOM & RODRIGUE (2005) introduced a 'port regionalization' phase. Empirical research has demonstrated that some port systems and port ranges are getting more spatially concentrated while others are evolving to a more evenly distributed system, see *e.g.* KUBY & REID (1992), NOTTEBOOM (1997), MCCALLA (1999) and LAGO *et al.* (2001).

This paper analyses cargo concentration patterns in East Asia. Observed concentration and deconcentration patterns in the multi-range container port

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system of East Asia will be decomposed using a Gini decomposition analysis. The first part provides an empirical overview of the evolution of container throughputs in East Asian ports. The second section zooms in on cargo concentration patterns based on Gini coefficients and their components. The last part of the paper gives a more qualitative insight in the obtained cargo concentration results and puts forward some likely developments for the future.

2. The East Asian Container Port System

For most of the past quarter century, no region of the world has been more economically dynamic than East Asia. The unprecedented economic growth of East Asia transformed the patterns of world trade. Especially China now attracts a lot of international attention. China achieved an average GDP growth of 9 %, which it has been able to maintain since 1979. In 2003 GDP growth reached 9.1 %, in 2004 9.3 %. Apart from strong growth in domestic consumption, import and export volumes increased by 35 to 40 % per annum in the last five years. China now ranks fourth in the world when it comes to international trade volumes. While China has seen exponential growth, Japan has witnessed a temporary slowdown in economic development. Export-oriented Taiwan and South Korea continue to show healthy growth figures by benefiting from the shifts in economic power in the region and in the world.

The Chinese economic boom, the Japanese setback and the export strategies of Taiwan and South Korea have affected container flows moving in and out the vast East Asian region. Shipping lines are dedicating higher capacities and deploying larger vessels to cope with the increasing Chinese container imports and exports, especially in relation to the China-Europe trade. The East Asian port system is earmarked by remarkable growth and has dramatically changed the ranking of the world's largest container ports. Nine of the twenty largest container ports in the world in 2004 are located in East Asia (tab. 1). The position of Japanese ports has weakened, while Chinese ports are climbing fast in the listing.

The East Asian container port system is a heterogeneous blend of subsystems or port ranges and individual ports, each with different characteristics with respect to cargo flows, cargo balance, commodity specialization, hinterland coverage, physical lay-out, port management system, etc. In many studies that focus on the analysis of seaports located in the same continent or region, authors have attempted to group ports together to form larger

Table 1
Top 20 container ports in the world (East Asian ports in bold)

	1975		1985		1995		2004	
RANK	PORT	mTEU	PORT	mTEU	PORT	mTEU	PORT	mTEU
1	Rotterdam	1.08	Rotterdam	2.65	**Hong Kong**	**12.55**	**Hong Kong**	**21.93**
2	New York/NJ	0.95	New York/NJ	2.37	Singapore	11.85	Singapore	21.33
3	**Kobe**	**0.90**	**Hong Kong**	**2.29**	**Kaohsiung**	**5.23**	**Shanghai**	**14.55**
4	**Hong Kong**	**0.80**	**Kobe**	**1.52**	Rotterdam	4.79	**Shenzhen**	**13.66**
5	**Keelung**	**0.56**	Antwerp	1.35	**Busan**	**4.50**	**Busan**	**11.43**
6	Oakland	0.52	**Yokohama**	**1.33**	Hambug	2.89	**Kaohsiung**	**9.71**
7	Seattle	0.48	Hamburg	1.16	**Yokohama**	**2.76**	Rotterdam	8.22
8	Bremerhaven	0.41	**Keelung**	**1.16**	Los Angeles	2.56	Los Angeles	7.32
9	Long Beach	0.39	**Busan**	**1.15**	Long Beach	2.39	Hamburg	7.00
10	Melbourne	0.36	Long Beach	1.14	Antwerp	2.33	Dubai	6.42
11	**Tokyo**	**0.36**	Los Angeles	1.10	New York/NJ	2.28	Antwerp	6.06
12	Antwerp	0.36	**Tokyo**	**1.00**	**Tokyo**	**2.18**	Long Beach	5.78
13	**Yokohama**	**0.33**	Bremerhaven	0.99	**Keelung**	**2.17**	Port Kelang	5.24
14	Hamburg	0.30	San Juan	0.88	Dubai	2.07	**Qingdao**	**5.14**
15	Sydney Harbour	0.26	Oakland	0.86	Felixstowe	1.90	New York/NJ	4.47
16	San Juan	0.26	Seattle	0.85	Manila	1.67	Tanjung Pelepas	4.02
17	Tilbury	0.23	Bremerhaven	0.83	San Juan	1.59	**Ningbo**	**4.01**
18	Le Havre	0.23	Dunkirk	0.71	Oakland	1.55	**Tianjin**	**3.81**
19	**Kaohsiung**	**0.23**	Baltimore	0.71	**Shanghai**	**1.53**	Laem Chabang	3.62
20	Jacksonville	0.21	Jeddah	0.68	Bremerhaven	1.53	**Tokyo**	**3.58**

Source: Containerisation International — CI Online.

functional or spatial units. FLEMING (1997) presented an alternative world container port ranking by making some selective and imaginative combinations to define regional load centres such as Tacoma/Seattle and Los Angeles/Long Beach. The locational relationship to nearby identical traffic hinterlands was one of the criteria used to cluster adjacent load centres. While analysing the nature of port competition, VERHOEFF (1977) referred to the spatial and functional dimension of port ranges. He defined a port range as a number of ports or port areas situated along the same coast and with a more or less common potential hinterland. Based on later work on port ranges, we can identify a number of criteria to group ports together to form a port range: (i) geographical characteristics (*e.g.* situated along the same coastline), (ii) ports of call within the same set of loops of intercontinental liner service schedules, and (iii) the hinterland capture area (*i.e.* ports in the same range typically have a large shared or overlapping hinterland).

Based on this approach we can split up the East Asian port system in several port ranges. The East Asian container port system as considered in this paper consists of 27 container ports divided over seven port ranges (see fig. 1). Container traffic data in TEU for the period 1978-2004 were collected from the respective port authorities and Containerisation International Online.

Total container throughput in the seven East Asian ranges evolved from 5.7 million TEU in 1978 to 114 million TEU in 2004. It can be observed the Chinese port ranges are gaining in importance after decades of moderate growth (fig. 2). In 1992, the Pearl River Delta surpassed the Japanese port system to become the most important range in East Asia. Also the Yangtze

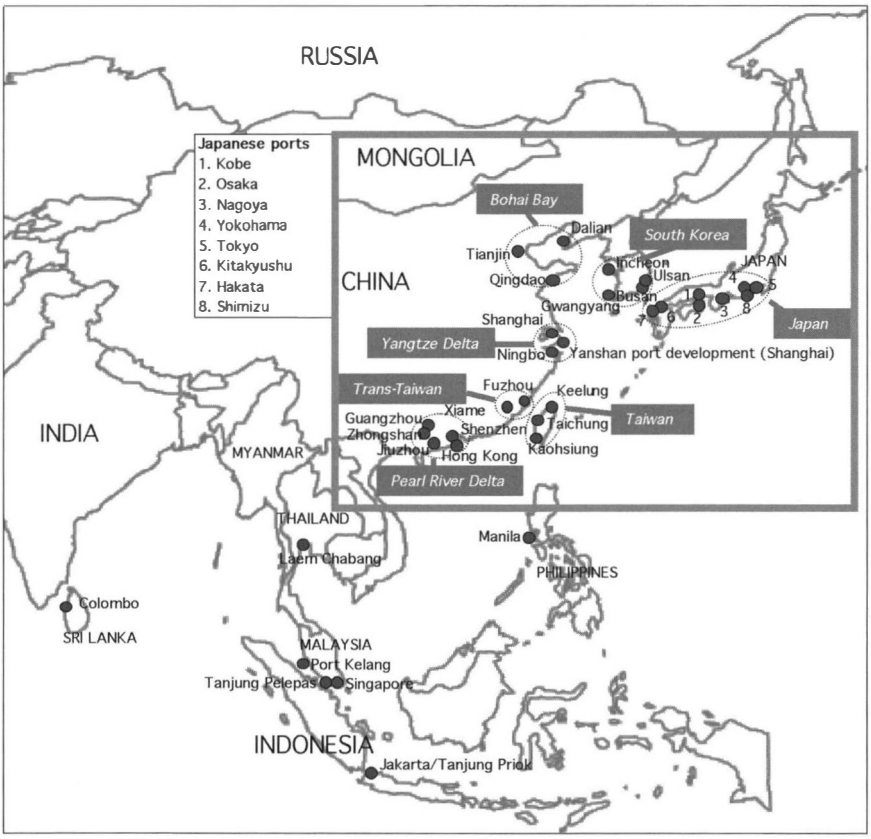

Fig. 1. — The East Asian port system and port ranges.

Delta range is rapidly becoming a strong cargo concentration point in the East Asian container port system.

Figure 3 provides more insight in the evolution of the relative positions of the observed ranges for three-year periods, starting from 1980-1983 till 2001-2004. At present, the average container growth in the Japanese port system is as low as in the early days of containerisation (around half a million TEU per year). Its market share declined dramatically from 43 % in the early 1980s to only 12 % in 2004. The Japanese range was recently passed by the Yangtze Delta and the South Korean range, making it today only the fourth largest range. It is expected that the Taiwan range and the Bohai Bay range will overtake the Japanese range in the next couple of years.

The market share of the Pearl River Delta range stabilized at around 35 % (after years of strong increase), while absolute annual growth figures now exceed 5 million TEU. Even more spectacular is the steep rise of the Yangtze Delta and the other smaller ranges in China. Only twenty years ago the Chinese container port system was still in its infancy stage. Hong Kong acted as the only container gateway to China handling more than 2 million TEU in 1985, whereas all mainland container ports together only handled 0.2 million TEU in the same year. Since the second half of the 1990s container throughput at mainland ports started to accelerate. In the period 1995-1998 container traffic at the main Chinese container ports doubled to reach almost 10 million TEU in 1998. In 2003 the Chinese container port system

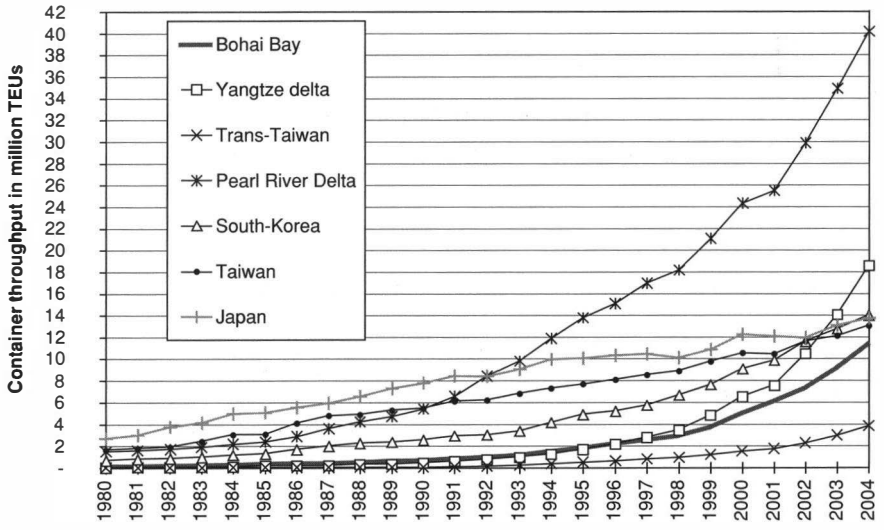

Fig. 2. — Container traffic for given port ranges (in million TEU, 1978-2004).

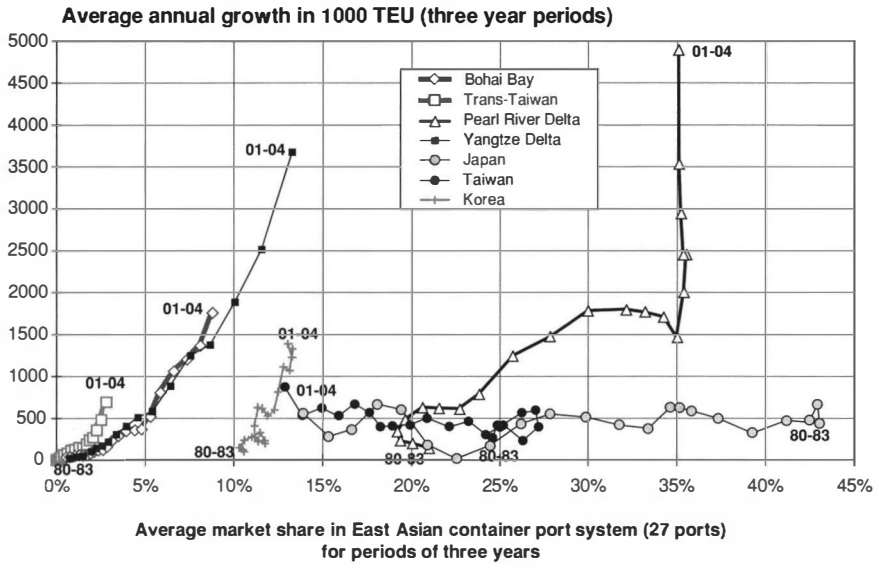

Fig. 3. — A dynamic positioning of port ranges based on market share and TEU growth.

(excluding Hong Kong) handled four times more compared to 1998. The main container ports, at present, are Shanghai, Tianjin, Dalian, Qingdao, Shenzhen, Ningbo, Guangzhou and Xiamen. In 2004, the ports of Shanghai and Shenzhen reached a throughput figure of more than 13 million TEU, thereby narrowing the throughput gap with Hong Kong. Shenzhen port in South China's Guangdong Province has seen the fastest growth in the past years, taking the second place among Chinese container ports for six successive years. The rise of individual Chinese container ports is depicted in table 2. The dominance of Hong Kong is eroding as ports from mainland China are moving up.

3. Concentration Patterns in the East Asian Container Port System

Transport geographers often deploy Gini coefficients as a method to measuring traffic concentration at transportation nodes such as airports, intermodal terminals and seaports. There are different methods to calculate the Gini, but a simple formula applied to ports, is shown below:

$$G = 1 - \sum_{i=0}^{N} (\sigma Y_{i-1} + \sigma Y_i)(\sigma X_{i-1} + \sigma X_i)$$

Table 2

Top 15 container ports in East Asia

	1978			1985			1995			2000					2004
		1000 TEU	%		1000 TEU	%		1000 TEU	%		1000 TEU	%		1000 TEU	%
1	Kobe	1447	25.4%	Hong Kong	2289	18.8%	Hong Kong	12550	31.3%	Hong Kong	18098	26.3%	Hong Kong	21930	19.2%
2	Hong Kong	1226	21.5%	Kaohsiung	1901	15.6%	Kaohsiung	5053	12.6%	Busan	7540	10.9%	Shanghai	14557	12.7%
3	Kaohsiung	570	10.0%	Kobe	1519	12.5%	Busan	4503	11.2%	Kaohsiung	7426	10.8%	Shenzhen	13660	11.9%
4	Tokyo	551	9.7%	Yokohama	1327	10.9%	Yokohama	2727	6.8%	Shanghai	5612	8.1%	Busan	11430	10.0%
5	Busan	507	8.9%	Keelung	1158	9.5%	Tokyo	2177	5.4%	Shenzhen	3994	5.8%	Kaohsiung	9710	8.5%
6	Yokohama	500	8.8%	Busan	1155	9.5%	Keelung	2170	5.4%	Tokyo	2899	4.2%	Qingdao	5140	4.5%
7	Keelung	474	8.3%	Tokyo	1004	8.3%	Shanghai	1527	3.8%	Yokohama	2317	3.4%	Ningbo	4006	3.5%
8	Nagoya	170	3.0%	Osaka	423	3.5%	Nagoya	1477	3.7%	Kobe	2266	3.3%	Tianjin	3814	3.3%
9	Osaka	149	2.6%	Nagoya	422	3.5%	Kobe	1464	3.6%	Qingdao	2120	3.1%	Tokyo	3358	2.9%
10	Incheon	48	0.8%	Shanghai	202	1.7%	Osaka	1159	2.9%	Keelung	1955	2.8%	Guangzhou	3308	2.9%
11	Shimizu	34	0.6%	Kitakyushu	161	1.3%	Tianjin	702	1.7%	Nagoya	1912	2.8%	Xiamen	2872	2.5%
12	Shanghai	15	0.3%	Tianjin	148	1.2%	Qingdao	603	1.5%	Tianji	1708	2.5%	Yokohama	2718	2.4%
13	Taichung	2	0.0%	Incheon	131	1.1%	Guangzhou	515	1.3%	Osaka	1474	2.1%	Dalian	2211	1.9%
14			0.0%	Shimizu	128	1.1%	Kitakyushu	449	1.1%	Guangzhou	1430	2.1%	Kobe	2180	1.9%
15			0.0%	Hakata	60	0.5%	Taichung	447	1.1%	Taichung	1130	1.6%	Nagoya	2155	1.9%
	Top 5	**4300**	**75.6 %**	**Top 5**	**8194**	**67.3 %**	**Top 5**	**27010**	**67.3 %**	**Top 5**	**42670**	60.2%	**Top 5**	**71287**	62.3%
	Top 10	**5640**	**99.1 %**	**Top 10**	**11400**	**93.6 %**	**Top 10**	**34806**	**86.7 %**	**Top 10**	**54227**	78.7%	**Top 10**	**90913**	79.5%
	Top 15	**5691**	**100.0 %**	**Top 15**	**12027**	**98.8 %**	**Top 15**	**37522**	**93.5 %**	**Top 15**	**61881**	89.8%	**Top 15**	**103049**	90.1%
	TOTAL (27 ports)	**5691**	**100 %**	**TOTAL** (27 ports)	**12173**	**100 %**	**TOTAL** (27 ports)	**40132**	**100 %**	**TOTAL** (27 ports)	**68878**	100%	**TOTAL** (27 ports)	**114349**	100%

with:
σX = cumulative percentage of number of ports
σY = cumulative percentage of cargo throughput
N = number of ports (observations)

If all the ports in a port system are equal of size, the Gini coefficient will equal zero. In case one port accounts for the total volume of containers, the Gini coefficient equals unity. The Gini coefficient has previously been successfully applied to the US general cargo port system (KUBY & REID 1992), the US container port system (HAYUTH 1988, MCCALLA 1999, LAGO *et al.* 2001) and the European container port system (NOTTEBOOM 1997). The Gini coefficients for the East Asian container port system and its ranges are given in figure 4.

The port system as a whole shows a clear trend towards a less concentrated system, although the Gini coefficient levelled out in the last few years. The Pearl River Delta has the highest concentration ratio of all ranges. The intense competition Hong Kong is facing from mainland Chinese ports such as Shenzhen and Guangzhou has dramatically decreased the inequality in the range. The South Korean load centre group witnessed a similar evolution,

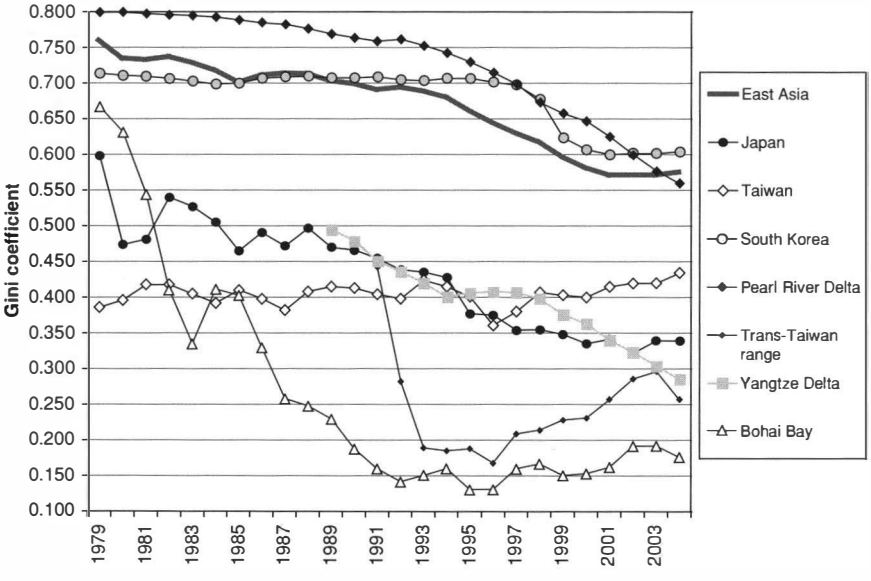

Fig. 4. — Evolution of the Gini coefficients for port system and individual ranges.

mainly triggered by the development of the port of Gwangyang in the late 1990s to form a twin-hub system with main port Busan. The Bohai bay ports do not substantially differ in size and have a similar growth pattern, so concentration levels are very low. The sharp decline of the Gini coefficient in the 1980s was caused by the start of container operations in Qingdao and Dalian to challenge market leader Tianjin. Also the Japanese port system is becoming more evenly distributed. Kobe, Tokyo and Yokohama accounted for most of the container traffic for years. However, Kobe never fully recovered from the earthquake that hit the city in 1995: container throughput abruptly fell from 2.9 million TEU in 1994 to 1.46 in 1995 and today volumes are about 2.2 million TEU. Another factor contributing to falling Gini coefficients relates to Nagoya and Osaka playing a more significant role in the Japanese container scene. Concentration levels in the Taiwanese port range fluctuated slightly over time. In the last couple of years the Gini coefficient is rising, an observation that mirrors the stagnation of throughput levels in Keelung combined with strong growth in Kaohsiung.

Literature provides some techniques to decompose the Gini coefficient neatly into a weighted sum of within and between group inequality. DAGUM (1997) has shown how the Gini inequality index can be additively decomposed into the weighted sum of three components: (i) the Gini inequality within the subpopulations, (ii) the Gini inequality between subpopulations net of transvariation (the so-called overlapping effects between groups or subpopulations) and (iii) the intensity of transvariation between groups.

A closer look at the Gini coefficient technique introduced by DAGUM (1997) gives the following mathematical expressions when applied to multi-range container port systems.

Let us consider a container port system P which is partitioned in k port ranges P_j (j=1,…,k). The size and the container throughput average of P_j are given by n_j and μ_j. Using the Dagum technique the Gini index of port system P can then be written as:

$$G = \frac{1}{2n^2\mu} \sum_{j=1}^{k} \sum_{h=1}^{k} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |t_{ji} - t_{hr}|$$

The Gini within the range P_j (*i.e.* a measure for the within-range inequality) is then defined as:

$$G_{jj} = \frac{1}{2n_j^2\mu_j} \sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |t_{ji} - t_{jr}|$$

and the between-range Gini ratio, that calculates the inequality between port ranges P_j and P_h, is

$$G_{jh} = \frac{1}{n_j n_h (\mu_j + \mu_h)} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |t_{ji} - t_h r|$$

which is related to the mean difference between the two port ranges. All these Gini ratios are included in the interval [0,1]. If they tend towards 1 the container throughput repartition is unequal, and if they tend towards 0 the repartition is equal.

Dagum proved that if we define the relative size of the jth port range as $p_j = (n_j / n)$, and its container throughput share as $s_j = (n_j \mu_j / n\mu)$, the Gini index for the total port system can be written as (see also MUSSARD *et al.* 2003):

$$G = \sum_{j=1}^{k} \sum_{h=1}^{k} G_{jh} p_j s_h$$

The first component of the Gini decomposition is the inequality within port ranges. It can be computed as a weighted average of the ranges' Gini coefficients:

$$G_w = \sum_{j=1}^{k} G_{jj} p_j s_j$$

The second component, *i.e.* the inequality between port ranges, can be defined as:

$$G_b = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} D_{jh} (p_j s_h + p_h s_j)$$

Applied to port systems, we can interpret G_b as the between-range Gini coefficient obtained if every port throughput in every range were to be replaced by the relevant range mean.

The third component is formed by the transvariation or the overlapping effects between port ranges:

$$G_t = \sum_{j=2}^{k} \sum_{h=1}^{j-1} G_{jh} (1 - D_{jh}) (p_j s_h + p_h s_j)$$

D_{jh} is a normalized index that indicates the 'distance' between port ranges P_j and P_h (see DAGUM (1980) for a more in-depth discussion of this index).

The term distance is not to be interpreted as the physical distance (*e.g.* in nautical miles), but as a measure of the structural differences between the subgroups' structures.

The Gini coefficient for the total container port system decomposed in three components can now be written as:

$$G = G_w + G_b + G_t$$

In this paper we customised the Gini decomposition software developed by MUSSARD *et al.* (2003) for application to the East Asian container port system. The software tool not only generates the three components of the decomposition exercise (G_b, G_w and G_t). It also shows the preparatory calculations (*e.g.* the normalized index) and the disaggregated underlying data (*e.g.* the between Gini index G_{jh} for each pair of port ranges). In the next paragraphs, we will discuss the relative importance of the components in the Gini ratio of the total East Asian port system and at the same time unravel some of the underlying data layers where desirable (*i.e.* decomposing the components).

The results in figure 5 lead to the following conclusions with respect to the Gini decomposition exercise. The East Asian container port system shows a moderate shift from within-range inequality to between-range inequality

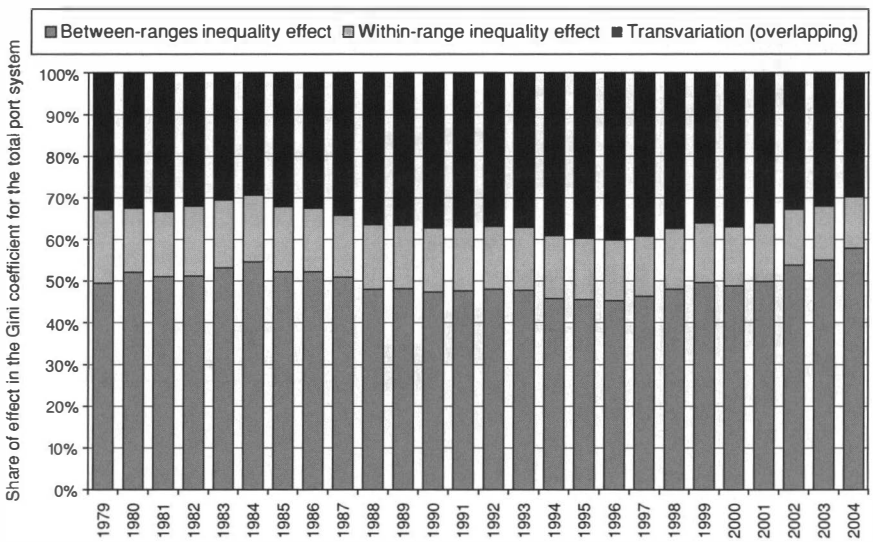

Fig. 5. — Gini decomposition analysis for the East Asian port system (relative shares of G_w, G_b and G_t).

effects, in particular since the new millennium. The share of the within-range inequality component amounted to 12.3 % in 2004, the lowest share ever. The weight of the between-range inequality reached 58 %.

The relatively high inequality between the Pearl River delta range and the Japanese range is having an ever larger share in the total Gini coefficient (fig. 6, tab. 3). At the same time, the relative importance of other between-range inequalities is decreasing, thereby contributing to a decline in the overall Gini coefficient for the East Asian container port system (as earlier depicted in fig. 4).

The inequality between the Pearl River Delta and the Japanese range (*i.e.* the between-range index G_{jh} in tab. 3) to a large extent is responsible for the relative explanatory power of G_b. In 1980 the net contribution of G_{jh} for the observed port range pair still amounted to a very low 0.009 or 1.3 % of the Gini ratio for the entire port system (see ratio (3)/(1) in tab. 4). By 2004 this share had increased to more than 14 %, thereby contributing to the observed increase in the ratio G_b/G.

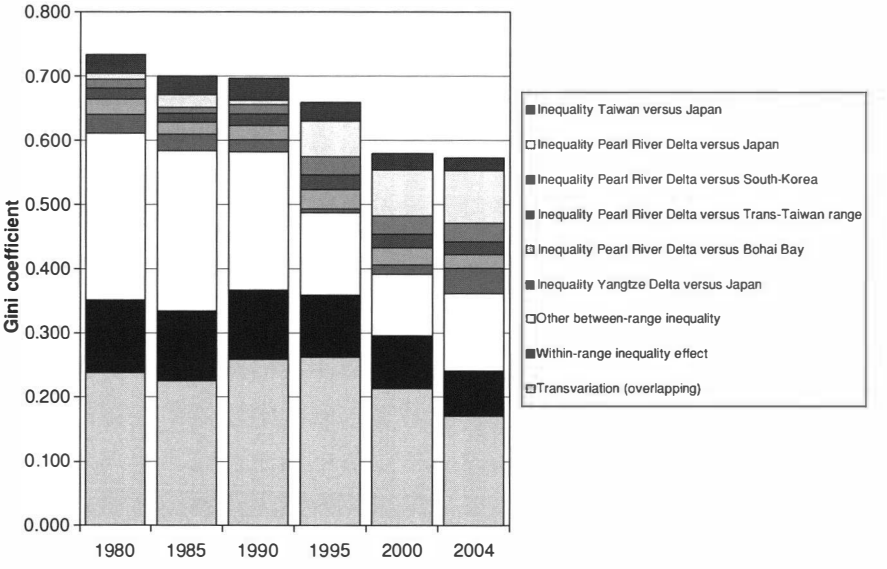

Fig. 6. — Detailed Gini decomposition for the East Asian port system (contribution of G_w, G_b and G_t in absolute terms).

Table 3
Selected between-range Gini indexes (G_{jh})

G_{jh}	**East Asian port system** Pearl River Delta *vs* Japanese range
1980	0.784
1985	0.750
1990	0.757
1995	0.763
2000	0.697
2001	0.698
2002	0.721
2003	0.733
2004	0.746

Table 4
Contribution of the inequality between the Pearl River Delta and the Japanese range to the total Gini G and the between-ranges Gini G_b

	G (1)	**G_b** (2)	**$G_{jh}D_{jh}$ ($p_j s_h + p_h s_j$)** (3)	**Ratio** (2)/(1)	**Ratio** (3)/(1)	**Ratio** (3)/(2)
1980	0.733	0.382	0.009	52%	1.3%	2.4%
1985	0.700	0.366	0.020	52%	2.8%	5.4%
1990	0.697	0.331	0.007	47%	1.0%	2.1%
1995	0.659	0.300	0.055	46%	8.4%	18.4%
2000	0.580	0.284	0.072	49%	12.3%	25.2%
2001	0.569	0.284	0.073	50%	12.8%	25.6%
2002	0.568	0.306	0.078	54%	13.8%	25.6%
2003	0.569	0.313	0.080	55%	14.1%	25.6%
2004	0.573	0.332	0.082	58%	14.3%	24.6%

4. A Qualitative Analysis

The last section in this paper provides a more in-depth qualitative analysis of the factors underlying observed concentration and deconcentration trends in the East Asian container port system, with a special focus on Chinese load centres.

4.1. The Dynamics in Liner Service Networks

Shipping lines and ports are constantly redesigning their service networks and terminal operations in order to cope with the increased flows. The hierarchy among the ports in East Asian container port system is being challenged by the strong growth of smaller container ports and the outspoken hub ambitions of many large ports.

The recent strong growth of the ports of mainland China introduced a new dynamic in the East Asian container port system. Robinson (1998) showed that the liner shipping networks in East Asia evolved from a complex set of feeder services connected to the major hubs in the 1980s into a hierarchy of liner networks with high cost/high efficiency hubs in the higher order networks and a mix of hub and direct-call ports in the lower order networks. The highest order ports identified were Hong Kong, Kaohsiung and Busan. Hong Kong served as the load center for the Pearl River Delta with substantial amount of containers moving through the port originating from or was destined for its immediate hinterland in the Guangdong province in China. For Kaohsiung, strong export-led growth of the Taiwanese economy enabled the port to become a major hub and the authorization of cross-straits shipping is expected to further boost container handling at the port. For Busan, considered a load center for South Korea, cost-competitive and -efficient strategies pursued by the port initially attracted a lot of Chinese and Japanese containers to be transshipped through the port (Fleming 1997). Busan was thus able to expand its hinterland beyond South Korea into Northeast Asia. Fleming also noted that as late as the mid-1990s, all of China was served by feeder services through Hong Kong or Japanese ports while Busan and Kaohsiung were newcomers to the scene to vie for Chinese container traffic.

The above demonstrates Hong Kong, Busan and Kaohsiung have long dominated container handling in East Asia. This development corresponded with the boom in external trade that resulted from successful export-oriented economic strategies pursued by Hong Kong, Taiwan and South Korea. Container flows to and from Northeast China relied on connections to the main hubs in order to reach the global markets.

From the 1990s, however, the gradual shift in the gravity of economic growth and trade from Japan to China led to the emergence of new gateway ports such as Shanghai and Shenzhen. The incumbents now also face the prospect of intensified competition from other potential candidates, including some emerging North-Eastern ports vying for a greater share of container traffic in East Asia.

The main ports of North-Eastern China include five ports: Dalian, Qingdao, Tianjin, Shanghai and Ningbo. Dalian plays a very important role in terms of shipping grain and oil produced in the Northern provinces. Qingdao is a diversified port, dealing with bulk, oil, container, vegetables and sea products. Forty per cent of the vegetables consumed in South Korea come from China via Qingdao port. Tianjin port excels in bulk shipping and container

Table 5
Hinterland region of the five Northeast Chinese ports

	Population (10,000 persons)	**Gross Domestic Product** (100 million yuan)	**Water way worker** (person)	**Water way freight traffic** (10,000 t)	**Value of import and export** (10,000 USD)
Beijing	1423	3213			5250529
Tianjin	1007	2051	3482	5979	2281140
Hebei	6735	6123	1896	1105	666525
Shanxi	3294	2018	31	36	231154
Inner Mongolia	2379	1734			243402
Liaoning	4203	5458	9977	3071	2173965
Jilin	2699	2264	544	79	370248
Heilongjiang	3813	3882	4914	708	434915
Shanghai	1625	5409	31839	23174	7262711
Jiangsu	7381	10632	51847	22411	7028854
Zhejiang	4647	7796	11309	24564	4195576
Anhui	6338	3569	16393	5471	418097
Shandong	9082	10552	14152	4899	3393448
Henan	9613	6169	1701	505	320316
Hubei	5988	4976	22504	5630	395314
Chongqing	3107	1971	23229	1907	179307
Sichuan	8673	4875	6767	2579	446853
Xizang	267	161			13037
Shanxi	3674	2036	88	98	222403
Gansu	2593	1161	59	40	87740
Qinghai	529	341	9		19664
Ningxia	572	329	49		44291
Xinjiang	1905	1598			269170
Subtotal	91547	88319	200790	102256	35948659
Total China	127518	118039	281451	137983	62076610
Subtotal in total	*71.8%*	*74.8%*	*71.3%*	*74.1%*	*57.9%*

Source: based on yearbook of China, 2003.

shipping and can rely on its advanced distribution system with excellent access to its hinterlands. Shanghai and Ningbo mainly put their developing emphasis on container shipping, especially cargoes shipped from the Yangtze River to the sea. The hinterlands of those five ports are very huge and cover above 70 % of China in terms of area, population, gross domestic product and waterway freight traffic. The value of imports and exports also takes up more than half of the total value of China.

The hinterland of Dalian mainly consists of the three provinces of North China, namely Heilongjang, Jilin and Liaoning, which are the main grain and heavy industry provinces of China. About 85 % of maritime cargoes of these three provinces are transported by Dalian port. Qingdao port is the most important port in Shandong province. With the strong economic development of Shandong province, Qingdao port gets the opportunity to develop, as 90 % of maritime cargo flows of the Shandong province are shipped via Qingdao port. Meanwhile, Qingdao port is also striving to attract some cargoes from the northern provinces. Tianjin port has the whole middle parts of China as its hinterland, ranging from north-east to the north-west, especially the capital city Beijing. The hinterlands of Shanghai and Ningbo are more or less overlapping, covering the whole Yangtze Delta and the eastern regions of China.

4.2. More Direct Calls in the Bohai Bay Region

In East Asia, concentration within the liner shipping industry allowed shipping lines to reorganize their services to capitalize on the booming Chinese port traffic while at the same time, call directly at more ports in the region. Altogether, mainline services offered by the top twenty shipping lines called at 35 ports in the region in 2001, seven more from 1995 (Yap *et al.* 2003). These direct calls had the effect of reducing market shares of Japanese and Taiwanese ports while increasing those of Chinese ports (tab. 6). The share of South Korean ports, other than Gwangyang, was also reduced. The recent evolution in the slot capacities calling at East Asian ports demonstrates a huge increase in direct calls to Chinese ports in recent years, including the Bohai bay ports. These findings are consistent with the recent strong growth in the cargo throughput of the Chinese container port system. Table 7 summarizes the number of port calls according to the schedules of some leading shipping lines. A large number of shipping lines started or will initiate services with direct port calls in Northeast China mainly thanks to the upsurge in cargo volumes related to that region.

Table 6
Share of Slot Capacity Deployed by Mainline Services at Major Ports in East Asia

Port	2001 (%)	Change from 1995 (%)	Port	2001 (%)	Change from 1995 (%)
Hong Kong	89.5	-0.6	Xiamen	12.3	12.2
Kaohsiung	52.5	-9.3	Osaka	11.9	-11.3
Shenzhen	49.1	40.0	***Ningbo***	***11.6***	***11.6***
Pusan	41.2	-4.6	***Qingdao***	***10.4***	***7.5***
Kobe	33.6	-8.6	Keelung	9.0	-12.7
Shanghai	***28.1***	***20.7***	Hakata	8.0	-3.7
Tokyo	27.2	-11.8	***Tianjin***	***7.1***	***3.4***
Yokohama	26.6	-6.9	Shimizu	3.8	-12.4
Nagoya	25.8	-13.2	***Dalian***	***2.4***	***-0.4***
Kwangyang	12.7	12.7	Naha	1.8	0.4

Source: YAP *et al.* (2003).

It is apparent that Dalian, Qingdao and Tianjin are not located along the world's main shipping lanes, which means the deviation distances to these ports are relatively high compared to the ports of Shanghai and Ningbo. In a situation of low cargo volumes the high deviation distances might impede shipping lines to call directly at these ports with their mainline vessels. However, rising cargo availability and the vast hinterland potential of the three Bohai bay ports now seem to counterbalance the extra shipping costs incurred by the high deviation distance linked to reaching the ports in the Bohai bay.

The current nature of mainland Chinese ports points to gateway ports rather than to transhipment hubs. Only one per cent of containers handled in Shanghai relates to sea-sea transhipment. In Hong Kong the transhipment percentage amounts to about 30 %, in Busan to around 40 % and in Kaohsiung to about 55 %. The transhipment cargo percentage of the Bohai bay ports are low as well, partly due to the less favourable maritime location for serving the whole of East Asia and the associated high deviation distances. However, it does not imply the Bohai bay ports have a feeder port status. The three Bohai bay ports are strengthening their role as gateway ports to large hinterland regions, even though they do not play a role as sea-sea transhipment centres.

The ports in the Bohai bay are doing everything they can to strengthen their position as direct ports of call, including investing huge amounts of

Table 7
Number of port calls for each shipping line (number of loops / number of vessels)

	Dalian	Qingdao	Tianjin
Maersk	6 (12)	6(12)	6(12)
MSC	0	6(24)	6(24)
Evergreen	2(6)	4(10)	4(10)
P&O Nedllord	1(4)	2(8)	1(4)
CMA-CGM	1(5)	1(5)	1(5)
Hanjin	1(3)	4(12)	4(12)
APL	0	4(20)	0
NYK Line	0	2(6)	0
COSCO	5(10)	12(24)	4(8)
China Shipping	11(22)	13(26)	12(24)
K-Line	3(12)	3(12)	5(20)
OOCL	1(6)	1(6)	1(6)
Mitsui O.S.K	0	0	0
ZIM ISREAL	1(3)	1(3)	1(3)
CCNL	0	0	0
Yang Ming Line	3(6)	2(4)	4(8)
HMM	7(28)	8(32)	8(32)

Source: Compiled from information on http://www.jctrans.com/banqi/. Data on April 1, 2004. Backhaul not included. COSCO and China Shipping: domestic shipping and feeder calls excluded.

money on new projects to enlarge the port capacity, improving the service level and port efficiency, cooperating with global terminal operators and shipping lines and striving to develop rail, road and other hinterland systems. The near future could see greater vertical and horizontal integration attempts as logistics service providers actively expand on their business scope to capitalize on the economic opportunities presented by China. The Bohai Bay ports place greater emphasis on logistics and intermodal concerns, on capitalizing on economic opportunities from China and on exploiting possibilities presented by information and communication technological advancements.

4.3. Enhancing the Development of Chinese Ports

To maintain economic expansion, the Chinese government has focused a great deal of its resources on modernizing China's infrastructure. This includes roads, airports and seaports in coastal regions. Seaports have

always played a key role in the government's policy with regard to infrastructure provision. In the earlier stage of New China (1970s), port construction began from almost nothing. By 1985, deep-water berths at major coastal ports increased to 198, along with 156 medium-class berths for a combined annual handling capacity of 310 million tons. In the 1990s, construction of ports was a key element in infrastructure development. During the 9th five-year plan period progress has been made in the construction of coastal ports. 133 medium and above classed berths were built, among which 96 are deepwater berths (figures of Ministry of Communications). The Chinese government started to allow foreign businesses to build and operate berths in the form of a joint venture, to engage in the stevedoring business, cargo storage and other related services. These measures have promoted port construction. The hinterland infrastructure still needs further upgrading to prevent the Chinese giant from crumbling on weak (hinterland) legs.

With the accession to WTO, Chinese ports are opening up to the world. Some world famous companies already built terminals in Chinese ports, such as Hutchison, CSX World Terminals, PSA Corp, APM Terminals and P&O Ports. Table 8 lists all the international terminal operators in Chinese ports.

4.4. Serving East Asia via the Korean Twin Hub System

The Korean container port system is in fact a 'twin hub system' based on Busan and Gwangyang. These ports have shown a substantial growth in container throughput and transhipment, and attracted new investments from several major private terminal operators. The Korean port Busan and to some extent also newcomer Gwangyang traditionally play an important role in Northeast Asia, especially in relation to Japan and the North-Eastern Chinese ports. Transhipment accounts for some 36 % of the 12 million containers handled in the Korean ports in 2003. Chinese transhipment boxes represent some 30 % of total sea-sea transhipment volumes.

Transhipment cargo is expected to increase every year. However, forecasts to the year 2015 show that the share of Chinese traffic in the overall traffic is likely to stabilize at around 10 %. Given the strong expected growth of Chinese containerised trade in the coming decades, this observation clearly points to an expected relative decline in the importance of Korean ports in relation to China. This finding supports earlier observations on increasing direct calls at the load centre ports of Northeast China.

Table 8
Shareholding structures among selected ports and terminals as of June 2002

Region	Port	Container Terminal	Shareholding Structure
Pearl River Delta	Guangzhou	Guangzhou container terminal	PSA 49%, Guangzhou Harbor Bureau 51%
	Shenzhen	Yantian International	HPH 58%, Maersk 10%, Yantian Port
	Holdings 27%,	Container Terminals	Holdings 27%, COSCO Pacific 5%
	COSCO Pacific		P&O Ports 25%, Swire 25%, China,
		Shekou Container Terminals	Merchant 32.5%, COSCO 17.5%
			MTL+China Merchants 25%,
		Chiwan Container Terminals	Kerry Logistics 25%,
			Chiwan Port Holdings 50%
Taiwan Strait	Fuzhou	Fuzhou Container Terminals	PSA 49%, Fuzhou Port Authority 51%
		Fuzhou Aofeng Container	PSA 49%, Fuzhou Port Authority 51%
	Shantou	Terminals	HDP 70%, Shantou Port Authority 30%
	Xiamen	Shantou International	HDP 49%, Xiamen Haicang Ports 51%
		Container Terminals	Pacific Ports 92%,
		Xiamen International	Xiamen Xianyu Group Corporation 2%
		Container Terminal	Pacific Ports 60%,
		Xiamen Xianyu Quay Co.Ltd	Xiamen Xiany Group Corporation 40%
			Xiamen Xianyu Group Corportation 100%
		Xiamen Xianyu Free Trade Zone Qua	
		Xiamen Xianyu Free Port Development	
Yangtze River Delta	Ningbo	Ningbo Beilun Container Terminals Phase I	Ningbo Port Authority 100%
			HPH 49%, Ningbo Port Authority 51%
	Shanghai	Ningbo Beilun Container Terminals PhaseΠ	HPH 37%, Shanghai Port Container 63%
			HPH 40%, Shanghai Port Authority 30%
		Shanghai Container Terminals	COSCO Pacific 20%, Shanghai Shiye 10%
		Shanghai Wai Gao Qiao Phase I	
Northern China	Dalian	Dalian Container Terminals	PSA+Maersk 49%, Dalian Port Authority 51%
	Qingdao	Qingdao Qianwan Container Terminals	P&O Ports 49%, Qingdao Port Authority 51%
	Tianjin	Tianjin Sinor Terminals	Conaust (P&O subsidiary) 22.5%, Gerrbulk Shipping 22.5%, Tianjin Port Authority 55%
		CSX Orient Container Terminals	Pacific Ports 24.5%, CSX World Terminals 24.5%, Tianjin Port Authority 51%

Source: based on WANG *et al.* (2003).

4.5. Shanghai: the New Transhipment Hub?

The world top twenty shipping companies have all set up business in Shanghai. Chinese port officials reported 18 million TEU in 2005. To manage this, the Shanghai Port Authority has converted general cargo terminals into container terminals, building dedicated container terminals at the Waigaoqiao area. Efforts are also being made to build the Waigaoqiao area into a procurement and distribution centre for the Asia Pacific Region.

The capacity problem and the lack of deep-water berths can be solved by the construction of a new deep-water port. The Chinese authorities are constructing a new port with 52 berths and a capacity of 20 million TEU in 2020 at the Yangshan islands, 100 km south of Shanghai and 30 km offshore. A bridge of 32.2 km will connect the port with the mainland. With the construction of phase one, which consists of 5 berths and a capacity of 2.2 million TEU, the pressure on Shanghai Port can be diminished. Phase one became operational in late 2005.

Shanghai port has an intense network of routes, covering not only the main international routes, but also covering more than 300 domestic routes connecting the Yangtze River with the inland port system. Shanghai port is building its own domestic and international transport network so as to become the container transhipment centre of China. A high frequency service between the port of Shanghai and the main three Northeast ports would make transhipment between these ports possible.

Transhipment will incur some additional container handling costs. The relatively low handling cost of Shanghai port is however a good opportunity for it to compete with other hub ports. The estimated cost to handle one container in Shanghai is between US$30-40 compared to US$200 in Hong Kong. In practice the total bill for shippers and carriers is not that low, because of extra charges incurred for other procedures. This factor constitutes an important barrier to Shanghai while competing with other ports. Shipping lines require transparency of charges when selecting their ports of call. A transparent port charging system needs to be in place, so as to sustain the port's competitive position, in particular in view of developing sea-sea transhipment.

Taking advantage of its geographical location, Shanghai strives to consolidate its position as a pivot in an emerging domestic container shipping network with 40 other ports from the north to the south of China.

With a solid basis for developing Shanghai port into a transhipment hub already in place, Shanghai port still faces many challenges, such as government support, competition from ports of northern China and the integration problem of Waigaoqiao and Yangshan ports.

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Rise of Logistic Hubs in Asia: Implications for the Region

by

Jose TONGZON*

1. Introduction

The international environment faced by countries in Asia and in particular Southeast Asia is increasingly becoming more competitive. This growing competition is not only between firms in the same country but also between countries across many industries. The inter-country competition is especially intense in the area of logistics where the economic benefits are becoming significant as a result of the increasing trade and investment flows between countries. A number of factors are responsible for this increasing international trade and investment flows including the increasing growth and openness of countries in Asia and the Pacific, intensifying globalization and deregulation, continued industrialization of the newly emerging economies and improvements in transportation technology.

With the sophistication of the industry and the rapidly growing demand for a specialized supply chain management services, the logistics industry is expected to grow at an annual rate of 3-10 %, which is valued at US$320 billion [1]**. This expectation is a strong stimulus for countries to develop their logistics industry and position themselves as a regional logistics hub to gain from the enormous growth in demand. Competition has been particularly tense in the Asia where many countries have launched new initiatives to position their economy as the leading logistics hub in the region.

Singapore, which has assumed the status of a logistics hub of Southeast Asia, has been intensively challenged by its competitive neighbors who are

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** The numbers in brackets [ ] refer to the notes p. 132.

eagerly upgrading their technology and infrastructure in an effort to compete as a more effective and cost efficient distribution hub of the region. Particularly, pressure has been mounting from countries such as Malaysia, Taiwan, Hong Kong and South Korea. Many have come up with new institutions that are set up especially to boost the growth of the industry and many others are eagerly upgrading their labor force and infrastructure. The changing global economic climate has also affected the industry's development, particularly with an increasing number of firms relocating to other markets especially to China.

In the light of this sharpening competition and of the potential economic benefits in the logistics sector, the objective of this paper is to examine the determinants of competitiveness in logistics and identify the key factors that are required for a successful logistics hub. For the logistics hub, the analysis of the determinants of competitiveness focuses on Singapore as a case study before drawing some implications/lessons for the countries in the Southeast Asian region.

2. Determinants of Competitiveness

There are several factors that determine international competitiveness in logistics, such as costs of production in which wage costs constitute an important component, particularly in labor-intensive production; management quality; prices and the quality of the service; exchange rates; government policies; political stability; investments in human and physical infrastructure and other factors that may set a country ahead of its competitors. These factors can be classified into macro and micro factors.

At the *micro level*, the most relevant factors are *costs* and *service quality*. Michael Porter in his book *The Competitive Advantage of Nations* has identified these factors as the key to the success of a particular firm or particular industry. According to Porter, the success of a firm in the international market depends on the following major factors:

— Cost-based advantage in the production of relatively standardized products/services;
— Product-based advantage in the development of differentiated products/services.

An industry or firm can break into new markets or increase its shares in its existing markets based on its cost advantages. These cost advantages are usually relevant in a price-conscious consumer market, but quality also plays

a significant role in consumers' buying decisions. There are consumers who can sacrifice quality for a lower price, but this preference for a lower price, at the expense of quality, has certain limits. For some consumers there is a minimum level of quality, below which poor quality cannot be accepted even at lower price. This imposes a minimum benchmark on the quality variable.

Porter's evidence also suggests that it is not possible for a firm to pursue both strategies simultaneously. This is because strategies to develop differentiated products/services almost always increase costs and it is believed that cost-based advantages are not sustainable unless successfully converted into a differentiated product-based advantage subsequently.

In a more recent article PORTER (1990) stressed that the only meaningful concept of competitiveness at the national level is productivity. Productivity depends on both the quality and features of products (product quality) and the efficiency with which they are produced (technical efficiency). Porter comments that a nation's standard of living depends on the capacity of its firms to achieve high levels of productivity, and sustainable productivity growth requires that an economy continuously upgrades itself. This is done by raising product quality, adding desirable features, improving product technology and of boosting production efficiency.

It should also be pointed out that the government plays an important role by promoting a competitive environment conducive for improving quality, efficiency and innovation.

To illustrate the critical importance of *efficiency* and *service quality*, an attempt is made to choose one important sub-sector within the logistics industry to study the effects of the determinants of competitiveness — the port industry. Since the environment in which ports operate has changed dramatically, ports are affected by various new forces driving global competition, including the far reaching unitization of general cargo, the rise of mega-carriers, the market entry of logistics integrators, the creation of network linkages among port operators, the development of inland transport networks, and so on (NOTTEBOOM & WINKELMANS 2001) [2].

In this context, eight key determinants of competitiveness are proposed based on the existing literature. These determinants include:

— Port (terminal) operation efficiency level;
— Port cargo handling charges;
— Reliability;
— Port selection preferences of carriers and shippers;
— The depth of the navigation channel;

— Adaptability to the changing market environment;
— Landside accessibility;
— Product differentiation.

2.1. Port (Terminal) Operation Efficiency Level

Since carriers view ships' time at ports as an expensive activity, the speed of container handling and consequent vessel turnaround time is a crucial issue in terms of competitiveness for port authorities and port operators (Peters 2001). Thus, substantial productivity improvements are generally required to enable ports to meet the stringent service requirements of their customers and to obtain competitive advantages. Productivity is a measure of the efficiency of port or terminal operations, and accounts for the amount of resources usually required to perform a given task in a given time. Therefore, the level of efficiency can represent how quickly containers are handled and how quickly vessels are turned around at ports. The higher the efficiency level of a port or terminal operation, the more port users are likely to choose it as their port of call, which, in turn, will make the port gain more market shares.

2.2. Port Cargo Handling Charges

The price of goods or services is always an important factor that consumers will consider when selecting products with similar characteristics. This rationale will also happen, or even more likely, to the services provided by port authorities or port operators since carriers or shippers think that port charges constitute a significant part of their total transportation costs. In addition, carriers are also confronted with severely competitive environment in shipping market and must pursue the ways to reduce the total shipping costs to gain competitive advantages. Nowadays, port charges become a major source for shipping lines to cut down total operation costs. Therefore, they usually prefer ports that can offer relative lower service charges [3], holding other factors constant. Since the cargo handling services are most important for port users in terms of total charges, these charges significantly affect a port's competitive position (Trujillo & Nombela 1999).

2.3. Reliability

That price is an important factor for producers to attain more market shares does not mean that price are the decisive variable. Reliability of port

operations also influences a port's performance (TONGZON 1995), which in turn will affect the choices of shipping lines and shippers. Reliability means a steady and predictable performance adapted to shipping lines' schedules. If a port authority or port operator always faces delays during the operation processes due to strikes, equipment breakdown, bad weather, etc., shipping companies and shippers will suffer huge losses due to these kinds of unreliability. Definitely, carriers and shippers will bypass this kind of ports despite their more attractive price.

2.4. PORT SELECTION PREFERENCES OF CARRIERS AND SHIPPERS

Globalization of industry is fast breaking down the traditional practice whereby shipping companies favored certain ports. Increasingly, carriers and shippers are showing less loyalty to specific ports. Ports face the constant risk of losing important clients, not because of deficiencies in port infrastructure or terminal operations, but because the client has rearranged its service networks or has engaged in new partnerships with other carriers (NOTTEBOOM & WINKELMANS 2001). Thus, this variable is not fully correlated with port specific variables, such as efficiency and reliability, so it should be included as an independent port competitiveness indicator.

2.5. THE DEPTH OF THE NAVIGATION CHANNEL

To accommodate trade growth and to offer economies of scale in a highly competitive market, many shipping companies intend to increase the size of their container ships from Panamax [4] to Post-Panamax, or even to the Super Post-Panamax. Increasingly large tonnage, especially of vessels deployed in the container shipping market, will have significant effects on port competition. These larger size container ships are always used among loading centers or hub ports, the kind of port that most ports want to be, to enhance the amount of total throughput. In many cases, however, insufficient water depths in access channel and port basins prevent some ports from being a transshipment center (PETERS 2001).

2.6. ADAPTABILITY TO THE CHANGING MARKET ENVIRONMENT

The market environment in which ports operate has changed significantly, and this continuous process of change raises the question about the role of port authorities. A successful port must constantly be prepared to adopt new roles in order to cope with the changing market environment (NOTTEBOOM &

WINKELMANS 2001). For instance, in order to improve terminal operation performance and to integrate door-to-door transport, many shipping lines want to expand their scope to include terminal operation. If port authorities cannot realize the importance of this trend, they will lose certain competitive advantages. That the Port of Singapore Authority (PSA) has recently lost its two most important clients is a convincing example. Thus, seaports that will succeed in the 21st century will be those that are "consumer-led", with a good understanding of customer needs.

2.7. LANDSIDE ACCESSIBILITY

Originally, ships loaded and discharged their cargoes in towns or cities where producers and consumers are located. Expansion of land transport systems has altered things somewhat. The days when ships were forced to call at city terminals blocked in on the landside by congested city streets are long gone. New remote coastal terminals with good landside connections, and ports strategically located close to the main global trade lanes, increasingly offer carriers and shippers a more appropriate option (FLEMING & BAIRD 1999). Efficiency of inland transport to serve an increasing and most often disputed hinterland has become a critical factor of ports' potential future as well as of their overall trade growth prospects. Since ports have become a prominent node in integrated logistics chains, quick and safe access to port facilities from an inland transport system becomes a basic requirement for port users to evaluate their port selection options.

2.8. PRODUCT (SERVICE) DIFFERENTIATION

A differentiation strategy aims at providing specific port services in market niches distinct from those provided by other ports, offering greater value to the port users. This is so-called economies of scope. If a port authority or port operator has some specific competencies (*e.g.*, advanced information system and high service quality) that are inimitable and durable, it is easier to achieve competitive advantages over his competitors (NOTTEBOOM & WINKELMANS 2001). Studies on priority systems [for example, HOLGUIN-VERAS & JARA-DIAZ (1999) and HOLGUIN-VERAS and WALTON (1997)] have shown the need for product (service) differentiation in an environment in which the total number of containers is steadily increasing and terminal expansion becomes more difficult.

The findings of TONGZON (2002), as shown in table 1, provide empirical support for the above argument that competitiveness is determined by some

factors, some of which are beyond the control of the government authorities and operators such as the selection preferences of carriers and shippers that are decided by their service network instead of the ports' performance. However, two most statistically significant variables, *operation efficiency* and *adaptability*, can be controlled by the operators. We can easily understand their importance in determining competitiveness since these two variables represent the quantity and the quality of the services provided by services providers, respectively.

Table 1
Determinants of Container Port/Terminal Competitiveness
(Dependent Variable: the natural logarithm of port/terminal throughput)

Variables	Coefficient	T-ratio	P-value
Constant	-7.118	-1.450	0.1633
In (EFF)	3.433	4.239	0.0004
In (DEP)	-0.747	-0.493	0.6277
In (NDC)	0.355	4.722	0.0001
In (LAN)	1.650	1.691	0.1072
In (ADA)	3.336	3.035	0.0068
R-squared	0.8497		
F-test	21.489		0.0000
White Test*			0.2713
NORM	0.066		

Source: TONGZON (2002).
* White Test is the test for functional mis-specification. NORM is the Jarque-Bera test for the normality of the residuals. Ln = natural logarithm.

3. Determinants of Competitiveness as Logistic Hubs

Apart from operational efficiency and adaptability, there are other factors that will determine a country's competitiveness as a logistics hub.

Firstly, it should be strategically located, for example, in the main shipping and air routes. It should have an air terminal that provides extensive linkages and connectivity to the world. Its seaport should be the focal point of shipping lines and have good linkages to other ports worldwide. It should have good capabilities in warehousing and related services. On top of all these, there must be adequate and highly efficient infrastructure available.

Human capital availability is vital to make a country's logistics hub successful. For example, workers must possess language skills such as English,

which is an international language, be open-minded and accept changes, such as changes brought about by globalization. Workers must also be well equipped with knowledge to work in the logistics sector, for example, hence the availability of logistics professionals is of vital importance. Political and economic stability, a strong and supportive government that promotes growth of the logistics sector through implementation of transparent policies and harmonious management-labor-government relations are also critical success factors.

To confirm the importance of the above factors, a survey by personal interview was conducted by the author among selected multinational companies operating in Singapore. The survey covers a total of 12 companies: 6 international manufacturing firms and 6 international logistics firms, both functioning as regional distribution centres. Most of the companies in the sample started investing in Singapore already in the 1970s.

3.1. International Manufacturing Companies

Amongst the six international manufacturing firms interviewed, one has a total asset of US$500 million in Singapore (Micron). Four are new investments and one (Micron) results from taking over an existing industry. Apart from manufacturing, all firms are also engaged in at least one more activity. Out of the six firms interviewed, two consider themselves as manufacturing firms (HP, Siemens), the other four are more actively engaged in other activities, such as logistics, research and development, international trading and investment, retailing, sales and marketing, information and technology.

Their employment levels in Singapore range from 115 (Mitsubishi) to 6,000 (HP) and 12,000 (Mitsubishi) to 400,000 (Siemens) worldwide. Total trade in value terms in Singapore ranges from S$13 million (Siemens) to S$10.5 billion (HP). Collectively, they have as many as 1,000 subsidiaries all over the world.

1. The main role of most of these firms includes:
   - Manufacturing of their products and redistributions to their regional subsidiaries;
   - Some of the companies in the sample are also responsible for redistribution to other destinations, such as Europe;
   - Some provide technical and maintenance support to their subsidiaries in the region;
   - Others include distribution of material and parts to worldwide subsidiaries;

— A base for research and development for the region or world wide;
— International trading and investments and wholesaling.

For the strategy of logistics operations overseas, 1 (HP) outsourced all activities via 3PLs, while the rest outsourced some of the logistics activities while owning some of the facilities and assets at the same time. If 3PLs are engaged, activities outsourced mainly include transportation, warehousing, containers, invoicing, administration, manpower, sales engineering, procurement and business planning. In some cases, when 3PLs are engaged, all activities will be outsourced.

3PLs are chosen based on requirements such as economies of scale, global investments/extensive networks, price competitiveness, reliability, value-added services/quality of services, flexibilities, IT capability and local know-how.

3.1.1. Country Selection Factors

Tables 2 and 3 show that fiscal incentives for investors, infrastructure development and domestic economic/political environment rank high as factors influencing their choice of countries as location for their investment.

How successful Singapore is rated, in the light of the above factors is shown in table 3. Singapore is considered very successful in terms of infrastructure development, domestic economic/political environment, incentives for foreign investors and supply and logistics chain management strategy.

3.1.2. Support from Government

The government of Singapore has successfully created a stable, transparent and cost-effective environment for foreign business by investing in world-class infrastructure and offering tax incentives including tax concessions on profits, tax holidays, investment credits, accelerated depreciation, double tax avoidance agreement and tax exemption for venture capital. Furthermore, foreign investors have been attracted to Singapore to base their headquarters for sales, marketing and distribution because of transparent laws on foreign investments and their effective and efficient administration which has made doing business in Singapore more predictable.

3.1.3. Relevant Laws and Regulations for Foreign Investment

Singapore has one of the most liberal laws and regulations for foreign investment. Being an open economy with more reliance on foreign capital than any other country in Southeast Asia, Singapore has the most liberal

Table 2
Country Selection Factors for International Manufacturing Firms

	HP	Micron	Mitsubishi	Panasonic	Siemens	Philips	Average	Rank
a) Market Potential/Purchasing Power	5		5	2	2	4	3.60	8
b) Domestic Economic and Political Environment	4		4	5	5	4	4.40	2
c) Related and Supporting Industries	4		3	4	3	5	3.80	5
d) Technology Base	3		3	4	3	3	3.20	9
e) Government Policy and Regulations	3		4	4	5	3	3.80	5
f) Social and Cultural Environment	2		3	3	2	2	2.40	11
g) Executive Procedures and Services	2		3	4	2	3	2.80	10
h) Incentives for Foreign Investors	5		3	5	5	5	4.60	1
i) Business Practices and Operation Systems	3		3	4	5	4	3.80	5
j) Infrastructure Development	4		3	5	5	5	4.40	2
k) Supply and Logistics Chain Management Strategy	4		4	3	5	4	4.00	4
l) Others				4			0.80	
(Local Partner)			5				1.00	
(Total Cost of Operationing)	4						0.80	
(Competitive Environment)				4			0.80	
(Availability of Trained People)						5	1.00	
(Financial/Foreign Currency Stability)			5				1.00	

Table 3
Reasons for Choosing Singapore: Manufacturing Firms

	HP	Micron	Mitsubishi	Panasonic	Siemens	Philips	Average	Rank
a) Market Potential/Purchasing Power	1	1	2	3	5	2	2.33	11
b) Domestic Economic and Political Environment	5	5	4	4	5	4	4.50	3
c) Related and Supporting Industries	5	3	5	4	5	4	4.33	7
d) Technology Base	3	3	3	5	5	3	3.67	10
e) Government Policy and Regulations	4	5	5	5	5	4	4.67	2
f) Social and Cultural Environment	3	4	5	4	5	2	3.83	9
g) Executive Procedures and Services	3	4	5	4	5	3	4.00	8
h) Incentives for Foreign Investors	4	5	4	4	5	5	4.50	3
i) Business Practices and Operation Systems	5	5	4	4	5	4	4.50	3
j) Infrastructure Development	5	5	5	4	5	5	4.83	1
k) Supply and Logistics Chain Management Strategy	5	5	4	3	5	5	4.50	3
l) Others							0.00	
(Local Partner)							0.00	
(Government-led Business Environment)							0.00	
(Regional Management, Language)	5						0.83	
(Intellectual Property Protect)		5					0.83	
(Competitive Environment)				4			0.67	
(Availability of Trained People)						4	0.67	

policies on foreign ownership of business with no specific rules and regulations for foreign investors except in banking and brokerage. However, quite recently Singapore has embarked on a policy of liberalization and relaxation on foreign investment in banking. There are no restrictions on foreign participation in telecommunication and public utilities. A survey of foreign direct investment policies and incentives across the major members of ASEAN has shown that Singapore has the most liberal and pro-business policies.

3.2. International Logistics Companies

The 6 international logistics firms hold assets with values amounting to as much as US$5.8 billion in Singapore (AVNET: the maximum value reported in the survey). Four of them are new investments while the rest (AVNET and EGL) are investments via acquisition. Their number of employees in Singapore range from 195 (EGL) to 700 (DHL), and from 600 (CWT) to 130,000 (TPG, parent of TNT) worldwide. Their total trade in value terms in Singapore ranges from S$6 million (EGL) to S$60 million (TNT) — some with as much as US$600 million in Asia (AVNET). These companies together have as many as 228 subsidiaries all over the world. Out of the six logistics firms, five have operations in almost all the regions in the world while one (CWT) has operations only in Asia.

The main role of these companies in Singapore is to provide a full spectrum of logistics services to companies and to act as headquarters in the region. Three of the companies (EGL, UPS and DHL) own all their logistics facilities and assets, while two (CWT, TNT) outsourced some of the logistics activities. AVNET did not answer this particular query..

When 3/4PLs are engaged in their logistics operations, services outsourced include sea freight, IT services, trucking, and cargo handling. When 3/4PLs are chosen, they are based on requirements such as local players, existing relationships and solutions that they could provide including costs.

3.2.1. Country Selection Factors

The ranking of country selection factors by 6 international logistics firms interviewed is presented in table 4. The factors considered quite important to country selection include market potential/purchasing power, government policy and regulations, incentives for foreign investors, infrastructure development and technology base. The presence of related and supporting industries and social/cultural environment are the least important. Other

Table 4
Country Selection Factors for International Logistics Firms

	Avnet	CWT	DHL	EGL	TNT	UPS	Average	Rank
a) Market Potential/Purchasing Power	5	5	5	5	5	2	4.50	1
b) Domestic Economic and Political Environment	3	4	5	5	4	4	4.17	4
c) Related and Supporting Industries	2	3	5	4	3	3	3.33	10
d) Technology base	4	4	5	5	4	3	4.17	4
e) Government Policy and Regulations	5	5	5	5	3	4	4.50	1
f) Social and Cultural Environment	3	3	3	4	3	2	3.00	11
g) Executive Procedures and Services	1	3	3	5	2	5	3.17	4
h) Incentives for Foreign Investors	5	5	5	5	3	3	4.33	3
i) Business Practices and Operation Systems	4	3	4	5	3	4	3.83	8
j) Infrastructure Development	3	4	5	5	3	5	4.17	4
k) Supply and Logistics Chain Management Strategy	4	3	5	4	3	3	3.67	9
l) Others							0.00	
(Local Partner)	5						0.83	
(Total Cost of Operation)				5			0.83	
(Competitive Environment)							0.00	
(Availability of Trained People)						4	0.67	

Table 5
Reasons for Choosing Singapore: International Logistics Firms

	Avnet	CWT	DHL	EGL	TNT	UPS	Average	Rank
a) Market Potential/Purchasing Power	2	3	3	3	3	2	2.67	11
b) Domestic Economic and Political Environment	5	5	4	5	3	3	4.17	6
c) Related and Supporting Industries	3	5	2	3	5	4	3.67	10
d) Technology Base	2	4	5	5	5	3	4.00	9
e) Government Policy and Regulations	5	4	5	5	5	4	4.67	1
f) Social and Cultural Environment	5	4	4	5	4	3	4.17	6
g) Executive Procedures and Services	4	4	4	5	4	4	4.17	6
h) Incentives for Foreign Investors	5	5	5	4	4	4	4.50	3
i) Business Practices and Operation Systems	4	4	4	5	4	5	4.33	5
j) Infrastructure Development	4	4	5	5	5	5	4.67	1
k) Supply and Logistics Chain Management Strategy	4	4	5	5	5	4	4.50	3
l) Others							0.00	
(Local Partner)	4						0.67	
(Government-led Business Environment)		5					0.83	
(Regional Management, Language)							0.00	
(Intellectual Property Protect)							0.00	
(Competitive Environment)							0.00	
(Availability of Trained People)						4	0.67	
(Government's Foresight)				5			0.83	

factors that were considered important include the presence of a local partner, the low cost of operation, a competitive environment and the availability of trained and skilled people.

Table 5 presents the reasons of choosing Singapore as their investment location. Singapore is perceived to be quite successful in terms of providing adequate infrastructure, adoption of appropriate government policy and regulations, incentives for foreign investors, supply and logistics chain management strategy, business practices, domestic economic and political environment, social and cultural environment and executive procedures/services. Other factors where Singapore has performed well were also cited, such as government foresight, availability of trained people, competitive environment and pro-active role of the government. However, Singarpore is rated poor in terms of market potential/purchasing power, related and supporting industries and technological base.

3.2.2. Government Support

The government of Singapore is perceived to be supportive towards foreign logistics companies based in Singapore. Apart from the tax incentives mentioned in the preceding section for manufacturing firms, the government of Singapore has facilitated international trade through its efficient customs administration and by maintaining security, good sanitation and business environment and giving foreign logistics companies an easy access to funds.

4. Implications for Countries in the Southeast Asian Region

The global logistics market is estimated to grow on average by 10 per cent over the next five years to reach US$173.7 billion by 2005. Worldwide trends indicate an increasing preference by companies to opt for integrative SCM outsourcing models, encompassing the coordination of 3 flows — goods, information and funds. Demand for SCM services are likely to grow against the backdrop of greater outsourcing, globalization, the origination of new products, the increasing sophistication in product designs and the shortening of product life cycles. Further, Asia is where robust growth in demand for logistics is expected to occur with China being touted to provide a major stimulus as it is taking steps to accelerate the liberalization of its trade and logistics sectors.

Against this backdrop of tremendous business opportunities, more and more countries in Asia are positioning themselves to become the preferred

logistics hubs in the region. The increasing regional competition for foreign direct investments and for a slice in the growing logistics market make it imperative that Southeast Asia develops an effective logistics hub policy and strategy to become internationally competitive.

It is found that operational efficiency is very important for policy makers and operators to gain a competitive advantage and win in the competition race. It also implies that the customers of logistics services do pay more attention to operation efficiency when selecting the services. The results show that another most important determinant of competitiveness is the adaptability to the customers' demand. Since logistics is a service industry, it is reasonable that operators should well understand the requirement of their customers and make efforts to meet and exceed their expectations.

Countries in Southeast Asia should therefore focus on improving their product and service quality through innovation and improved technology, efficiency and reliability. To enhance their level of technology, they should invest in strengthening the scientific and technological capability of their citizens. This is an area where more ASEAN cooperation can bring about technological progress throughout the region. In the case of the CLMV (*i.e.* Cambodia, Laos, Myanmar and Vietnam) countries, technical assistance provision and other capacity-building measures from the more developed member countries should be intensively pursued so as to expedite their catching up in terms of human skills and technology development and thus expedite the process of economic integration within the region.

While joint technology (especially in the area of information technology) enhancement is important to improve their level of competitiveness, there is also some scope for cooperation instead of engaging in competition to become the logistics hub of Southeast Asia. Further cooperation and win-win alliances among the major seaports and airports in the region should be explored to make the region more competitive and attractive for foreign manufacturing and logistics firms. For example, in the area of sea and air transport, regional alliances in the form of marketing, cargo handling, training and research which lowers overhead and operational costs are desirable and feasible and would make the region more attractive as distribution centers for logistics companies. However, alliances in terms of price fixing and profit sharing would be difficult, if not impossible, especially when these ports are government-owned due to nationalistic and political factors, apart from the tendency for countries to capture the largest slice of the logistics market.

Singapore and the rest of ASEAN have followed different industrialization paths and adopted different policy orientation due to their differences in market size and factor endowments. Thus, since its political separation from

Malaysia, Singapore has adopted an export-oriented industrialization strategy with heavy reliance on foreign investments. This is in contrast to other ASEAN countries' import-substitution strategy in the early stages of their economic development.

However, the experience of Singapore as a logistics and distribution hub can be of relevance to other ASEAN countries which also aspire to strengthen their logistics sector to take advantage of the growing economic opportunities from logistics.

Especially for the less developed countries of the region, a number of institutional and non-institutional changes must be undertaken individually before economic opportunities can be realized amidst increasing regional competition, as follows:

- To make a freer trading and investment environment. They should be more outward-looking and welcoming to foreign investors by liberalizing its markets, improving the customs clearance and treating foreign and large businesses on the same footing as the local and small and medium size firms (SMEs), respectively.
- To improve the level of English proficiency and increase the number of logistics professionals. English proficiency needs to be further improved to make it easier for foreign investors to operate their businesses. A more varied menu of short and long term English and logistics courses may be offered in universities and non-profit educational organizations.
- To improve the consistency and transparency in government policy towards the industry. Foreign investors need to have a sense of security thanks to consistent and predictable policies since their investment is usually bulky and requires a long gestation period. Transparency also implies that the rules must be open so that they know what they can do and cannot do. Since the government plays a significant role in economic development and other economic initiatives, transparency of government policy is critical.
- To have a clean government with efficient and simplified administrative processes. Clean government and efficiency in bureaucracy is one of Singapore's unique features which made the island attractive as a base for multinational corporations' regional and global operations.
- To foster harmonious relations between the government, management and labor unions. No doubt, harmonious labor-management relation is vital to the smooth functioning of transportation, distribution and other aspects of logistics operations, as shown by the 2002 long-shore labor strike at the 29 ports in US West Coast, which costs the US economy US$2 billion a

day with damaging ripple effects rolling into the Pacific resulting from international trade disruption and non-just-in-time delivery of goods (*The Straits Times*, 26 October 2002, p. 29). Singapore is well known for its tripartite peace of government-union-management and political stability. Singapore has not had any labor strikes since the mid 1980s.

— To foster good partnership between the government and the private sector. Although the government sector is important for the formulation and implementation of appropriate policies, it needs the private sector to carry out and translate the overall policy direction into action. Thus, a good partnership between the government and the private sector is an important ingredient to the success of a logistics hub strategy. Based on Singapore's experience, the government of Singapore has always been pro-active and supportive to the logistics providers by providing world-class infrastructure and a broad range of logistics solutions and services including the establishment of efficient customs procedures and pro-business environment.

NOTES

[1] The report of the working group on logistics *Developing Singapore into a Global Integrated Logistics Hub* (Economic Review Committee, September 2002).

[2] Although the port environment generally has become increasingly competitive, it varies between regions and places depending on the extent to which these forces have impacted the nature of the port environment.

[3] The geographical aspect of port choice is certainly important which goes above and beyond pricing. Thus, the choice discussed in this paper is among ports that can equally reach the final destination.

[4] Panamax refers to those ships whose sizes can pass through the Panama canal, whereas post-Panamax ships are ships whose sizes are so huge that they can no longer transit through the Panama canal.

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pp. 135-150.

Integrated and Strategic Environmental Assessment of Port Developments in the Vung Tau Area (South Vietnam)

by

Cindy RUTTEN*, Luc HENS* & BINH DAO KIM NGUYEN**

1. Introduction

Vung Tau is a province in South Vietnam, East of Ho Chi Minh City. The area is economically fast developing. Port and industry areas are located in mainly 10 different industry zones: Phu My 1 (Tan Thanh district), My Xuan A (Tan thanh District), My Xuan A (expand), My Xuan B1 (Tan Thanh District), Cai Mep (Tan Thanh District), Dong Xuyen (Vung Tau City), Phuoc Thanh (Vung Tau City), Long Huong (Ba Ria Town), Go Dau (Long Thanh District).

To evaluate the environmental impacts of this development, the different projects have been assessed on an individual basis according to the Vietnamese legislation. However, no integrated strategic environmental assessment is performed yet, although effects of cumulative impacts might be expected *e.g.* on the most valuable mangrove areas in which the developments occur.

A basis for strategic environmental assessment (SEA) are the Vietnamese port development master plans. The plan of 1999 had already profound impacts on the environment. The new master plan of 2005 indicates further expansion of both the port and the industry areas.

The aim of this study is to assess the impacts of the port developments in the area between HCM City and Vung Tau. This study identifies the realizations of the master plan of 1999 and the caused impacts. These impacts are used to predict the impacts of the master plan of 2005.

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This paper focuses on land use, water and sediment quality, socio-economics, archaeology and cultural history. Other environmental aspects are evaluated in the wider SEA (SORESMA *et al.* 2005).

2. Materials and Methods

The study area is a rectangular zone of 43 by 16 km of which the corner points are (fig. 1):

— E107°12'/N10°22'
— E107°03'/N10°18'
— E106°54'/N10°41'
— E107°03'/N10°45'

This area covers the cities and surrounding areas of mostly Ba Ria Vung Tau (Tan Thanh district, Vung Tau City and a small part of Ba Ria Town), the Southern part of the Dong Nai province (part of the Nhon Trach and the Long Thanh District) and Ho Chi Minh City (small part of Can Gio mangrove forest).

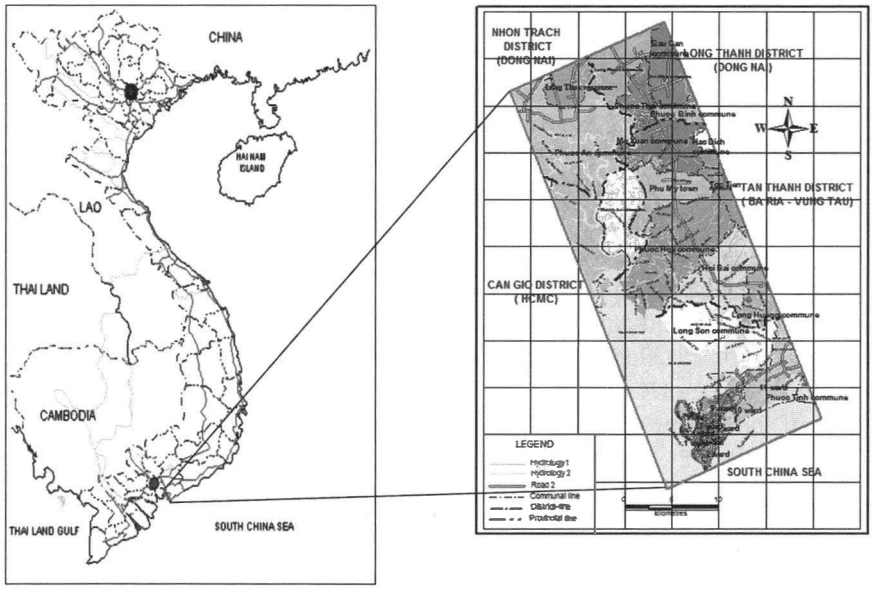

Fig. 1. — Location study area.

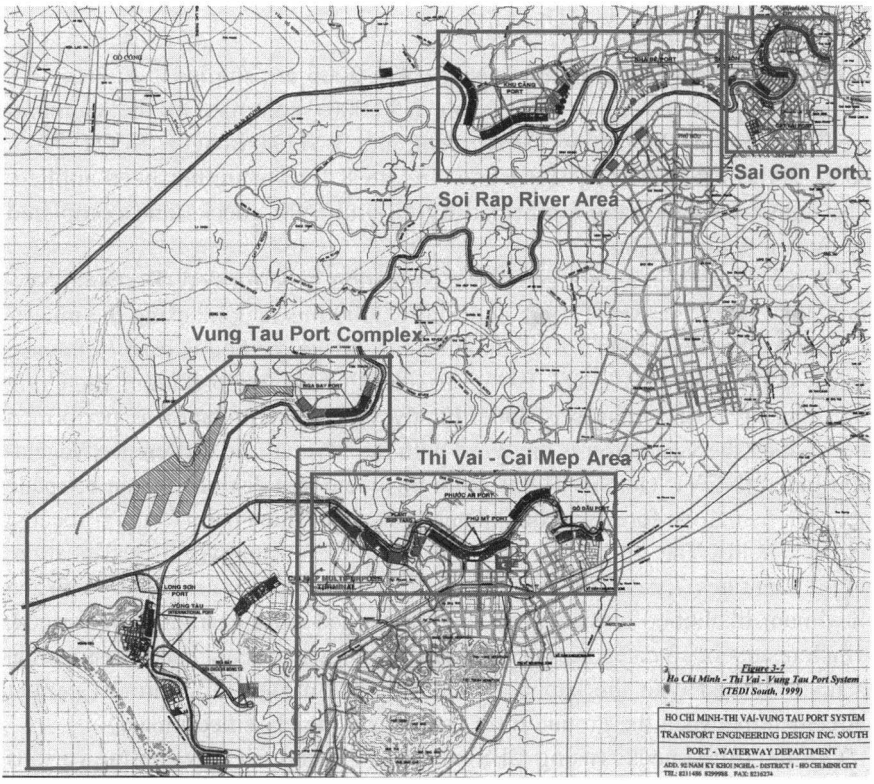

Fig. 2. — Master plan of 1999 for the Thi-Vai-Vung Tau region.

The Ministry of Transport edited in 1999 a general master plan for the port developments in the Ho Chi Minh City — Thi Vai — Vung Tau area (fig. 2). Four main port areas are identified in this plan: the Soi Rap River area, The Sai Gon port, The Vung Tau port complex and the Thi Vai — Cai Mep area (HAECON 2002). On the 12th of August 2005 a new master plan was approved by the Prime Minister on port developments in Ho Chi Minh City — Dong Nai - Ba Ria Vung Tau up to 2010 and development orientation up to 2020. About 28 new ports are planned.

Strategic environmental assessment (SEA) for 5 disciplines, is addressed in this paper.

2.1. Land Use and Land Use Changes

Land use changes during the period 1995-2005 are studied.

The topographic map of 1993 (scale 1/50 000), compiled by the Vietnamese Topographic Publishing Department, and 3 SPOT images (SPOT 1995, 2000, 2005) are used. ENVI 3.6 and ArcGIS 8.1 software has been applied. The computer data were confirmed by ground truth checks and completed by questionnaire findings.

On the satellite images a geometric correction is performed (Research Systems Inc 2002). For SPOT 1995 and SPOT 2000 this is done using the image-to-map method. For SPOT 2005 the image-to-image method is used (reference image is the corrected SPOT 1995). To allow visual interpretation, stretching and filtering of the images is done. Firstly visual interpretation is performed after which the vegetation is analyzed with the Normalized Difference Vegetation Index (NDVI) (Jensen 1986). With this method a distinction can be made between mangrove forest, coconut plantations, trees, nipa palm (Nipa fruticans) and rice fields. The Isodata method is used for the unsupervised classification, which identifies 7 categories of land use (Tou & Gonzalez 1974). With the maximum likelihood classification, the supervised classification is performed, which results in 13 categories (excluded hydrology and sea). This classification is finally tested with the kappa coefficient. This results in an almost perfect agreement between the ground truth checks and the classified image.

Ground truth checks (using GPS) allow to distinguish between the various characteristics of the land use categories and to identify the areas under cloud cover on SPOT image 2000 (6,431.5 ha).

Furthermore, 4 land management officers are interviewed using the questionnaires, which mainly address 3 items: location (GPS), land use (14 categories) and period (1995, 2000 and 2005).

2.2. Water Quality

The results are based on existing literature (tab. 1) and on the monitoring results of 35 sites at three occasions (July, September and October 2005).

The 3 × 35 samples were analysed in the following way:

Measurements performed in the field concern: salinity (salinity meter SM — 802, APEL Instruments), EC (EC-meter SCM 2000A, Digital Conductivity meter), DO and temperature (DO-meter Oxi 330i, cat.no.2B20-001-7, Germany), pH (pH-meter pH 62K, APEL), NaCl, Turbidity (WQC — 22A. DKK — TOA Corporation, Japan).

Table 1
Data used for water quality analysis

Number of papers	Nature	Origin
4	Governmental reports	Department of Science and Technology, Department of Environmental Analysis
2	Publications in book	Environmental management of ports in Vietnam
5	Environmental Impact Assessments	Petrovietnam
1	Study report	Haecon

The following measurements are performed in the laboratory: Cl^- (Mohr method), SO_4^{2-}(titration method), Al (Aluminon method), Total Fe (phenanthroline method), PO_4^{3-} ($SnCl_2$ method), NO_3^- (Sodium salixylate method), NH_4^+ (Nessler method), SS (weight method), color (Colorimetric method), COD (Bichromate method), BOD (dilution and seeding method), E.coli (membrance filter techniques), oil and grease (TCVN 5070 — 1995), Pesticides (GC/ECD) (NGUYEN THO *et al.* 2005).

The evaluation of the water quality is based on a comparison with mainly the Vietnamese and Flemish standards. The Kruskal-Wallis test is performed to detect possible differences among the sampling sites (Cai Mep area, Go Gia River, Go Dau-Phuoc An, Phu My area, Vung Tau City, Dong Xuyen, Ganh Ria Bay, aquaculture area). The analysis is performed using SPSS 11.0 for Mac OS X.

2.3. SEDIMENT QUALITY

The sediment quality is evaluated on the basis of existing literature (tab. 2) and measurements in the field at 25 sampling sites (each of the sites were monitored once, in June 2005). The samples are taken at a depth of 0-20 cm in the riverbed (NGUYEN THO *et al.* 2004).

Table 2
Data used for sediments analysis

Number of papers	Nature	Origin
4	Environmental impact assessment	Petrovietnam
1	Publications in book	Environmental management of ports in Vietnam

The following parameters are analysed: pH (pH-meter: 1/2.5 w/v — wet soil), EC (EC-meter (1/5 w/v converted to 25 °C — wet soil), OM (Tiurin method), dissolved cations (Ca, Mg, Na, K, Mn) (extracted by distilled water AAS), exchangeable cations (Ca, Mg, Na, K, Mn) (extracted by CH_3COONH_4 1N AAS), Mn (extracted by H_2SO_4 0.1N AAS), Fe^{2+}, Fe^{3+} (extracted by H_2SO_4 0.1N Cadarinop method), dissolved Cl (Mohr method), dissolved SO_4 (Turbidity method), P_2O_5 (Oniani method), Al (Titration method), total SO_4 (complexon method), oil and grease (TK TCVN 5070-1995).

The Kruskal-Wallis test allows to detect differences between sampling sites (Dong Xuyen area, Go Dau-Phu My area, Cai Mep area, Go Gia River area and the aquaculture area). The Long Son area is excluded from the analysis because this area only includes 1 sample. The analysis is performed by SPSS 11.0 for Mac OS X.

2.4. Socio-Economics

A descriptive analysis of selected socio-economic parameters allows to describe trends from the past. Data are provided by the published literature (tab. 3) and during interviews (December 2004 and January 2005: 5 general information providers, 13 companies and 2 ports).

Table 3
Data used for socio-economic analysis

Number of papers	Nature	Origin
9	Governmental reports	Ba Ria Vung Tau Statistics Bureau, Department of Agriculture and Rural Development, People's Committee of Ba Ria Vung Tau, People's Committeen of Tan Thanh district, Department of Science, Technology and Environment
2	Internet	Statistical Office Vietnam and Worldbank

The following indicators are used: demography (population, population density, urban and rural population), labour and income (labour force per sector, average income), economic structure and performance (GDP per sector), education (education facilities, amount of pupils, amount of trained labourers), medical care facilities (medical health care facilities), migration (physical, natural and total growth), tourism (receipts from tourism operations, number of tourists). The Pearson correlation allows to quantify the relationship between any two variables. Calculations are performed by SPSS 11.0 Mac OS X.

2.5. Archaeology and Cultural History

153 cultural sites are included in this study. The impacts of air pollution (sulphur dioxide (SO_2), hydrogen ions (H^+), temperature and precipitation) on corrosion and soiling are calculated. Corrosion means the gradual deterioration of material by chemical processes, in this case attacks by acid. Soiling means the degradation of surfaces that can be measured as the reflectance contrast of a darkened surface, by comparison to the reflectance of the base surface (Pio *et al.* 1998). For corrosion the methods recommended by the 'International co-operative program on effects on materials, including historic and cultural monuments (ICP materials)' are used (http://www.corr-institute.se/ICP-materials). This program developed dose-response functions for different materials. The equation for limestone, which is the most currently used material for monuments in the study area, is the following (Swedish Corrosion Institute 2001):

$$R = 2.7\ [SO_2]^{0.48} \exp\{-0.018T\}t^{0.96} + 0.019\ Rain[H^+]t^{0.96}$$

In which:

R	Surface recession, µm
$[SO_2]$	Concentration of SO_2, $\mu g/m^3$, annual average
$[H^+]$	Wet deposition, mg/l, annual average
T	Temperature, °C, annual average
t	Exposure time, years
Rain	Amount of precipitation, m, annual average

The $[H^+]$ is calculated based on the pH of the rain, using the following equation:

$$[H^+] = 10^{-pH}\ (g/l)$$

The following parameters allow to calculate the effects of soiling: traffic and related air pollution, location, climate, type of exposure (sheltered or unsheltered), type of material and colour of stone (Viles *et al.* 2002, Grossi *et al.* 2003).

3. Results

3.1. Land Use and Land Use Changes

The master plan of 1999 resulted in a significant land use change. This master plan projected developments at the Thi Vai-Cai Mep area and the

Vung Tau port complex. However, when comparing this plan with the satellite image of 2005, it is clear that not all ports are yet constructed. Phu My, My Xuan and Go Dau area are already largely, but not fully, developed. Also, only a limited number of ports are present at the Cai Mep and the Dong Xuyen area (Vung Tau port complex). So, the master plan of 1999 is put into practice to some extent, but not fully.

The analysis resulted in 13 land use categories in 2005: annual crops, rice, rubber, long term tree, aquaculture, shrimp forest, natural forest, planted forest, "specialized" land (port area, industry area etc.), salt march, settlement, settlement garden and wasteland. In 1995 and 2000, there was no shrimp forest.

Table 4 shows the changes of the different categories between 1995 and 2005. During this period important changes occurred.

Table 4
Land use categories for 1995, 2000 and 2005

Category	1995		2000		Change 1995-2000 (%)	2005		Change 2000-2005 (%)	Change 1995-2005 (%)
	Area (ha)	%	Area (ha)	%		Area (ha)	%		
Annual crops	2,075.45	2.58	1,803.42	2.25	-13.11	1,090.73	1.36	-39.52	-47.45
Rice	3,309.02	4.12	4,586.87	5.71	38.62	1,842.88	2.30	-59.82	-44.31
Rubber	1,764.81	2.20	1,836.81	2.29	4.08	1,963.24	2.45	6.88	11.24
Long term tree	13,056.03	16.26	12,941.48	16.12	-0.88	9,568.91	11.92	-26.06	-26.71
Aquaculture	2,277.90	2.84	2,832.75	3.53	24.36	3,851.05	4.80	35.95	69.06
Shrimp forest						352.40	0.44	100.00	100.00
Natural forest	9,764.40	12.16	6,745.02	8.40	-30.92	4,915.05	6.12	-27.13	-49.66
Planted forest	5,443.61	6.78	9,823.00	12.23	80.45	10,622.00	13.23	8.13	95.13
Specialized land	1,176.69	1.47	1,337.08	1.67	13.63	4,628.94	5.77	246.20	293.39
Salt marsh	3,398.96	4.23	1,252.57	1.56	-63.15	1,475.15	1.84	17.77	-56.60
Settlement	1,565.43	1.95	1,594.23	1.99	1.84	9,422.15	11.73	491.02	501.89
Settlement garden	5,715.08	7.12	7,393.00	9.21	29.36	2,406.52	3.00	-67.45	-57.89
Wasteland	2,898.61	3.61	299.00	0.37	-89.68	307.00	0.38	2.68	-89.41
Hydrology	9,990.00	12.44	9,990.00	12.44	0.00	9,990.00	12.44	0.00	0.00
Hydrology (sea)	17,857.00	22.24	17,857.00	22.24	0.00	17,857.00	22.24	0.00	0.00
Total	80,293.00	100.00	80,292.23	100.00		80,293.00	100.00		

The major land use changes are recorded for settlements and "specialised" land (fig. 3). The surface of the settlements increased over the last 15 years by 502 %. This change occurred mainly during the last 5 years. People settle near the National road 51 and in Vung Tau City. The "specialised" area increased by 293 %. Also this change occurred mainly during the last 5 years. These figures show the large impacts of the master development plan of 1999. It is expected that this evolution will continue with the new master plan. The mangrove area increased with 329 ha. This is the result of the forest policies of the Vietnamese government between 1995 and 2000. Large surfaces of mangroves were planted during this period. Between 2000 and 2005 the mangrove area decreased by 1,031 ha, as a result of the developments. The new master plan of 2005, will again put mangroves under stress by locating the ports and the accompanying industrial zones in these areas. It is expected that in 2010 an estimated amount of 315 ha mangroves will be lost because of the ports; in 2020 this will be about 600 ha. For the purpose of the industry zones, land is already cleared in the past. This means that mangroves are already cut in these areas. It is also expected that agriculture area will change in settlement area (in rural area: houses with garden) and residential area (in urban area: houses without garden).

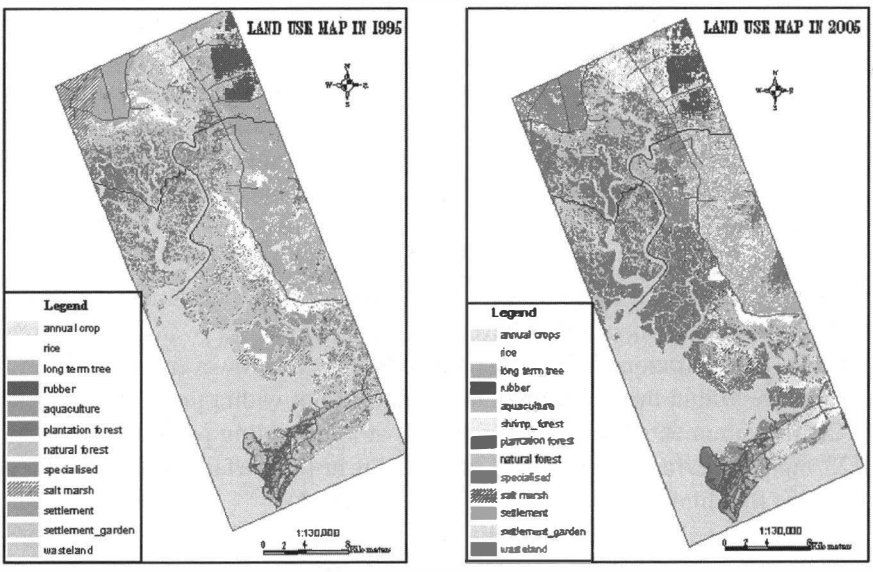

Fig. 3. — Land use change between 1995 and 2005.

In conclusion, on the basis of the new master plan, it is expected that the settlement and "specialised area" will probably continue to increase, while the mangrove area will shrink (about 600 ha in 2020) because of the ports.

3.2. Water Quality

The average temperature of the water in the study area is 30 °C. It is a rather saline area because of intrusion of seawater. The pH is on average 7.61. Of the chemical-physical parameters, dissolved oxygen, chemical oxygen demand, suspended solids, nitrite, ammonia, phosphate and sulfate exceed the Vietnamese and/or Flemish standards. The Kruskal-Wallis test shows that differences exist among the sampling points. Especially the DO is very low in the upper part of the study area (Go Dau-Phuoc An and Phu My). Go Dau-Phuoc An shows results below 1 mg/l, what is hardly compatible with aquatic life. The surface water in these areas also contain high amounts of ammonia and phosphate, which indicate eutrophication. The low values of DO, were not present in Phu My in the past (2000) (tab. 1). This points to increasing pollution during the last few years mainly because of discharge of waste water without treatment.

E. coli values exceed the EPA limits in Phu My (358.67 organisms/100 ml) and the aquaculture area (444,20 organisms/100 ml) (Environmental Protection Agency 1986). Although the bathing water in Vung Tau City as a rule conforms with the standards, some individual samples show very high levels of E. coli bacteria. This points to fecal source pollution and means that this bathing area is not suitable for swimming. However, the proposed European standards are less strict than the US standards, but even then some individual samples exceed the standards (Commission of the European Communities 2002).

Concentrations of iron are mostly below the Vietnamese standards. Only the coastal water shows levels, which are too high (0.87 mg/l and 0.88 mg/l). Though, comparing these values with the Flemish standards, every area exceeds the permitted iron levels (see tab. 1) (Flemish Environmental Agency 2002). Most other metals that have been identified in the water in the area occur in concentrations below the standards (tab. 1). However cadmium and chrome are within the Vietnamese standards but not within the Flemish ones.

Oil measurements show too high levels at all sampling points (average of 4.23 mg/l). Previous studies also indicate oil in the surface water, but they were not that high as measured in 2005 (see tab. 1).

Only a limited number of samples (10 areas each measured 3 times) were analysed for pesticides (DDT, DDE and lindane). The results show traces of these pesticides.

The ground water quality of the My Xuan and the Phu My communes is acidifying with pH values ranging from 4.38 to 5.11. High amounts of coliforms are found which makes it unsuitable as drinking water.

In conclusion, the water quality of the study area is poor, especially the dissolved oxygen is of major concern. E. coli values are too high, which is especially important in bathing water and makes the ground water unsuitable for consumption. Oil is found in high concentrations in the surface water of the study area.

3.3. Sediment Quality

Most of the samples have pH values above 7. Organic matter is high. However, P_2O_5 is low and reduction conditions predominate in the soil. The sediments are saline, because of the intrusion of seawater. Na^+ and Cl^- concentrations are high. These conditions are positive for mangroves. High amounts of oil are found.

According to the literature (tab. 2) copper and chrome occur in high concentrations in the sediments, which are related to industrial pollution. As the industrial activity is increasing in this area, this pollution is expected to increase. This can result in either acute or chronic effects on benthic organisms (Binning *et al.* 2001). No major differences are found between the sampling areas with the Kruskal-Wallis test.

In conclusion, the results show that the soils constitute a perfect environment for mangroves. Heavy metals and oil are present in high concentrations.

3.4. Socio-Economics

During the past 9 years the population in Ba Ria Vung Tau increased from 719,003 in 1996 to 908,233 in 2004 (Ba Ria — Vung Tau Statistics Bureau 2004, 2005) (People's Committee of Ba Ria Vung Tau 2000). This increase is mainly driven by migration. Only in Ba Ria Town, the migration rate decreases. This might be related to the fact that currently, the industrial zone located in this area is not operating yet. 55.53 % of the workers in the factories in the study area originate from outside the province. People also tend to cluster in urban areas.

The GDP structure of Ba Ria Vung Tau shows that industry is the most important sector of the province. In 2004 the GDP from industry counted for 85 % (reference price 1994), while services only counted for 11 % and agriculture for 4 %. The area is also characterised by a fast economic growth. Between 2000 and 2004 the provincial GDP increased by 63 %. This increase

is mainly due to construction (504 %), production and distribution of electricity, gas and water (254 %), and processing industry (134 %). Furthermore, transport, stocking and telecommunication increased by almost 84 %.

Also tourism grows. Between 1997 and 2004 the total amount of the receipts from tourism increased by 43 %.

The companies need properly trained workers. Therefore it is necessary that education evolves together with the port development. A strong significant positive correlation exists between the number of people and the amount of education facilities. The correlation between the population and the amount of schools, classes and teachers is respectively 0.979, 0.939 and 0.985 (significant level of 0.01).

Currently, most people are employed in the agricultural sector. However, the last few years the largest growth of employees is recorded in industry (between 2002 and 2004: 23.87 %) (Ba Ria — Vung Tau Statistics Bureau 2004, 2005).

The sharp increase of the population necessitates an increase of medical health care facilities. This increase is visible but no significant correlation exists between the population and the health care facilities (treatments, beds, clinics and pharmacies).

To conclude, the job opportunities in the ports and the related industrial areas impact demography and migration. The economic growth will continue and industry gradually becomes the most important sector.

3.5. Archaeology and Cultural History

In the study area, 153 cultural sites are identified of which most are located near the national road 51 and in Vung Tau City. Most monuments are made of limestone, which is prone to deterioration by air pollution.

SO_2 is the most important pollutant causing erosion. In 2000, the environmental report of Ba Ria Vung Tau reported high values of SO_2, with an average of 0.073 mg/m^3 (March). However, more recent figures show much lower concentrations of SO_2, with values below 0.010 mg/m^3 (Department of Science, Technology and Environment 2000, 2005). When comparing concentrations in 2000 with those of 2004, an obvious decrease of SO_2 is visible. The decrease is very apparent and is possibly attributed to factors, which were present at the time of measuring in 2000. When comparing the SO_2 values of 2002, 2003 and 2004 no changes appeared. On the basis of these trends no major impacts are expected resulting from the master plan of 2005.

The equation for unsheltered limestone, using the SO_2 concentrations of 2004, shows that after 8 years a surface recession of 36.598 μm is expected.

When comparing this figure with the background corrosion rate (atmospheric deterioration of materials is a process that even occur without pollutants), 35 μm can be explained by background pollution. Moreover, when comparing this result with European values, where only 4 sites out of 37 have lower recessions than in the study area, it shows that the values in Ba Ria Vung Tau are quite low.

Table 5 gives a summary of the factors favoring or restraining soiling (blackening of surfaces) in Ba Ria Vung Tau. Pollution and location are the most important factors. In the study area, impacts are expected on 24 cultural sites of the 153, this mainly because their location and the nature of the material (fig. 4).

Table 5
Factors favoring or restraining soiling Ba Ria Vung Tau

Type of factors	Factors favouring soiling	Factors restraining soiling
Pollution (related to traffic)	TSP values are about 0.24 mg/m^3. This is expected to increase because a lot of traffic is expected because of the developments.	
Climate		The climate has a very wet season. Wind is a positive factor slowing down soiling, but there does not seem to be much wind in the study area.
Location — Structure	The closed city structure is more favourable to soiling as the buildings are close to the roads and as the air (containing the pollutants) is less ventilated. More people tend to live in urban areas with the result that the city structure probably will get closer.	The monuments standing along the road are less prone to soiling than when located in the city, as there can be more dispersion of pollutants. Moreover, the further from the road, the lower the chance for soiling.
Location - Traffic	The traffic will dramatically increase along road 51. This may cause larger soiling rates along the road and in the city, where the traffic is also expected to increase but maybe not in the same proportions.	
Characteristics of monument	As soiling is more visible on light surfaces, whitewashed monuments will be more affected. Sheltered monuments will probably be faster soiled, as they will not (or less) be washed by the rain.	Soiling will be less visible on monuments covered with darker paints. The rain can wash unsheltered monuments; this slows down the soiling process.

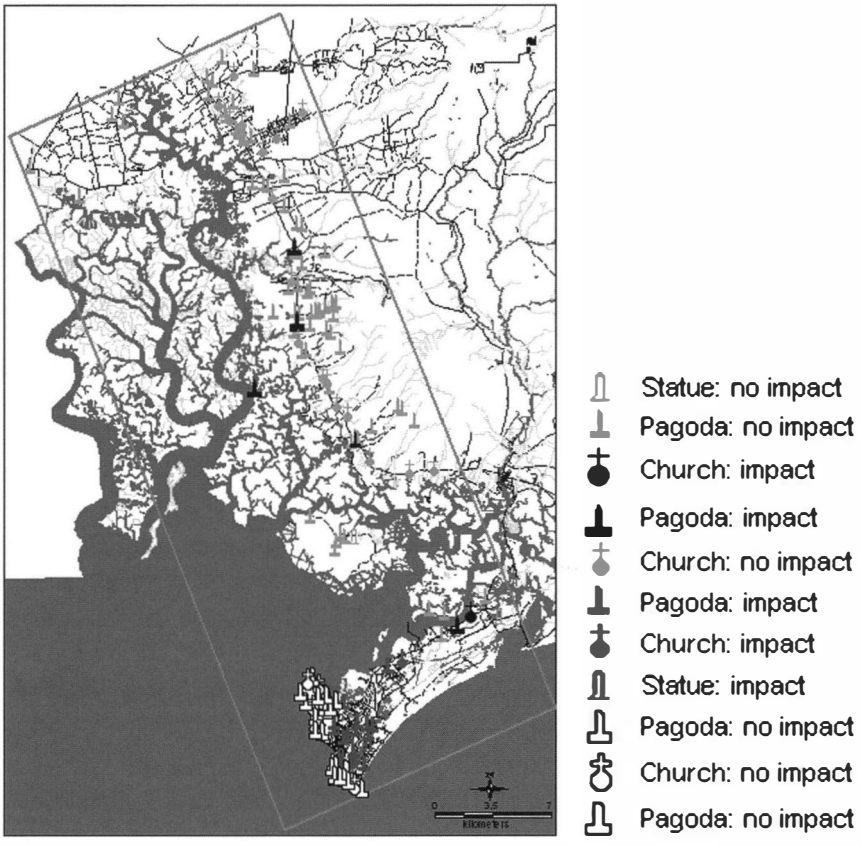

Fig. 4*. — Location categories of the cultural sites in Ba Ria – Vung Tau.

In conclusion, mainly impacts of soiling are expected. This is predominantly due to an expected increase of traffic. Corrosion rates are low, especially compared with results of European countries, and will not result in major effects on the monuments.

4. Discussion and Conclusion

The results show that the development based on the 1999 master plan caused major impacts. This evolution of trends in the past is expected to

* See also power point presentation on CD-ROM.

continue with the master plan 2005. Especially land use experiences major changes, this mainly because of the settlement (between 1995 and 2005: 502 %) and "specialised" (between 1995 and 2005: 293 %) area increase. People cluster near the national road, near the job opportunities and in Vung Tau City.

Sediments in the area are favourable for mangroves. Although the mangrove area increased during the past 15 years by 329 ha, a decrease is expected when the new master plan will be implemented. The ports will use about 600 ha of mangrove area. The national reform policy resulted in planted forests. However, natural forests are known to represent a higher biodiversity than planted areas. Therefore, it is important to keep the original mangrove areas protected. Inevitable, mangrove area will cut down, but measures should be taken to preserve the original, highly bio diverse mangrove fields areas. The 28 planned ports will be built in mangrove areas.

The water quality is poor. In particular the amount of dissolved oxygen is low. Also, E. coli and oil are of concern. The global water quality picture points to a degrading environment and health risks resulting from exposure to bacteria. The area experiences a positive evolution, in terms of the GDP and tourism receipts. Migration results from the job opportunities that are offered. This causes a population increase affecting other sectors including education and health. The expected impacts on the monuments are limited. This because of relatively low SO_2 concentrations compared with other countries. Soiling is likely to happen in a limited number of monuments (24), mainly because an increase of traffic. Overall, the impacts are limited because of their reversible character. Repainting, washing or cleaning of monuments is feasible.

In conclusion, the master plan of 2005 will have many negative impacts for the area, especially on land use, but also on water quality. Positive impacts are expected, mainly in socio-economics.

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Considerations on the Design and Construction of a Large Sand Embankment on Soft Sedimented Dredged Material

by

William VAN IMPE* & Daniel VERASTEGUI FLORES**

1. Introduction

Land reclamation activities in the harbour of Antwerp in Belgium have encouraged the planning of construction of a 27 m-high sand embankment on soft recently consolidated dredged material within the harbour. Figure 1 illustrates the project. The sediment surface is located about 18 m below the water table. The low initial shear strength of the dredged material, together with the magnitude of the overload imposed by the sand embankment, turns this into a challenging problem.

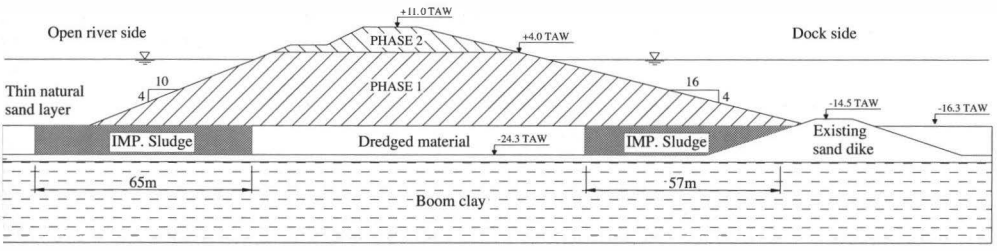

Fig. 1. — Layout of the partially submerged embankment.

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The embankment is to be built on sand, partially reinforced with geotextiles, to provide extra deformation stiffness and to protect the slopes against the erosive action of limited harbour waves. The consistency of the sludge remains low even after inducing vacuum consolidation with horizontal drains (VAN IMPE 2002). Although such vacuum consolidation was successfully applied, it proved time consuming for the particular characteristics of this material.

In view of the particular difficulties and after an extensive geotechnical analysis an interplay of staged construction and deep mixing methods has been proposed for the execution of this project.

2. Geotechnical Properties of the Dredged Material Involved

The dredged material layer, with a thickness of about 8 m, overlying a deep layer of highly OC Boom clay, is located at a depth of about 19 m. Some physical characteristics are summarised in table 1.

Table 1
Physical properties of the virgin deposited material

Index	Dredged material
Liquid limit	124.4
Plastic limit	46.7
Plasticity index	77.7
Natural water content, %	115.0
Organic content, %	6.0
Natural lime content, %	13.9
Sand fraction, %	10.4
Wet density, g/cm^3	1.4
pH of the pore water	7.2

An extensive geotechnical characterisation of the Boom clay can be found elsewhere (VAN IMPE 2001). Boom clay is a heavily over consolidated fissured clay that has been studied for years in Belgium. The undrained strength can be estimated with the well established correlation c_u (kPa)=75 + 3.5 D, where D is the depth in meters. The drained shear angle varies in a narrow range and ϕ'=19° seems to be a reasonable value. Also, from laboratory tests a drained Young's modulus in the order of E'_{50} = 40 MPa can be evaluated.

2.1. Undrained Shear Strength

The undrained shear strength (c_u) of the soft dredged material has been estimated by means of extensive laboratory and field testing. Figure 2 summarises several measurements in the area of study. It is clear that the average c_u varies in a range from 2 to 4 kPa. In the design phase an initial value of c_u=3 kPa has been assumed as the most representative of the layer of sediments. Apparently from about 6m depth below the bottom, the dredged material is already, to some extent, mixed with the thin natural sand layer overtopping the OC Boom clay.

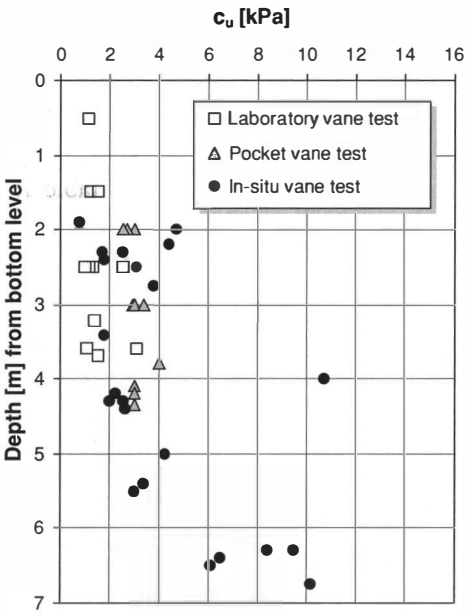

Fig. 2. — Initial undrained shear strength of the dredged material layer.

Furthermore, laboratory tests have been focused on the determination of the undrained strength ratio (as defined by Ladd 1991) from a series of triaxial tests on isotropically consolidated specimens. Figure 3 illustrates the outcome of the testing programme. An (isotropic) undrained strength ratio S_0=c_u/?'$_c$ of about 0.49 was evaluated.

It is well known that isotropic triaxial testing in such case, however, overestimates S_0 to a large extent.

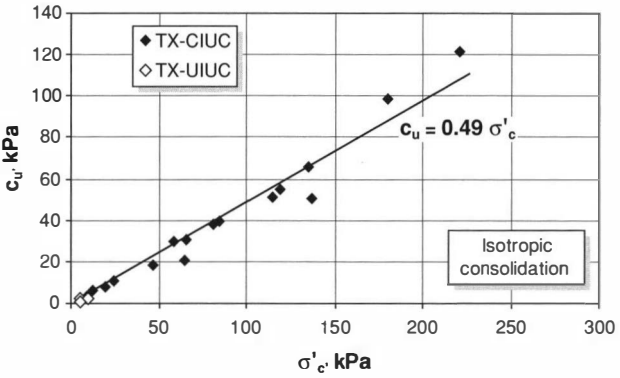

Fig. 3. — Undrained strength ratio from laboratory testing.

In an attempt to assess a more realistic S_0, a linear correlation has been established between the undrained strength (measured from in-situ vane tests) and the actual vertical effective stress (estimated with measurements of unit weight from borings). An (anisotropic) undrained strength ratio S_0 of about 0.3 has been evaluated (see fig. 4).

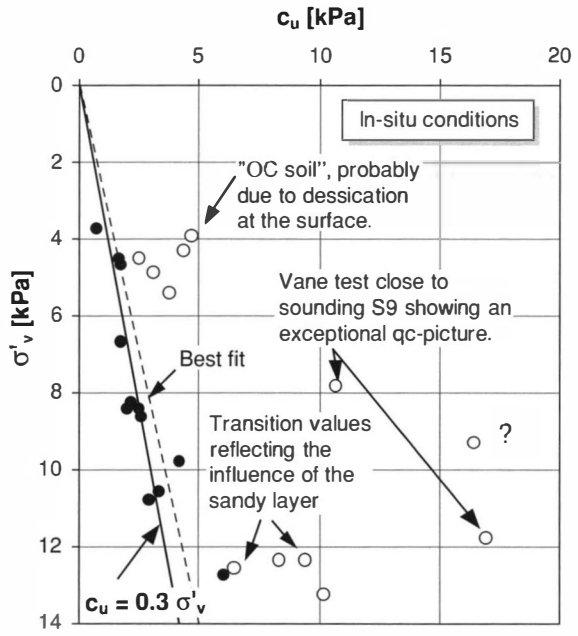

Fig. 4. — Undrained strength ratio from field testing.

2.2. Consolidation Parameters

The consolidation behaviour of the dredged material has been assessed by means of Constant Rate of Strain (CRS) tests, hydraulic conductivity tests and oedometer tests. Figures 5 and 6 summarise the results of all tests performed. A best fitting curve have been drawn on each graph; in this way the following constitutive equations have been evaluated:

$$k = 6 \cdot 10^{-8} \cdot \sigma'^{-1.18}_{v} \quad (1)$$

$$k = 6 \cdot 10^{-12} \cdot e^{5.52} \quad (2)$$

where k is the hydraulic conductivity (m/s),?'$_v$ the vertical effective stress (kPa) and e the void ratio.

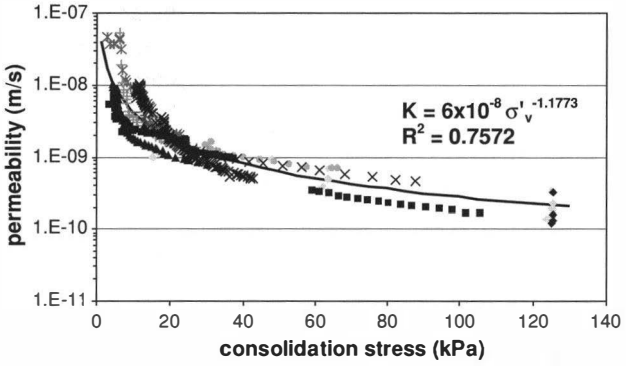

Fig. 5. — Hydraulic conductivity *vs* vertical effective stress.

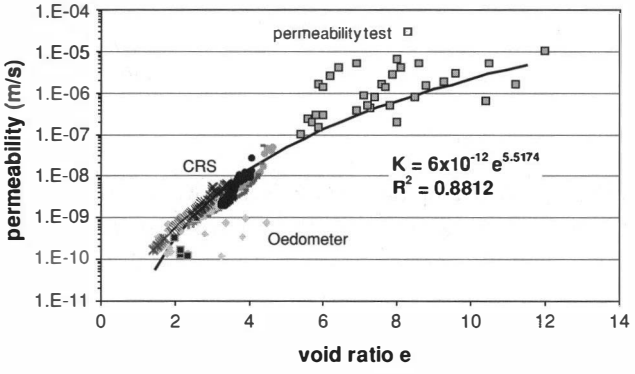

Fig. 6. — Hydraulic conductivity *vs* void ratio.

3. Staged Construction for the Embankment

3.1. Principle

The principle of staged construction of an embankment is rather simple and is illustrated in figure 7. The soft soil underneath is loaded (undrained) until a close-to-yielding stage and subsequently is allowed to consolidate. After consolidation, the soft soil has reached a higher potential of undrained strength allowing to continue with the construction of the next layer in the same way, until completion of the project.

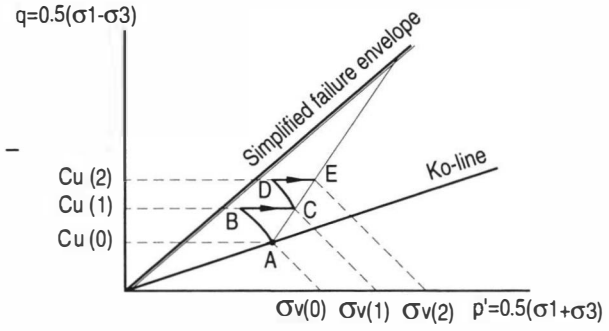

Fig. 7. — Staged construction.

The most critical situation takes place when the soil is close to yielding point, when the excess of pore water pressure is maximum. At this moment a careful undrained stability analysis is essential and also a good quality prediction of the consolidation phenomenon, since this estimation will determine the time required for putting the next layer, or the maximum allowable surcharge preventing failure.

3.2. Consolidation Analysis

It is generally known that the simple Terzaghi consolidation procedure may provide poor estimations when dealing with layered systems or with very soft soils. Such situations require for numerical analysis taking into account features such as the non-linearity of the consolidation parameters (expressed as functions of the void ratio or the effective stress) and more realistic boundary conditions; *cf.* the finite strain consolidation theory — Gibson *et al.* (1967).

The most general consolidation formulation is governed in such case by:

$$\frac{\delta}{\delta z}\left[g(e)\frac{\delta e}{\delta z}\right] - b(e)\frac{\delta e}{\delta z} + \frac{\delta e}{\delta t} = 0 \qquad (3)$$

where

$$g(e) = -\frac{k(e)}{\gamma_w(1+e)}\frac{\delta\sigma'}{\delta e} \qquad (4)$$

$$b(e) = \left(\frac{G_s}{\gamma_w}\right)\frac{d}{de}\left(\frac{k(e)}{1+e}\right) \qquad (5)$$

in which e is the void ratio, k(e) the hydraulic conductivity function and z a reduced coordinate.

The function g(e) plays the role of consolidation coefficient and b(e) introduces the effect of the gravity. Equations 3, 4 and 5 with appropriate boundary conditions and constitutive properties (Eq. 1 and 2) provide the framework from which a solution can be numerically evaluated. This framework has been implemented in our evaluation with a number of computer codes, *i.e.*: FISCC and CBFISCC - VAN IMPE (1999). The codes allow the analysis of one-dimensional consolidation of a single clay layer subjected to a constant instantaneous load.

It is generally accepted that the conventional infinitesimal theory would generally under predict the rate of settlement and over predict the degree of consolidation (U), which in turn may lead to an unsafe prediction of strength gain in staged construction problems. Figure 8 illustrates the outcome of a comparative study for a clay.

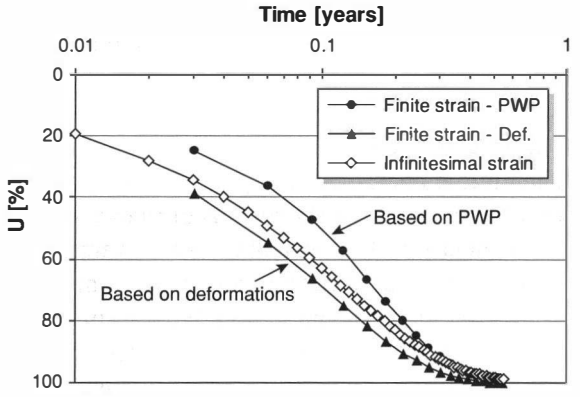

Fig. 8. — Comparative analysis finite *vs* infinitesimal consolidation theory.

The finite strain theory is outspokenly a better approach to the phenomena of consolidation. Nevertheless, at the very first stage of design, the infinitesimal strain theories may still provide the basis for further refinement of calculations, and in a number of cases the accuracy of the infinitesimal strain theory may suffice for practical purposes. Experience and engineering judgement are required in this matter.

3.3. Stability Analysis

The work of Ladd (1991) establishes quite correctly the current methodology for the stability analysis during staged construction. Figure 9 shows a simplified methodology for the analysis where four basic steps are identified.

	Step 1	Step 2	Step 3	Step 4
Components	Initial stress history and strenght	Factor of Safety at stage 1	Stress history and strenght at $t=t_N$	Factor of Safety at stage N
Determination of initial state variables	✔			
Determination of undrained strenght, c_{u0}	✔			
Determination of consolid. parameters			✔	
Modelling consolidation progress			✔	
Stability analysis		✔		✔

Fig. 9. — Methodology for stability analysis during staged construction (after Ladd 1991).

Step 1 deals with the geotechnical characterisation of the site (*i.e.* estimation of stresses and initial undrained strength of the soft soil). On Step 2 the undrained stability for the first loading stage is evaluated on the basis of data from Step 1. Subsequent stability analyses for determination of safety factors (Step 4) require a knowledge of the consolidation behaviour of the soft soil (Step 3) in order to predict the gain of undrained strength or the waiting time required for the next loading stage. These predictions may have an enormous impact on the feasibility of the project; therefore, a rigorous evaluation of consolidation properties is always recommended.

3.4. Application to the Embankment in Antwerp

After several simulations to evaluate the feasibility of the project (Van Impe 2001), it has been proposed to continue with the construction of the sand embankment in Antwerp in 2 phases with a waiting period in between (fig. 1). The length of the improved zones under the embankment has been designed implementing widths of 65 m and 57 m, to the left (water side) and to the right side (backfilling side) respectively. All material characteristics at the start, and for the dredged material also the design values after improvement by deep mixing, are given in table 2.

Table 2
Mechanical parameters for the stability analysis

Description	c' (kPa)	ϕ' (°)	c_u (kPa)	γ (kN/m³)	E'_{50} (Mpa)
Natural sand	0	32	–	20	15
Boom clay	0	19	100	19	40
Dredged material (starting values)	0	18	3	12.8	0.5
Partially improved dredged material	0	25	50	13.5	7.5
Backfilling	0	18	0.5	12.5	0.3

Construction phase 1 goes from the level of the dredged material (-16.3 TAW) up to the level + 4.0 TAW just above the water table; it means about 20 m of submerged sand. On the other hand, phase 2 extends from + 4.0 TAW to + 11.0 TAW.

For the construction of phase 1 of the embankment dike, a construction schedule has been elaborated and introduced in the stability analysis. Figure 10 illustrates the progress of construction proposed for phase 1 in subsequent layers of 2 meters. The foundation layer undrained shear strength at the start of each sand layer of the embankment taking into account the previous improvement with consolidation time (analysed with finite strain theories), is also indicated. Each new layer is to be continuously built up after 60 days and a reinforcement of geotextiles will be placed at the interfaces.

Figure 11 summarises the stability analysis of the embankment staged construction phase 1. Factors of safety above the limiting value 1.3 were accepted here. To be on the safe side, the benefit of the geotextile reinforcement has not been taken into consideration in these calculations. Figure 12 illustrates the potential large strain surface and the factor of safety (FS = 1.45) at the end of the construction of phase 1 of the embankment.

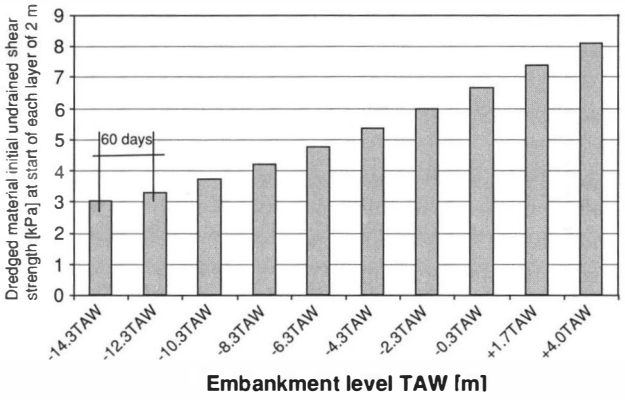

Fig. 10. — Construction schedule for phase 1.

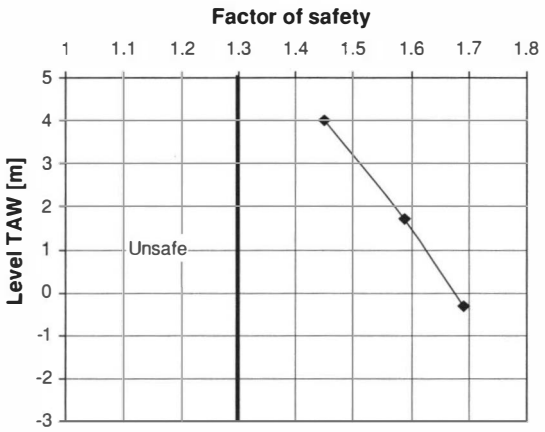

Fig. 11. — Factors of safety — phase 1.

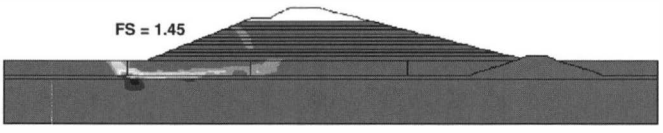

Fig. 12. — Factor of safety at the end of phase 1 (FS = 1.45).

From further stability calculations it follows that the construction of phase 2 (starting from level + 4.0 TAW), when executed immediately after phase 1, brings the embankment close to failure with a factor of safety FS=1.04 (fig. 13). In order to avoid such unacceptable condition, an additional period allowing the foundation soil to continue consolidating and to improve its strength has been implemented. Figure 14 shows the results of a stability analysis for the phase 2 of the embankment (starting from level + 4.0 TAW), however now taking into account the design strength (T_d) of the geotextile reinforcement. The figure illustrates the relationship between reinforcement strength and waiting time necessary to reach a minimum FS = 1.3. For example, if a geotextile design strength of T_d = 50kPa is selected, then the construction of phase 2 should be delayed for 8 years in order to allow the foundation soil to reach an adequate undrained strength.

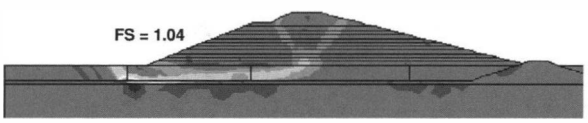

Fig. 13. — Factor of safety if phase 2 is built immediately after phase 1 (FS = 1.04).

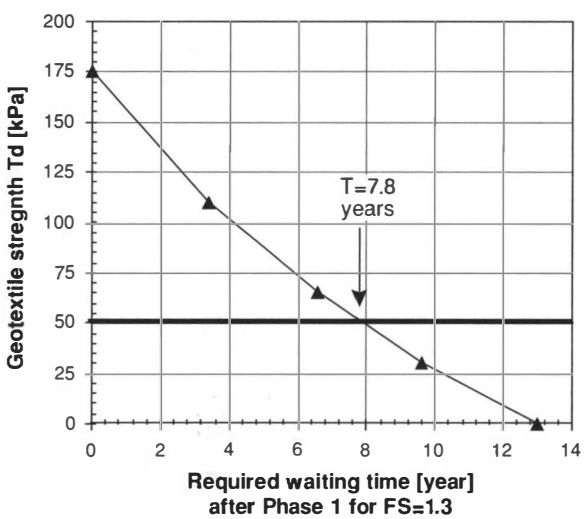

Fig. 14. — Geotextile design strength *vs* waiting time (after phase 1).

4. Deep Mixing Methods

For marine structures, Deep Mixing (DM) known as a technology for decades now, has been used in the construction of quay walls and breakwaters, for reinforcing the foundation layers of embankments, tanks, bridges, retaining structures, high-rise buildings, etc. Newer applications of DM technologies are focused to the mitigation of liquefaction and remediation of contaminated sites.

The DM method is a ground modification technology that improves the quality of the natural ground by in-situ treatment. The main objectives of improvement are to increase the strength, to control deformations; also, to reduce the permeability of loose deposits and more recently to clean a contaminated site. A modified DM method was developed here (fig. 15), featuring wet injection of a slurry and pressurised mixing for the stabilisation of the dredged material. This alternative DM technology is called the SSI (Soft Soil Improvement) deep mixing technique.

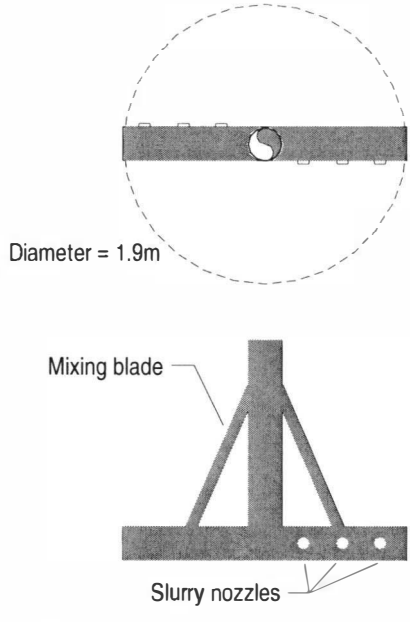

Fig. 15. — SSI mixing technique implemented in this project.

4.1. Selected Binders

In this project, various types of cement have been tried out. Table 3 lists the binder types employed, however omitting the details of the cement characteristics.

Table 3
Cementing agents employed here

Binder designation	Type
A	Blast furnace cement
B	Blast furnace cement
C	Blast furnace cement
D	Portland cement
E	Soil stabilization cement
F	Jet-grouting cement

For blast furnace cements; the slag content in Binder A varied in a range from 36 % to 65 % and in a range from 66 % to 80 % for binders B and C. Binder D is a Portland cement. Binder E is a commercially available binder designed for under water stabilisation of soil. And binder F is a binder very often employed for common Jet-Grouting applications.

4.2. Laboratory Simulation of the Binder Mixing

4.2.1. Preparation of Stabilised Specimens

The virgin dredged material collected from borings has been homogenised prior to stabilisation. Moreover, a dough powerful mixer has been employed for mixing of soil with a cement slurry (w/c = 0.8). A mixing time of about 10 minutes was implemented here in an attempt to recreate intensive (high-pressure) mixing in the field.

The stabilised mix has been poured into split PVC moulds (? = 57mm). The split moulds have prevented damage of the specimens during the extraction of the sample, after hardening.

Finally, the specimens have been sealed and cured under water at 10 °C (and some at 20 °C to study the effect of temperature on the improvement).

4.2.2. Unconfined Compressive Strength

On those laboratory prepared samples, a number of unconfined compression (UC) tests have been performed at different time intervals. The intervals were 7, 14, 28, 56, 84, 120 and 240 days.

The results of the testing programme on sludge specimens cured at 10 °C have been summarised in figure 16. Note that a single binder dosage of 275 kg/m^3 has been implemented in the stabilisation. A more detailed description can be found in another contribution to this conference (VAN IMPE *et al.* 2004).

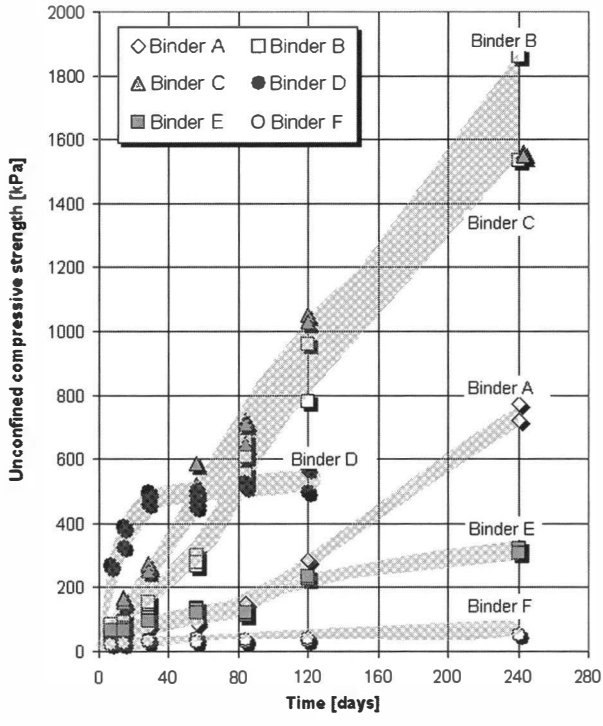

Fig. 16. — UC strength of specimens (T=10 °C).

It seems that, from the group of binders tested, the blast furnace cements (binders A, B and C) do perform by far the best, showing a continuous improvement even after 240 days. The Portland cement (binder D) instead suggests rapid hardening during the first days but the strength increase ceases almost completely after one month approximately. The other binders (E and F) seem to develop only limited improvement even at such high dosages.

4.2.3. Effect of the Curing Temperature on the UCS of Sludge Specimens

An additional series of UC test have been carried out on specimens stabilised with a blast furnace cement (binder C). The results of the UC tests are

illustrated in figure 17. The results have shown that compressive strength of samples cured under water at 20 °C could be about 1.7 to 2 times larger as compared to the strength of samples cured at 10 °C. As shown in figure 17, the hydration of blast furnace cement benefits apparently from high curing temperatures.

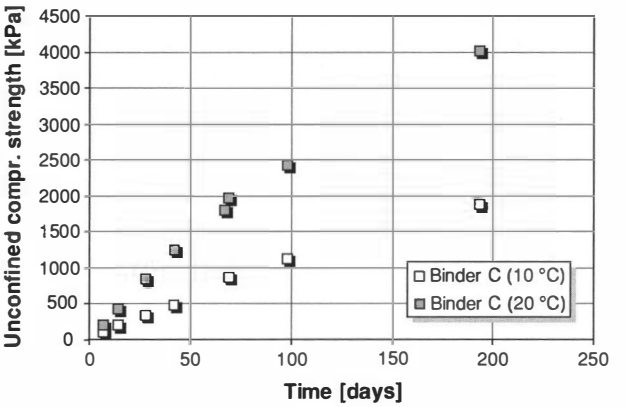

Fig. 17. — Effect of curing temperature on the strength of specimens stabilized with binder C.

4.3. Cement SSI-Stabilisation in the Field

4.3.1. Installation of Trial Columns

To the extent of controlling the quality of the SSI technique, a number of trial stabilised columns (□ = 1.9 m) have been installed in the test site, offshore. Figure 15 illustrates the mixing tool employed for this purpose. A slurry of water and binder C has been injected at very high pressure (up to 300 bar approximately) through nozzles distributed across the diameter to obtain a dosage of about 275 kg/m^3. All operations have been performed from an anchored floating platform as illustrated in figure 18.

For this SSI method the very high pressures at the nozzles, and to a much lesser extent the mixing blade action, enhance the incorporation of the binder slurry into the soil.

4.3.2. Quality Control of the Trial Columns

The excavation of the SSI real scale installed columns allows for the evaluation of the homogeneity of the columns. An alternative way has been fol-

Fig. 18. — Installation of stabilized columns offshore.

lowed as well by means of vertical core sampling through the entire column length. A number of stabilised columns have been selected for inspection. Core specimens (? = 100 mm) have been obtained over the full length of each column, about 56 days after installation.

The visual inspection of the specimens has shown a rather homogeneous and compact stabilised mass with some zones of coarser texture. A few segments of the core specimens have been selected for UC testing (fig. 19). Figure 20 illustrates the UC strength of the specimens at different depths. A trend of UC strength increase with depth has been noticed. This could be explained by the more sandy nature of the deeper dredged material layer and some overburden effect. The UC strength in the profile ranges

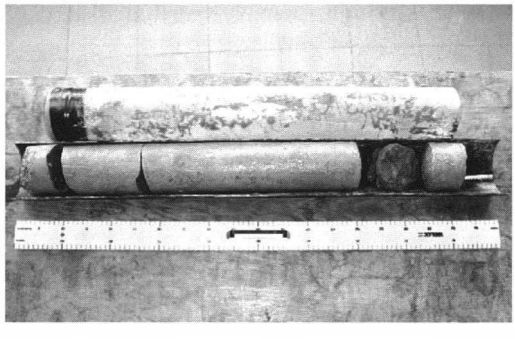

Fig. 19. — Inspection of core specimens.

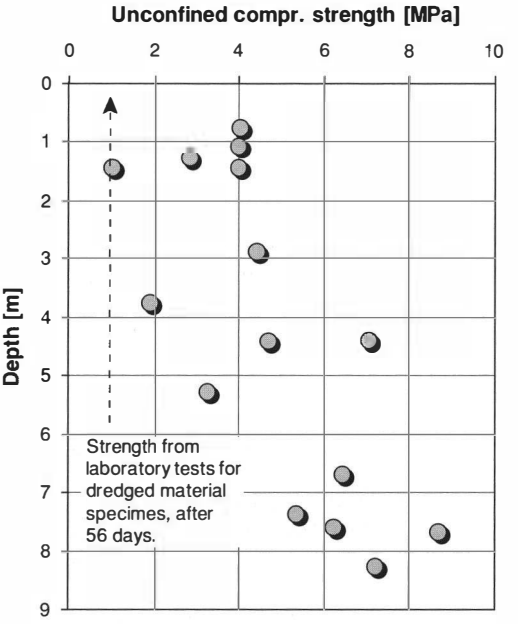

Fig. 20. — UC strength of 56-day old core specimens from the SSI trial columns.

from 2 to 5 MPa in the zone where pure dredged material was treated; and from 5 to 8 MPa in a zone of more sandy dredged soil.

The figure also shows the UC strength from laboratory testing, limited to about 0.9 MPa. This clearly indicates that the common practice of mechanical mixing (with a dough mixer) of specimens in the laboratory has underestimated very severely the strength of very-high-pressure stabilised soil in the field, with a factor of 2 to 5.

4.4. Evaluation of the Reasons for Discrepancy Between Laboratory and Field Tests Results

In order to evaluate the improvement of the dredged material, an untreated specimen, a laboratory reconstituted and mechanically mixed cement-stabilised specimen and an undisturbed sample from borings in the SSI cement-stabilised columns (implementing binder C, a blast furnace cement), have been analysed by means of Scanning Electron Microscopy (SEM) aiming at investigation of the microstructure and composition of each specimen.

4.4.1. SEM Analysis of the Untreated Dredged Material

A specimen of untreated dredged material has been analysed on SEM. The specimen was prepared to simulate the natural in situ conditions of the dredged material with light compaction and it was carefully dried prior to the test. Figures 21 and 22 do illustrate SEM pictures with amplifying factors of 500 and 1100 respectively.

Clay particles (platy shaped) can be identified by their more bright colour in the pictures. They seem to be uniformly spread and are interacting with the silt and sand particles (in edgy or rounded shape and darker in colour). It is also possible to find traces of organic material showing a very regular micro morphology.

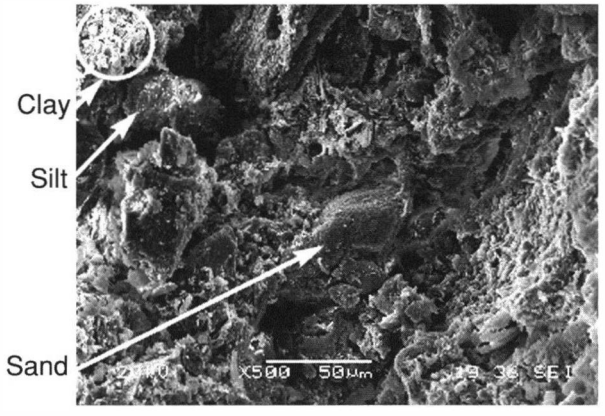

Fig. 21. — Untreated dredged material specimen – amplification factor x500.

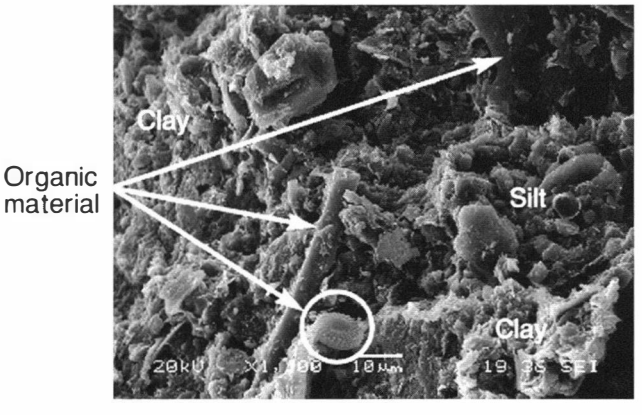

Fig. 22. — Untreated dredged material specimen – amplification factor ×1100.

4.4.2. SEM Analysis of the Dredged Material Stabilised in the Laboratory and in the Field

Figures 23 and 24 do show the specimens (4 cm × 4 cm × 1 cm) carefully cut with a water-cooled sawing system, starting from stabilised samples either mixed in the laboratory either from SSI field samples.

It is clear already from this pictures that the specimens differ in texture. At the moment of the microscopy analysis, the sample from the laboratory was about 300 days old and had been kept sealed, under water, in a T = 10 °C conditioned room. On the other hand the sample from the field was

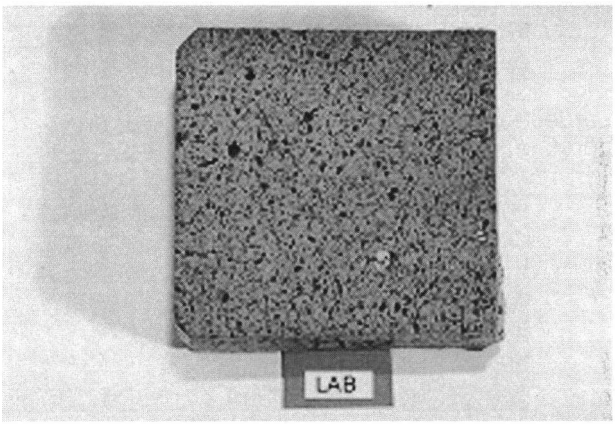

Fig. 23. — Mechanically cement-stabilized specimen prepared in the laboratory.

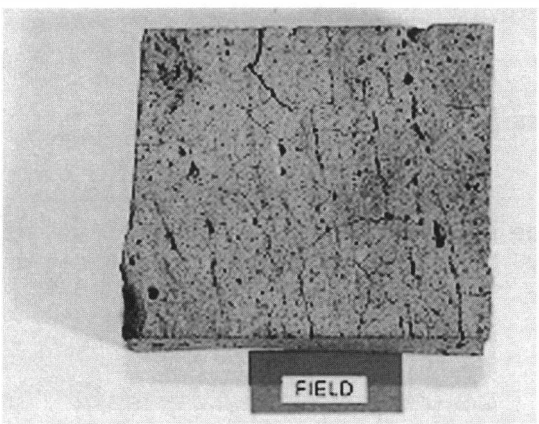

Fig. 24. — SSI cement-stabilized specimen from field boring.

about 270 days old; this specimen was cored from a trial SSI column about 3 months after its installation and then it was kept under water as well, until the day of SEM analysis.

Figures 25 and 26 do show both specimens with an amplification factor of 35. The presence of large pores (>5□ m in diameter) and macro pores (>0.05□ m in diameter) in the laboratory specimen is evident. This is by far less pronounced in the SSI improved field specimen where a more compact and more homogeneous texture can be seen. At this point one might already state that the mechanical cement-mixing in the laboratory (by means of a dough mixer) could have caused the incorporation of air bubbles later

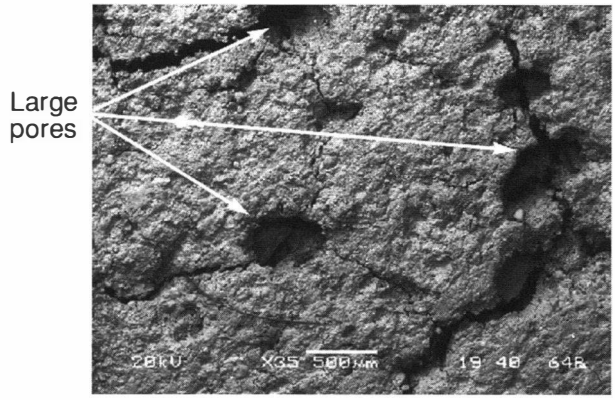

Fig. 25. — Laboratory specimen – amplification factor ×35.

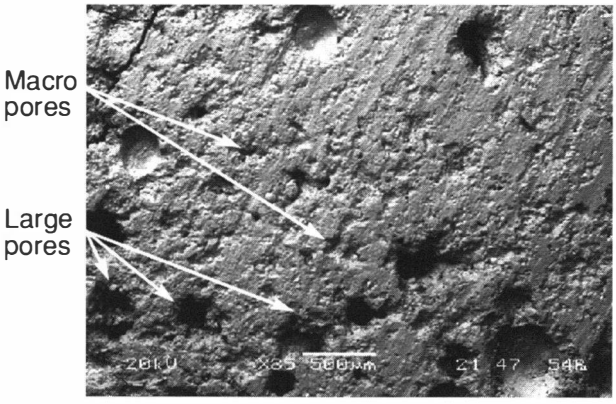

Fig. 26. — SSI-improved field specimen – amplification factor ×35.

becoming large pores. Pores of smaller diameter (micro pores) observed in both specimens could have produced during the cement hydration process. The presence of macro pores in the laboratory prepared samples suggests already a lower strength in the specimens mixed in the laboratory.

Figures 27 and 28 do illustrate the specimens from the laboratory and the SSI-improved field sample, this time with an amplification factor of 1200. It is, again, quite clear that the micro structure is diverse. The specimen from the field has a much more homogeneous structure with a more regular disposition of hydration products, such as the calcium silicate hydrate (C-S-H phase) and the calcium hydroxide (CH). On the other hand, the mechanically

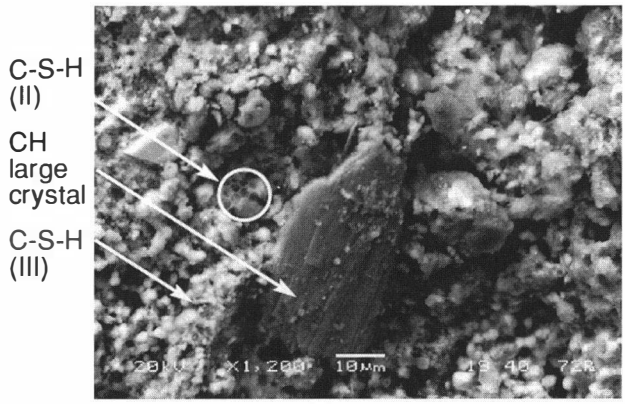

Fig. 27. — Laboratory specimen – amplification factor ×1200.

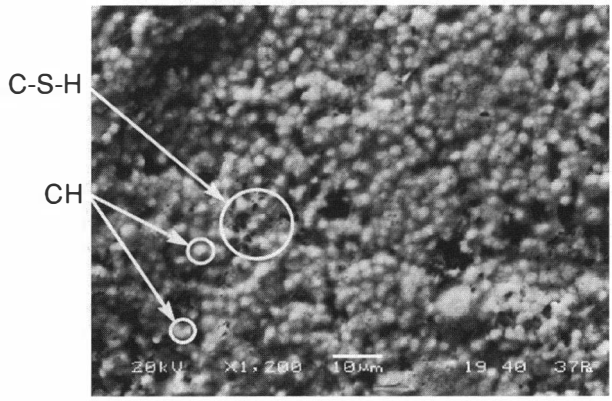

Fig. 28. — SSI-improved field specimen – amplification factor ×1200.

mixed laboratory sample shows a rather heterogeneous composition. Judging for the morphology of the different C-S-H phase structures and the large CH crystals,clearly identified, a less advanced degree of hydration can be perceived in the laboratory sample.

Here one may also suggest that the much more intensive SSI mixing method has played an important role (the specific area around each soil particle has been reached by the binder, by far better). It seems that the high-pressure SSI mixing in the field has improved the distribution of cement particles around the soil particles and as a consequence a faster hydration and hardening has taken place. In the laboratory, where purely mechanical mixing with a dough mixer was put into practice, the cement paste may have not been well distributed only reaching the soil particles within clods. This causes a retardation in the overall hardening of the improved mass and a decrease in the final strength.

Finally, figures 29 and 30 do illustrate the sample mixed in the laboratory and the SSI improved field sample with an amplification factor of 1700. Also here one can observe the same pattern, the structure of the field specimen again looks much more homogeneous than the laboratory specimen.

In the pictures one can clearly identify the main hydration products of the cement (ODLER 2000). The (mature) C-S-H phase can be recognized in the field specimen together with uniformly distributed CH crystals that cover almost completely the soil. As expected, again, the laboratory sample shows less CH crystals, few and small portions of the C-S-H phase and some ettringite (AFt phase) that is formed during the early hydration process, this phase is usually absent in mature and well hydrated cement pastes.

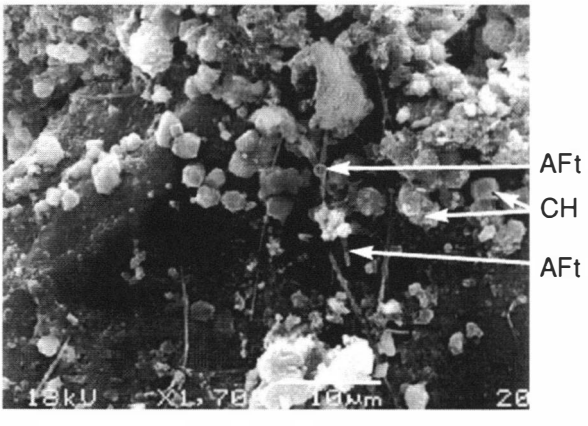

Fig. 29. — Laboratory specimen – amplification factor ×1700.

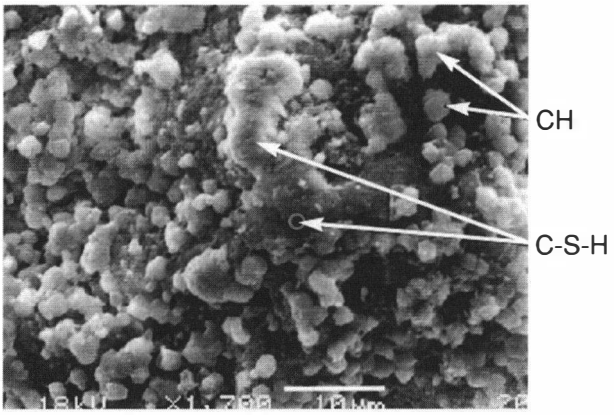

Fig. 30. — SSI-improved field specimen – amplification factor ×1700.

5. Conclusions

The aim of this paper has been to illustrate the state of an uncommon project dealing with the construction of a large under water embankment on soft dredged material in the harbour of Antwerp. The dam engineering and geotechnics' research data developed in this paper are however equally valid and applicable in all overseas areas of near-shore and deltaic conditions. Especially the newly-developed SSI method has been designed for underwater soft soil applications such as the ones encountered in deltaic areas. After several simulations to evaluate the feasibility of the project, it has been proposed to continue with the construction of the sand embankment in stages respecting the required waiting periods in between. A well designed staged construction should allow to safely proceed with a slow ongoing construction; however, given the characteristics of this particular material, this option went beyond the allotted construction period. A partial soil improvement at foundation level was proposed to reduce the construction period and increase the safety.

A newly developed deep mixing method was implemented here, the SSI (Soft Soil Improvement) method. It makes use of very high pressures for injection of a slurry of cement as binder to ensure a thorough mixing of the binder and the soil particles.

An extensive laboratory testing campaign on specimens mixed mechanically with a number of binders by means of a dough mixer has shown that blast furnace cements are very suitable for the stabilisation of such dredged material. The UC strength (UCS) keeps increasing, even after 240 days, unlike the strength of sludge specimens stabilised with Portland cement increasing rapidly the first month but ceasing afterwards.

It has been found that the effect of the curing temperature on the compressive strength of laboratory stabilised specimens with blast furnace cements is quite significant. The ratio $UCS_{20°C}/UCS_{10°C}$ is of the order of 2 for the time interval studied here (100 days approximately).

The inspection of trial columns (mixed with binder C, a blast furnace cement) installed at the site, in under water conditions, implementing the SSI method has proved to guarantee a rather good incorporation of the cement slurry around the particles of the dredged sludge. This probably is due to the very high pressures providing an intensive mixing.

In fact, the strength of samples from the field was found to be much higher than the strength of laboratory mechanically mixed samples.

The ordinary laboratory practice of unconfined compression testing on small specimens (mixed with a binder wet or dry in a conventional dough mixer) has indeed under predicted the strength on site of SSI stabilised soil with a ratio $UCS_{field}/UCS_{lab} = 2$ to 5. Clearly, a dough mixer is unable to recreate the intensive mixing of the cement slurry for this specific SSI installation method.

Moreover, a Scanning Electron Microscopy (SEM) analysis has been carried out to investigate the reason for such discrepancy of the results on samples entitled "laboratory mixed" and "field mixed". The analysis has put into evidence the presence of many large pores and macro pores in the laboratory specimen. That was less pronounced in the field specimen, with a more compact and more homogeneous texture.

In the samples from the field, a more regular disposition of hydration products (i.e. C-S-H, CH) can be identified. Judging for the morphology of the different C-S-H structures and the large CH crystals identified, a less advanced degree of hydration can be perceived in the laboratory specimen. The mixing method, leading to clods of particles, could be responsible for this. It seems that the SSI high-pressure mixing in the field has improved the more uniform and thorough distribution of cement particles at the soil fabric and as a consequence a faster hydration and hardening has taken place. In the laboratory, where purely mechanical mixing (with a dough mixer) was put into practice, the cement paste may have not been well enough distributed. This produces a retardation in the overall hardening of the improved mass and a decrease in the final strength.

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pp. 177-191.

Evaluating the Environmental Condition of Ports and Harbours: Can Minimum Monitoring Specifications Be Developed?

by

Chris HALEY*, Christopher DOYLE* & John MORRISON*

1. Introduction

Ports have been described as 'places equipped to facilitate the necessary relations between ships, as agencies of sea transport, and the land' (MORGAN & BIRD 1958). In essence, ports are commercial centres. They are places of refuge, frequently occurring in estuaries where the protection of the estuary (barrier or delta) provides a haven for ships during the key processes of loading and unloading. Many of the world's ports are, therefore, located in or on sensitive coastal environments (*e.g.*, Bangkok, Calcutta, London, New York, Rotterdam, Saigon, Shanghai, Sydney, Vladivostok). This location of ports in 'naturally protected' areas may reduce circulation and locally exacerbate problems created by human activities.

Activities occurring at ports include:

- Loading, unloading and storage of cargo including containers, bulk materials, bulk petroleum products, dangerous and hazardous cargoes;
- Loading of fuel (bunkering), food and other essential ship requirements;
- Solid and liquid waste handling including ballast water;
- Passenger movement;
- Associated industry - manufacturing for export or use of imports;
- Shipbuilding and ship repairs/servicing.

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Ports are compelled to accept all ships regardless of quality, unless they present a clear risk to the safety of the port. They are also subject to the pollution created by materials transfers that other transport modes bring. Ports often have little direct control over these environmental effects so they have tended to become pollution "hot spots" (European Sea Ports Organisation 2001). As ports are often at the downstream end of water catchments which can contain a mix of residential, industrial or rural land uses, they end up being the end user of water and sediment affected by upstream activities.

As little attention was paid to environmental concerns prior to the 1970s, many ports retain a legacy of poor environmental practices through having the contaminated sediments (buried or not), drainage systems that leak into groundwater, and buildings that are difficult to operate within adequate safety and health guidelines (*e.g.*, asbestos, ventilation). We thus have the classical dilemma faced by environmental managers worldwide — an area of essential commercial activity occurring in an environmentally sensitive location.

Major environmental issues for ports have been identified as: health and safety, waste management, dredging, water quality, air quality, dust, noise, port development, contaminated land, habitat loss (see *e.g.* BATEMAN 1996, ECOPORTS 1999). Table 1 (taken from DABRA *et al.* 2004) summarises a ranking of environmental issues in ports based on surveys carried out by the European Sea Ports Organisation (ESPO). Analysis of these figures indicates that the environmental issues over this period have remained largely unchanged (highlighted). There is evidence to indicate that these issues are of concern in many other ports of the world (http://www.dft.gov.uk/stellent/groups/dft_control/documents/contentservertemplate/dft_index.hcst?n=13077&l=3 and http://www.aapa-ports.org/govrelations/env_mgmt_hb.htm).

2. Environmental Management Systems

Environmental administration of ports has, to some extent, followed the pattern established for the development of environmental management elsewhere in the world, *i.e.*, the most obvious problems (major pollution events, spillages of oil and other hazardous materials, ship waste disposal, contingency planning) are addressed first, with more systematic development of plans coming later. In many locations, the development of fully effective port environmental management systems, including consideration of sustainability issues, has yet to be completed.

Table 1
Ranking of environmental issues based on the results of the ESPO Environmental Questionnaires of 1996 and 2003 (DABRA *et al.* 2004)

Rank	1996	2003
1	Port development (water)	Garbage/port waste
2	Water quality	Dredging disposal
3	Dredging disposal	Dredging
4	Dredging	Dust
5	Dust	Port development (land)
6	Port development (land)	**Noise**
7	Contaminated land	Hazardous cargo
8	Habitat loss/degradation	Air quality
9	Traffic volume	Water quality
10	Industrial effluent	Ship discharge (bilge)

In many countries, the development of national legislation or the implementation of international agreements has led to programs to monitor the environment around ports. Many of these are limited to water quality or sediment quality. Until recently, very few programs included biological investigations, but this has changed with the concern about the introduction of exotic organisms in ballast water (RIGBY *et al.* 1991). The resulting data are extremely valuable, but a comprehensive overview is not always undertaken as the data is often collected and reviewed by different agencies (*e.g.* environment agencies, port managements, marine departments, industries).

Many ports and maritime authorities have Environmental Management Systems (EMS), which they use to manage the environmental risks associated with their operations. Contained within these systems is a requirement to undertake monitoring to measure and quantify the outcomes of the risk they are seeking to manage. To help an EMS to be constantly reviewed and updated a number of ports now use software based management tools to keep their management system up to date in the ongoing pursuit of 'continuous improvement', which is a major theme of any EMS. The monitoring components are reliant on the system being dynamic and constantly evolving to ensure the monitoring system reflects not only the control of particular identified risks but addresses new risks which result from port development or a change in operations. There is also a need for clear demarcation of the responsibilities of the port managers, the ship owners, and the obligations of other port users depending on the legislative system operating locally.

This leads to the questions:

— What is the environmental risk associated with past, current or future operations?
— What minimum monitoring is required in order to assess the 'environmental quality' of a port?
— Who should undertake the necessary assessments?

2.1. Environmental Risk

Efforts to determine environmental risk and set priorities raise a multiplicity of questions as diverse environmental risks pose differing problems for humans and ecological systems. In many locations, certain legislative requirements exist but insufficient information is collected to understand the port's ecosystem. A further difficulty for port management is defining where the port 'environment' ends — both landward and seaward boundaries can be specified in law, but the ecological boundaries are usually less precise.

Separate questions that need addressing include:

— What environmental standards are established for a port?
— Which organisations should develop such standards?
— How can community views be included?
— How will implementation be achieved?
— Is community involvement in monitoring appropriate?

Selection of the "best" options is complicated by the varied nature of the risks, costs and benefits associated with different options. Comparative risk analysis is an analytical environmental decision-making tool used to systematically measure, compare, and rank environmental problems. The process focuses on risks to human health, the natural environment and quality of life, and results in a list of issue areas ranked in terms of relative risks. As well as helping management identify the worst problems or the greatest risks, it provides a common basis for evaluating the net benefits of different strategies for reducing or preventing those risks. Cura *et al.* (2004), however, emphasise that comparative risk assessment is a subjective and value-laden process. Typically, initial analyses are quantitative, relying upon scientific analysis, but the final rankings are normally qualitative, often developed by committees of technical and community members. Final rankings are usually categorised (high, medium, or low) and by definition involve qualitative judgments about the relative importance of different issues.

The comparative risk framework guides analysis and the comparison of different endpoints (*e.g.*, human health hazard indices and cancer risks, ecological toxicity, management costs, habitat loss/creation, etc.) that are expressed in different units and scales. The method can provide answers to such questions as:

— What is the normal situation and what are the limits of expected variability?
— How will the analyses address the decision drivers such as the legislative requirements?
— How will the adequacy of the analysis be determined?
— What are the analytical components/causal pathways in the analysis?
— Which alternatives minimise risk?
— Which alternatives maximises the risk reduction per unit cost?
— What are the sources of uncertainty and variability in the assessment?
— Which alternatives minimises uncertainty (BRIDGES *et al.* 2004)?

Using a comparative risk framework in ports involves a series of steps:

— Selection of the environmental issues and participants;
— Technical analysis by local scientific experts;
— Input from the community-increasing awareness about the environment is likely to result in greater involvement;
— Ranking of the risks;
— Environmental planning to address the ranked list.

2.2. CORPORATE OBJECTIVES ALIGNMENT

To optimise any port environmental planning program, a key component is the alignment of the monitoring objectives with the overall corporate goals of the port management. If the organisation does not address positive environmental and sustainability outcomes in its charter then any proposed program will not have the impetus or support to ensure that the program survives corporate scrutiny.

3. Monitoring — Some General Comments

All over the world, resources for monitoring activities are under pressure and so researchers are endeavouring to develop monitoring systems that provide the maximum value, in terms of information gained, for each dollar

spent. Part of the problem is that, in the past, monitoring activities collected data that often did not get used to assess changes, rather to ensure that some legal requirement was met. Data was collected but remained in agency files with no utilisation, and the value to the community of the whole operation was brought into question. It is, therefore, essential that the purposes of monitoring programs are accurately defined and the use of various parameters as indicators be clearly articulated.

Monitoring is a process, not a result; a means to an end, not an end in itself; monitoring identifies problems, it does not solve them. Usually, monitoring is used to detect change (or lack of change), or establish direction of change, and measure extent of change.

A useful definition of monitoring is the intermittent (regular or irregular) collection of qualitative and/or quantitative observations, made using some standardised procedure, that provides a time series of data, carried out to ascertain the extent of compliance with a predetermined standard, or degree of deviation from an expected norm.

Monitoring can be an expensive and time consuming undertaking, often requiring skilled personnel and sophisticated analytical equipment. Such an investment is only justified when one has a clear understanding of the purpose(s) of the monitoring, and implies that some action will be taken if the results are not as expected (*if no action will be taken, why monitor*?).

3.1. Integrated Environmental Monitoring

Integrated environmental monitoring has two distinctly different components. Firstly, it ensures that different organisations that are conducting environmental monitoring are undertaking monitoring that complements a common objective. To this end, two port users may be independently undertaking water monitoring, and, by collaborating, these organisations may decide to adjust the parameters monitored or the monitoring frequency to maximise outputs from the program and avoid duplication.

Secondly, integrated monitoring ensures that a co-ordinated approach is used to address marine and terrestrial monitoring results. This ensures the collation of data such as marine and terrestrial water quality, soil and groundwater data, ecological data, and sediment quality is monitored in a manner that maximises the opportunity to identify the impacts from one parameter on another (*e.g.* changes in groundwater quality could be impacting marine water quality, or alterations to pH may be affecting the mix of native versus introduced sessile organisms found on hard substrates).

3.2. Importance of Ecological Monitoring

Ecological monitoring is a recent practice that is associated with ports moving beyond water quality monitoring to actually assessing the direct ecological impact of port operations or development activities. Water quality monitoring has previously been the leading monitoring component undertaken to assess environmental impacts within the water column. Changes in the physical and chemical properties of water within ports have often been used, until recently, as the sole indicator of the 'health' of the port. In most countries, legislative requirements still focus on water quality and occasionally sediment quality monitoring in isolation as a means of monitoring environmental impacts.

Ecological monitoring is furthering the knowledge base obtained from water and sediment quality monitoring. The results from ecological monitoring do not necessarily render water quality monitoring results obsolete; it merely builds upon the water quality information available and provides a more quantitative assessment of environmental change and impact assessment. Water and sediment quality data in most cases will provide an explanation of the variance in ecological data that may be observed.

3.3. Introduced Marine Pests

Introduced marine pests are a serious global issue affecting ports. The consequences of marine pest incursions are costly removal and management measures. Hayes & Sliwa (2003) showed that there is a range of ten different phylum represented among the target and trigger pest lists in Australia. To effectively monitor all of these pests would involve the allocation of vast financial and human resources. As a result, a resource effective methodology is required to ensure that maximum coverage is gained from minimal resource allocation.

4. Minimum Monitoring in Ports

In attempting to design a minimum monitoring program, a number of key questions need consideration. A preliminary program may show that certain parameters are non-essential, or the periodicity may be reduced:

— *Purpose*: What is the aim of the monitoring?
— *Cost*: What funds are available?

— *Method*: How can this aim be achieved? What should be measured (parameters), where (how many sites, including reference sites), how often (time period and degree of replication) and by whom?
— *Analysis*: How is the data to be handled?
— *Interpretation*: What might the data mean, and what actions will be taken?
— *Fulfilment*: When will the aim have been achieved?

If the available resources are severely limited, a monitoring program *may not be advisable at all*, because a poorly planned, poorly financed, and hurriedly conducted monitoring program will not provide data that can be easily evaluated in terms of the program objectives. Such a program would tarnish the credibility of any future, well constructed, monitoring programs.

The development of a minimum monitoring program for environmental conditions in a port should follow a logical sequence. The priority environmental issues must be defined (see, for example, DABRA *et al.* 2004, 2005). As noted earlier, much of this work has been completed in a general sense, but the specific analysis must be carried out for each port. Comparative risk analysis will also facilitate determination of the critical data required for specific decision-making about the port environment (MCCLUSKY & ELLIOT 2004).

This assessment could require large data sets but it is possible to simplify the requirements by using some of the parameters on key issues listed in table 2. The type and quantity of data will depend on a number of interacting factors including the reporting requirements necessitated by local legislation, community aspirations about the port environment (*e.g.*, local people may wish to fish in port waters or use them for recreation), and the information required to improve the scientific understanding of the port.

Once a comprehensive analysis of data needs has been completed, this can be compared to what is available or being produced by other activities in the port region. This will enable planners/managers to assess what information should be provided by either one-off studies (*e.g.*, baseline inventory of introduced marine pests) or monitoring. From such an exercise a 'wish list' of monitoring activities is produced. In almost all cases, such a list cannot be totally funded within the available resources, and priority decision—making will be required on what monitoring should be undertaken by the specific agency. Some real thought must be given to what is the absolute minimum level of monitoring required for both port management and environmental protection.

This is a difficult issue, and one of the major concerns arising from reviewing past operations is that decisions have been made in isolation. Partnerships with

other government or private agencies have not been considered, nor has the involvement of the community groups (*e.g.*, recreational fishermen, environmental action groups) or local educational institutions (universities, technical colleges). Many such groups would welcome the opportunity to contribute to port monitoring either for community good or practical training reasons. There may be some resistance to such developments and it is true to say that in many

Table 2
Monitoring Parameters Providing Information on Key Port Environmental Issues

Environmental Issue	Parameters Measured	Comments
Port waste management including ballast water	Sources, Types, Quantities Collection frequency Storage Treatment or Disposal	Land and ship derived sources, ship building and repair facilities, with range of options. Introduced pest species are, difficult to assess and treat
Dredging	Frequency required Quantities extracted Contaminants	Often several techniques available Changing spoil disposal options (ocean disposal diminishing) Often large impacts but for short time periods
Dust and Air quality	Air particulates Settling volumes Clean-up activities Nitrogen oxides Sulphur oxides Hydrocarbons Disposal	Source identification difficult, often from outside port Cleanup expensive Large variations in quantities Source location difficult Significant temporal and spatial variations
Noise	Volume/intensity Frequency distribution OH&S activities	Wide range of impacts depending on worker activity Proximity to urban areas
Water quality	Large number possible, including: pH, dissolved oxygen, salinity, nutrients, turbidity, metals, organic contaminants, industry discharges, microbiology, ecology	Widely varying costs depending on type of equipment, frequency and replication of measurements. Seasonal variation is common Turbidity impacted by ship movement in shallow harbours

instances in the past there have been problems. Most of these arose from incomplete negotiations or inadequate consultations about the obligations of each partner and their capacity to undertake their contribution.

Once a monitoring program has been designed, final decision-making on the implementation will have to include agreed actions on data storage and exchange, allocation of data analysis and reporting responsibilities, and determination of which agencies will take action, when required, based on the monitoring information.

5. Minimum Monitoring — Some Issues

Decision-making on the parameters to monitor has additional complications, particularly when considering the financial implications. Apart from the problem of deciding which parameters will give the required information for management purposes, the issue of how to collect the data has to be resolved. For many parameters, a number of measurement techniques will be available. Should one use a continuous recording system or rely on spot measurements made by staff at regular intervals? Each technique has advantages and disadvantages, different cost implications (*e.g.*, high initial expense versus higher ongoing costs), and the equipment used will vary in price dramatically depending on the accuracy and precision required. Some examples of costs are shown in the case study below.

In planning monitoring programs, the situation will arise where a decision has to be made between a number of possible measurements as to which will be excluded. This can often result in an analysis of the technical needs versus financial constraints. In such situations, what is needed is some indication of the relative usefulness/technical value/efficacy of data collected. Unfortunately, very limited information on this issue is available in the literature, and there appears to be limited consolidated research on this important topic (MORRISON & HALEY 2002). Numerous scientists are carrying out appraisals within their organisations, but much of the analysis does not get circulated, some of it for propriety reasons.

The utility of data collected during monitoring needs to be regularly reviewed. The number of instances where programs contain extensive data sets that have not been analysed properly is alarming, *e.g.*, if no parameters violate the relevant legal limits, often no further patterns are looked for. This is an opportunity lost, as such an examination may clearly show a pattern of incremental change indicating an impending problem if action is not taken. Much environmental data collected in the past has been of little or no value

when subjected to any significant statistical analysis and thus has represented a waste of money (UNDERWOOD 1994). It is vital that all data is based on statistically valid program designs, including appropriate number of sites, degree of replication, frequency of data collection, and quality control.

A further point that needs consideration is the continual need to negotiate with the relevant legislative body to assess when a particular component of the monitoring program is no longer necessary and can be discontinued. For example, if the dissolved metal concentrations in a port have been below detection limits or regulatory standards for several years, and no new sources are identified, then continued monitoring seems unnecessary (at least the frequency should be markedly reduced).

6. Case Study: Port Kembla Port Corporation, Australia

6.1. BACKGROUND

The Port of Port Kembla is located 80 kilometres south of Sydney in New South Wales, Australia. The Port Kembla Port Corporation, a state owned business, manages the port. The Corporation has the responsibility of ensuring that the port is operated and developed in an economic, environmental and socially sustainable manner. Part of this responsibility includes the monitoring of pertinent environmental indicators to manage identified risks and monitor disturbances from operations and development activities.

Prior to 2003 the Corporation undertook the following environmental monitoring:

Soil & Groundwater Monitoring	— annually
Dust Deposition Monitoring	— monthly collation
Water Quality Monitoring	— pH and turbidity — weekly
	— metals — quarterly (by a third party)
	— nutrients — as required
Sediment Monitoring	— as required for dredging related projects
Climate Data	— continuous
Greenhouse Gas Emissions	— annually
Ecological	— only as required for development consent
Noxious Weeds	— annually

A review of the monitoring programs undertaken highlighted the lack of linkages between different parameters and the lack of any continuous data sets (except for climate information) which could highlight event related changes

to the port environment. As water quality monitoring is a key environmental indicator, the snapshot methodology used did not allow observed changes in water quality to translate into an understanding of the vectors affecting the results or convey the resulting ecological impact.

6.2. Ecological Monitoring

To best manage the risks associated with introduced marine pasts, port operations, and port development, the Corporation took a strategic decision to investigate monitoring of hard substrate invertebrate populations in the harbour. This decision was taken based on five contributing factors:

- Cost effectiveness of settlement plate monitoring;
- The ability to examine the presence/absence of hard substrate invertebrates (which will allow monitoring of up to 70 % of the species perceived as an introduced marine pest risk for the port);
- The opportunity to examine native versus introduced species population dynamics;
- An opportunity to measure the impacts of port development and dredging on port ecology;
- The partnership possibilities with universities or research organizations.

Initially, the Corporation enlisted a university research group to undertake settlement plate monitoring at eight locations within the port (four in the Outer Harbour, and four in the more polluted Inner Harbour). The initial monitoring undertaken during 2003 yielded a number of interesting results:

- For the Inner Harbour, introduced species dominated and out competed indigenous species;
- For the Outer Harbour, native species dominated the settlement plates over introduced species;
- Switching settlement plates from the Inner and Outer harbours resulted in dieback of the dominant species on the plates which were then replaced by the dominant species found in that portion of the harbour;
- *Despite the presence of introduced species, no nationally listed target pest species were present in Port Kembla harbour.*

The results achieved in 2003 then acted as a valuable baseline dataset for an analysis of the impacts of port development undertaken in 2004. Development work included dredging from the Inner Harbour and spoil disposal in the Outer Harbour; reclamation works using blast furnace slag (a by-product of the steel making process), and the construction of a sheet pile wharf.

Samples obtained from eight submerged settlement plates indicated colonisation by fouling invertebrates such as barnacles, serpulids, bryozoans and ascidians. The study looked for changes in assemblages at sites close to the dredging and reclamation activity, relative to those that were further away. In the Inner Harbour, one of the settlement plates was deployed at a site inside the dredged area silt curtain to observe the maximum effect of the resuspended material (JOHNSTONE & CLARK 2004).

The overall results indicated no clear effects from the dredging on the abundance of major taxonomic groups, nor on species richness or diversity. In the Inner Harbour, assemblages maintained about 20% available space and were dominated by small non-indigenous organisms, implying that they were frequently disturbed and remained in an early successional (developmental) stage. It is suggested that local populations were already exposed to a frequent disturbance regime from local sources (*e.g.*, runoff, industrial discharge, the resuspending of sediments by shipping), and this may have rendered communities permanently impacted and masked the effects of the dredging. Despite the background conditions, the monitoring showed that no noticeable impact was noted in an already disturbed environment (JOHNSTONE & CLARK 2004). The monitoring also provided further evidence regarding the status of marine pest activity and allowed nationally listed and target species to be continually monitored.

6.3. FUTURE MONITORING AND COSTS

In light of the results obtained from ecological monitoring and an examination of the water quality monitoring activities undertaken within the port, the Corporation committed to a program of continuous water quality and ecological monitoring. The monitoring involved the following two programmes:

1. Purchase of two (2) water quality data loggers to continuously monitor temperature, pH, salinity, dissolved oxygen (DO), oxygen reduction potential (ORP) and turbidity. The continuous monitoring of these parameters can allow event based identification of alterations obtained from environmental snapshot monitoring such as seasonal metals testing, ecological monitoring or groundwater changes. Telemetry and software also provides for a 'live' reading of the listed parameters and comparisons over any selected timeframe. The data-loggers will be placed in both the Inner and Outer Harbours of the port and will allow for direct comparison.
   - Initial Outlay: US$20,000 for two (2) data loggers with telemetry.
     a) US$10,000 for installation cabling, security casing and data management hardware.

— Ongoing Costs: US$4,000 per year for calibration contractors and probe replacement costs.

2. Contract ongoing ecological monitoring to a university research organisation to include the deployment of 12 Perspex settlement plates across the port. The contractors will monitor the plates eight times a year and analyse species diversity and monitor populations and the status of marine pests.
   — Initial Outlay: Nil.
   — Ongoing Costs: US$15,000 per year for monitoring and analysis.

The two additions to the overall environmental monitoring conducted by the Corporation will have an initial five year lifespan as this is the anticipated time span of proposed future port development. Over this period, the overall water quality monitoring from the data loggers will total US$50,000. Similarly, the biological monitoring will cost US$75,000. This represents an average cost of US$25,000 per year over five years for the water quality dataloggers and ecological monitoring.

7. Conclusions

Ports represent a critical component of the land-water interface and the interaction of human activities with this part of the global environment. They highlight the importance of taking an integrated view of management, with the port environment being influenced by both land-based and ship-based activities. Improved environmental management of ports requires a component of environmental monitoring, and it is essential that such monitoring be carried out effectively and efficiently. For many ports, this has not occurred in the past, and continuing governmental and community pressure will necessitate significant improvements in many locations. Determining the minimum environmental monitoring that is required will become an intricate part of port strategic planning.

In this paper, we have attempted to highlight the key issues relating to the environmental situation in ports and mechanisms to monitor changes in the port environment caused by human activities. Issues relating to the design of monitoring programs and the activities derived from the data obtained have been outlined. A case study has indicated how port environmental monitoring programs evolve, and how any required changes can be funded in the medium term.

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Microscopy on Undisturbed Sediments as Help in Planning Dredging Operations. A Case Study from Thailand

by

Georges STOOPS* & Dirk DEDECKER**

1. Introduction

Interpretation of drilling cores in marine "sediments" for preparatory studies for dredging operations, civil engineering works, etc. is commonly based exclusively on results of the analyses of bulk samples. During these treatments samples are disturbed and the geometric relationship between the different components totally overlooked. The aim of this paper is to demonstrate the possibilities of microscopic studies of undisturbed samples as a complementary technique. Such a study does not only yield data directly applicable for the technical preparation of the project, but also information on the genesis of the materials, their former behaviour and possibly on palaeo-environmental conditions, important to understand the nowadays behaviour of the material. This will be illustrated using a case study from Thailand.

Micromorphology is a method for microscopic studies of undisturbed soil and regolith materials, the latter including also weathered rock (saprolite) and sediments. It comprises two main approaches: a compositional study (mainly based on optical mineralogy) and a fabric study (STOOPS 2003). The latter deals with the organisation of the components, their mutual distribution and orientation, even as their shape, relative size and frequency. From this geometric information the investigator derives conclusions with respect to the genesis of the material and the chronology of the genetic processes.

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Far less elaborated is the system for interpretation with respect to the possible mechanical behaviour.

Recognising distribution and orientation patterns of "coarse constituents" (particles larger than the resolution of the microscope, such as silt or sand grains) is relatively easy, but this is not the case for the fine mass, consisting of clay particles below the resolution limit of the microscope, and therefore not recognisable as individual particles. Clay particles are mainly phyllosilicates (the same group of silicates to which micas belong) and occur as thin, platy particles of less than 2 μm, often much smaller. It means that in a thin section of 30 µm at least 20 to 30 particles are superposed. When oriented at random, their optical properties are therefore not recognisable. Groups of parallel oriented particles act as a single crystal — a domain according to AYLMORE & QUIRK (1959) or a pseudocrystal in the Russian sedimentological terminology (DOBROVOL'SKI 1991) — and their general orientation is therefore visible by their interference colours and extinction pattern. This gives indirect information on the type of packing of the clay particles. Such parallel orientation can be the result of shearing (JIM 1990), slow sedimentation or colloidal transport (*e.g.* clay coatings in soils). These different origins, however, can be easily recognised by specific internal fabric characteristics (STOOPS 2003). In the case of shearing a discontinuous orientation pattern is seen, described as a *striated birefringence fabric* (b-fabric). If the orientation is associated with the surface of hard grains, a *granostriated* b-fabric is present.

The distribution pattern of coarse particles (mainly sand) with regard to the fine mass (mainly clay and fine silt), called the c/f related distribution pattern (c/f r.d.), yields information on mechanical behaviour of the material, especially with respect to the "skeletal function" of the coarse constituents (STOOPS & JONGERIUS 1975). Five main types are distinguished: *monic* (only coarse grains present, *e.g.* sand), *gefuric* (fine material forms bridges between the coarse grains), *enaulic* (fine material occurs as granules between the coarse grains), *chitonic* (fine material coats the grains) (plate 2D) and *porphyric* (fine material fills all intergranular spaces) (plate 2A). When the coarse components are in contact with each other they are considered to have a "*skeletal function*" (plate 2D, E). This is always the case in monic, in all the other cases the fine material may considerably separate the coarse grains, especially in the porphyric c/f r.d. patterns.

Special features, called pedofeatures, such as coatings of clay (plate 3A-C), nodules of iron (plate 2B) or new formations of specific minerals, give key information on the genesis and transformation of the material by pedogenic or diagenetic processes.

2. Material and Methods

End of the eighties, Dredging International N.V., as a member of the IDDD-Consortium, carried out dredging works for the new port facilities of the harbour of Laen Chabang in Thailand. The dredging was done using a cutter suction dredge. As the consortium was faced to an excess wear of their equipment during these works, several laboratories were contacted to determine the reasons of the unexpected abrasiveness of the sediments, which could not be explained with the results of the standard studies, used by the engineering company that made the preparatory study of the project. New core drillings were undertaken and several laboratories were invited to study the cores using new methodologies. One of them was the Laboratory for Mineralogy, Petrology and Micropedology of the Ghent University, Belgium, applying amongst others micromorphological methods.

Undisturbed cores of two borings (Core 1 and Core 2) were selected for this study. From the cores, transported in air-sealed rubber sleeves, 21 undisturbed representative samples were selected, after careful macroscopic observation, and taking into account the results of grain size analyses. Following investigation with a stereomicroscope, the air-dried samples were impregnated under vacuum with an unsaturated polystyrene resin. After hardening, thin sections of 60 by 90 cm, in a few cases 90 by 120 cm, with an overall thickness of 30 μm were prepared according to the standard procedures (MURPHY 1986, BENYARKU & STOOPS 2005). These sections were studied at different magnifications in transmitted light with a polarising microscope, using the micromorphological concepts and terminology of BULLOCK *et al.* (1985) and STOOPS (2003). Mineral weathering is described according to DELVIGNE (1998).

For a number of samples heavy minerals were separated from the sand fraction using bromoform. After mounting on a support glass with Canada balsam they were determined with the help of a polarising microscope in transmitted light. Where necessary, undisturbed bulk samples were investigated with a Jeol Scanning Electron Microscope (SEM). The silt and clay fraction of a series of samples was separated by sedimentation and analysed using X-ray diffraction techniques.

Depth of samples is expressed in metres below mean sea level, as approximate values. The sea bottom is situated at -10 m for Core 1, and at -16.5 m for Core 2 (fig. 1).

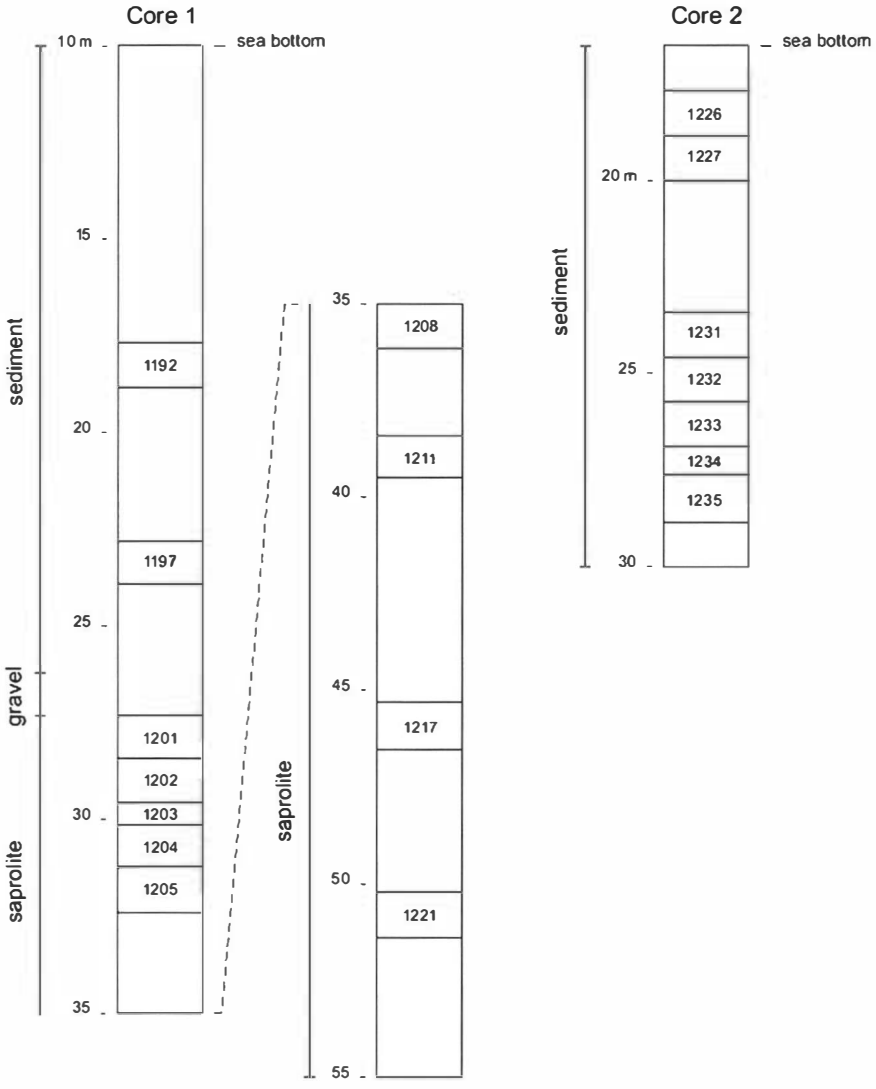

Fig. 1. — Schematic representation of the two investigated cores. Depth is expressed in meters below mean sea level. Numbers in cores refer to samples studied in thin sections.

3. Results

3.1. Macroscopic and Mesoscopic Study

Macroscopic investigations showed the presence of clayey bands at intervals of about 4 cm. The top of these bands clearly shows a concentric grooved surface, proving their formation to result from a rotation during drilling. They will be called further *drilling artefacts*. The material between the bands is not visibly affected by mechanical disturbance.

The mesoscopic study of Core 1 allows distinguishing two units separated by a gravel bed at -26 m. In the upper part (from the sea bottom, at -10 m, till -26 m) the quartz grains dominantly have a pinkish colour and are subrounded. Others are translucent and subangular. The presence at -21 m of a shell fragments points to a sedimentary origin. In the lower part (beneath -27 m) on the contrary the quartz grains are translucent and more angular, often stained by iron oxyhydrates. With depth (below -42 m), the fabric of weathered granite becomes clearer and large biotite and muscovite flakes appear.

In the second core the situation is less clear: the lower part (beneath -25 m) is partly similar to the lower part of Core 1, but with the presence of pinkish quartz grains. In the upper sedimentary part a mixture of granitic saprolitic material occurs.

From the results mentioned above it is clear that the lower part of Core 1 (below -27 m) is part of a deep saprolite, separated by a stone-line or basal conglomerate from a transported material, as proved by the presence of a shell fragment. The interpretation of Core 2 is less straightforward as a mixture of both materials seems to be present.

3.2. Particle Size Analysis

The fine earth fraction is slightly coarser in the saprolite than in the overlying sediment. In the sediment no specific trend is observed. In the saprolite of Core 1 the clay and silt fractions gradually increase with increasing weathering, indicating a chemical and physical breakdown of the minerals.

3.3. Mineralogy of the Sand and Clay Fraction

The study of the heavy minerals in the sand fraction of Core 1 confirm the interpretation of the macro- and mesoscopic study. The most striking feature is the change in morphology of the zircon grains. In the upper part (till -26 m)

they are rounded or subrounded, below that depth the grains are prismatic. In other words, the grains in the upper part clearly have been transported, whereas those of the lower part are euhedral, and released by in situ weathering. Another difference is the high amount of opaque particles in the saprolite samples. In the second core the prismatic shape of zircon throughout the profile is not in agreement with the possible presence of alluvial or marine sediment of the same type as that in the upper part of Core 1.

The mineralogical study by XRD of Core 1, between -27 and -47 m points to a typical weathering sequence. From the deepest part to the top of the saprolite one observes a gradual disappearance of biotite, chlorite, and towards the top, even of alkalifeldspars. In the lowest samples smectites occur, but they are gradually replaced by kaolinite higher in the sequence. The low amount of feldspars and quartz in the silt fractions points to a strong degree of weathering. In the overlying sediment only kaolinite is found in the clay fraction. The presence of goethite in the deeper part of Core 2 (at -29 m) evidences soil formation in a terrestrial environment.

3.4. Scanning Electron Microscopy

The quartz grains in the sediment (sample at -18) of Core 1 are subrounded with only minor dissolution features and no secondary crystal growth. In the upper part of the saprolite the grains are angular and strongly corroded, whereas they show less dissolution features in the lower part of the saprolite.

In Core 2 all grains are subrounded to rounded with only minor traces of corrosion.

3.5. Micromorphological Analysis

The *drilling artefacts*, described in the macromorphology, appear in thin sections as more or less horizontal zones, about 3-7 mm thick, composed of speckled brown to yellowish brown clay and subangular quartz and feldspar grains of coarse sand size (plate 1A, B). These grains are similar to those of the surrounding undisturbed material, pointing to their local origin. Between crossed polarizers a clear strial b-fabric is visible in the clay mass, resulting from rotational shearing during drilling. Many quartz grains too show a parallel optical orientation.

The lowest part (below -36 m) of Core 1 corresponds to a granitic saprock. Quartz grains (coarse sand size) form aggregates, up to 5 mm in diameter, generally dissected by fissures that increase in number in the

higher part. Black dotted linear distributed inclusions occur forming often an irregular pattern. In between the quartz aggregates, both large feldspar crystals (up to 5 mm) and biotite aggregates (up to 6 mm) occur (plate 1C, D). The feldspars are strongly sericitised and their fissures filled with clay, oriented perpendicular to the walls, pointing to an *in situ* neoformation. The alkalifeldspar crystals sometimes contain small rounded quartz crystals of 250-1500 μm. When liberated after total weathering of the feldspars these originally rounded grains may be confused with transported grains. The biotite is totally transformed to chlorite with abnormal blue interference colours and exsolution of iron hydroxides between the lamellae (plate 1C, D). In some cases islands of abnormal brown interference colours are visible, proving that the alteration took place in successive steps. Muscovite only occurs as a relative rare mineral. The presence of drilling artefacts, even in the deeper saprolite points to a weak coherence of the material.

Above -36 m the fabric of the material remains the same but minerals are more weathered, transforming the saprock to a real saprolite. The chlorite is partially or totally transformed to a 2:1 phyllosilicate with higher interference colours (end of first order, beginning of second order) (plate 1E, F) sometimes weakly pleochroic and still containing iron hydroxide segregations. Gradually the "biotite" pseudomorphs are transformed to kaolinitic meso-alteromorphs (DELVIGNE 1998). Also the strongly sericitised feldspar grains are first transformed to smectite and later replaced by kaolinite alteromorphs. Nevertheless several intact feldspar grains are present till the surface of the saprolite.

Impregnative iron hydroxides nodules and hypo-coatings are recognised in the upper part of the saprolite, starting from -30 m (plate 2B). These redoximorphic features indicate that the material has been subject to oxido-reduction processes in terrestrial conditions, as these iron oxyhydrates cannot form under marine conditions. In the highest samples (-28 m) microlaminated fine clay infillings evidence former soil formation.

Starting from -31 m towards the top of the saprolite small chalcedony nodules (up to 4 mm) and thin fissure infillings occur, pointing to a post-weathering silicification process.

Separated by a stone line, the overlying sediments appear in thin sections as rather a homogeneous mass, composed of sand grains and clay, with a weak bedding visible by small changes in grain size. The sand fraction is strongly dominated by moderately sorted rounded to subrounded coarse sand sized grains of quartz with many fine opaque speckles even as quartzite fragments. In addition a few grains of strongly weathered plagioclase and of microcline even as rare tourmaline grains are present.

The c/f related distribution pattern (c/f r.d.) is mostly close to single spaced porphyric; this means that the grains are touching or nearly touching, and all interstitial space filled with yellowish grey stipple speckled micromass that shows between crossed polarizers a granostriated b-fabric (plate 2F). In a few spots interstitial spaces are not filled, but the clay forms coatings (chitonic c/f r.d.) (plate 2D) or bridges (gefuric c/f r.d.) and has a speckled b-fabric. In addition, small fragments of clay coatings with a strong internal orientation are noticed.

Within the sediment some blocks of strongly cemented material occur, *e.g.* at -23 m. Indented quartz embedded in a completely recrystallised quartz matrix emphasise strong silicification and diagenesis.

In the lower part of Core 2 the coarse fraction consists of subrounded coarse sand sized grains of quartz, rarely of chalcedony, without clear sorting. Feldspars and micas are practically absent. The c/f r.d. pattern is single spaced porphyric (plate 3D). The micromass is a speckled yellowish clay with a stipple speckled and granostriated b-fabric. Two striking pedogenic features are noticed: very thick (up to 1000 μm) microlaminated infillings of yellowish grey fine clay, sometimes alternating with silt coatings (plate 3A, B), and impregnative iron hydroxide nodules and hypocoatings, locally taking the aspect of a lateritic material. The clay infillings show between crossed polarizers weak grey interference colours of first order (pointing to a kaolinitic composition) and sharp extinction lines. They are sometimes affected by iron impregnations (plate 3C). At about -24 m an alternation of greyish and more brownish zones points to a mottled clay. The clay illuviations are still present.

In the top of the core a close porphyric c/f r.d. pattern with a grey micromass is observed. The coarse material is not sorted and fragments of clay coatings or infillings occur. The micromass has essentially an undifferentiated b-fabric, indicating the absence of particle orientation in the micromass.

4. Discussion

In this discussion we want to highlight the fabric differences between the sediment at the top of the core and the underlying saprolite and saprock, after explaining the genesis of the material.

In Core 1 three units can be distinguished, from the bottom to the top respectively a saprolite, a gravel layer and a sediment. The granitic saprolite shows traces of pedogenesis in its highest layer but no soil fabric, indicating

that the regolith profile has been truncated. The gravel layer can then be considered as a surface accumulation of coarser constituents of the saprolite, mixed with transported material derived from the subsequent depositional phase. The origin of this sediment is not clear, but the characteristics do not correspond with marine sediment. The presence of plagioclases indicates a less weathered material, and therefore genetically not related to the saprolite. In this material an incipient pedogenesis took place in continental conditions, as ascertained by the granostriated b-fabric, the thin clay coatings and the iron hydroxide nodules. Weathering during this pedogenesis was limited, as shown by the preservation of plagioclases, and the absence of strong corrosion on the quartz grains (SEM observations). The formation of chalcedony nodules or bands took place after pedogenesis, as shown by the inclusion of iron hydroxide grain coatings and nodules.

In Core 2 a different situation is observed. The lowest part is clearly a tropical soil, developed probably in a colluvial material, derived from a weathering granite, similar to the saprolite in Core 1, but with admixture of grains of metamorphic origin. A transport by mass movements (*e.g.* colluvionation) seems more evident than by alluvial processes, taking into account the absence of sorting whereas the rounding of the grains, especially the zircon, points to abrasion during transport. A detailed study of the "laterite" at the bottom of the core suggests that it encloses older iron nodules, compatible with colluvial transport. The presence of clay illuviation infillings and of goethitic features points to a pedogenesis under continental conditions. The extraordinary amount of oriented clay infillings has no parallel in the present day soils, but has been observed by the authors in palaeosols.

The submergence of the soils by the sea is related to a rising of the sea-level after the last glaciations (SAWAMURA & LAMING 1974) in this area. It is however questionable whether the period of low sea-levels during the Quaternary has been long enough to explain a deep weathering as observed in Core 1.

According to the data obtained by sieving, grain size distribution in the sediment and the saprolite is not that different. In thin sections however it is clear that the grains in the sediment are individual, rounded to subrounded particles of coarse sand size, kept together only by the interstitial clay, whereas in the saprolite large interlocking aggregate of angular quartz grains occur that are dislocated during traditional grain size analysis, giving rise to a false interpretation.

If we compare the c/f related distribution pattern (c/f r.d.) in the sediment and the saprolite the difference is striking. In the sediment one sees essentially

a close porphyric c/f r.d. It means that the sand grains have a skeletal function. In the saprolite however the distance between the quartz aggregates is much larger, and therefore they have no skeletal function. When hit by a tool they can more easily move.

Another point of difference is the b-fabric, i.e. the orientation of the clay particles in the micromass. The strong orientation of the clay particles parallel to the surface of the grains (face to face arrangement) will withhold the grains much stronger in their position than in the more random arranged (partly edge to face) micromass in the saprolite. Especially in combination with a close porphyric c/f r.d. pattern this will increase the effect of a dense packing and less plastic behaviour.

Although the rounded grains of the sediment will cause less corrosion to tools than the angular grains in the saprolite, their denser packing, mixture with smaller grains and the binding effect of the oriented clay, will increase abrasion.

The presence of *in situ* silicifications, mainly of pedogenic origin, but possibly transformed by diagenesis, is surely an element explaining the higher resistance of the material to dredging tools than expected.

The interpretation of the results of the bulk sample analyses suggests that the cores consist of marine sediments overlying a granite saprolite. The reality however is much more complex. Except for a thin layer at the surface, all layers have undergone pedogenesis and therefore display an internal fabric (organisation) different from a normal sediment. Moreover, the fact that one is dealing here with a buried palaeo-landscape makes the material more heterogeneous, as a result of the ancient local morphology and hydrology, making horizontal extrapolations less evident.

The description of the drilling artefacts is important to prove that artificial disturbances are detected by micromorphological studies, and that most of the fabric of the cores is undisturbed.

5. Conclusions

The application of micromorphological techniques, allowing the study of the relation between the different constituents in an undisturbed sample, has several advantages over more destructive techniques. On the first place it helps to understand the mechanical behaviour of the constituents, taking into account their related distribution pattern, the clay orientation, the degree of fracturation of the coarse constituents and indications of cementation. In a more general way it helps to understand the type of material (saprolite, soil,

sediment) what in turn gives a better insight in possible changes in spatial distribution.

The genetic interpretation of cores sampled for engineering purposes also contributes to a better understanding of the local geology and palaeo-environment.

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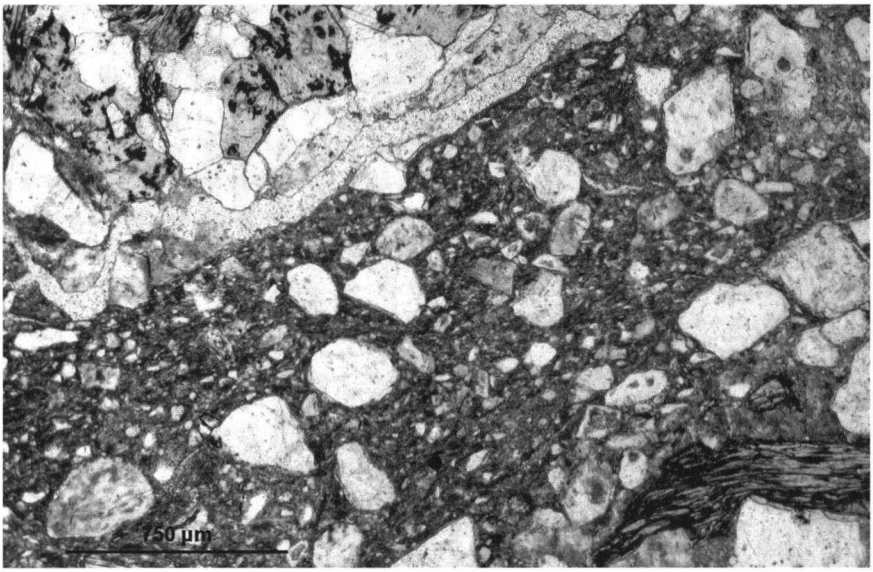
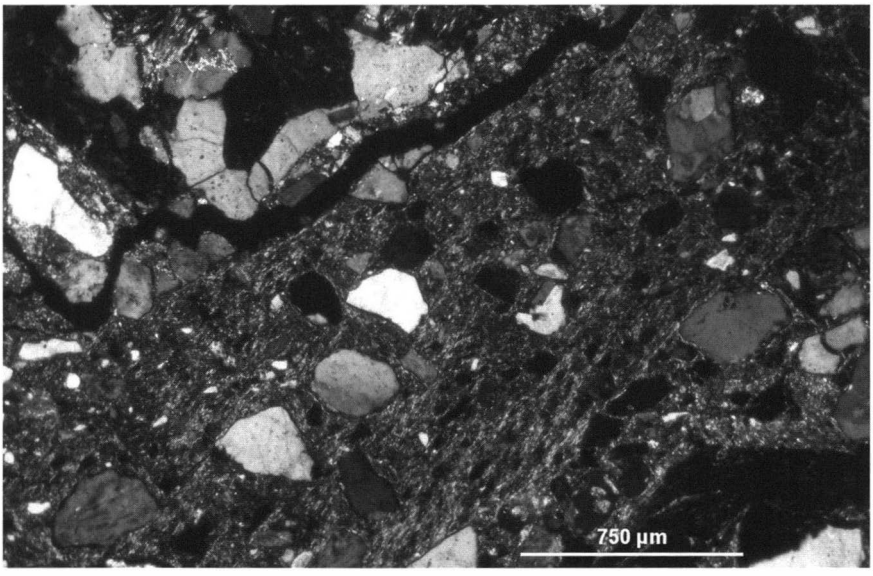


PLATE 1 A



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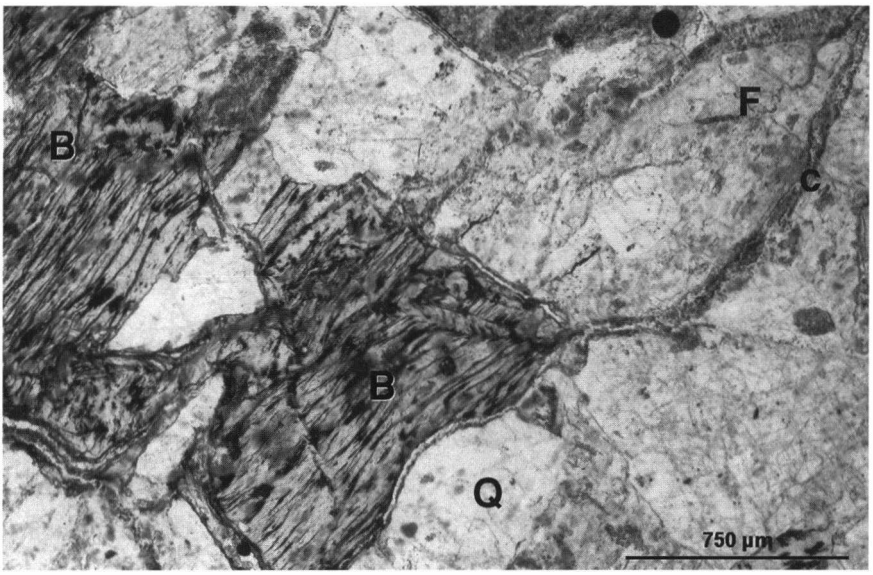

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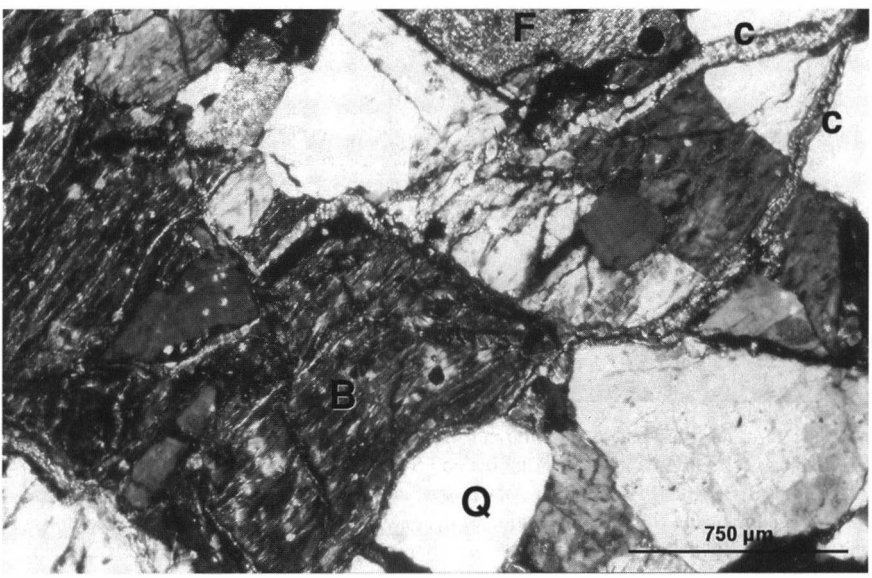

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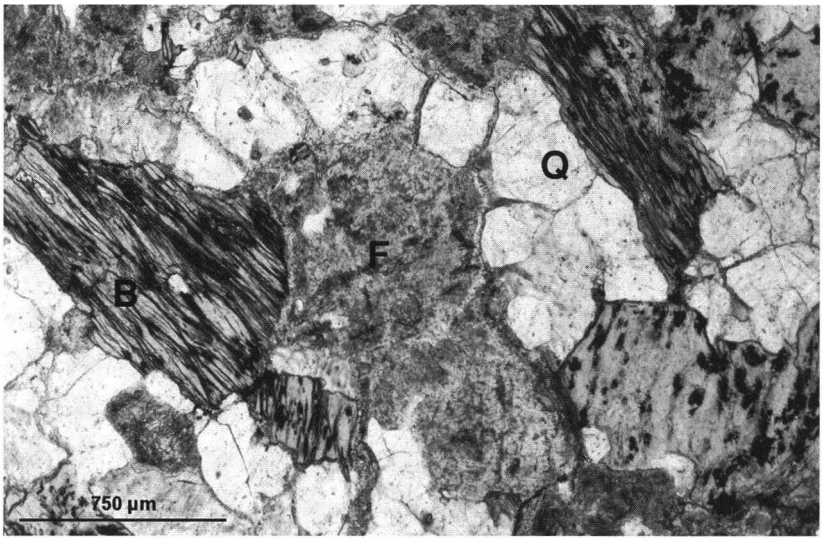

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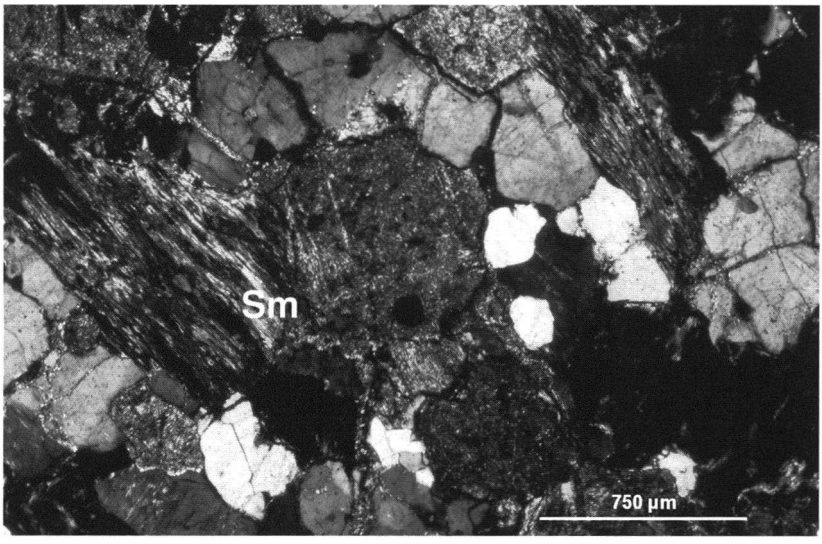


Plate 1. — Micrographs of saprolite in Core 1: A) Drilling artefact characterised by brown groundmass with fragmented quartz grains and SW-NE orientation of the clay. Sample 1217, plane polarised light (PPL); B) Same as A, but crossed polarizers (XPL). Note the parallel striated b-fabric caused by the orientation of the clay. The sample is tilted 45° in order to show the interference colours; C) Granitic saprock containing chloritised biotite crystals (B), sericitised feldspar (F) and quartz (Q). Note the coating (c) of newly formed clay, oriented perpendicular to the walls of fissures. Sample 1221, PPL; D) Same as C, but XPL; E) Saprolite, higher in the core, in a more advanced stage of weathering than shown in C and D. A strong fracturation of quartz grains (Q) corresponds to a loss of strength of the material. B: altered biotite, F: altered feldspar. Sample 1217, PPL; F) Same as E, but XPL. Transformation of chloritised biotite to smectite (Sm) is shown by appearance of higher interference colours.

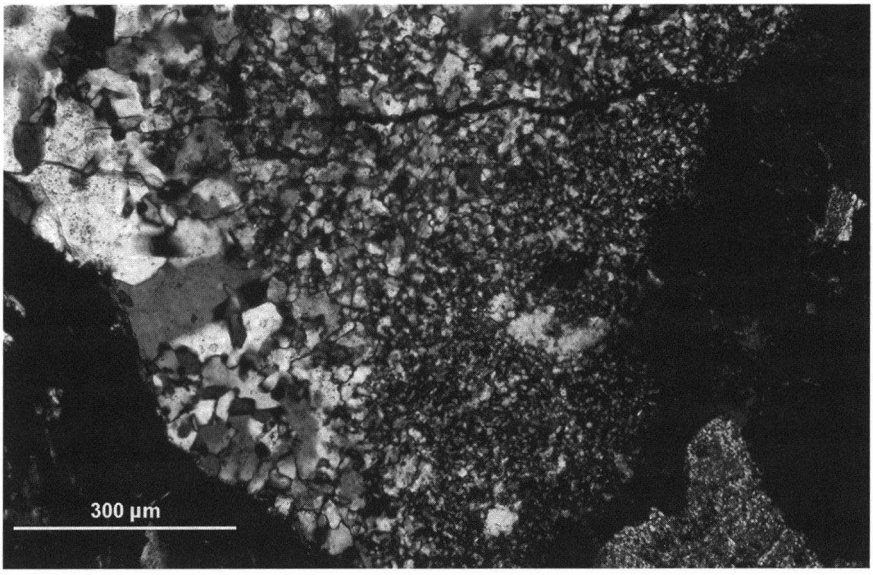
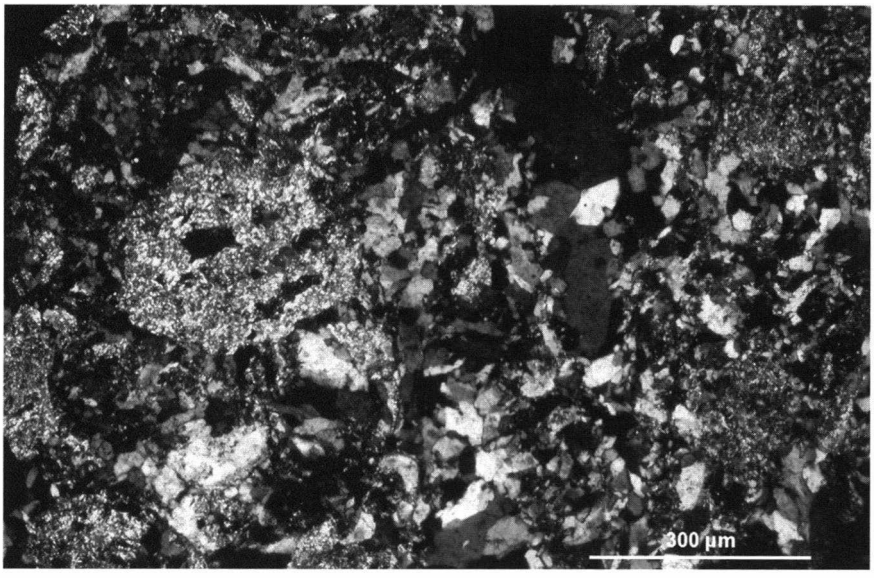


PLATE 2 A

PLATE 2 B



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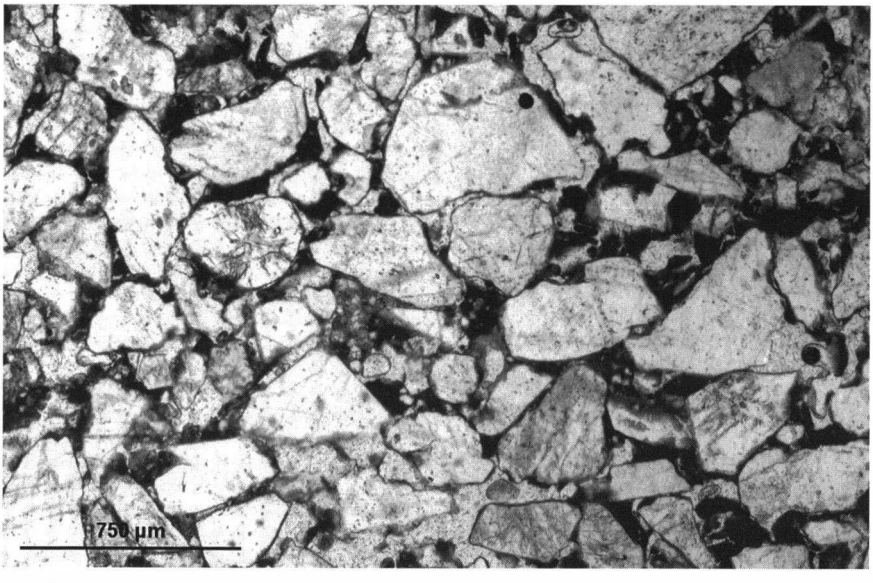

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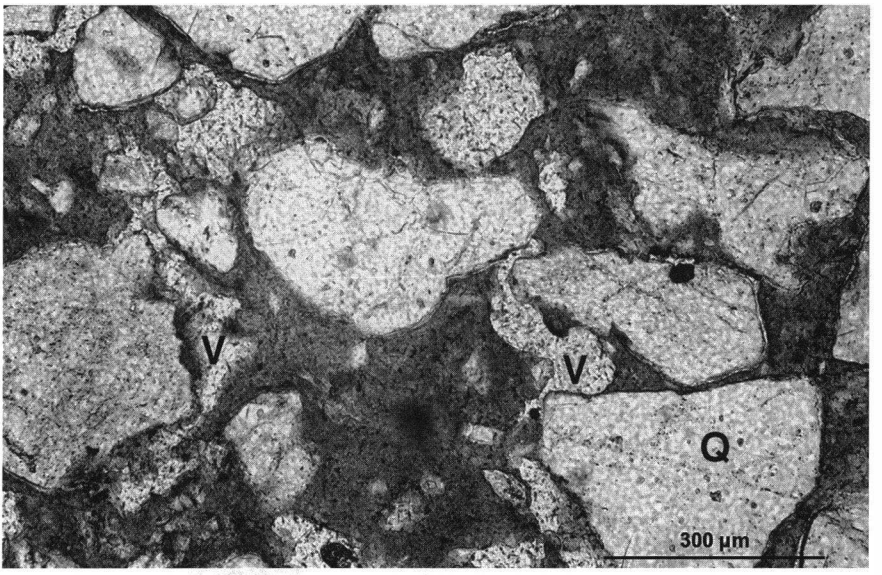

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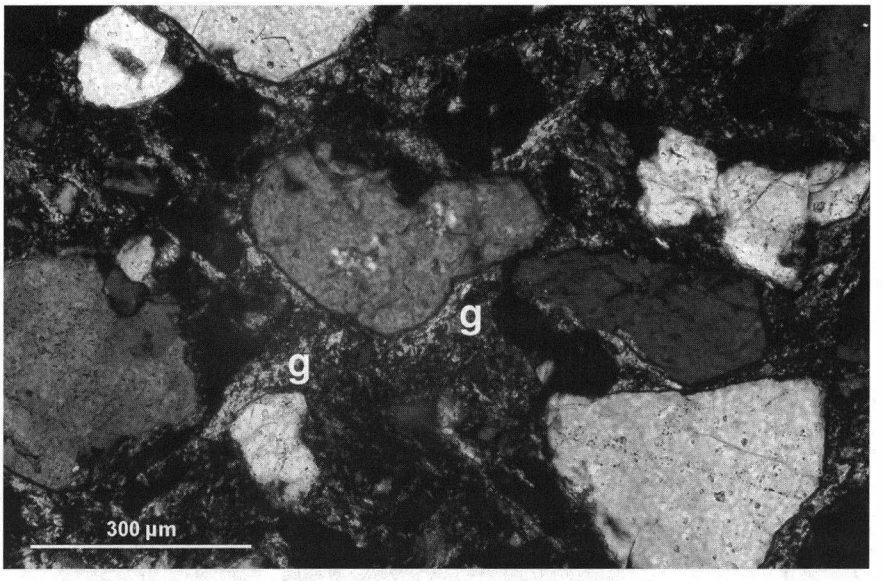

Plate 2. — Micrographs of saprolites and sediments in Core 1: A) Chalcedony crystallisation resulting from post-weathering silicification in saprolite. Sample 1205, XPL; B) Impregnative nodule of iron oxyhydrates in saprolite pointing to a pedogenesis in terrestrial environment. Sample 1203, PPL; C) Chalcedony crystallisation in sediment resulting from silicification. Sample 1197, XPL; D) Chitonic and gefuric c/f related distribution pattern in sediment. Note close packing of quartz grains and their skeletal function. Sample 1192, PPL; E) Subrounded quartz grains in sediment, showing close porphyric c/f related distribution pattern and skeletal function. V: voids, Q: quartz. Sample 1192, PPL; F) Same as E, but XPL. Note the granostriated b-fabric (g) (clay orientation parallel to the grain surfaces, made visible by the interference colours).

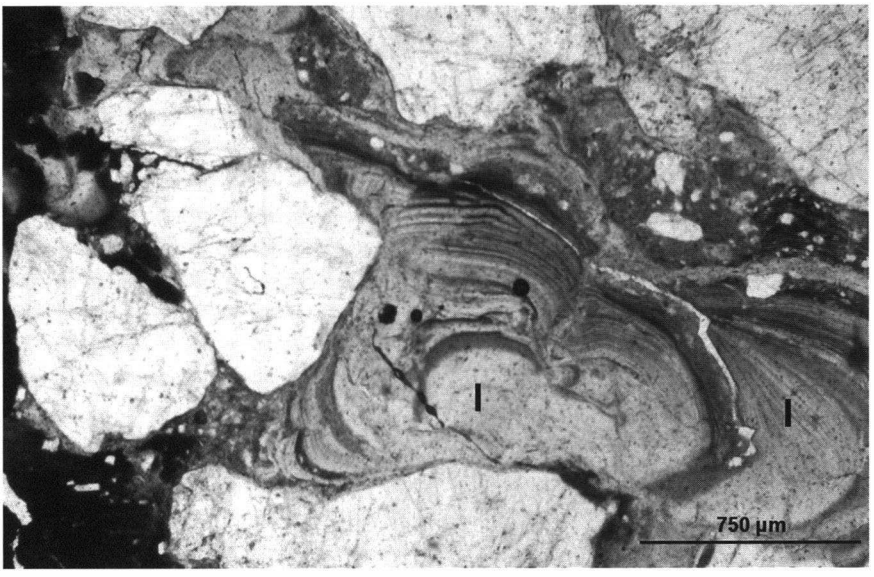

PLATE 3 A

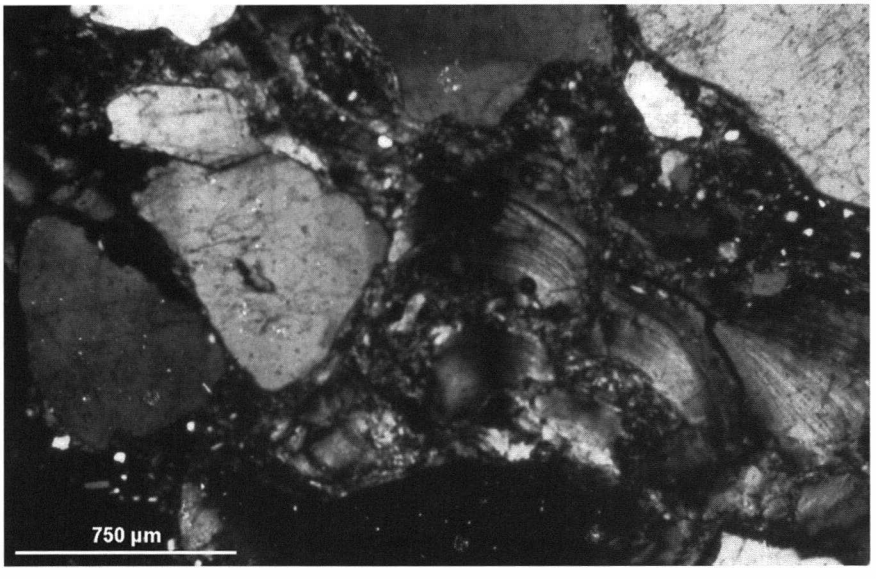

PLATE 3 B

PLATE 3 C

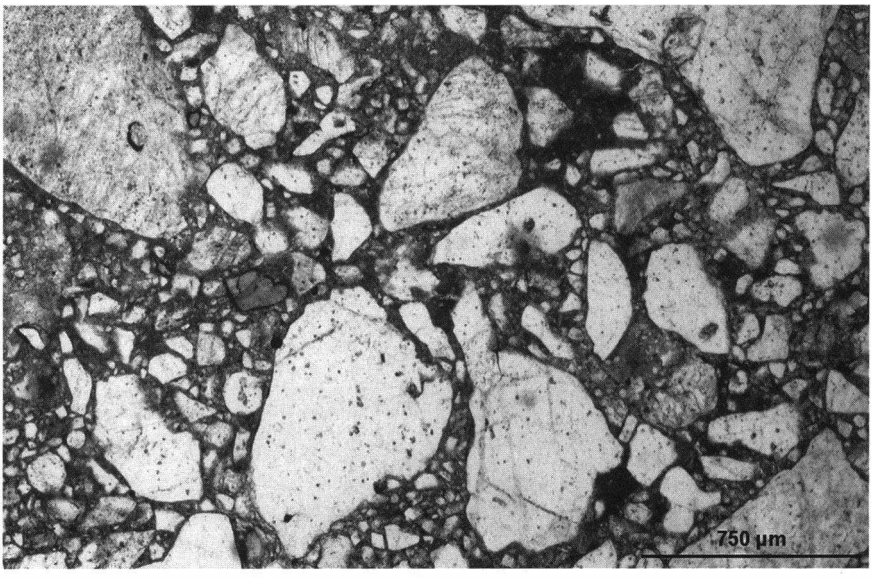

Plate 3. — Micrographs of sediment in Core 2: A) Large infilling (I) of illuvial fine clay, pointing to terrestrial pedogenic processes. Sample 1235, PPL; B) Same as A, but XPL. Weak interference colours point to a kaolinitic composition; C) Thick clay coatings and infillings impregnated by iron oxyhydrates as an indication of terrestrial pedogenesis after sedimentation. Sample 1232, PPL; D) Densely packed unsorted quartz grains in groundmass with close porphyric c/f related distribution pattern. Sample 1226, PPL.

Historical, Cultural and Linguistic Issues

International Conference
Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives
Royal Academy of Overseas Sciences
Phnom Penh, 6-8 February, 2006
pp. 215-229.

The Pearl River Delta Economic Zone as 'the World's Industrial Hub'

by

Sylvain PLASSCHAERT*

1. Introduction

The linking of three concepts in the very title of the Phnom Penh Conference connotes that a delta area favors the clustering of economic activities, *i.e.* of hubs. It is likely, indeed, that a delta area encompasses natural harbors, thus allowing to accommodate large volumes of exports and imports. As a delta may penetrate fairly deeply into the interior, harbors can also be constructed along a river, at some distance from the ocean, and close to important urban settlements. This is particularly beneficial in the present age of rapid globalization. The economically meaningful activities in such hub may be of a commercial nature, as when harbors only fulfill an entrepôt function. But the economic density of a delta area is substantially enhanced, when industrial production units blossoms within its confines, and is feeding inter-national trade.

Over the last quarter of a century, the Pearl River Delta (PRD) in China's southern province Guangdong — especially the area within its territory, that is delineated as a (preferential) economic zone (the PRDEZ) — has beaten all records of economic growth, so as to have become dubbed 'the world's industrial workshop'. The definite article 'the' seems to qualify the PRD as the foremost industrial hub in the world; this statement may be tinged by some hyperbole, but there can be no doubt that the PRD has enjoyed a meteoric rise to a hub of worldwide significance. The above flattering expression also suggests that industrial production is performed not only by local

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firms, but also that the area attracts a large number of direct investment projects by foreign firms, quite often as the result of the relocation of industrial productive capacity out of the 'home'country into the new 'host' PRDEZ. Such relocation, in the strict sense of the word, implies that the production thus moved to, say, the PRDSEZ is destined for exports to the world markets (including the home country of the foreign multinational enterprise that initiated the relocation).

In this paper, I intend to briefly analyze how the spectacular growth, almost overnight, of this area was driven both by momentous political decisions, more particularly the 'opening to the world' of the People's Republic of China (PRC) by the late Deng Xiaoping, as from 1980, and by favorable objective factors, amongst them foremost the symbiotic role of Hong Kong with the PRD. The choice of Shenzhen, and to a lesser extent of Zhuhai, which were selected as 'Special Economic Zones' (SEZ), has proven to be a highly judicious one.

Before embarking on such analysis, a few comments on the geographical and rather complex administrative architecture of the PRDSEZ divisions within Guangdong Province, are in order. And we must remind that, over many centuries, Canton, the capital city of Guangdong Province, was China's only door, but only opened ajar, to the outside world.

2. The Geographic and Administrative Configuration in the Area

Guangdong Province is hilly, for about 70 % of its land area. It has abundant water resources, with numerous rivers and streams, amongst them the mighty Pearl River (Zhu Jiang) system, which contains three entirely rain-fed components, viz. the West River (Xi), the North River (Pei) and the East River (Tung). But each of these components corresponds to a collection of rivers, whose names change when they join.

The Pearl River, in its strict sense, constitutes the central part of the system. It flows from Guangzhou (Canton), the capital city of Guangdong, in southeastern direction, over about 60 km, where it confluences with other rivers. Thus the Pearl River broadens into the Pearl River Delta (Zhu Jiang Kou), which is an extended estuary. "Hence, the Pearl River Delta can be defined in geographic terms as a triangle extending about 120 km from Guangzhou to Hong Kong (over Shenzhen) and with a westward leg of about the same distance from Guangzhou to Macao. The southern leg of the triangle is about 60 km of open water — except for a few islands — between Hong Kong and Macao" (Australia-China Chamber of Commerce and Industry of New South Wales, 2006, p. 3).

To circumscribe the Pearl River Delta Economic Zone (PRDEZ) proper, we must adapt the geographic approach to man-made layers of administrative authority. The PRDEZ is by far the most dynamic part of Guangdong. With 42,000 square km or 23 % of the land area, and 48 % of the population, it supplies 85 % of the Gross Provincial Product. The PRDEZ area was first delineated in 1984 and expanded to its present dimensions in 1987. It comprises nine cities (fig. 1). The Zone can be divided into two parts, which correspond to the two geographic 'legs' of the Pearl River Delta. The Eastern side contains the cities of Guangzhou, Dongguan, Huizhou and Shenzhen, whereas the Western side comprises the cities of Zhaoqing, Jiangmen, Foshan, Zhongshan and Zhuhai. Today, the Eastern part has developed more rapidly, although in the early 1980's the Western side was ahead. A 32 km long road bridge between Hong Kong and Zhuhai/ Macao nears completion and is meant to provide an extra push to the Western part of the PRDEZ.

Within that region, two municipalities have the status of 'special economic zones', viz. Shenzhen and Zhuhai — as elucidated in a moment. A few other 'leading' or 'peripheral' cities were also declared open (to international direct investments and trade) in the area. Besides, a large number of 'open'towns' are placed under the jurisdiction of open cities [1]*; thus,

Fig. 1. — Localities in the Pearl River Delta.

Guangzhou has been expanded by the annexation of Shunde and Panyu, which had already demonstrated their mettle by a manufacturing boom.

A recent, comprehensive book about the River Delta area transcends the boundaries of the PRDEZ proper and includes Hong Kong and Macao in its perimeter of what it calls the Great Pearl River Delta (ENRIGHT *et al.* 2002) Although not sanctioned as an administrative unit, the concept of such zone, thus expanded with the two former resp. British and Portuguese colonies, and driven by further integration, makes eminently sense from an economic viewpoint. Indeed, as will be substantiated below, the proximity of Hong Kong and Macao, which now formally belong to the PRC, but which constitute 'special administrative zones', and whose economies are distinct, and accounted for separately from that of the PRC, is of paramount relevance to the PRDEZ.

3. The Pearl River Area in Retrospect

It is noteworthy that, already centuries ago, the area, and particularly Huangpu, the river port of Canton, has acted as an important link with the outside world. During the long period, when Imperial China retreated into its own shell and haughtily turned down entreaties to institutionalize commercial contacts with the outside world, Canton provided China with a window, albeit a very tiny one, on the world beyond its frontiers. To remind:

— As from 714, Canton was a thriving port, involved in trade with Southeast Asia, at a time when China already excelled in maritime technology. As has been illustrated by the seven maritime expeditions 1405-33 by admiral Zheng He, who, heading a vast fleet, and displaying a remarkably advanced sailing equipment and techniques, reached as far as Mombasa on the Eastern Coast of Africa (these expeditions departed from Nanjing).
— In 1567, the Portuguese secured a concession in Macao, a peninsula, strategically located at the mouth of the Pearl river. They would retain a monopoly position in the trade between China and Europe for about a century. Macao has been retroceded to the VRC in 1999.
— In 1751 the then Manchu Emperor decided to close almost all ports to overseas trade. As from 1757 Huangpu became the sole outpost to engage in maritime trade with Europe. But even then several severe restrictions applied to European traders. They could approach Canton

* The numbers in brackets [ ] refer to the notes pp. 228-229.

only during a limited period per year; all trade had to be intermediated by Chinese middlemen, the powerful guild of the Hong; the foreign salesmen were even forbidden to learn Chinese ...

— In 1839 the first so-called Opium War was ignited in the Canton area. With only a few cannon salvos, British vessels shattered the Celestial Empire and, in accordance with the ('unequal') treaty of Nanjing (1842), enforced the opening of Canton, and some other ports for trade, including the import of the infamous opium, which had been banned previously by the Chinese government. The island of Hong Kong, renamed Victoria, was ceded to Great Britain. Subsequently, in 1860 and 1900, following further hostilities, more ports were 'opened'. Concessions, *i.e.* districts in coastal cities, in which the Western powers (soon imitated by Japan) exercised jurisdiction for their own nationals, were set up. In Canton, the Shamian island became a British-French concession in 1861.

— During the Mao Zedong (1949-76) era and the ephemeral interregnum under Hua Guofeng (1976-78), the international trade of the PRC was quite limited. Exports only reached $20 bln in 1980. As in other 'centrally managed' states, the Chinese economy was congenitally introvert; exports were aspired at, only to the extent their proceeds would allow to import goods which the country was unable to produce itself. The brutal break with the Sovjet Union in 1960 and the adversarial relation with the USA and other Western countries throughout most of the period, exacerbated the aloofness of the PRC from international economic intercourse. Yet, within such restrictive framework, the 'Chinese Export Commodities Fair' in Canton was the only window and trading link of some importance between the PRC and the outside world.

— During the 1949-78 period, Guangdong province was not favored by government policies. The political relation with the British Colony of Hong Kong was strained. The 'third front' strategy of the then leadership had aimed at converting each province into an entity, capable of sustaining itself in case of war; this approach benefited the inland regions. Moreover, Guangdong has a rather remote location vis-à-vis Beijing and the central regions of China. Neither was the province rich in natural resources, except that the narrow valleys with their alluvial soil and ample rainfall allowed for wet rice cultivation. Hence, in the PRD, agriculture initially was important and accounted in 1978 for 30 % of the gross product in that region; this proportion had dwindled to 6 % by 2000, following the industrialization and urbanization at breakneck speed.

4. The skyrocketing Growth and Transformation of the Pearl River Delta Economic Zone

The situation changed dramatically once the 'opening to the outside world (and reform)' strategy, masterminded by Deng Xiaoping, came on stream. The PRD became the vanguard in that new strategy, geared towards exports, which, together with the initial de-collectivisation of the agricultural sector (1980-83), must be viewed as the main engine of China's impressive economic growth performance, at an average pace of 9,5 % per year, during the last quarter of a century.

During the same period, exports from China have skyrocketed to $ 762 bln; accordingly, the average per annum growth rate has figured out at 15,7 %, thus converting China into a comparatively much more 'open economy' [2] than, say, India, Brazil, or Japan. This is truly remarkable as, other conditions being equal, large countries tend to be much less open to international trade than small one's. The PRDEZ has played a pioneer role and was the test case in this endeavor. In 2004, it accounted for 31 % of all exports from mainland China; and for almost all (95 %) of all exports from Guangdong province. One should add that Guangdong has been the fastest growing Chinese province over the whole reform period, so far. And this occurred in a massive country, with a population of far above one billion people, and which is nowadays the champion in the international growth league.

It would exceed the boundaries of this contribution if it were to enter into detailing the stupendous economic growth in the PRDEZ and its profound metamorphosis from a backwater, largely agricultural, into a densely urbanized area, in which thousands of manufacturing units and workshops generate rapidly growing outputs, which are predominantly exported. The monograph by ENRIGHT *et al.* (2002) contains ample details, not only sectorwise but also on each of the localities. Before dealing with the determinants of the meteoric growth in the area, we only add a few more general comments.

— Initially, the PRDEZ appealed essentially to labor-intensive manufacturing, on which Hong Kong had previously underpinned its dynamic growth performance. Low wage costs [3] have remained a trump card for the PRDEZ, as the ample supply of workers from the rural interior areas, willing to seek employment along the coast, tended to keep wages at a low, competitive level.
— Shenzhen no doubt has so far outshined the other successful preferential sites for export-geared direct investments. The original village of poor

fishermen has graduated into a modern metropolis. Its population grew to over 7 million in 2000, largely as the result of massive immigration — not all of it in line with legal prescriptions — from China's interior; thus, contrary to the rest of Guangdong, Mandarin, not Cantonese, is the most common spoken language in Shenzhen, as, noticed by ENRIGHT *et al.* (2002). Shenzhen's growth turned into overdrive after the celebrated visit of Deng Xiaoping in 1992 when he signaled the message that the move to a market economy and the associated opening to the outside world had to be resumed. Around 2000, it became the urban area with the highest per capita income in the PRC.

— The other localities have also prospered in conspicuous fashion. Dongguan, located between Guangzhou and Shenzhen, along the 130 km superhighway (now with 5 lanes in both directions) between those two cities, which was formerly a sleeping rural community, has experienced a growth record, which almost equals that of Shenzhen. While initially, with Shenzhen moving up the technology ladder, many labor-intensive processing units moved to Dongguan, and while retaining its imprint of light manufacturing, it "has become home to thousands of component and input suppliers for the city's electronic industry. In 2002 (it) was the third-leading export city in the Chinese mainland behind Shenzhen and Shanghai" (ENRIGHT *et al.* 2002, their description of other localities in the Zone quite often exudes a similar vista of frenetic growth).

— Within the PRDEZ, clusters of likewise activities have often developed, so that the various localities display some degree of specialization. "(Such) clusters (are) related by buyer-supplier links, common technologies, common channels or common customers" (ENRIGHT *et al.* 2002).

5. Explaining the Impressive Almost Overnight Growth of the PRD

Basically, two sets of factors explain the PRD success story. First, the designation of the PRD, and particularly of its SEZ, as the privileged areas to attract inward foreign direct investment and to test market-oriented experimental reforms, derived from a deliberate policy of the post-Mao leadership. Besides, and even more importantly, the choice of the PRD for such experiments has been a most judicious one. Indeed, the indented coastline of the Pearl River estuary hosts several natural harbors; whereas the proximity of bustling Hong Kong provided a propitious springboard to jumpstart export-geared industrial production.

5.1. The Preferential Treatment of Areas within Guangdong

Already in 1979, when the first inklings of the new growth strategy became perceptible, the Beijing government decided that Guangdong Province would be accorded a less restrictive framework for economic policies than elsewhere in the PRC. Guangdong was granted wider political and economic autonomy as regards finance and fiscal matters, foreign trade and investment, allocation of materials and resources, labour and price setting (most of those items were then still governed by the planned command system). In 1988, when an impressive take-off had already occurred, such powers of decision were expanded and the Province got the status of a 'comprehensive economic reform area'.

In 1985, Guangdong (and neighboring Fujien) also got a more favorable deal than was meted out to the other provinces, as regards the apportionment of fiscal revenues between the Centre and the Provinces; they only were committed to transfer a limited amount of their collected tax proceeds to the Centre.

5.2. The Initial Special Economic Zones

As from 1979, Guangdong was authorized to establish three 'special economic zones' (SEZ), viz. Shenzhen, Zhuhai (both of them within the confines of the PRD proper) and Shantou, slightly outside its territory, on the eastside. The fourth SEZ was to be set up in Xiamen, facing Taiwan, in the neighboring Fujien Province. Such zones, similar to those which had proven successful elsewhere in East Asia, such as Singapore, Malaysia, Taiwan and South Korea, were meant to attract foreign direct investments, and to form manufacturing platforms for the export markets. Thereto, the customary panoply of 'incentives' were accorded to foreign investors; they comprise a 15 % corporate tax rate, instead of the normal 30 % rate; tax holidays up to five years; the possibility to remit profits and the capital invested [4] to the parent company. Besides, the inputs (raw materials and intermediate goods) used in production for exports, could be imported duty free.

Two additional comments are appropriate. First, these 'incentives' are quite generous. Even today, foreign invested enterprises are subjected to a lower corporate tax rate than indigenous Chinese firms. (But this preferential treatment is bound to be terminated before long, the more that it conflicts with the rules of the World Trade Organization, to which the PRC acceded in 2002). Secondly, the 'special' character of the original economic zones has been

diluted soon since the early 1980s. In 1984, no less than 14 coastal cities were opened for foreign investment and trade; they were empowered to set up Economic and Technological Development Zones; amongst them were several cities, with harbor facilities, which have since substantially extended their traffic-handling capacities, such as Ningbo and Qingdao. In 1988, the 'opening of the economy' spread much wider, as eleven coastal provinces, with a total of 288 municipalities and counties were encompassed in what was called the 'open coastal belt'. The island of Hainan, in 1988, and the Pudong New Area in Shanghai in 1990 also secured the status of a 'special economic zone'; the latter rapidly became a potent development pole, now growing more rapidly than the PRD area, the more that it attracts a large number of high-tech investment projects. In 1992 new open economic development zones were allowed, no longer on the coast itself, but along the Yangtze river.

In the meantime, intense competition amongst local governments to attract foreign investments, prompted a lot of similar initiatives, under various appellations, which were meant to justify the granting of some incentives. This has resulted in a bewildering mosaic of incentive schemes. Eventually, the central government, with some success, has rolled back the proliferation of such gratifications for foreign investments and has re-established some order by way of categorizing the various schemes and calibrating the associated tax incentives. Yet, in principle and so far, the SEZ could offer the comparatively more favorable tax treatment.

5.3. The Proximity of Hong Kong as a Primary Catalyst

The proximity of Hong Kong, and its cultural affinity, have undoubtedly been vital factors in the success of the PRDEZ. The ethnical and cultural kinship between the two areas is obvious; the multifaceted economic links have been documented in great detail, and suitably stressed by Enright *et al.* (2002), who lay great stress on the catalytic role of Hong Kong. As a matter of fact:

— Most of the labor-intensive industry (such as garments, textiles, toys and footwear,but also light electronic goods and jewellery), which had been successfully built up in the 1950s and 1960s in Hong Kong and contributed mightily to the ascendancy of the then British territory, was relocated across the economic border with the PRC, particularly to the nearest site, namely Shenzhen. This move has been prompted by the rise in wage costs in the then British colony [5], from 1988 to 1992. Around 1995 almost all manufacturing had been relocated from Hong Kong

across the Chinese border; today, only 7 % of GDP in Hong Kong is still attributed to industrial activities. Thanks to the move across the border, Hong Kong firms could thus preserve the strong competitive position they had built up in several sectors, especially the labour-intensive one's.

— Even today, Hong Kong is still the predominant geographic source of inward investment into the PRC — if one excludes the unlikely Virgin Islands and Samoa, tax havens, which are known to cloak direct investments from Hong Kong and from Taiwan (which have been growing rapidly but cannot move straight to continental China); and if one discounts 'round-tripping' investments originating in the PRC itself, but rerouted over Hong Kong, with a view of benefiting from the tax gratifications granted to 'foreign investments' in the SEZ.

— In most cases, the affiliates of Hong Kong firms in Shenzhen or other localities in the PRDEZ thereby in essence perform the function of a production platform, while the other complementary business functions, such as the financing of exports, the marketing towards world markets and the overall management tasks remain entrusted to the Hong Kong parent company.

— A similar 'division of labor' applies when, alternatively, the manufacturing proper is carried out by local subcontractors, who operate according to the specifications of out-of-China firms. Such 'contract manufacturers' have become more prominent actors over the years. They often perform manufacturing for more than one principal, who may even be rivals in their sector. The largest contract manufacturer in the realm of electronics, Flextronics, incorporated in Singapore, is a case in point. Another one is Yue Yuen, a Taiwanese firm, specialized in sporting footwear, which employs 170,000 workers in the PRD and accounts for 17 % of world production (*Le Vif*, 11-17/2/2000). Others are concurrently involved not only as 'contract manufacturers' but also market their own brands.

— Hong Kong has accumulated a wealth of experience in such functions, that are highly valuable, and even essential to the manufacturing process proper. The anchoring of such activities and related contracts in the Hong Kong legal order, which is of British vintage, is another plus factor, as the legal and regulatory framework in the PRC, while improving perceptibly, still lacks certainty and transparency.

— Hong Kong also houses a large number of regional headquarters for the Greater China, or the whole East Asian region — although the extension of their activities within the PRC now leads some firms to move their headquarters to Shanghai or to Beijing.

5.4. The Closer Economic Partnership Arrangement between the PRC and the Hong Kong Special Administrative Zone (CEPA)

The CEPA, which is implemented as from 2004, further enhances the dense trade and other economic interconnections between the two entities; 273 goods of Hong Kong origin are thereby exempted from import duties and the access of Hong Kong direct investments to 17 sectors is thereby improved. Thus, the CEPA, a sort of free trade agreement, provides a preferential treatment, by way of lower import duties, when exporting to the mainland.

The CEPA is already credited with explaining part of the significant increase in the trade between Hong Kong and the PRC. Goods and resources flow not in a one-way direction. A growing number of Chinese firms set up affiliates in Hong Kong. An interesting phenomenon is that, as authorized by the CEPA, almost all retail banks in Hong Kong accept renminbi deposits; this, in a way, is the first step of the Chinese currency towards its eventual use abroad, *i.e.* external convertibility and perhaps the emergence of a new world currency, in use in a Greater China region. Anyhow, the CEPA strengthens the economic integration between the PRC and Hong Kong.

5.5. The Availability of Maritime Outlets

While a major determinant, the vicinity of Hong Kong alone does not account for the spectacular take-off of the formerly comparatively backward PRDEZ. Another favorable nature-given parameter lies in the availability of several maritime outlets, within the ample delta, with its extensive river network — apart from the harbor of HongKong, still the busiest container port in the world — not to mention Hong Kong's (new) airport on Lantau sland, which equally tops the league of air cargo traffic operators.

In the PRDEZ several harbors allow the handling of the massive inbound and outbound flow of commodities, deriving from the zone's role as a major manufacturing platform. Such ports are being expanded, most often with financial inputs from Hong Kong business. Zhuhai and Jiangmen can be mentioned. But the most spectacular transformation has occurred in Shenzhen, with its three harbor sites for container traffic (Yantian, presently the largest one; Shekou and Dachan Bay). Shenzhen already ranks as the 4th largest container port in the world and, considering the projected enlargement of its handling capacity, it may well soon overtake the Hong Kong harbor, according to expert opinion (Enright 2002). It enjoys the important

comparative advantage of a lower cost of moving cargo by truck to the respective port terminal. The competition between the two ports is fierce, but although the previous relative pre-eminence of Hong Kong is declining and even to be reversed, as more exports and imports now physically pass over Shenzhen, the prospective further expansion of the absolute volume of overall maritime traffic in the Greater Pearl River Delta does not condemn Hong Kong to a significant downturn in absolute terms.

Guangzhou itself, remembering the prominent, almost 'solo' role which its Huangpu port has performed in previous centuries, wants to recover part of its former luster and to enable today's giant ships to reach its urban districts. The Huangpu port is no longer appropriate for accommodating ships which nowadays allow a much larger carrying capacity, the more that the river at Huangpu is prone to silting.

But the extension of the jurisdiction of Guangzhou over two island districts, Nansha and Longxue, located more southwards where the Pearl River becomes much wider, allows it to cherish such objective. Berths will be built there that can accommodate 50,000 tonne ships. The Guangdong authorities also intend to allow the construction of a steel mill and of a shipyard in such appropriate maritime surrounding. Honda and Toyota have also announced investment projects in the area. All in all, the major centers in the Greater Pearl River Delta — Guangzhou, Shenzhen and Hong Kong —, although contiguous and belonging to the same PRD, are waging an intense rivalry.

5.6. The Vast Reservoir of Manpower

Finally, the availability of a large supply of manpower, willing to man the hundreds of industrial workshops which multiplied like mushrooms, was a contributing factor to the spectacular rise of the PRDEZ. The supply did not originate only in Guangdong itself, but was formed predominantly by persons, often females, living in the interior provinces where they constitute a massive 'reserve army' of underemployed rural workers, for whom even the low wages earned in the workshops in the PRDEZ, and the related Spartan working and residence conditions, were viewed as a less repugnant alternative than the bleak employment prospects and living conditions, in their home regions. Initially, the workforce in the PRDEZ consisted of temporary workers, with short-term contracts (if at all), who returned to their families. Later, after 1985, the migrant workers were eager to obtain the right of permanent residence with their families and a number of them settled in the PRDEZ.

6. In Conclusion: Prospects for the Pearl River Delta

As substantiated in this paper, the PRDEZ has benefited not only from its extremely favorable natural configuration, with its extensive network of waterways and harbors and from the vicinity of vibrant and skilled Hong Kong, but also from a 'first entrant's premium', as the zone was designated by the Chinese leadership as the first test case in its endeavor to attract foreign firms and to experiment with the institutions of a market economy. A main objective consisted in activating export activities.

In gauging the likely future of the PDREZ, and acknowledging that uncertainty is the hallmark of the future, the following comments appear to rest on a plausible underpinning:

— The lead position of the PDREZ, in terms of its relative strength, cannot be maintained forever, as wages even for unskilled labor are starting to rise in the PRDEZ and significant labor shortages have recently been reported. Since 2003, farm product prices rose significantly, thus moderating the eagerness of potential migrants from the inland regions to seek a job in the workshops in the PRDEZ, the more that working conditions can be harsh, despite labor legislation about minimum ages and overtime pay [6]. Some firms in the area are reported to envisage moving their production capacity further inland or to Vietnam.
— But, as stressed above, the PRDEZ is no longer wedded only to labor-intensive manufacturing. Many units in the area are moving upwards along the technology ladder and value chain. They now produce goods of higher quality, or with a higher technological content, which earn them a higher profit margin. Guangzhou and Shenzhen ambition to become major hubs in the provision of services to business, competing thereby with Hong Kong [7].
— The PRDEZ has been spearheading China's conspicuous entry in the international arena. It has briefly enjoyed a monopolistic stance, but other areas in China have since joined in the conquest of market outlets abroad and have thereto attracted foreign investors. The Yangste delta, around hyperdynamic Shanghai — which is presently equipping a new harbor that is already the largest in the world —, now projects a serious challenge to any supremacy of Shenzhen, Guangzhou and even of Hong Kong. That Yangtze, more centrally located delta region, with a much deeper hinterland, now scores a higher growth rate than the PRDEZ. It also has immediately stressed high-tech industries, and has succeeded impressively in attracting such ventures. These have transformed the

Pudong area, in 1990 still a marshy expanse, into an exuberant industrial powerhouse.

— The preferential treatment in the corporate tax field which the SEZ could mete out of foreign investors will also be discontinued before long.
— The relative importance of export-geared labor-intensive goods, in China's output portfolio, is also likely to decline as a result of various factors, namely (a) the technology-driven further substitution of manual work by machinery; (b) the competition by other, as yet poorer countries in Asia; and (c) by the reorientation of the overall development strategy recently underwritten by China's leadership, which henceforth focuses on the inland provinces and the development of the internal market in the rural areas. This message appears to be noticed in the PRD region, as a grand plan is being nurtured to involve it in the development of a vast hinterland, that would encompass 9 provinces in Southeast China and Hong Kong as well. This would create the 9 + 2 Pan Pearl River Delta area. This forward-looking projection, admittedly still in its conceptual stage, would no doubt confer benefits to the PRDEZ as the inland provinces possess rich mineral resources and as today Guangdong lacks such hinterland, with which it is poorly connected.
— The PRDEZ itself, with its comparatively high per capita income, already offers fairly substantial market outlets for local and outside producers.

NOTES

[1] In contrast to cities, towns are not endowed with (some) fiscal autonomy. Understandably, towns strive for city status.

[2] As measured by the ratio of the sum of exports and imports against the 'gross domestic product'.

[3] It bears reminding that the concept of 'labor costs' not only looks at wage levels, but weighs the latter by their productivity.

[4] However, foreign direct investors had to comply with the so-called 'foreign exchange adequacy' rule, whereby their investment was expected to generate as much foreign exchange earnings as were spent on establishing and running the investment venture. This amounted to a built-in pressure stimulus in favor of exports as against production for the domestic market (see PLASSCHAERT 1993). (This rule has since fallen in desuetude, the more that it conflicts with WTO rules.)

[5] The peg of the Hong Kong with the US dollar, within a Currency Board system, was one of the drivers in the rise of wage costs (see KUEH & NG 2002).

[6] Although abuses persist, the situation of migrant workers in the area appears to be improving, in part thanks to international pressures on multinational firms, that source much of their goods with subcontrators (see *e.g.* the *Financial Times*, April, 22, 2005). At the end of March 2006, the Central Government issued a

long series of instructions to local governments in order to eliminate abuses vis-à-vis migrant workers. The need to better the position of the migrants is now recognized on the political level, even if the implementation of such measures by the local authorities is likely to erode the competitive position of a number of labor-intensive enterprises in the PRDEZ.

[7] Thus, the Pearl River Piano Group, has become the number top producer of piano's and other musical instruments, behind Yamaha. It exports already large numbers of products but also rapidly expands its sales within China itself (*Le Vif*, 11-17/2/2002).

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Trading Belgium Rediscovers the Orient. Subsidized Liner Traffic to South-East Asia (1834-1851)

by

John EVERAERT*

The marriage of convenience between Belgium and Holland, resulting in the United Kingdom of the Netherlands (1815-1830), largely opened the Dutch colonies to the Belgian shipowners and export traders. In 1824, the creation of the "Nederlandsche Handels-maatschappij", establishing from 1827 onwards trading posts in the Dutch East Indies (present-day Indonesia), offered Belgian textile products a privileged outlet in order to compete with their British rivals. Thus the cotton factories of Ghent, the wool mills of Verviers, as well as the domestic linen industry of Flanders largely benefited from this situation. As for the return cargos (coffee, sugar, cotton, rice and hides), the Antwerp port succeeded in acquiring a dominant, yes even a monopolizing position [1]**.

Initially the revolutionary events of 1830 should have resulted in closing this colonial market. As it was, by the bypass of Dunkirk and with the help of Dutch and English straw men, the Ghent cotton fabrics were to be seen again in the storehouses of Rotterdam with a destination for Java. During the years 1831-33 the Dutch government connived at this contraband. Meanwhile several Belgian shipping companies (de Cock Brothers in Ghent, Serruys and Donnet in Antwerp, Sinave in Bruges) had already temporarily settled in Dutch ports. Nevertheless, when in 1834 the Netherlands, in order to protect their upcoming cotton industry, were raising by 50 to 70 % their import duties in Java on products manufactured abroad, it meant the deathblow for the Belgian export traders [2].

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** The numbers in brackets [ ] refer to the notes and references pp. 246-248.

In spite of this, during the years 1833-39 Antwerp continued to receive colonial wares coming from the East Indies and transported by American and British three-masters, respectively carrying two and one third of the ladings (tab. 1). From Batavia and now and then from Semarang and Soerabaya — three colonial ports that were open to foreign trade — mainly came sugar, coffee, rice, blocks of tin and bundles of rattan. Next to that there were woods (fir and sapan, suitable for dying), cotton, dry hides, the purgative *cassia*, spices, turtle-shells and even Japanese art products. The island of Sumatra supplied mainly pepper but also coffee and rattan. About a dozen of vessels even came from Manila, usually also calling at Java and exceptionally at Singapore. Their cargos presented an analogue diversity, containing furthermore Philippine sugar and Chinese spices (ginger, cinnamon) [3].

Table 1

Port of Antwerp: direct navigation to the East Indies. Ships sailing under foreign coulours

	Routes											*Coulours*											
	Back/inbound							*Outward*				*Arrivals*							*Departures*				
	Batavia	Semarang	Soerabaya	Sumatra	Singapour	Manille	Akyab	Batavia	Sumatra	Manille	Akyab	américain	anglais	danois	suédois	hannovrien	français	hollandais	américain	danois	hollandais	espagnol	?
1833	3			1		3		1				5	2						1				
1834	5							1	1			2	3						1				1
1835	2			1		2			1			4	1						1				
1836	3					4			1			5	2						1				
1837		1				2						2	1										
1838				1		1						1	1										
1839	2	1	2		1	1		1				6	1						1				
1840		1				1		2		1		1	1						2	1			
1841	4					3						1	4	1	1								
1842	2				4								4		1	1							
1843	2					3							3										
1844	3			1		4		1				3	4			1			1				
1845				1	1	1			2			2	1						2				
1846				3					1			3							1				
1847				1		1		2				2									2		
1848			1	1			4					1	3			1	1						
1849	1		2			2		2					3				1	1			2		
1850							2				1		2		1				1			1	
Total	27	3	5	10	6	28	6	10	6	1	1	38	36	1	3	3	2	1	12	1	4	1	1

Source: Journal du Commerce d'Anvers.

Most of the oriental shipments remained consigned to foreign firms established in Antwerp, such as Alfred Borrow, Putnam & C°, James Clegg & Brothers, Hamilton, Ortman & C°, Th. Maigny & C° and others. Some rare American ships even directly sailed back again to the Indies and most often in ballast. Obviously, the majority of them returned to their homeport from where they started a new journey. That was the case in 1837 with the "Logoda", a three-master (ca 400 tons) of a superior speed — since it was copper-covered — and equipped with all desirable comfort for the passengers. Her future route, advertised in Antwerp, was significant for this kind of navigation around the globe, passing by New York, Brazil and the East Indies [4].

Since the end of the 18th century (1785-90) the American shipping traders had valorised the transpacific road. Having discovered the Chinese market, they financed there their purchases of tea not only by exploiting the resources of the coasts (furs, sealskins) and isles (sandalwood) of the northern Pacific, but also by exchanging their manufactured products against precious metals in the western ports of former Spanish America. Thanks to this currency, directly obtained at their advantage, they succeeded in thoroughly infiltrating in Canton, Manila and Batavia. Quite some time later, the Dutch shipowners at their turn would prospect this alternative road. During the years 1826-29 the house Insinger & C° of Amsterdam launched a try-out campaign to the East, doubling Cape Horn. However, the results were quite disappointing due to a series of set-backs [5].

The Flemish shipowners very well knew about this long transpacific road (tab. 2). A few months after Insinger's initiative, the Ghent shipping company of J. J. de Cock & Brother sent their recently built brig "Louisa-Augusta" on a world tour. The vessel firstly arrived in the Chilean harbour of Valparaíso and consequently called at two ports of Peru (Callao and Trujillo) in order to sell its national manufactured products in exchange of silver *piastres*. Afterwards the ship headed for the Sandwich Isles (*i.e.* the Hawai archipelago) and ultimately landed in Manila. Carrying a large amount of sugar, *abaca* (Manila hemp) elephant teeth and so on, the ship sailed back to Antwerp, calling on its way home at the ports of Batavia and Cape Hope. The entire trip had lasted over eighteen months [6]. In spite of the positive results at first sight, de Cock gave up this new route for the conventional one.

Unlike their Ghent colleagues, the Cateaux-Wattel & C° shipping company of Antwerp opted straightly for the transpacific route. In the course of 1830-37 they undertook four campaigns with their brig "Flora" (250 tons), each time under the command of the German-born captain Rickmers. At Valparaíso — where all the Belgian products were highly appreciated, in particular textiles and window-glass — and in other ports of South America

Table 2
Belgian transpacific expeditions (1827-1837)

A. N.J. DE COCK & Brother (Ghent): 1 campaign

Brick "Louisa-Augusta" (250 tons/built 1825), capt. Steven St-Martin (Rotterdam).
Flushing, 30 August 1826 — Antwerp, 12 April 1828.
Route: Valparaíso, Callao, Trujillo, Honolulu, Manila, Batavia.
Return cargo: sugar,abaca (Manila hamp), ivory.

B. CATEAUX — WATTEL & C° (Antwerp): 4 campaigns

Brick "Flora" (250 tons/built 1830), capt. J. Rickmers.

1) Antwerp, April 1830 — Trieste, 19 January 1832.
Peru, Batavia, Surabaya, Manila, Canton

2) Antwerp, ? — Antwerp 2 May 1834.
Peru, Manila, Canton.
Return cargo: sugar, cinnamon, tea.

3) Antwerp, 23 August 1834 — Antwerp, 23 November 1835
Vaparaíso, Arica, Callao, Payta, Honolulu, Manila* (full cargo of colonial products).
Saint Helena.

4) Antwerp, June 1836 –
Planned itinerary: Valparaíso, Cobya, Sandwich Islands, Manila, China.
Looted and set afire in Mazatlán (Gulf of California/Mexico), February 1837.

the holds were emptied. This profitable stopover had to be made, for with the thus gained silver coins they would buy a shipment of colonial products in Manila and additionally also in Canton. Prematurely the last expedition ended up in the Mexican port of Mazatlán, where the brig — which had strongly penetrated into the northern waters — was looted and burnt down [7]. For the third voyage, the Belgian government agreed to grant the shipowner a subvention of 20,000 francs (80 frs/ton) on the condition of transporting a commercial agent who had to gather information and deliver a general report. Joseph Partoës was designated to do so and he turned out to be an excellent reporter and a first rate memorialist with an accurate judgement [8]. Anyway, the other shipowners as well as the Belgian exporters hesitated to reconvert to this alternative route to the East Indies.

Nevertheless, in the beginning of the 1830-40 decade, the Belgian long-haul navigation had known a severe crises. Many ships, captains and shipowners had emigrated to Holland. In the Dutch Indies, differential import duties eliminated the Belgian import (1834); even the Scheldt was temporally "closed" for the Belgian pavilion (1833-39). When in 1834 the brig "Jean Key" (350 tons) — baptized after its Antwerp owner and the first to

leave its homeport under the national colours — returned from Batavia loaded with coffee for account of the "Handel-Maatschappij", it was forced to unload in Ostend [9].

Quite logically our shipowners-exporters went looking for financial support in order to overcome this situation. Already in 1832 the Bruges trader J. B. De Lescluze had launched the idea of an institution that "will be exclusively meant for advancing money without any interest calculation and at a part of the value of the merchandise that will be sold overseas". The following year he set out to the minister his project of a campaign to Singapore and Manila, to be financed by the government. But all his attempts were in vain [10].

However, the free port of Singapore, established in 1824 [11], would serve as an ideal springboard to get accustomed to the whole area of the Asiatic South East, at the same time putting an end to the Dutch maritime-commercial stranglehold. Early 1835, the Antwerp shipowner P. Wattel (partner of J. F. Cateaux) proposed to the minister of Internal Affairs and Marine to equip his intentionally constructed vessel "Henriette" (captain L. Heyde) and send it to the East Indies with a cargo of about 4 to 5,000 francs worth. In order to open up new markets for the Belgian industry, the government could create a trade post in Singapore, from where our cotton products would easily be re-exported to India and Java. As a "compensation" for the free passage of a commercial agent, the shipowner requested the government to take care of the equipment and provisions, cover the possible losses for about 15% and on top of that grant him a premium. As a matter of course the deal did not succeed [12]. However a few months later our national shipowners could from than on (Order in Council of July 13, 1834) enjoy a substantial support in form of marine officers and sailors, paid and fed by the treasury. That was a double-aimed measure: on the one hand the stimulation of the maritime commerce, on the other hand a new start for a national navy.

The first shipowner to enjoy this new regime was J. Key. In September 1834 his brig "Sophie-Dorothea" sailed to Singapore with a cargo of cloths, Swedish iron, lead and salmon [13]. On board travelled also Joseph Lannoy, the first commercial agent to settle in the Orient on initiative of the government, with an annual pay of 6,000 francs. He reported to our minister that several Belgian products (gin, linen, lead, window glass, gunpowder, weapons) could be transhipped in the pre-mentioned freeport with destination to Manila, India (Bengal, Bombay), the Dutch colonies (Sumatra, Celebes) and Siam. The return cargo mainly consisted of sugar, coffee, tin from Billiton and rice [14]. After a few years, Lannoy was promoted to the function of Belgian consul at Manila (1837-48), while in Singapore Auguste Moxhet succeeded him [15].

Quite soon, Singapore turned out to be the pivot for the Belgian maritime trade with the Orient. In the course of the years 1840-50 the majority of our national ships called in at that port (tab. 3). In Antwerp, two shipping companies — namely J. B. Donnet and especially Cateaux-Wattel — showed a particular interest by sending their ships on a regular base not only to Singapore and Manila, but from 1840 onwards to Batavia as well. Indeed, the peace treaty of 1839 with Holland allowed the Belgian ships to call again at Java on a footing of equality with other favoured nations. In 1842, the consul A. Moxhet pointed out that of all European nations, Belgium — second to England of course — participated most actively in the Singapore traffic with an annual average (1841-42) of three to four vessels [16]. At that moment the subsidized regular service was about to become operational, as we will see further on.

In Belgium, during the years 1838-48, some industrialists, exporters and shipowners tried to combine their efforts in order to stimulate the maritime commerce. The "Société de Commerce d'Anvers", active in Antwerp between 1838-43, concentrated its transactions mainly on Singapore, Manila and Batavia, as well as on the Rio de la Plata region. After a few years (1840-41) of a slightly positive balance, substantial losses — caused by a downright fall in prices of the colonial products — caused the dissolution of this company. From then on, the Ghent cotton manufacturers would distrust all overseas operations [17]. In 1844-45, F. Oldenhove, a protagonist from Brussels, made an effort to establish a firm for maritime commerce with a working capital of 25 million francs and for that matter almost resembling a cartel. In fact, this combination should group the Florival enterprise — a spinning and weaving mill complex located on the river Dyle — an exportation company in Antwerp and a branch office in Singapore, with possibly other agencies in China, in the Philippines and in Batavia [18]. In 1849 a consortium of the most important merchants in Antwerp (Fuchs, Cateaux, Osy, Weber & C°) formed a limited partnership (1,5 million francs) in view of the exploitation of the direct trade with the East Indies as well as the establishment of a central trade post in Singapore [19]. Incidentally we know that J. F Cateaux (already?) had opened a branch office in Singapore, temporarily run by his son Leopold. The forenamed plan, with which the government would preferably be associated, came exactly after the moment the latter had decided to cut down its policy of equipping private trading vessels.

From October 1837 on, the Netherlands already had reduced by half (to the rate of 25%) the import taxes on Belgian products brought to Batavia.

Table 3

Port of Antwerp: direct navigation to the East Indies. Ships sailing under Belgian flag

	Duration	Ship's name	Type	Tons	Captain	Shipowner	Destinations: Singapour	Batavia	Manille	Canton	Akyab
1834	10.01.34 / ?	Prés. Schimmelpenninck	trois-mâts (°1830)	1100	F. Meulenbroeck	A. Sinave (Bruges)				C	
	13.09.34 / 26.10.35	Sophia-Dorothea[1]	brick (°1826)	210	Stappers	J. Key	S				
1839	19.11.39 / 23.01.41	Progrès	trois mâts / brick		J. F. P. Smit	Société de Commerce d'Anvers	S	B	M		
1840	04.01.40 / 13.05.41	Charles[1]	brick	229	Jurgendsen	Cateaux-Wattel	S	B	M		
1841	11.04.41 / 12.02.42	Rubens I[1]	brick	284	De Rijcke	J. B. Donnet		B			
	17.06.41 / 24.05.42	†Sophia-Dorothea[2]	brick (°1827)	179	Van Benninghen / Demeire	J. Key	S		M		
	02.10.41 / 01.09.42	Infatigable	koff (°1840)	242	Moller	David & De Boe	S				
	29.10.41 / 01.02.43	Charles[2]	cfr. plus haut		Jorgensen	Cateaux-Wattel & Cie	S		M		
1842	30.06.42 / 31.05.43	†Macassar[1]	trois-mâts (°1830)	637	G. Van den Broecke	J. B. Donnet	S	B			
	10.08.42 / 15.05.43	Rubens[2]	cfr. plus haut		De Rijcke	J. B. Donnet		B			
	? / 22.07.43	Louise[1]	trois-mâts / barque	250	Lams	P. Serruys		B			
1843	04.02.43 / 08.02.44	Magellan	trois-mâts / barque	239	Meyer	Cateaux-Wattel	S	B	M		
	10.02.43 / 12.05.44	Jean Key	barque (°1829)	350	De Pauw	J. Key		B[a]			
	17.06.43 / – (1)	*Charles[3]	cfr. plus haut		F. Hoed	Cateaux-Wattel	S		(M)		
	02.09.43 / – (2)	Rubens I[3]	cfr. plus haut		De Rijcke	J. B. Donnet	S	B			
	03.09.43 / 27.06.44	Louise[2]	cfr. plus haut		Lams	P. Serruys		B			
	11.11.43 / 22.11.44	*Macassar[3]	cfr. plus haut		Van den Broecke	J. B. Donnet	S	B	M		
	26.12.43 / 12.04.45	*Emmanuel[1]	trois-mâts (°1834)	851	Van Haverbeke	Bisschop-Basteyns & de Cock	S	B	M	C	
1844	04.05.44 / 22.06.45	*Schelde[1]	barque	310	Eyckholdt	Cateaux-Wattel	S		M	C	
1845	22.05.45 / 03.08.46	*Macassar[3]	cfr. plus haut		C. Swarts	J. B. Donnet	S	B[b]	M		
	22.09.45 / 07.10.46	*Ambiorix[1]	trois-mâts (°1845)	375	Roose	J. B. Donnet	S		M		
	17.12.45 / 03.05.46	*Schelde[2]	cfr. plus haut		Claeys	Cateaux-Wattel	S		M	C	
1846	14.09.46 / 29.07.47	*Emmanuel[2]	cfr. plus haut		C. Swarts	Th. de Cock & F. Bisschop	S		M		
	23.12.46 / 10.03.48	*Macassar[4]	cfr. plus haut		Hoed	J. B. Donnet	S	B[c]			
1847	17.03.47 / 13.02.48	*Louise[3]	cfr. plus haut		Lams	P. Serruys	S	B			
	26.07.47 / 09.08.48	*Schelde[3]	cfr. plus haut		Claeys	Cateaux-Wattel	S				
	03.11.47 / 10.09.48	*Emmanuel[3]	cfr. plus haut		T. Schwartz (Swarts?)	Th. de Cock & F. Bisschop	S				A
	23.12.47 / 01.11.48	*Duc de Brabant[1]	trois-mâts	430	Schmidt	Spilliaerdt & Caymax	S				A
	? / 12.09.48	Charles-Quint	trois mâts	488	Mussche	Cateaux-Wattel					A
1848	01.04.48 / 22.06.49	*Rubens II[1]	trois-mâts / barque	375	Meyer	Cateaux-Wattel	S	B		C[d]	
	25.10.48 / 20.11.49	*Emmanuel[4]	cfr. plus haut		Schwartz	de Cock & Cie		B			A
1849	01.06.49 / 08.07.50	*Macassar[5]	cfr. plus haut		De Ruyter	J. B. Donnet	S				A
	26.09.49 / 01.10.50	Duc de Brabant[2]	cfr. plus haut		Schmidt	Spilliaerdt & Caymax	S				
	07.12.49 / 20.12.50	*Stanislas	trois-mâts / barque	452	J. B. Gombert	Spilliaerdt & Caymax	S	B			
	? / 14.11.50	Schelde[4]	cfr. plus haut		Claeys	Cateaux-Wattel			M		
1850	05.05.50 / ?	*Henry-Joseph	trois-mâts	507	Parmentier	J. A. Elsen & Van Linden	S				A
	? / 08.10.50	Philomène	koff	93	Bernard / Klein	Spilliaerdt & Caymax					A
	? / 31.10.50	Harriet	?		Zellien	?					A
	14.08.50 / ?	Théodore	barque		Meulenbroeck	?					A
	08.09.50 / ?	Jeannette-Marie	koff	225	Claeys	J. A. Elsen & Van Linden			*		
	25.10.50 / ?	Mélanie	barque	286 (?)	Sikkens	Ch. van Nyen (?)					A
	08.11.50 / – (3)	*Rubens II[2]	cfr. plus haut		Meyer	Cateaux-Wattel	S	B			
	22.11.50 / ?	Macassar[6]	cfr. plus haut		De Ruyter	J. B. Donnet					A
1851	08.05.51 / ?	*Mercator	trois-mâts (°1850)	440	Zellien	De Ceuster (Boom)	S				
	15.10.51 / ?	*Julie	trois-mâts	618	L. Meyer	Cateaux-Wattel & Cie	S	B			

Explanatory notes :

(1) Captured in Strait of Makassar
(2) Condemned not seaworthy (Braz
(3) Shipwrecked Cap Verde Islands

\+ Subsidized campaigns
° Supported regular line

a Destination "Java"
b Batavia & Sourabaya
c Batavia & Semarang
d Shangai & Hongkong
e Destination « Far East »

However the shipowners will patiently wait for the guarantee of a peace treaty (1839) before tackling the Javanese market. J. Lannoy, the Belgian consul in Manila, who at the end of 1840 had made a prospective tour in view of examining the outlets of the Javanese ports, did not hesitate to recommend Batavia as well as Manila for being the most interesting markets. Batavia imported a lot of Indian calicoes and opium in exchange of sugar, coffee, rice, spices and tin [20]. Some Belgian ships were even exclusively meant for Batavia (1841-43) and that in spite of the bankruptcy of the "Java Bank" (1841) which highly impeded the commercial activities on that island.

Anyway, the consul Lannoy intended to promote the Philippines in the first place. In Manila, during the years 1838-40, the Union Jack already had supplanted the Spanish flag, which was closely followed up by the American colours, while the French and Dutch ships stayed a minority. Among the foreign traders in control of the export trade, the English — like almost everywhere else — were most successful in business. Cotton and window-glass in particular were in demand. As for the home market, that was almost entirely in hands of the Chinese, serving as middlemen between the European merchants and the indigenous producers. Doing excellently as export products, we see sugar, tobacco, *abaca* (also called Manila hemp = stem fibres of a banana plant), coconut oil and last but not least hard cash in the form of silver piastres. Lannoy even was in favour of a colonial possession or at least of a company like the Dutch "Handel-Maatschappij", if necessary granting it the monopoly for some colonial products [21]. By giving this advise, he played the game of the shrewd business man G. F. Ouvrard: this manager was planning to establish a monopoly company trying in 1840-41 to arouse the interest of the Belgian government — hesitating as it was confronted with the international opinion — for annexation attempts in the Philippines [22].

The first Belgian ship with a combined destination to Batavia-Singapore-Manila was the brig "Progrès", equipped at the end of 1839 by the Antwerp based "Société de Commerce". Before this campaign, the company already had undertaken diplomatic steps in view of establishing in Manila an agency under the direction of Ernest Maniglier, who had stayed before on the isle of Luzon. By the way, the return cargos transported by the vessels "Rubens", "Sophia-Dorothea" and "Infatigable" — whereby only the second one had sailed up to Manila — almost exclusively belonged to this company. Moreover, up to its liquidation (1843) it would receive three, two and three shipments, respectively arriving from Manila (1841), Singapore (1842) and Java

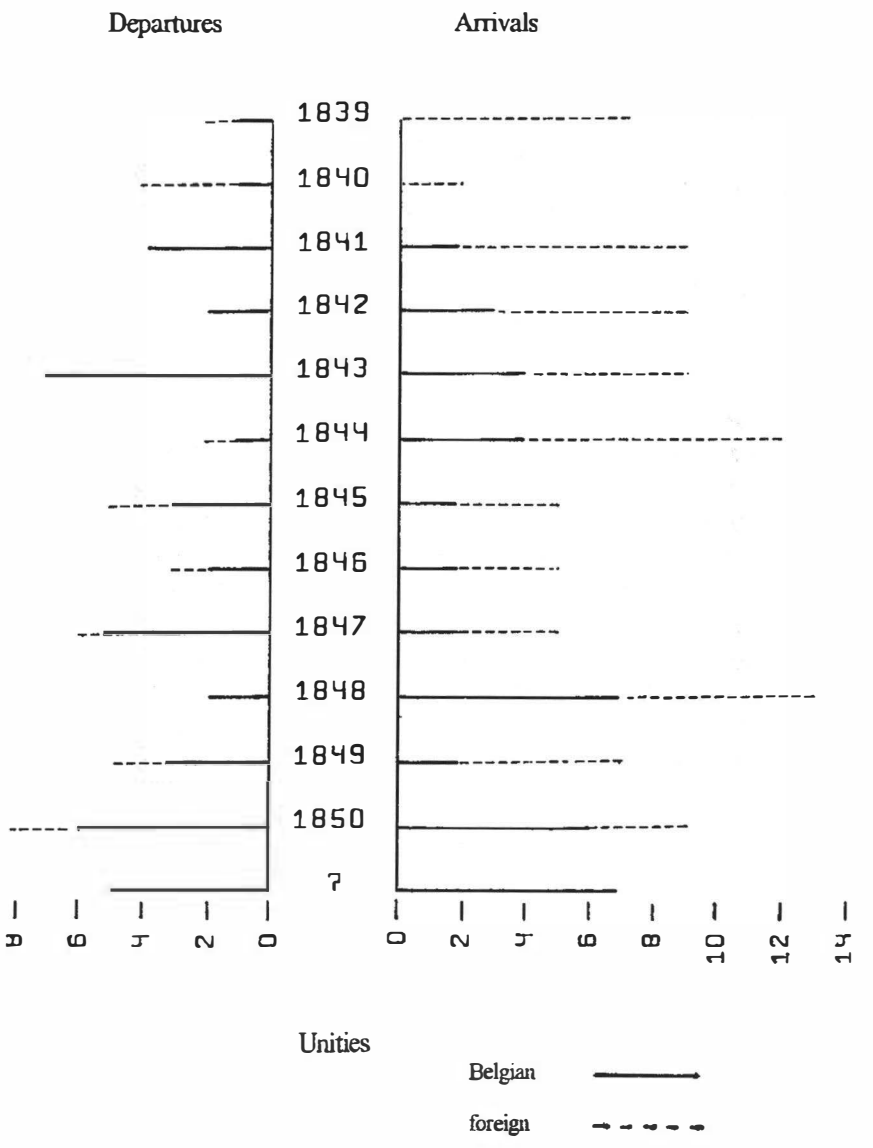

Fig. 1. — Port of Antwerp: shipping traffic with the East Indies (1839 →).

(1841-43), almost all of them carried under the English colours. After the bankruptcy of the forenamed company, the firm of the Notteboom Brothers so to speak ensured the following of its activities [23].

From 1841 onwards, the Belgian navigation to the East Indies took off really well with four departures, mainly heading for Singapore (fig. 2) and sometimes even sailing to the Philippines. Next to that, during the same period, seven ships under foreign flag coming from Batavia and Manila, unloaded in Antwerp. In April 1841, the "Société de Commerce d'Anvers", having applied for financial aid in view of a campaign to Singapore and Manila, was allowed by the government a subvention of 7,000 francs. The "Sophia-Dorothea", belonging to the shipping company of J. Key, transported a Belgian 100,000 francs worth cargo [24]. Meanwhile the same shipowner had sent his "Charles" to Batavia.

Encouraged by the excellent results realized by the "Charles", the firm Cateaux, Wattel & C° had sent off their brig once more. Nevertheless, it was only after the coming back of the "Rubens" from Batavia — its freight (coffee, sugar, rice, rattan and sapan wood) being entirely consigned to the forenamed "Société de Commerce d'Anvers" in which the government had thorough interests — that the shipowner and the minister set up an agreement to start a regular navigation line to Southeast Asia. Indeed, since the summer of 1841, Donnet had already tried in vain to gather a sufficient number of freighters for his "Macassar", an imposing three-master (800 tons), "newly built (dating from 1830 but transformed in 1849), firmly doubled with copper blades", under the command of captain De Wilde "who had regularly made the voyages to the East Indies". Facing the promising prospects on the Asian markets, the government was going to save the shipowner from difficulties in April 1842: for the latter expedition the Belgian navy would procure the crew (44 sailors) that would get its wages and be maintained by the Ministry of Foreign Affairs. The cargo, sent for a part to Singapore and for the other to Batavia, would pay the officially fixed freight rates; moreover merchandize meant for Manila was going to be accepted, even if it was transhipped in Singapore at the cost and risk of the charter partners themselves; ultimately some passengers could embark free of charge [25].

Simultaneously, the ministry consulted the "Commission for transatlantic sailing navigation" about the propitious moment to start a regular overseas line between Antwerp and Singapore [26]. Since the Belgian tariffs were far from competitive, such a line would require an initial premium of at least 12,000 francs per campaign. On the other hand, a possible extension to Batavia was not to be considered for lack of cargo — a point which was

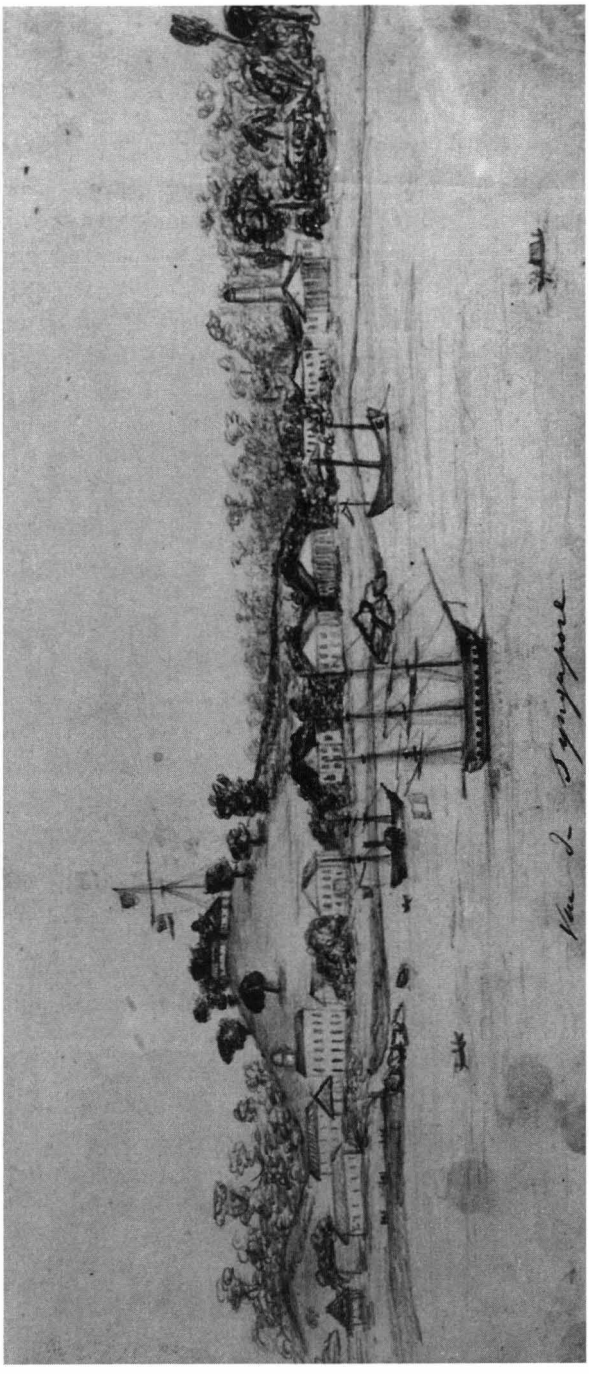

Fig. 2. — View from the roadsted of Singapore (1844). (Pen drawing by Oscar Ducolombier during the calling in of the Ghent based three-master "Emmanuel".)

contradicted by the actual facts and an all the more suspect reasoning since the shipowner F. Donnet was a member of the commission. However, in the autumn of 1841 the government came up again with its intention to launch a regular sailing line to Singapore and Batavia. By way of encouragement, a crew of the national navy was installed aboard. This time the advisory council approved of the ministerial project, pointing out serious objections as to the extension to the line to Batavia. The formula got to be operational from May 1st 1843. Every year two Belgian or nationalized ships with a capacity of at least 250 tons gauge would respectively leave at the beginning of May and at the end of December. Moreover, the government had at its disposal two free passenger seats and could put on board as apprentices two students of the naval schools (Ostend and/or Antwerp) [27].

On paper, the subsidized navigation line was a fact, but the actual launching turned out to be somewhat difficult. By suggesting their brig "Charles" — for that matter of an insufficient tonnage and incidentally in a rather deteriorated shape — the shipping company Cateaux-Wattel only used its candidature to turn Batavia into an optional stopover. They proclaimed that many Belgian manufacturers-exporters still preferred the Dutch ports for the profitable freight tariffs there and also because of the arrangements between them in order to enjoy the preferential import taxes in Batavia, where — on top of everything — Belgian ships were not allowed to sail in [28]. The campaign turned out to be disastrous. After colliding with a coral reef in the Sunda Strait, the "Charles" needed thorough repairs in Singapore. From there heading for Manila, an attack by native pirates in the Macassar Strait brought the finishing stroke: the crew was forced to flee head over heels and the ship was plundered and burnt down, amounting to a total loss of 130,000 florins [29]. Apart from this accident, 1843 was a very busy year: seven expeditions under Belgian colours, of which three subsidized departures under the above-mentioned regime; furthermore four national ships as well as five foreign vessels returned to Antwerp. The favourite destination port was Batavia, then came Manila, followed by Singapore. Never again would the Belgian maritime traffic to the East Indies reach such peaks.

Up to now there was one destination that failed to turn up: China and more specifically the port of Canton (fig. 3). As early as 1834 the shipowner Sinave from Bruges was already heard of having sent an imposing three-master to China but we know nothing of its return. Than, about 1840 the Belgian consulates in Manila (1838) and in Singapore (1841) amply informed our exporters about the commercial modalities regarding China. However, the British and the Americans almost monopolized the maritime trade, respectively thanks to their import of opium — smuggling poppy by the

roadsteads of Sintin and Hongkong — and silver piastres. For this reason the Antwerp Chamber of Commerce rejected early 1840 a governmental suggestion to organize a subsidized campaign, since the Belgian wool and cotton fabrics would not be in the least competitive over there. Meanwhile the hostilities with the English in the so called "opium war" will trouble till 1842 all commercial relations with China. The facilities, dictated by the Nanking treaty, tolerating from then on the foreign traffic in the five Chinese ports, resulted in the opening of Canton from the summer of 1843 on [30].

In the course of 1843 the Chinese outlet was to be explored: some Belgian textile samples, sent off via London (1842) sold really well. So a prospective tour made by Auguste Moxhet posted in Singapore would give high

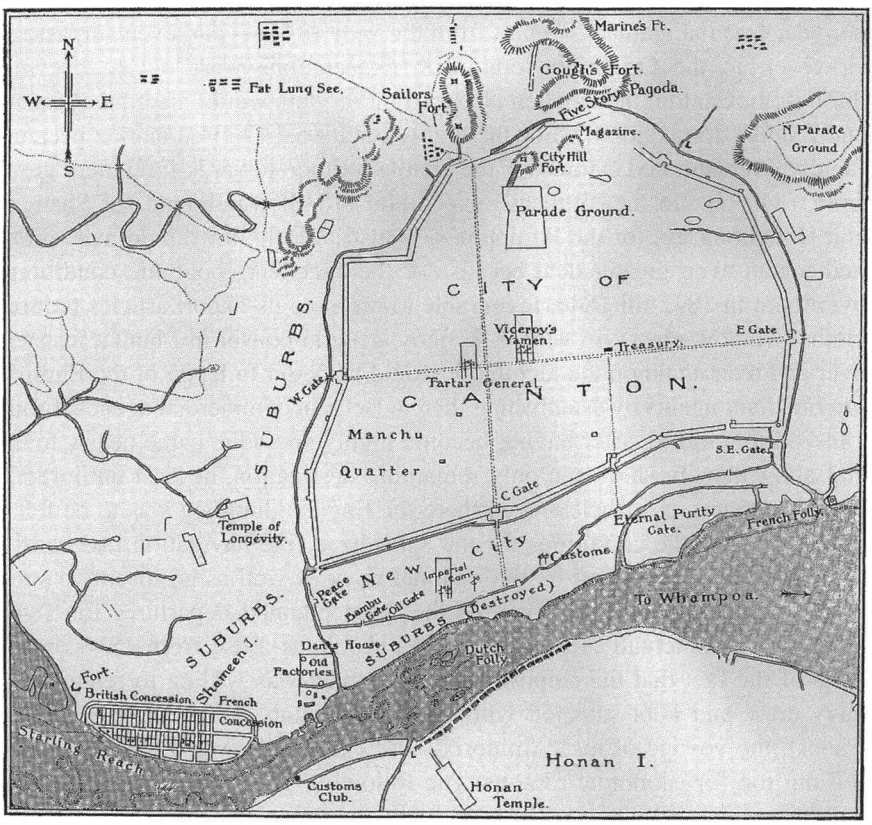

Fig. 3. — Map of Canton — nowadays Guanzhou — compulsory staple harbour for all Western shipping to China.

hopes for the near future [31]. At the end of 1843, the minister had decided to prolong the regular navigation line till China. Two shipping companies — Cateaux-Wattel and N. J. de Cock — were rivals to be the first to undertake the voyage. Finally the three-master "Emmanuel" (851 tons) of the Ghent firm would call near Canton after having forced its passage on the Pearl River. For the first time since 1784-85 our national flag was there to be seen again. In the course of the years 1844-48, only three Belgian ships — each time sent out by the Cateaux-Wattel company — would risk to sail to Canton. Meanwhile, thanks to the mediatory efforts of the French diplomacy, Belgium already had received commercial concessions similar to those assigned to the great naval powers [32].

From 1844 on till half-way 1848, all Belgian expeditions to the East Indies — a dozen in total — were subsidized under the convention regime of 1842. At the same time, the initially planned frequency of two sailing campaigns per year was maintained — apart from the year 1844 — and even surpassed. However, in the Orient the optimistic expectations were not to become through. In Canton, the woollen cloths from Verviers would meet the Russian and English competition, while the highly traditional Chinese market became rapidly oversaturated. Moreover the hostile attitude towards foreigners grew from 1845 on. So the "Rubens" expedition (1848) was bound for Shangai and Hongkong. As for the Philippines, industrial Belgium should have profited for an even greater deal because of the excellent economic conditions over there in 1842 till 1846, favourable to promote its export articles (cotton cloths, window-glass). In vain, J. Lannoy, general-consul in Manila, insisted over and over again on the fact that it would be better to let go of the English intermediary agents by establishing there a Belgian commercial agency. From 1847 on this traffic, after having become highly sporadic, came nearly to an end altogether. In short, the only remaining destination, at least until 1850, was Singapore; nevertheless even there the English dumping was to be felt.

Up to 1847, the conditions for the subsidized line navigation had hardly changed: a crew assigned by the national navy as well as an incentive subvention of 50 frs/ton. However, of the three planned departures for 1846 only two were actually realized. Serious problems arose from 1848 on: in spite of the fact that the shipowner J. B. Donnet was willing to renounce a navy crew and kept satisfied with the usual bounty (more or less 12,000 francs), the voyage of his "Ambiorix" was cancelled. Two more departures fell out too for economic reasons. The following year, only two campaigns would be financially supported by the government at the rate of 25 frs/ton; next to that half of the load of the "Stanislas" consisted of coal, hardly a typical merchandise to conquer the oriental markets [33].

In 1850-51, the regular service to Singapore — a shipping line that would possibly be prolonged to Batavia — survived with the same interval of about a semester, a face that often turned out to be irregular as well. Nevertheless, from then on no other non-subsidized Antwerp vessel sailed that far. As it happened our shipowners had found a much more lucrative and far less complicated traffic: rice from Burma, where Akyab was the main exportation port. In the course of 1848-51 about a dozen Belgian units unloaded this foodstuff in Antwerp, where it meant the start of a new industry of alimentary treatment, namely the husking becoming a very prosperous branch till about 1875 [34]. Among the subsidized campaigns, several ships would make a stop in Akyab on their way back from Singapore. As that was, even more private expeditions under national and under foreign flags directly returned from over there. Some incoming ships even had left Antwerp in ballast, bound for the free port of Akyab. At the same time, next to the traditional shipping companies choosing this customary route, some newcomers showed up like Spilliaerts & Caymax and J. A. Elsen & Van Linden.

Conclusion

During the first decade of its independence, Belgium knew a serious commercial and maritime depression. In order to overcome this crisis, manufacturers-exporters and shipowners actively explored new outlets. Some isolated successes, linked with the combined transactions on the Latin American and South Asian markets via the transpacific route, did not have any effect at all. Only after our relations with Holland had become normalized, the Belgian navigation to the East Indies definitely took off. However without having lost its initial attraction, Batavia was to be eclipsed by the free port of Singapore, the turning table for the lucrative traffic to the Philippines and China. Impressed by the outcome of several particular campaigns, the Belgian government wanted to encourage these new destinations by subsidizing a regular service from 1843 on.

During the following years, the action radius of the Belgian navigation first expanded — combining Singapore, Batavia, Manila and even Canton — but decreased afterwards in spite of the fact that the harbour of Akyab was added to the destination list. The explanation was to be found with the Belgian manufacturers, hesitating to meet the governmental efforts as well as the suggestions of our consuls to export and deal directly to the Orient. Obviously, instead of heading for the Asiatic markets, controlled by the

British and the Americans, the Belgian businessmen continued to prefer the relations with the American markets (New York, Central America, the Antilles, Brazil, Rio de la Plata) which they were accustomed to.

From 1846-47 on, the regular line started to suffer from a series of perturbations: cancelled campaigns, frequently delayed departures at the request of the freighters, increasing tonnage of the ships and hence unability of the government to meet the needs of a free crew and to grant a considerable bonus. Consequently in 1848 the financial support by the Belgian authorities was radically cut down. Nevertheless at that moment the Antwerp shipowners had already found a new resource: the rice traffic from Burma, of which the large-scaled consumption was propagated since the 1846-47 famines.

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'The Advantages of Commerce, and Commerce Alone': The Financial Fictions of the Straits Settlements and Occidentalist Imaginings of the Globe

by

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The prevailing fictions, or cultural myths, of finance generated in and about Singapore originated in colonial discourses on "romantic commercialism" and a "benign" or "gentlemanly" capitalism that grew out of late-eighteenth-century liberalist economics, and which have despite an onslaught of revisions of orientalist geographies been perpetuated through and beyond a postcolonial re-mapping. Representations of flows of finance have, in fact, long been working this way around critical readings of the impact of traditional commercial hubs on postcolonial as well as colonial imaginaries, even while they undoubtedly run through them. As it aims to re-examine critically the fictionalisation, in the widest sense of the term, of the "financial straits," the former British straits settlements, now stretching across the postcolonial nation-states Singapore and Malaysia, this paper seeks to analyse the commercial and commercialised clichés created by both orientalist and occidentalist cultural myths, tracing their historical origins and persisting legacies. It draws on a variety of textual sources to elucidate colonial and postcolonial developments in literature and art in this specific region. While local contemporary art increasingly works against the postcolonial label, the status of the anglophone, or English-language, novel forms a revealing illustration of a critical and, at its best, a self-critical representation catering for the global as well as, in significantly different manifestations, the local book-market.

Historical overview: legacies of "Romantic commercialism" for the financial hub Singapore.

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First of all, I shall provide a brief historical overview of the origins and re-conceptualisation of "romantic commercialism" and its legacies for the cultural fictions and specifically the literary fictionalisations of the financial hub Singapore. When Thomas Stamford Raffles, persistently evoked as the "founder" of Singapore, sought to stress "the reciprocal advantages of commerce, and commerce alone, that we may best promote our own interests and their advancement" (RAFFLES 1819, p. 24), as he put it in his minutes on the establishment of a Malay college in Singapore in 1819, he significantly, albeit inadvertently, marked out a twofold interest in a region he regarded as at once exotic and vital to British commerce. He considered the role of the empire as premised exclusively on commercial relationships, on the consolidation of strategic trading-posts, and the exchange of goods and people, and in the process, he conceptualised categories that stuck, as it were, in and to the region.

Following Raffles's mythologised vision — and I shall come back to the significance of this mythologisation — port-cities were laid out for the advantage of the British and their subjects, both local and "imported." These "imports" of human resources for the benefit of commerce fed at once on and into the region's multiethnic make-up, generating the racial categorisations that became central to an ethnically stratified colonial division of labour. Classificatory systems such as the cmio categories of Chinese, Malays, Indians, and others still current in postcolonial Singapore and likewise the continued use of racialised categories in Malaysia are rooted in orientalist fictions of a multiethnicity tied up with commercial stratification.

As one of the perhaps most persistent cultural fictions of the "financial straits," the "Raffles myth" calls for a re-examination that strives to engage with the growing complexities and problematics of occidentalism as a discourse, or field of discourses, that continues to set itself up as much more than simply orientalism's counterpart. A commercial hub always constitutes also a new and often fascinatingly diverse inter- (if not necessarily multi-) cultural hub — a new centre of a unique society and culture that is not simply reflected, but nourished and re-formed, by literature and art. In his recent work on the straits Chinese community that developed in the British straits settlements over the nineteenth century, Mark Frost speaks of the formation of a "transcultural diaspora" as the new port-cities came to emerge as nodal points and cultural as well as administrative centres in their own right (FROST 2003).

In an attempt to draw the significance of the straits settlements for colonial history and literature into new debates, this paper therefore reassesses not so much Raffles's construction of "benign" commerce, but the ways in which it

was reused in the course of the following centuries to set the scene for many contemporary financial straits. Through John Crawfurd's racialised reconstruction of economic mapping and the works — administrative as well as literary — of Victorian residents of Singapore and Malaya, such redevelopments of the "raffles myth" group themselves together as a pivotal centrepiece of the region's financial fictions and their current rerepresentation.

In fact, as colonial administrators used fiction and non-fiction to promote free trade as an advantage for both the colonisers and colonised, they set these commercial centres firmly on the map. At the same time, they increasingly introduced racial categorisations into the representations of the region's population. Incorporating Victorian racialism in their recasting of climatic as innate differences, they moreover also contributed significantly to the invention of "the West" as well as to the more prevalent orientalisation of "the East." This in turn formed the foundation for a new polarisation of the globe that preceded a growing self-consciousness about the occident at the end of the nineteenth century.

The centrality of British commercial hubs in Southeast Asia for this "proto-globalisation" was ironically the result of a British "lateness" in the region. Starting out only with port-cities established between 1786 (Prince of Wales Island, or Penang) and 1819 (Singapore), the East India Company was a late-comer in Southeast Asia. As opposed to the Dutch East Indies, these trading-posts were peppered across the Malayan peninsula and its surrounding islands. It was only during the napoleonic wars that the British empire was able to cut successfully into local trading-routes, as colonial conflicts were invaded and redefined by imperialist ventures within Europe. Commerce expectedly formed a vital flow of influence in the formation of a — specifically commercially oriented — colonial culture, and ultimately also its literary representations.

Although at first only as a wishful fantasy, commerce had of course already been capitalised on in early-eighteenth-century writings on the region. William Dampier and, in his wake, Daniel Defoe generated orientalist fictions of commercial resources that pertained particularly to a region deemed to be at once unexplored (by the British at least) and commercially exploited by the Dutch. Accounts of travel (imaginary ones included) conjured up the fabulous riches of an uncharted far east. As Robert Markley has shown in his reading of Defoe's *A New Voyage Round the World* (1724), they were implicated and functioned within "the financial fantasies [...] of explorers, pirates, merchants, and venture capitalists" (MARKLEY 2003, p. 495). For Defoe, the Spice Islands featured as an insatiable market for European exports and a supplier of luxury goods. It was this imaginative

force of inexhaustible resources, as fuelled by literary speculation, that was to direct plans for exploration.

Nevertheless, at the end of the eighteenth century, the Dutch still dominated European trade in Southeast Asia. They exercised political control over most of Java and, having replaced the Portuguese, had taken Malacca. Thus, they effectively shut out the British from any significant shares of trade in the Far East. It has therefore repeatedly been argued (ever since Raffles, in fact) that the Dutch consolidation of economic power was affected more ruthlessly than by their European or Asian competitors (MARKLEY 2003, p. 495). This vilification of the Dutch was to become central to Raffles's romantic commercialism as underpinning his arguments for the establishment of trading-posts.

The founding of a "factory", as he was to put it, on the island of Singapore in 1819 was meant to secure a British port in the region precisely in order to break through the Dutch monopoly. As H. F. Pearson has sensationally put it in his biography of Raffles, this other India, Raffles was "grasping an island out of the hands of the Dutch and handing it to an unwilling England" (PEARSON 1957, p. 112). The new trading-port soon flourished, though it was Crawfurd, not Raffles, who signed the treaty that was to make Singapore a British possession in 1824. Although he was never to return to the port-city he had found, or founded, Singapore's commercial success guaranteed Raffles's elevation into a near-mythical figure as a visionary foreseeing Singapore's successful commercial future — a fascinatingly financial mythologising that not only obliterated Singapore's pre-colonial history, but also obscured the importance of colonial administrators, and writers, such as Crawfurd. The latter, however, not only contributed materially to the establishment of Singapore as a commercial port, but his emphasis on racialised economic qualities, or values (monetary and otherwise), irrevocably stratified representations of the region.

The founding myth that put Raffles's role in the "discovery" of Singapore into the foreground was essentially a Victorian invention. It was instigated by the memoir of the life and public Services of Sir Thomas Stamford Raffles in 1830, written by Raffles's second wife, Sophia. Building on his fusion of economic interest and ethnography, it helped to generate the region's twofold allure as a site of commercial enterprise and exoticism. The 1880s saw the erection of a statue in Singapore; by the beginning of the next century, biographies were eagerly idealising him as a romantic discoverer. Hugh Edward Egerton's 1910 Sir Stamford Raffles: England in the Far East introduces Raffles as a man "to whom more than to politicians or treaties Great Britain owes her position in the Far East" (EGERTON 1900, p. 1). The creation of

Singapore as an epitome of free trade set against Dutch mercantilism is cast as his main achievement.

Nirmala Puruhsotam has pointed out that the underlying fiction of Raffles's hagiography is that of discovery, a narrative in which Raffles "landed on a piece of property whose value could not have been recognised up to then for it was but inhabited by a few people, primarily named as 'Malay' and 'fishermen'" (PURUSHOTAM 1998, p. 207). As part of Singapore's founding myth, it has continued to inform its (self-) representations. The promotion of "civilisation" as a result of commerce became central to the "raffles myth" and, even more tellingly, what Nicholas Tarling has pointedly termed the "rafflesian aspirations" of Victorian commercial explorers such as James Brooke, first white rajah of sarawak (TARLING 1993, p. 37).

Poising the virtues of British trade policies against Dutch mercantilism, Raffles indeed repeatedly preached a need for "[t]he entire abolition of forced deliveries at inadequate rates, and of all feudal services, with the establishment of a perfect freedom in cultivation and trade" as well as for the reform of the principles of land rental and detailed settlement (RAFFLES 1817, vol. 1, p. 155). Commerce, he emphasised, was "universally allowed to bring many benefits in its train, and in particular to be favourable to civilisation and general improvement" (RAFFLES 1819, pp. 23-24).

The Dutch, Raffles further argued, had ruined pre-colonial commerce, which the British would restore by opening it up to free trade: the Dutch had "very much diverted [commerce] from its ancient course by the restrictive system of Dutch colonial policy [, resulting in] the loss of that commerce, which may be said to be as much the growth of the country as any of its indigenous plants" (RAFFLES 1819, vol. 1, p. 193). Anthony Forge has argued that this emphasis on the differences between Dutch and British colonial systems is clearest in his views on the economic nature of the Javanese, whom he cast as "civilised" and therefore, "like all civilised men, an example of 'economic man'" (FORGE 1994, p. 109).

When Crawfurd took up this economically motivated and mapped ethnographic stratification, he developed a racialised discourse that anticipated Victorian racial science. His history of the Indian archipelago of 1820 combined anxieties of degeneration and a new understanding of inherited racial characteristics, in the process also conceptualising "the West" as a new entity, even while it newly categorised Southeast Asia's peoples. Lumping together European nations, Crawfurd speculated on what he considered the probable outcome if people from "the West" were to compete in the mining industry with Chinese and indigenous people on the Malayan peninsula: "were the European race to engage in the same occupation on fair terms,

that is, supposing them legitimately colonised, we should find a new and higher grade added to the scale, if indeed their superior vigour and intelligence did not soon banish competition" (CRAWFURD 1820, p. 459). Thus, he prefigured a racialism that was to be consolidated by the works of Darwin and, with specific focus on Southeast Asia, Alfred Russell Wallace's *The Malay Archipelago* (1869). As Mary Quilty succinctly puts it, when Crawfurd stressed advancements in "the West," which native peoples were to emulate, he was "not referring to the west of the archipelago, but rather use[d] 'west' as a generic term for Europe" (QUILTY 1998, p. 75). Yet, Crawfurd went much further than merely working towards the inclusion of a little explored region in an ever-expanding orientalist imaginary. In fact, he anticipated interest in an occidentalism that grew simultaneously: first as a largely emulative study of "the West" and then as a retaliatory counter-discourse.

Thus, while critics of Joseph Conrad's "Malay fiction" (primarily set in what is now Indonesia, with brief excursions to Singapore) have recently unearthed the significance of the region for a new idea of "the West" (GOGWILT 1995), its creation as an ideological entity, in fact, originated in pre-Victorian concepts of commerce: in the economics underpinning Raffles's romantic commercialism and the "Raffles myth." Nearly a century after Crawfurd's adaptation of the economic arguments underpinning this myth and significantly via Victorian (hi)stories of a romanticised Raffles, it resurfaced in Conrad's novels and ultimately also in the postcolonial fiction in which he continues to figure strongly.

Repackaging the Commercial Hub in New Exotic Fiction for a Global Consumer

The second part of this paper will therefore more particularly set a framework for the reassessment of both (neo-)orientalist and occidentalist clichés in the cultural fictions produced in and about Singapore. This continued focus on the commercial relationships that have formed and continue to inform the region's (self-)representation brings together studies of colonial and postcolonial discourses.

In Conrad's 1895 *Almayer's Folly*, the first published novel in his trilogy of "Malay novels" (written in English, but set primarily in the Malay archipelago, and comprising *Almayer's Folly, An Outcast of the Islands*, and *The Rescue*), the titular protagonist wallows in unconsummated desires for elusive riches, for treasure to be hunted, but also for participating in flows of commerce that are perceived as running through a largely unexplored, but

commercially mapped, Southeast Asia: "it was the point in the islands where tended all those bold spirits who [...] invaded the malay archipelago in search of money and adventure [...], not disinclined for a brush with the pirates that were to be found on many a coast as yet, making money fast" (CONRAD 1947, pp. 6-7). As I have argued elsewhere, this forms an important emblematic meeting of Malay pirates and European businessmen that expresses central anxieties about uncertain financial speculations at the time (Wagner, forthcoming). Most poignantly, Almayer's ambitions to send his half-Malay daughter to Singapore for a "western" education, his dreams of "returning" to a Europe he never saw, and his unrealised visions of intangible riches explode the myth of discovery and adventure, of the "Rafflesian aspirations" of elusive explorers.

Conrad's novels thus conflict, but ultimately reinforce, the significance of commerce in the "financial straits." The presence of his works, or of times, places, events associated with them, in the region's postcolonial literature illustrates the ways in which he helped to make orientalist Southeast Asia and its most pertaining cultural fictions. Combined and entangled with invocations of Raffles and the "Raffles myth" (with Crawfurd forming a striking absence, overshadowed, or indeed absorbed into this cultural myth), a central fiction of commercial adventure continuously figures as a centre-piece in (neo-)orientalist spectacles as well as in its occidentalist repackaging.

Paul Theroux's 1973 novel *Saint Jack*, in fact, coined the phrase the "financial straits" for the straits of Malacca (THEROUX 1973, p. 101); J. G. Farrell's iconic *The Singapore grip* (1978) describes Singapore as a city that "was simply invented one morning early in the nineteenth century by a man looking at a map" (FARRELL 1978, p. 3). It is the "Raffles myth" once more: "'here,' he [Raffles] said to himself, 'is where we must have a city, half-way between India and China. This will be the great halting-place on the trade route to the far east.'" (FARRELL 1978, p. 3).

The most intriguing reflux of this confluence of financial flows in their literary representations, however, has occurred in works that self-consciously sport their interest in occidentalist revisionism. The intersections of influence map out the ongoing transformation of a commercial hub into a cultural (and multicultural) one. Singaporean anglophone fiction forms a markedly useful point of entry, as it indicates the immense divergence of locally produced writing and the repacking of neo-orientalist mythologisation for a global readership. The local "heartlander novel" that increasingly ousts ethnographic observations for a new emphasis on class issues perhaps most sharply contrasts with the marketing of an often indeterminately vague Southeast Asia abroad (WAGNER 2003), as part and parcel of what Graham Huggan has

termed the "postcolonial exotic" (PASSIM 2001). Still, both genres exhibit a new interest in financial fictions specifically, and this is surely telling.

What is of central significance here, however, is the re-representation not simply of the financial hub Singapore, but of Singapore as a financial hub. Rather than taking up the ways in which historical novels, for example, present the past, I shall illustrate the pervasiveness of the region's financial fictions by taking a brief look at two novels about globalised Singapore: Tan Hwee Hwee's tellingly titled Mammon Inc. and Catherine Lim's *Following the Wrong God Home*, published abroad in 2001, they cater for the global consumption of a "postcolonial exotic" that is moreover specifically concentrated on financial flows in a globalised, urban culture. They thereby set up a new orientalist imaginary of an urban Asia self-defined by economic drives. As their revisionist occidentalism aims to turn "Asian affairs" inside out and upside down, they re-imagine "the West" and the imported "westerner" as a weak — or weakened — subaltern that fails to live up to what is presented as a peculiarly Singaporean strife for economic excellence. This revisionism will then be compared with a more creative reworking of, rather than feeding on, the postcolonial label in Ho Tzu Nyen's recent installation and short film Utama — every name in history is I (HO 2003).

In Lim's novel, the perennially popular story of marrying for money is given a local slant, as the heroine has to choose between her sleek, successful, somewhat dull Singaporean husband and a scruffy, unreliable, but exotic American expatriate. In the tumble that results from a rough turning upside down of "Asian affairs," heavily stereotyped Ben Gallagher is victimised, and so is the lovelorn heroine: she dies in a plane-crash in China, appearing on the passenger list under her lover's surname. The predictable love-story is made more interesting by the symbolism of the god-with-no-home. This unidentified figure is expelled from "the staircase gods" that reside in a secret shrine the heroine's mother-in-law keeps hidden under a staircase since her son's conversion to christianity as well as from the more openly displayed nativity group in the living room. Neither does it fit in a touristy religious theme-park, where the lovers explore their desire for a god of love. While the unclassified god's homelessness externalises the confusions of multiculturalism, it also builds up to the ultimate irony of the mammon-worship underpinning values of work and economic success: "Singapore was dominated by the acknowledged gods of common sense, duty, money, security, power, who could not be put to flight by love" (LIM 2001, p. 209).

Tan's tellingly titled *Mammon Inc.* even more emphatically sets Singapore on a globalised map. Its version of postcolonial self-exoticisation capitalises precisely on new cultural fictions of a commercial hub that seeks to be fur-

ther interconnected to globalised networks of economic, cultural, and other forms of exploitation and also a self-exoticising exhibitionism. cultural adaptation is presented as a global enterprise, as a system developed by the devil-like draco sidious and his "ueber-managers," "adaptors" of "global nomads" who see themselves as creators of a new "master race" (TAN 2001, p. 64). Globalised cultural hybrids put on sale, they promote an identity-politics that functions like a credit card: to "be accepted by business vendors around the world — sort of like visa" (TAN 2001, p. 59).

Again, a fragile, red-haired, naïve "westerner" is victimised, and on top of that, the novel's heroine shuttles aimlessly between occidentalist desire for a medieval ("western") mysticism and what is presented as modern (Singaporean) materialism in a rather rough realignment of "eastern" and "western" values. She is tellingly "zenned out" (TAN 2001, p. 208) by the spirituality she experiences in the fictitious oxbridge college dagobah hall (named with an allusion to star wars), but there is little patience with such an emulative occidentalism in a money-minded globalised society. Most importantly, however, instead of wallowing in sentimental evocations of a pre-colonial, pastoral bliss poised against "western" modernisation, recent novels like these describe a distinctly Asian urban culture, engaging with an occidentalist revamping in more ways than one.

In Conclusion: Re-visioning Revisionist Occidentalism

However, if these globally marketed novels rework fictions of financial hubs by playing with stereotypes of modernisation, globalisation, or international commerce past and present, local literature at its most intriguing tends to treat the theme of discovery altogether as a running joke. Thus, Douglas Chua's science fiction novel *The Missing Island* (2002) features a Singaporean "crafty and successful businessman" and "classic opportunist" who sets out to rediscover mysteriously vanished Singapore in order to claim it as a piece of property in his own neo-imperialist venture.

> Christopher Columbus discovered America and he became the founder of America in history. Similarly Sir Stamford Raffles founded Singapore and Sun Yat Sen landed on Taiwan. History had a long list of founders and they seemed to own what they discovered from gold mines to precious minerals. Now if Richard Shaw were to find a missing island, would I not be the founder and owner of this piece of property (CHUA 2002, p. 99)?

The myth of discovery is thus very much present in evocations of the region's useful harbours, discoverable islands, or commercial opportunities

(and through a natural extension, opportunists). I shall conclude this presentation with a brief look at Ho's recasting of Singapore's discovery in Utama — every name in history is I. As it reworks myths of Sang Nila Utama, legendary first king of the Malays, who is said to have given Singapore its name after having spotted a lion on the island (hence "Singapora," "Lion-city"), it intermixes myths of Raffles, of the theme of discovery that has continued to circulate in Singapore's success stories as well as in their cultural critiques. It thereby conceptualises a creative revising rather than an ideologically revisionist occidentalism that pointedly resituates both occident and orient as cultural imaginaries. While I can hardly do justice to the complexities of the works of literature and art I have taken up as illustrations here, their interpretation has, I hope, become enriched by an awareness of the origins of the cultural myths they take up and transform. Their new engagement with orientalist and occidentalist discourses, in fact, increasingly works through, but ultimately seeks to transcend, self-exoticising revisionism.

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Such maritime hubs have been important not just for consequential exchange of useful and valuable commodities, but also for less materialistic exchange in terms of religion, science and technology, and culture, including political philosophy. Thus tea, porcelain and silk went from the premier maritime hub in the Pearl River Delta of China to Europe in the 19th century, mostly in exchange for opium. At the same time many less immediately tangible ideas and cultural artifacts which were no less consequential went in the opposite direction. It is thus not surprising that many of the great and influential reformers of Qing Dynasty China came from the Pearl River Delta region where they were influenced by Western ideas sometimes via the missionaries who had an established presence. [1]* Moreover, new and distinct cultural trends with indicative markers have surfaced. These are the contact induced neologisms, and the partner languages in the contact situation can serve in turn as *donor* and *recipient* languages in the diffusion of the new words.

However, like contact situations in general, the two-way lexical and linguistic transfers might not be equal and balanced. Any imbalance results in non-reciprocity in the encounter and the extent and nature of the imbalance deserve examination. China coast Pidgin has had mostly English words but Chinese syntax. It produces interesting historical data for such study. This paper will focus on the more recent developments. In particular, it attempts to explore the differential nature of the bi-directional exchange of lexical items and the cultural artifacts they represent, as well as the wider implications for our appreciation of river deltas and their role in the diffusion of materialistic substance and cultural traits.

2. Material Exchange and Cultural Contact

Until the advent of air travel, maritime hubs have provided greater flexibility than land locked cities or metropolis not only in the two-way flow of trade, but also of cultural artifacts and ideology. A number of interesting questions can be raised about the nature of the interflow:

1) How *reciprocal* and *equal* is the two-way flow mediated through human contact?
2) If it is not, what may be the extent and causes of the imbalance?
3) What may be the greater implications for the study of the nature and mechanism of cultural diffusion?

* The numbers in brackets [ ] refer to the notes and references pp. 282-284.

Answers to the first question can be easily found but not the others. This is because reciprocal and equal bi-directional interflow is exceptional, especially in a non-global context. Take the example of the flow, in one direction, of primary industrial products such as minerals, grains, fabric and the contrary flow of manufactured products such as machineries or vehicles, processed food stuff, and clothing. There is often imbalance in terms of the *volume* or *value* of goods exchanged (*e.g.* difference between crude iron ore exported and the import of finished products such as shinny vehicles). Such a situation would be typical of the many economic links between the developed and the underdeveloped countries of the world.

In the last few centuries, following the expansion of European interests in Asia, and the development of the silk route by sea, much material exchange and cultural contact have been conducted through the major maritime hub of Canton in the Pearl River Delta as designated by the Imperial Court in Peking. In the 19th Century there were identifiable gatekeepers and human agents who exerted strong control on the extent and impact of material inflow and outflow: (a) government civil and military officials; (b) merchants; (c) missionaries [2] as well as (d) translators and other intermediaries such as compradors. These gatekeepers became stake holders for the following kinds of exchange.

Outflow-Exports:

Materials/Products	*Agents*
Tea	Merchants
Silk	Merchants
Porcelains	Merchants

Inflow-Imports:

Materials/Products	*Agents*
Opium	Merchants
Science	Missionaries (doctors)
Medical	
Physical	
Military	
Religion	Missionaries
Political Philosophy	Intellectuals
Democracy	

The critical nature and extent of the regulated control exerted by human agents can be seen from an examination of the following Articles of the 1858 Tianjin Treaty between Britain and China, after the First Opium War:

ARTICLE 50

All official communications, addressed by the Diplomat and Consular Agents of Her Majesty the Queen to the Chinese Authorities, shall, henceforth, be written in English. They will for the present be accompanied by a Chinese version, but it is understood that in the event of there being any difference of meaning between the English and Chinese text the English Government will hold the sense as expressed in the English text to be the correct sense. This provision is to apply to the Treaty now negotiated, the Chinese text of which has been carefully corrected by the English original.

第五十款

一、

嗣後英國文書俱用英字書寫，暫時仍以漢文配送，俟中國選派學生學習英文、英語熟習，即不用配送漢文。自今以後，凡有文詞辯論之處，總以英文作為正義。此次定約，漢、英文字詳細較對無訛，亦照此例。

The Chinese version of Article 50 contains an extra sentence not found in the English version: "Upon China selecting and sending students to study English, and upon their acquiring familiarity with the English language, a Chinese version will not accompany the English" (俟中國選派學生學習英文、英語熟習，即不用配送漢文).

This extraordinary additional sentence reveals the extent of influence exerted by intermediaries such as translators in a closed society in which they held the exceptional key to critical international communication. It is clear that these translators harboured a desire and the ambition to go abroad to study English, a possibility prohibited by the Qing Dynasty government, which had stringent policies restricting contact between ordinary Chinese citizens and foreigners, such that violations could result in capital punishment. Thus, the translators on the Chinese side could take advantage of the occasion of the Treaty to make personal gains. This is because there was minimal calculated risk either of the British side uncovering their errors, or of more senior officials in the Chinese Court challenging their translation. By seizing this unique opportunity to maneuver the Imperial Court into providing opportunities for language study abroad for themselves or other interested parties, the court translators unexpectedly exercised their own control and so became opportunistic gatekeepers. A comparable situation among European nation would have been quite unlikely.

Setting the stage for codifying the imbalance between the English and Chinese languages in the region, the next and penultimate sentence in Article 50 also stipulated the supreme status of English over Chinese in

the international transaction. Thereafter, for 150 years, and until recently, the linguistic imbalance remained in colonial Hong Kong which replaced Canton as the premier Treaty port on the China coast.

The next article is also of interest:

ARTICLE 51

It is agreed, henceforward the character 夷 "I" (barbarian) shall not be applied to the Government or subjects of Her Britannic Majesty, in any Chinese official document issued by the Chinese authorities, either in the capital or in the provinces.

It indicates an unusual quirky language concern, in terms of an undesirable nickname and an unrealistic as well as naïve attempt to regulate linguistic terms [3]. Such a concern remains exceptional and significant in diplomatic history for the gravity of the concern could be hardly comparable to another Article in the same Treaty which stipulated an enforceable and very significant provision: the indemnity of several hundred thousand taels of silver. It can be therefore argued that the drafters of the original treaty in English unknowingly became opportunistic gatekeepers on language *use* in addition to language *choice*. A timely appreciation of the rationale and motivation behind this effort probably inspired the Chinese court translators in their own unusual and inappropriate attempt while attending to the translation of Article 50.

From Articles 50 and 51 of the Treaty of Tianjin, we can have a glimpse of the uncommon but interesting background of the social forces at play in the formation stage of the Pearl River Delta hub.

Bi-directional flow of goods has had overwhelming significance for Britain and the West (who were at loggerheads at times over the sharing of benefits and over participation in the lucrative China trade) such that Britain was able to repatriate much net profit to fuel the Industrial Revolution already in full swing at home.

History has generally viewed this exchange as a negative experience for China because of the spread of opium addiction and the forced opening of its territories to foreign power as well as material loss through the harsh indemnities China had to pay for her military defeats.

When not viewed in materialistic terms, there could be argument that some significant gains were made in other contexts of exchange. They pertain to exposure to western sciences, politics, philosophy, and culture, and

the subsequent diffusion of relevant knowledge in these areas, following the Age of Enlightenment in 18th Century Europe, and these far imported ideas combined to hasten the end of feudalism in China after several millennia.

It is little wonder that many of the intellectual giants responsible for the transformation of feudal China were from the Pearl River Delta and were direct beneficiaries of such contact. Dr SUN Yatsen, founder of the First Republic, Mr LIANG Qichao, and Mr KANG Youwei are good examples of such influential gatekeepers. Not only did the Chinese elite benefit from the enriched delta and hub culture and the unusual ambience it provided, but there were also other fellow travelers passing through these intellectual cross-roads, such as Jose Rizal, the leading reformer of the Philippines under Spanish rule, who lived for several months in Hong Kong in the early 20th Century, before Dr Sun graduated from medical school in Hong Kong. Against this background, it would be useful to explore the importation of ideas and cultural artifacts and what may be possible causes for any imbalance. Of special interest will be the filtering processes which resulted in the imbalance. We have seen that human agents or gatekeepers could be identified to have exerted control in the exchange of material goods. What about the filtering of the flow of ideas and cultural artifacts?

We propose to explore this through an examination of the associated neologisms representing new ideas and cultural artifacts. This is justified because a language does not take on new words without its speakers gaining awareness in respect of the concepts or cultural artifacts the neologisms stand for. The neologisms resulting from the lexicalization process embody conscious or sub-conscious recognition of new concepts or artifacts within the recipient culture. We shall begin our analysis on the basis of such lexicalization in English and Chinese within a well-defined and comparable framework, and explore both *quantitatively* and *qualitatively* the nature and extent of the exchange of cultural artifacts underlying the neologisms. It is methodologically important for the analysis to be based on a rigorous and comparable framework, for it would be grossly inadequate to take on piecemeal examples without a proper context of time and of the content of coverage. Dictionaries can offer a usable framework which presents an unusual window on the relevant linguistic community and the lexical entries have been filtered by lexicographers who would be in tune with the cultural scene in the community. However, the comparison of two dictionaries can readily introduce considerable difficulties because of the different timing of the publications and so the issue of comparable temporal framework can be a serious one. Also, the invariable differences in the size of the dictionaries, and perhaps the lexicographical effort could pose a problem because the number of

words collected and so the window opening they offer on the relevant society, would be subject to different constraints and very likely would not allow suitable and rigorous comparison. It would be preferable if the comparison could be made objectively on a synchronous basis by agents wielding comparable yardsticks.

3. Lexical Innovations and Cultural Contact

We have taken a Windows approach with two sets of words carefully selected by Kwok and Chan (1982) [4]. The first is a list of English words phonetically adapted from Chinese and the second a list of Chinese words phonetically adapted from English. Appendix I contains the list of English neologisms with Chinese origin. Its Column 2 contains the entries; Column 3, the English glosses; Column 4, the source language glosses; Column 5, occurrence of the neologisms in the Oxford English Dictionary (OED) (online) to be compared with Column 6, occurrence in the South China Morning Post (SCMP) (3 years from 2003 to 2005) published in Hong Kong, and Column 7, general cultural spheres relevant to the neologisms.

Of special interest in this paper are the added columns 5 (*OED*), 6 (*SCMP*) and 7 (*Sphere*). They allow *synchronic* and *diachronic* comparisons to be made on the entries as a whole with reference to the OED (online), and the local South China Morning Post. The last column *Sphere* also allows us to make other internal comparisons, as will be elaborated on below.

Some initial quantitative comparison may be useful. It can be seen that after a quarter of a century 40 out of the 59 sets of neologisms are found in the recent OED (online) whereas 47 sets of the entries are found in the South China Morning Post. Furthermore, 35 overlapping items are found in the two lists. This would indicate that a large percentage of words have remained stable in English and are in current usage in Hong Kong, though a sizeable number has been dropped. Moreover, many more items are found in the OED than in current usage.

The authors referred to the Chinese traditional classification of daily life into 4 major *spheres*: (1) 衣 *Clothing*, (2) 食 *Food*, (3) 住 *Accommodation* and (4) 行 *Transportation*. We have utilized an expanded scheme to include other spheres such as *Entertainment, Medicine, Measurement* and *People* as well as *Others*. On the basis of this augmented scheme, it can be seen that *Food* (32.2%) embraces the greatest majority of English words of Chinese origin in use in 1970's, as summarized in table 1. This is followed by (H) *People* (13.6%) in second place. From these distributions it can be suggested

that: (1) Chinese *cuisine* and (2) social role differentiation in Chinese society, were of utmost interest to English speakers, mostly likely because of their novelty, and the relevant Chinese words have been adopted as phonetic loans by the English language. It is also interesting to note that English neologisms relating to Chinese *Food* outnumber those relating to *People* by about two and a half times. We shall further explore this difference.

By comparison, the number of items on the second list of Chinese neologisms of English origin is much greater as it contains more than 480 sets of entries, contributing more than 300 sets of basically synonymous words. The size of this list is at least four times more than that of the list of English words of Chinese origin. The distribution of the Chinese words of English origin also provides interesting indications of qualitative differences in this contact situation: Again from the Chinese neologisms in Table A, the saliency of 68 *Food* items (21.94%) outweighs the 31 *People* items (9.35%) by more than two folds. Furthermore, *Entertainment* also outweighs *People*. This indicates that the Chinese of Hong Kong have had lesser communal awareness (if not lesser interest) involving English (or Western) social role differentiation than western food. In absolute numerical terms, we note that in the *Food* sphere there have been many more Chinese neologisms of English or Western origin than the reciprocal English neologisms in a cross-linguistic comparison. This presents interesting contrast with the intra-linguistic comparisons made above and involving other spheres in Chinese.

Table 1
Comparison of Neologisms in Cantonese and English (CHAN & KWOK 1982)

%	**English Neologisms** (from Chinese)	**Chinese Neologisms** (from English)
A. Clothing / Fashion	3.39	7.42
B. Food	32.2	21.94
C. Accommodation	0	2.26
D. Transportation	3.39	3.87
E. Medicine	0	6.77
F. Entertainment	1.69	14.19
G. Measurement	5.08	8.39
H. People	13.56	9.35
I. Others	40.68	25.81
TOTAL (%)	**100**	**100**

The quantitative imbalance in the linguistic exchange favors the importation of a greater variety of English words and so cultural artifacts into

Chinese than in the reverse direction. This is complementary in nature to the situation involving the variety of material goods being imported or exported in the contact situation. Thus, there is also qualitative difference in the cultural artifacts being imported, as reflected by the neologisms, just as is the case with material exchange between primarily silk, porcelain and tea on the one hand and opium on the other.

To further explore the qualitative imbalance we could compare the 19 food related English neologisms of Chinese origin listed in Appendix I, with the much larger number of 68 food related Chinese neologisms of English origin, as listed in table 2.

Table 2
Cuisine Related Neologisms in Chinese

	Chinese	Jyutping	English origin		Chinese	Jyutping	English origin
1.	啤	be1	beer	19.	吉列	gat1 lit6	cutlet
2.	黑加侖子	haak1 gaa1 leon4 zi2	blackcurrant	20.	地厘蛇	dei6 lei6 se4	delicious fruit (apple)
3.	檳	ban1	bun	21.	冬甩	dung1 lat1	doughnut (donut)
4.	香檳	hoeng1 ban1	champagne	22.	毡酒	zin1 zau2	gin
5.	芝士	zi1 si2	cheese	23.	漢堡飽	hon3 bou2 baau1	hamburger
6.	車梨	ce1 lei4	cherry	24.	克戟	haak1 gik1	hotcake
7.	朱古力	zyu1 gu1 lik1	chocolate	25.	冰淇淋	bing1 kei4 lam2	ice-cream
8.	西打	zau1 daa2	chowder	26.	占	zem1	jam
9.	西打	sai1 daa2	cider	27.	啫喱	ze1 lei2	jelly
10.	咯爹	gok3 de1	cocktail	28.	奇偉	kei4 wai5	kiwi (fruit)
11.	啥咕	kuk1 ku2	cocoa	29.	檸檬	ning4 mung1	lemon
12.	咖啡	gaa3 fe1	coffee	30.	利嬌	lei4 giu1	liqueur
13.	哥啦	ko1 laa1	cola	31.	芒果	mong1 gwo2	mango
14.	干邑	gon1 jap1	cognac	32.	孖芝蓮	maa1 zi1 lin4	margarine
15.	曲奇	kuk1 kei4	cookie	33.	免翁	min5 jung1	mignon (steak)
16.	克力架	haak1 lik6 gaa2	cracker (biscuit)	34.	奶昔	naai5 sik1	milkshake
17.	忌廉	gei6 lim1	cream	35.	奄列	am1 lit6	omelet
18.	咖喱	gaa3 lei1	curry	36.	鎊	paang1	pan

	Chinese	Jyutping	English origin		Chinese	Jyutping	English origin
37.	班戟	baan1 gik1	pancake	53.	沙嗲	saa3 de1	satay
38.	啤梨	be1 lei2	pear	54.	些拔	se1 bat6	sherbet
39.	批	pai1	pie	55.	些厘	se1 lei6	sherry
40.	布林	bou3 lam1	plum	56.	西冷	sai1 laang1	sirloin (steak)
41.	砵	but1	port	57.	梳打	so1 daa2	soda
42.	波打	bo1 daa2	stout	58.	疏乎利	so1 fu4 lei2	soufflé
43.	布丁	bou3 ding1	pudding	59.	士多啤梨	si6 do1 be1 lei2	strawberry
44.	賓治	ban1 zi6	punch (drink)	60.	撻	taat1	tart
45.	律啤	leot6 be1	root beer	61.	多士	do1 si2	toast
46.	冧	lam1	rum	62.	拖肥	to1 fei2	toffee
47.	西米	sai1 mai5	sago	63.	雲厘那	wan6 lei1 naa2	vanilla
48.	沙律	saa1 leot2	salad	64.	伏特加	fuk6 dak6 gaa1	vodka
49.	三文魚	saam1 man4 jyu2	salmon	65.	威化	waai1 faa3	wafer
50.	三文治	saam1 man4 zi6	sandwich	66.	華夫	waa4 fu1	waffle
51.	沙甸	saa1 din1	sardine	67.	威士忌	wai1 si6 gei2	whisky
52.	沙士	saa1 si2	sarsparilla	68.	桑比	song1 bei2	zombie

From table 2 above, it can be seen that the 68 majority words in the cuisine related sphere cover a great variety of items novel to the Chinese, such as:

1. Fruit — *pear, blackcurrant, cherry, strawberry, plum, lemon,*
2. Diary product — *cheese, milk shake, cream,*
3. Meat — *sardine, salmon, sirloin (steak), mignon (steak),*
4. Pasties and snacks — *tart, pie, donut, sandwich, tart,*
5. Desert, sweat — *cookies, ice cream, jelly, sherbert, pudding, pancake, wafer soufflé, chocolate,*
6. Drinks —

a) alcoholic — *whisky, cognac, brandy, vodka, liquor, gin, port, sherry, rum, champagne, cocktail,*
b) non-alcoholic — *coco, cola, cider, soda, root beer, coffee,*

7. Cooking utensil — *pan*

It can be seen that many of the food items can be traced to seaborne contact, in the early days of the maritime hub and in the context of ship-board living. Some examples are *crackers (biscuit), curry, port, punch,*

rum, sardine, sherry, and *whisky*. These words have been in the Chinese language much longer than the other *haute cuisine* related items such as *sirloin* (steak), *cutlet* (filet), *mignon* (steak), *soufflé*, *pudding*, and *salmon.*

The range and diversity represented by the 68 neologisms offer stark contrasts to the small number of 19 food related English neologisms of Chinese origin. As can be seen in Appendix I, these neologisms involve:

a) New varieties of food stuff: *vegetables and fruits*, including bean product such as tofu and lychee as well as the potent liquor *maotai*, and
b) Manner of food preparation: *fried rice* and *fried noodles, chopsuey, scrambled egg* with other ingredients and,
c) A novel utensil used in food preparation: the spherical bottom *wok*.

A cross-linguistic comparison with the Chinese neologisms of English origin shows that these words reflect uncommon food items not usually found on western dinner tables or in regular cuisine (until perhaps in recent years). There have been interesting re-interpretations such as *wonton* ***soup*** and *lychee* ***nut***, because wonton is traditionally not associated with soup in the *donor* Chinese culture, nor is the soft skin *lychee* seen as a nut [6]. This is because soup in Chinese cuisine is a liquid in which other ingredients have been cooked so that much of their essence would have been extracted and dissolved in the resultant broth. In the case of *wonton* and *noodles*, they are usually served in a broth to enhance the flavour of the *wonton* or *noodles* which are the main food items (head-noun) rather than having a secondary role of flavouring the soup. On the other hand, for Western cuisine an entrée consisting of broth with or without other ingredients cooked with it would be usually a soup. In the case of the *Lychee*, its size and leathery though soft peel could make it appear more like a nut to anyone who has not handled or tasted it. Such a situation draws attention to the subconscious filtering function which is performed by the recipient culture.

Why is there such a great difference between the two languages? One possible explanation could be a major difference in the acceptance of (or resistance to) new and foreign cultural artifacts in the two communities. On the basis of the limited items, Westerners could be said to show greater caution about accepting Chinese food items than Chinese acceptance of Western food or Western *haute cuisine* in the 1970s. There is also a likely reflection of Western based globalization which had been already in place.

Let us further compare *People* related Chinese neologisms (*i.e.* items referring to humanoid forms) of English origin, with English neologisms of Chinese origin. There are 8 cases of English neologisms of Chinese origin, represented by:

a) 3 instances referring to the professions *fokei* (waiter), *mafu* (stable boy) and *taipan* (executive, comprador);
b) 2 instances being labels with negative connotations: *lapsapchung* (litter bug) and *gweilo* (foreigner, "devilish one"); and

1 instance each referring to:

c) terms of address: *taitai* (madam, Mrs)
d) religious figure: *Tinhau* (Goddess of the Sea), and
e) race: *Tanka* (fishing population)

In contrast, the situation with the more numerous (20) Chinese neologisms of English origin are quite different:

a) professionals: *sargent, model, number-one* (meaning *taipan*)
b) religious figures: *Christ, Satan, angel*
c) terms of address and derived terms: *baby, daddy, boss, missy, mummy, darling, gentleman,* and
d) uniquely cultural bound and proper-noun derived items: *Napoleon, Newton, Tsar, Nazi, Fascist, Gypsy, Hippie* (including Christ and Satan).

It may be suggested that there is greater importance attached to interactions in verbal encounter and the power and solidarity relationship, as reflected by the greater variety of address terms and proper nouns. Quantitatively, there have been many more derived Chinese terms, indicating greater Chinese awareness of social differentiation in the West than the reciprocal English or Western awareness in the contact situation. A comparison of the terms related to the professions indicates the saliency of some low status professions (such as *waiter* or *stable boy* in Hong Kong's popular local horse-racing and related culture) to the Westerners. There is the exception of *taipan* ("a very senior executive") which is a localized term with a historical past such that a very high level executive in a trading firm or a bank in Hong Kong, for example, could be called a *taipan* but not the head of the Hong Kong Government, who is known as the Chief Executive (CE) of the Hong Kong Special Administrative Region of China (HKSAR).

By comparison, *sargent* with the associated connotation of authority, and *model,* with the associated connotation of glamour (in contrast to traditional Chinese prudishness about the public display of one's body) have higher accepted social status in Chinese than *waiter* or *stable boy* in English. Their adaptation as neologisms reflects the saliency and acceptance of the different social roles by the language partners in the contact situation.

Another noteworthy difference is the much greater Chinese acceptance of western cultural icons: *Napoleon, Newton, Tsar, Nazi, Fascist (Don Quixote)* [7] etc. than the reverse, where perhaps only the omitted *Confucius* [8] in English may be cited as relevant to the period. Each of the proper nouns have salient connotations which are mostly carried over into Chinese. They cover different icons of one-time ruling Western classes (*Napoleon, Tsar, Nazi, Fascist*), outstanding scientists (*Newton*) and non-conformists (*gypsy, hippie, Quixote*).

It should be noted that cross-linguistically and cross-culturally there are many more *people*-related Chinese neologisms of English origin, when compared with English neologisms of Chinese origin in the same *people* sphere. This observation indicates an overall greater saliency and social acceptance of the foreign and novel personalities among the Chinese than among the Westerners and so contributes to a form of imbalance in this contact situation.

4. Manner of Cultural and Linguistic Transmission

Furthermore, it is noteworthy that the majority of Chinese neologisms under discussion pertain to words which have been phonetically adapted from English, with some notable exceptions. Taking this restrictive perspective, we could also note that when the same word list is compared with OED online (2006) and with the local South China Morning Post, some notable observations may be made in terms of the attrition and growth of neologisms.

At the same time, it is important to note that neologisms may not be exclusively manifested as phonetic adaptations. Thus, there are alternate forms for some items in Appendix I, such as the following synonymous pairs: No. 14 *tofu* vs *bean curd* and No. 45 *kungfu vs martial art*. These examples draw attention to two major alternative means for the creation of neologisms: (1) *phonetic adaptation* and (2) *semantic adaptation (calques)*. Items in table 2 discussed above are manifested in Chinese via *phonetic adaptation* or are *phonetic replicas* of the English terms which provided the *model*. Similarly *tofu* and *kungfu* are respectively *phonetic replicas* of the Chinese words for *bean-curd* and *martial arts*, which, being *semantic replicas* of the Chinese words 豆腐 and 功夫, are also neologisms in English.

There is the additional possibility of a combined means of adaptation, known as *hybrid* adaptation, where both phonetic and semantic adaptations are involved. No. 2 *blackcurrant* 黑加侖子 (***hak****galunzi)*, and No. 34 *milkshake* 奶昔 (***nai****sik*) in table 2 are examples of this *hybrid* [semantic +

phonetic] adaptation. For the former, ***hak*** 黑 means *black* while for the latter ***nai*** 奶 means *milk*. Although both *hak* and *nai* are rendered semantically in Chinese, their modifier position in the compound nouns indicates subtle cognitive limitations. *Hak* only describes the color of the item and the uninitiated language user may not readily know that the item refers to a kind of fruit. Similarly, *nai* 奶 (milk) indicates that the item involves dairy product but cannot be certain what the item is.

On the other hand, Appendix II produces different examples of *hybrid* [phonetic + semantic] adaptation: No. 18 *be—zau* 啤酒 (beer-wine), No. 120 *hon-bou-baau* 漢堡飽 (hamburg-bun), No. 210 *be-lei* 啤梨 (pear-peach) and No. 239 *saam-man-yu* 三文魚 (salmon-fish). In these examples, the head noun is a native Chinese word but the pre-modifier is a phonetically adapted word of foreign origin. In such cases, the uninitiated language users would readily know the food *sphere* to which the words belong. *i.e. wine, bun, pear* and *fish,* though not the cognitively less significant new attributes attached to them.

Given the three alternative modes of renditions, the question can be raised as to the wider significance of the alternations. It has been noted that the choice of the means for adoption may not be random but could be very likely correlated with the *Cultural Compatibility* of the new item with the recipient culture, generally with associated manifestations of degrees of *familiarity, accessibility* and *agreeability* of the item in the recipient community [9]. This hypothesis will suggest that neologisms with *low* cultural compatibility tend to be rendered as semantic adaptation since the rendition can provide basic information about the nature of the item. On the other hand, neologisms adapted phonetically refer to concepts which have gained *familiarity* and cultural compatibility for the users of the language. Thus, before well-known film stars such as Bruce Lee and Jackie Chan became famous, phonetically adapted *kungfu* (功夫) was known as *martial arts*, which is a semantic adaptation. Similarly, semantically adapted *bean curd* predated the phonetically adapted *tofu* (豆腐), when the food item was not yet popular. In this context, it can be seen that phonetic adaptation is *exocentric* because the model uses non-native (??) sound segments as building material whereas semantic adaptation would be *endocentric* because native words would be used as the building material. Furthermore, items between the two extremes usually adopt the hybrid approach.

We can further ask whether following changes in cultural comparability such as an item gaining *familiarity* or *accessibility* could change the mode of adaptation. It can be postulated that these semantically adapted neologisms

may be *relexified* and there could be progressive development from semantic adaptation to phonetic adaptation when the artifacts they represent gain popularity over time and become *familiar*, *accessible* or *agreeable* to the members of the community. The hybrid approach provides an intermediate stage for the relexification process and we can chart and compare the changing distributions of these related neologisms among different communities so as to explore the degrees of cultural compatibility of these artifacts in each community.

We have selected 10 common Chinese neologisms which have been variously manifested both as phonetic adaptation and hybrid [phonetic-semantic] adaptation. table 3 below provides information on their distributions in Hong Kong (HK), Shanghai (SH) and Singapore (SG), based on an alternative Windows approach using a synchronous database, LIVAC [10]. As noted earlier above, the neologisms provided by Chan & Kwok were mainly based on their observations and experience in research on the language situation in Hong Kong. The selection of items sometimes reflected personal preference as well as constraints on data source. Moreover, the list was compiled more than two decades ago. It would be meaningful for us to re-examine these lexical items with more up-to-date objective statistical information and, more importantly, to further tighten up the methodology so that cross-communal comparisons of lexical development can be carried out on a more objective basis. This has been achieved by adopting a **common** window opening of time period in LIVAC so that the nature and extent of lexical development can be compared. Thus, the data from LIVAC drawn on the three communities not only provide a common objective basis for cross-communal comparison, but also reflect the actual use of language in these communities.

It is noteworthy that 8 out of 10 phonetically adapted items in each pair have the highest frequency of occurrence in Hong Kong. The only exception is No. 6 *Beer* and No. 8 *Waltz*. In the case of No. 6 *Beer,* the exception is predictable because *be-zau* 啤酒 (beer-wine) is a disyllabic word which conforms to the general trend of lexical development in Chinese. In the case of *Waltz* as a cultural or entertainment event, it seems to draw lesser interest in Hong Kong than among Mainland Chinese residents [11]. On the other hand, items related to *wine/liquor* such as *vodka*, *champagne* and *cognac* are rendered mainly phonetically in Hong Kong, where it is much often drunk than in Mainland China. A summary of the overall distributions of these two adaptations across the three communities is shown in table 4:

Table 3
Chinese Neologisms of 10 Consumables of English Origin

No.	Words	Jyutping	English gloss	HK %	SH %	SG %	Total
1	曲奇	kuk1 kei4	Cookies	94.44	5.56	0.00	***100.00***
	曲奇餅	kuk1 kei4 beng2	Cookies-biscuit	64.29	7.14	28.57	***100.00***
2	沙甸/沙丁	saa1 din1 / saa1 ding1	Sardine	16.67	66.66	16.67	***100.00***
	沙甸魚/沙丁魚	saa1 din1 jyu2/ saa1 ding1 jyu2	Sardine-fish	33.3	23.8	42.9	***100.00***
3	拖肥	to1 fei2	Toffee	100.00	0.00	0.00	***100.00***
	拖肥糖	to1 fei2 tong2	Toffee-candy	100.00	0.00	0.00	***100.00***
4	伏特加	fuk6 dak6 gaa1	Vodka	44.44	44.44	11.11	***100.00***
	伏特加酒	fuk6 dak6 gaa1 zau2	Vodka-wine	18.18	45.45	36.36	***100.00***
5	威化	wai1 faa3	Waffer	100.00	0.00	0.00	***100.00***
	威化餅	wai1 faa3 beng2	Waffle-biscuit	100.00	0.00	0.00	***100.00***
6	啤	be1	Beer	0.00	0.00	0.00	***0.00***
	啤酒	be1 zau2	Beer-wine	25.65	51.55	22.80	***100.00***
7	香檳	hoeng1 ban1	Champagne	55.07	16.67	28.26	***100.00***
	香檳酒	hoeng1 ban1 zau2	Champagne-wine	14.29	57.14	28.57	***100.00***
8	華爾茲	waa4 ji5 zi1	Waltz	0.00	66.67	33.33	***100.00***
	華爾茲舞	waa4 ji5 zi1 mou5	Waltz-dance	100.00	0.00	0.00	***100.00***
9	干邑	gon1 jap1	Cognac	100.00	0.00	0.00	***100.00***
	干邑酒	gon1 jap1 zau2	Cognac-wine	0.00	0.00	0.00	***0.00***
10	梳打/蘇打	so1 daa2 / sou1 daa2	Soda	50.00	50.00	0.00	***100.00***
	梳打水/蘇打水	so1 daa2 seoi2/ sou1 daa2 seoi2	Soda-water	33.33	66.67	0.00	***100.00***

Table 4
Summary on Consumables with respect to Linguistic Modes of Adaptation

%	Hong Kong	Shanghai	Singapore	TOTAL
Phonetic adaptation	54.68	22.66	22.66	***100***
Hybrids	26.58	49.94	23.48	***100***

Table 4 shows that phonetic adaptation is the favored mode in Hong Kong whereas hybrid adaptation is the most favored in Shanghai [12].

Another observation deserving attention is that for some items, such as *cookies*, *sardine*, *champagne*, both renditions are found in the same community. It is therefore useful for us to compare, for each item, the distributions of these two renditions in each community and explore the significance of the differences. Table 5 below provides the relevant data.

Table 5
Distributions between Phonetic and Hybrid Adaptations of Consumables in Hong Kong, Shanghai and Singapore

No.	Words	Jyutping	English gloss	HK (%)	SH (%)	SG (%)
1	曲奇	kuk1 kei4	Cookies	65.38	50.00	0.00
	曲奇餅	kuk1 kei4 beng 2	Cookies-biscuit	34.62	50.00	100.00
	TOTAL			***100***	***100***	***100***
		saa1 din1 jyu2/ saa 1 ding1 jyu2				
2	沙甸/沙丁	saa1 din1 / saa1 ding1	Sardine	12.50	44.44	10.00
	沙甸魚/沙丁魚	saa1 din1 jyu2/ saa1 din1 jyu2 tol fei2 tol fei2 tong2	Sardine-fish	87.50	55.56	90.00
	TOTAL			***100***	***100***	***100***
3	拖肥	tol fei2	Toffee	33.33	0.00	0.00
	拖肥糖	tol fei2 tong2	Toffee-candy	66.67	0.00	0.00
	TOTAL			***100***	***0***	***0***
4	伏特加	fuk6 dak6 gaa1	vodka	80.00	61.54	33.33
	伏特加酒	fuk6 dak6 gaa1 zau2	Vodka-wine	20.00	38.46	66.67
	TOTAL			***100***	***100***	***100***
5	威化	wai1 faa3	Waffle	50.00	0.00	0.00
	威化餅	wai1 faa3 beng2	Waffle-biscuit	50.00	0.00	0.00
	TOTAL			***100***	***0***	***0***
6	啤	be1	Beer	0.00	0.00	0.00
	啤酒	be1 zau2	Beer-wine	100.00	100.00	100.00
	TOTAL			***100***	***100***	***100***
7	香檳	hoeng1 ban1	Champagne	97.44	74.19	90.70
	香檳酒	hoeng1 ban1 zau2	Champagne-wine	2.56	25.81	9.30
	TOTAL			***100***	***100***	***100***
8	華爾茲	waa4 ji5 zi1	Waltz	0.00	100.00	100.00
	華爾茲舞	waa4 ji5 zi1 mou5	Waltz-dance	100.00	0.00	0.00
	TOTAL			**100**	**100**	**100**
9	干邑	gon1 jap1	Cognac	100.00	0.00	0.00
	干邑酒	gon1 jap1 zau2	Cognac-wine	0.00	0.00	0.00
	TOTAL			**100**	**0**	**0**
10	梳打/蘇打	so1 daa2 / sou1 daa2	Soda	66.7	50.00	0.00
	梳打水/蘇打水	so1 daa2 seoi2/ sou1 daa2 seoi2	Soda-water	33.3	50.00	0.00
	TOTAL			**100**	**100**	**0**

We can generalize in terms of the overall preferred adaptation in each community. In table 6 below, the plus sign indicates a preference for exclusive "phonetic adaptation" while the minus sign a preference for hybrid [phonetic + semantic] adaptation where the semantic component is enclosed by brackets. Zero indicates that both are equally used. The summarized results are shown in Table 6.

Table 6
Comparison of Phonetic vs Hybrid Adaptations

No.	Words	Jyutping	English gloss	HongKong	Shanghai	Singapore
1	曲奇(餅)	kuk1 kei4 (beng2)	*Cookies*(-biscuit)	+	0	–
2	沙甸/丁(魚)	saa1 din1/ding1 (jyu2)	*Sardine*(-fish)	–	–	–
3	拖肥(糖)	to1 fei2 (tong2	*Toffee*(-candy)	–	0	0
4	伏特加(酒)	fuk6 dak6 gaa1 (zau2)	*Vodka*(-wine/liquor)	+	+	–
5	威化(餅)	waai1 faa3 (beng2)	*Waffle*(-biscuit)	0	0	0
6	啤(酒)	be1 (zau2)	*Beer*(-wine)	–	–	–
7	香檳(酒)	hoeng1 ban1 (zau2)	*Champagne*(-wine)	+	+	+
8	華爾茲(舞)	waa4 ji5 zi1 (mou5)	*Waltz*(-dance)	–	+	+
9	干邑(酒)	gon1 jap1 (zau2)	*Cognac*(-wine)	+	0	0
10	梳/蘇打(水)	so1/sou1 daa2 (seoi2)	*Soda*(-water)	+	0	0

Of these ten consumables, five are rendered phonetically in Hong Kong which is the highest among the three localities. As discussed above, the lower preference for single phonetic adaptation in the case of *be* 啤 (beer) in Chinese is understandable, given the general and important linguistic preference for disyllabic words in the Chinese language. We could note that *be* 啤 (beer) has been used to form new words which are form disyllabic neologisms such as (生)啤 (*draft beer*), (鮮)啤 (*fresh beer*), (凍)啤 (*cold beer*). Thus, neologisms continue to develop after they are created and can be as productive as other native words. Moreover, linguistic and extra-linguistic factors are both at play in determining the mode of linguistic adaptation.

Besides those consumables that have entered into the Chinese culture and daily life, we can also examine in greater detail other relevant examples on the basis of LIVAC. A good example could be "Internet", a common and important term in IT in the past decade. According to LIVAC, "Internet" has had at least 13 different neologisms since its inception in 1995, as shown in table 7 below:

These 13 items can be divided between semantic adaptation (No. 1 — No. 10) and hybrid [phonetic + semantic] adaptation (No. 11 — No. 13).

Table 7
Alternative Renditions of "Internet" in LIVAC

1.	互聯網	mutual-link-net
2.	互聯網絡	mutual-link-network
3.	交互網	cross-mutual-net
4.	信息網	information-net
5.	訊息網	information-net
6.	國際網	international-net
7.	國際聯網	international-link-net
8.	網際網絡	inter-net-network
9.	網際網路	inter-net-network
10.	遞訊網	transmit-information-net
11.	英特網	INTER-net
12.	因特網	INTER-net
13.	萬維網	10K-dimension-net

Item 13 exemplifies a creative approach to neologisms. The pronunciation of 萬維網 (10K-dimension-net) in Mandarin is *wan-wei-wang* whose initials are identical to its English counterpart *World-Wide-Web*. Moreover, the meaning of 萬維網 (10K-dimension-net) best depicts the nature and characteristics of this IT artifact which can have a multi-dimensional connection. This special overlapping integration of both semantic and phonetic adaptation, known as *blend*, is important for the commercial promotion of new and foreign products within a recipient society. Some well-known examples can be found for products like *Coca-Cola* 可口可樂 (*ke-kou-ke-le*) meaning "tasty and enjoyable", *vitamin* 維他命 (*wei-ta-ming*) meaning "to sustain one's life".

It would be useful for us to explore the development among the 13 renditions of Internet in Chinese. We begin with comparing the progressive development among these different modes of renditions in the Chinese communities. It is interesting to note that in the metropolitan cities of Mainland China such as Beijing and Shanghai, there has been a gradual shift from using the *semantically adapted* items to the *hybrid* ones. To illustrate this, we compare the distributions between 因特網 (INTER-net) and 互聯網 (mutual-link-net) in the LIVAC sub-corpora of Beijing (BJ) and Shanghai (SH) for a period of five years (1995-2000), as shown in table 8 below.

In the first two years (1995-1996), both communities only used semantic adaptation to render this newly introduced IT artifact. With increasing

Table 8
Distributions of 因特網 (INTER-net) and 互聯網 (mutual-link-net) in Beijing and Shanghai

%	95-96		96-97		97-98		98-99		99-00	
	SHG	BJG	SHG	BJG	SHG	BJG	SHG	BJG	SHG	BJG
互聯網 (mutual-link-net)	100	100	100	100	42.4	20	38	75	41.2	26.9
因特網 (INTER-net)	0	0	0	0	57.6	80	62	25	58.8	73.1

familiarity and *accessibility* in addition to *agreeability*, the users have switched to the hybrid [phonetic-semantic] adaptation: 因特網 (INTER-net). We note from the above figures that relatively speaking, Beijing is in a more advanced state of progressive lexical development than Shanghai.

When we expand the window to have a broader view of the alternate renditions of "Internet" to include other Chinese speech communities between 1998 and 2001, we immediately note a convergent development, as shown in table 9 below:

Table 9
Alternate Renditions of "Internet" in Chinese Speech Communities between 1998 and 2001

Year		Hong Kong	Macau	Taipei	Singa-pore	Shanghai	Beijing
98-99	**most frequently used**	互聯網 mutual-link-net	互聯網 mutual-link-net	網際網路 inter-net-network	網際網路 inter-net-network	因特網 INTER-net	互聯網 mutual-link-net
	next frequently used	--	因特網 INTER-net	互聯網 mutual-link-net / 訊息網 informa-tion-net	互聯網 mutual-link-net	互聯網 mutual-link-net	因特網 INTER-net
99-00	**most frequently used**	互聯網 mutual-link-net	互聯網 mutual-link-net	網際網路 inter-net-network	網際網路 inter-net-network	因特網 INTER-net	因特網 INTER-net
	next frequently used	--	因特網 INTER-net	互聯網 mutual-link-net	互聯網 mutual-link-net	互聯網 mutual-link-net	互聯網 mutual-link-net
00-01	**most frequently used**	互聯網 mutual-link-net	互聯網 mutual-link-net	網際網路 inter-net-network	互聯網 mutual-link-net	互聯網 mutual-link-net	互聯網 mutual-link-net
	next frequently used	--	因特網 INTER-net	互聯網 mutual-link-net	--	因特網 INTER-net	因特網 INTER-net

From the above distributions, we note that there were alternate renditions for "Internet" across the Chinese communities. Only Shanghai, Beijing as well as Macau used the hybrid approach (*i.e.* 因特網, INTER-net) to render this artifact. The other three communities mainly used the semantic approach. In 1999, we note that 因特網 (INTER-net) became the most frequently rendition in Beijing. However, in 2000, it is interesting to note that there was a switch from 互聯網 (mutual-link-net) to 因特網 (INTER-net) in Beijing and Shanghai. It would be relevant to pursue the reason for this change. The above overall distributions in fact show that there is a convergent development for the lexical variants for this IT artifact. Although the use of their hybrid form 因特網 (INTER-net) reflects the high cultural compatibility of this artifact to the users of the communities, there can be other factors that might contribute to this lexical development. In fact, with frequent cross-communal contact, lexical items can diffuse from one community to others and this might result in relexification and eventually brings in convergent development.

5. Concluding Remarks

Contact between interacting parties or cultures invariably induces diffusion of physical or cultural traits. They could range from gene mixing, to exchange of physical commodities, to the inter flow of abstract concepts. Such transfer is often non-reciprocal and inequitable. Imbalance and their resolution is not unusual in nature. Thus, when there is an imbalance between two interacting parties, there is often a transfer of affected content from the direction of *originator* to the *recipient* until some equilibrium has been established. A common and simple example would be floods and water levels. In the Pearl River Delta Hub, we have seen considerable exchange material goods as well as cultural artifacts. Moreover both kinds of exchange can be subject to constraints.

We asked if it was possible for constraints to be exerted at some critical point to impede or regulate the flow of content. For example, electronic products have benefited from the basic idea of exerting control on the flow of positive or negative electrons across physical barriers which also serve as contact points. Thus, the basic idea embodied in the PNP junction has contributed to the miniaturization of binary logical operations underlying much of modern solid state devices.

There is analogy in the case of maritime hubs, where totally bi-directional free flow has been rare, and for material there have been gatekeepers,

representing government and other agents transfer. But the filtering of more abstract cultural artifacts may not be easily controlled by small groups of individuals the work of court translators and governmental treaties notwithstanding. Rather communal dispositions reflecting a collective ethos could play a part, as we have seen by studying neologism.

Moreover, we have tried to explore if and how both kinds of exchange can be subject to constraints.

NOTES

[1] For coverage of their presence and contributions in China, before and after the Opium War, especially in the Pearl River Delta, see D. MacGillivray (1905).

[2] Barnett & Fairbank (1985) has provided a detailed account of their major writings.

[3] It is therefore not surprising that a casual examination of Chinese official documents issued by the Chinese authorities subsequent to the Treaty, either in the capital or in the provinces, would show non-compliance.

[4] The Chinese neologisms of English origin were based on personal observation over many years on the part of the authors who were university teachers and keen observers of the language scene in Hong Kong, and were also drawn from their analysis of 30 hours of popular variety shows on television, as well as one month of newspaper and other journalistic material in Hong Kong. Some of the items constitute pairs or sets of alternative renditions for the same cultural artifact (*e.g.* cashmere: 咖士咩 *kasime* and 開士米 *hoisimai* in Cantonese) and we have grouped the items into relevant sets and the list of words should be understood as lists of sets of synonymous words. The English neologisms of Chinese origin were similarly based on their personal observations over many years, up to the late 1970's, and their examination of the Oxford English Dictionary.

[5] The Chinese neologisms of English origin were based on personal observation over many years on the part of the authors who were university teachers and keen observers of the language scene in Hong Kong, and were also drawn from their analysis of 30 hours of popular variety shows on television, as well as one month of newspaper and other journalistic material in Hong Kong. Some of the items constitute pairs or sets of alternative renditions for the same cultural artifact (*e.g.* cashmere: 咖士咩 *kasime* and 開士米 *hoisimai* in Cantonese) and we have grouped the items into relevant sets and the list of words should be

understood as lists of sets of synonymous words. The English neologisms of Chinese origin were similarly based on their personal observations over many years, up to the late 1970's, and their examination of the Oxford English Dictionary.

[6] Both the OED Online (2006, citing the OED 1989 edition) and the Webster's New World College Dictionary (1997) refer to both deep-fried *wonton* and *wonton soup*. However, *wonton* would not come under the heading of soup in Chinese menus, even when they come in a broth, similarly, noodles do not come under soup in Chinese menus. In the case of *lychee nut*, there was already the 1876 reference to "*litchi-nuts*" in John Harley's *Royle's (J. F.) Manual of Materia Medica*, for additional reference see OED (1989), and the Merriam Webster Online Dictionary still refers to *lychee nut* as an alternative to *lychee*.

[7] Two notable exceptions: *Don Quixote* and *patnaa* (meaning "partner" as in social or business partnership) have been omitted from the list though found in the Chinese media of different communities. Their adaptation as neologisms in Chinese reflects similar salience and such omissions will not have major impact on the analysis proposed here.

[8] The well known Chinese sage has not been included in the two lists by the authors, though there are references to *confucian* in the OED indicating its appearance in English texts in the mid 19th century. This was after the 1687 Latin translation of three of the four major classics by Roman Catholic missionaries as *Confucius Sinarum Philosophus, sive Scientia Sinensis Latine exposita*. The term has also been found in the South China Morning Post.

[9] For fuller details on this hypothesis, see Tsou (2001a).

[10] LIVAC stands for **LI**nguistic **VA**riations in **C**hinese Speech Communities (http://www.rcl.cityu.edu.hk or http://www.livac.org). It is an unusual Chinese synchronous corpus developed by the Language Information Sciences Research Center at the City University of Hong Kong since 1995. This corpus rigorously draws data from the Chinese media of the following eight Chinese speech communities on a regular basis: Hong Kong, Taipei, Beijing, Shanghai, Singapore, Macau, Canton, Zhuhai. Up to 2005, LIVAC has processed over 200 million characters of representative texts and has accumulated over 1 million word types from the above Chinese communities. Its rigorously cultivated database on usage frequency across the different speech communities over 9 years therefore offers an alternate and viable framework with considerable depth and range of flexibility, including window size.

[11] The Waltz is comparatively less popular on Hong Kong social occasions than in the Chinese Mainland, where it can be found on popular social-cum-exercise occasions, such as street dances for mature adults in the evening.

[12] This situation in Singapore differs from the others. Its Chinese media undergo editorial scrutiny on linguistic appropriateness. In any case, there would be frequent and typical code-switching in verbal encounters in Singapore, so that the phonetic replica would be a much closer approximation of the English model than that in spoken Chinese there. See Tsou 2002b.

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APPENDIX I

English Neologisms of Chinese Origin

No.	Word	Meaning	Chinese words	OED (online)	SCMP (2003-2005)	Sphere
1.	chow fan	fried rice	炒飯	–	–	Food
2.	chow mein	fried noodles	炒麵	+	+	Food
3.	chop suey	chopsuey	雜碎	+	+	Food
4.	choy sum	a kind of leafy vegetable	菜心	–	+	Food
5.	dim sum	dim-sum (Chinese pastry, snack, etc.)	點心	+	+	Food
6.	fooyong, fu-yung	a kind of scrambling eggs (Chinese pastry, snack, etc.)	芙蓉	+	–	Food
7.	ketchup	ketchup	茄汁	+	+	Food
8.	kumquat, cumquat	small citrus fruit	金橘	+	+	Food
9.	quat	small citrus fruit	桔	–	+	Food
10.	loquat	plum-like fruit	盧橘	+	+	Food
11.	lychee, litchi	lychee	荔枝	+	+	Food
12.	maotai	strong Chinese alcoholic drink	茅台	+	+	Food
13.	pok choy	pok choy (vegetable)	白菜	–	+	Food
14.	tofu	bean curd (vegetable)	豆腐	+	+	Food
15.	tea	tea	茶	+	+	Food
16.	wok	Chinese frying pan	鑊	+	+	Food
17.	wonton	won-ton	雲吞	+	+	Food
18.	yum cha yum cha	yum cha	飲茶	–	+	Food
19.	yum-sing	bottoms up!	飲勝	–	–	Food
20.	fo-kei	waiter/employee	伙計	–	–	People
21.	gweilo	Westerners ("devilish one")	鬼佬	–	+	People
22.	lap sap chung	litterbug	垃圾蟲	–	+	People
23.	mafoo	stable boy (in Jockey Club)	馬夫	+	+	People
24.	taipan	Taipan* (CEO)	大班	+	+	People
25.	tanka	Tanka (fisherman population)	蛋家	+	+	People
26.	tinhau	Tin Hau (goddess)	天后	–	+	People
27.	tai tai	wife / Mrs / Madam	太太	–	+	People

* Originally comprador in Chinese trade.

No.	Word	Meaning	Chinese words	OED (online)	SCMP (2003-2005)	Sphere
28.	yuen	dollar	元	+	+	Measure
29.	renminbi	Renminbi	人民幣	+	+	Measure
30.	fen	cent	分	+	+	Measure
31.	cheongsam	long garment (for ladies)	長衫	+	+	Clothing
32.	samfoo, samfu	tunic-trouser	衫褲	+	+	Clothing
33.	pak pai	white label (car)	白牌	+	-	Transpor-tation
34.	sampan	sampan	三板 / 舢舨	+	+	Transpor-tation
35.	mahjong	mahjong	麻雀	+	+	Others
36.	ching ming	Ching-ming festival	清明	–	+	Others
37.	chung yeung	Chung-yeung festival	重陽	–	+	Others
38.	feng shui	geomancy	風水	+	+	Others
39.	hoey	club	會	+	–	Others
40.	hong	company / firm	行	+	+	Others
41.	I-Ching	Book of Changes	易經	+	+	Others
42.	jo sun	good morning	早晨	–	–	Others
43.	kaolin	fine white clay	高嶺	+	+	Others
44.	kowtow, kotow	kneeling with head touch-ing ground	叩頭	+	+	Others
45.	kuk	association / bureau	局	–	+	Others
46.	kung fu	kungfu / martial art	功夫	+	+	Others
47.	kung hei fat choy	kung hei fat choy (new year greeting)	恭喜發財	–	+	Others
48.	kylin, kilin	unicorn	麒麟	+	+	Others
49.	lapsap	rubbish	垃圾	–	+	Others
50.	lai-si	red pocket (for New Year)	利事 / 利是	–	–	Others
51.	pinyin	pinyin	拼音	+	+	Others
52.	putonghua	Putonghua	普通話	+	+	Others
53.	t'ai chi	tai-chi	太極	+	+	Others
54.	ting hou	most excellent	頂好	–	–	Others
55.	tong	hall	堂	+	+	Others
56.	typhoon	typhoon	大風 / 颱風	+	+	Others
57.	yin	yin	陰	+	+	Others
58.	yang	yang	陽	+	+	Others
59.	Zen	Zen	禪	+	+	Others

APPENDIX II

Chinese Neologisms of English Origin

No.	English	Chinese	Sphere	No.	English	Chinese	Sphere
1.	ace	煙士	F	38.	card	卡	I
2.	alleluia	亞里路亞	I	39.	cardigan	卡爾提根	A
3.	aluminium	鋁	I	40.	carnival	嘉年華	F
4.	Amen	亞孟	I	41.	cartoon	卡通	F
5.	ammonia	阿摩尼亞	E	42.	cashmere	咖士咩	A
6.	amoeba	阿米巴	I	43.	cassette	卡式	I
7.	ampere	安培	G	44.	cast	卡士	F
8.	angel	安琪兒	H	45.	Celsius	攝氏	G
9.	antimony	銻	I	46.	cement	士敏	I
10.	aspirin	亞司匹靈	E	47.	cha cha	查查	F
11.	baby	啤啤	H	48.	champagne	香檳	B
12.	baccarat	百家樂	F	49.	cheese	芝士	B
13.	ball	波	F	50.	cherry	車梨	B
14.	ballet	芭蕾	F	51.	chloroform	哥羅仿	I
15.	bar	酒吧	F	52.	chocolate	朱古力	B
16.	barbitone	巴比通	I	53.	chowder	周打	B
17.	bazaar	巴沙	I	54.	Christ	基督	H
18.	beer	啤(酒)	B	55.	cider	西打	B
19.	beret	巴黎帽	A	56.	cigar	雪茄	I
20.	blackcurrant	黑加侖子	B	57.	cinchona	金雞納	I
21.	boric acid	硼	I	58.	clutch	極力子	D
22.	boss	波士	H	59.	cocaine	可卡因	E
23.	bow tie	保呔	A	60.	cocker	確架狗	I
24.	bowling	保齡	F	61.	cocktail	咯爹	B
25.	boxing	卜成	I	62.	coco	啒咕	B
26.	boycott	杯葛	I	63.	coffee	咖啡	B
27.	brakes	逼力子	D	64.	cognac	干邑	B
28.	bun	檳	B	65.	cola	哥啦	B
29.	butchery	砵遮利	H	66.	cologne	古龍水	A
30.	calories	卡路里	G	67.	conga	康茄舞	F
31.	camera	開麥拉	F	68.	cookies	曲奇	B
32.	can can	肯肯	F	69.	court	大葛樓	I
33.	cap	噏	A	70.	cracker	克力架	B
34.	car	卡車	D	71.	cream	忌廉	B
35.	carbine	卡賓	I	72.	curry	咖喱	B
36.	car-coat	卡曲	A	73.	cushion	咕啞	C
37.	card	啤牌	F	74.	cut	咳	F

No.	English	Chinese	Sphere	No.	English	Chinese	Sphere
75.	cutlet	吉列	B	115.	golf	高爾夫	F
76.	Dacron	的確涼	A	116.	gram	克	G
77.	daddy	爹哋	H	117.	Grand Pix	格蘭披士	F
78.	dahlia	大利花	I	118.	guitar	結他	F
79.	darling	打玲	H	119.	Gypsy	吉普賽	H
80.	delicious (fruit)	地厘蛇	B	120.	hamburger	漢堡飽	B
81.	democracy	德模赫拉斯	I	121.	helium	氦	I
82.	derby	咁吡	F	122.	hello	哈囉	I
83.	dettol	滴露	E	123.	heroine	海洛英	E
84.	diesel	狄塞爾	D	124.	hippy	嬉皮士	H
85.	disco	的士高	F	125.	hormone	賀爾蒙	E
86.	Dolby	杜比	F	126.	hotcake	克戟	B
87.	Don Quoxite	唐吉訶德	H	127.	hula hoop	呼拉圈	F
88.	double quinella	孖Q	I	128.	humor	幽默	I
89.	doughnut	冬甩	B	129.	husband	蝦子餅	H
90.	dozen	咁	G	130.	hustle	哈蘇舞	F
91.	encore	安歌	F	131.	hysteria	歇斯底里	I
92.	ether	依打	E	132.	ice-cream	冰淇淋	B
93.	Fahrenheit	華氏	G	133.	inch	煙子	G
94.	fail	肥佬	I	134.	indanthrene	陰丹士林	I
95.	farad	法拉	G	135.	inspiration	煙士披利純	I
96.	Fascist	法西斯	H	136.	insurance	燕梳	I
97.	fashion	花臣	I	137.	iodine	碘酒	E
98.	fiber	快把	I	138.	jam	占	B
99.	file	快路	I	139.	jazz	爵士音樂	F
100.	film	菲林	I	140.	jeep	吉普	D
101.	flannel	法蘭絨	A	141.	jelly	啫喱	B
102.	floorshow	科蘇	F	142.	jersey	啫士	A
103.	fluorine	氟	E	143.	jumbo	珍寶	D
104.	forecast	科卡士	F	144.	karat	卡	G
105.	formalin	福爾馬林	E	145.	khaki	卡其	A
106.	Formica	佛米卡	I	146.	kid	咭	H
107.	franc	法郎	G	147.	King	老開	F
108.	furlong	化郎	F	148.	kiwi	奇偉	B
109.	fuse	灰士	C	149.	Koran	可蘭經	I
110.	gabardine	急巴甸	A	150.	lacquer	力架	I
111.	gallon	加侖	G	151.	lemon	檸檬	B
112.	gas	瓦斯	C	152.	lift	粒	D
113.	gentleman	尖頭鰻	H	153.	linen	連仁	A
114.	gin	毡酒	B	154.	liqueur	利嬌	B

No.	English	Chinese	Sphere	No.	English	Chinese	Sphere
155.	logic	邏輯	I	195.	nylon	尼龍	A
156.	lorry	羅厘	D	196.	offset	柯式	I
157.	lymph	淋巴	I	197.	ohm	歐姆	G
158.	mach	馬赫	G	198.	omelets	奄列	B
159.	madam	馬當	H	199.	opium	鴉片	E
160.	magnesium	鎂	I	200.	order	柯打	I
161.	major	咩咋	H	201.	organdy	奧近地	A
162.	manganese	錳	I	202.	Oscar	奧斯卡	F
163.	mango	芒果	B	203.	ounce	安士	G
164.	marathon	馬拉松	F	204.	outside	歐西	I
165.	margarine	孖芝蓮	B	205.	pan	鎊	B
166.	margin	孖展	I	206.	pancake	班戟	B
167.	marijuana	大麻	E	207.	partner	拍𡆥	H
168.	mark	馬克	G	208.	party	派對	F
169.	maxi	密實	A	209.	pass	派司	I
170.	merchant	孖毡	H	210.	pear	啤梨	B
171.	meter	米	G	211.	pence	便士	G
172.	meter	咪	G	212.	penicillin	盤尼西林	E
173.	methadone	美沙酮	E	213.	pie	批	B
174.	microphone	咪高峰	I	214.	pint	品脫	G
175.	mignon	免翁	B	215.	place	披士	I
176.	milk shake	奶昔	B	216.	plum	布林	B
177.	mini	迷你	A	217.	port	砵	B
178.	miss	密斯	H	218.	porter	波打	B
179.	model	模特兒	H	219.	pose	甫士	I
180.	modern	摩登	I	220.	pound	磅	G
181.	mollie	摩利	I	221.	pudding	布丁	B
182.	montage	蒙太奇	F	222.	pump	水泵	I
183.	morphine	嗎啡	E	223.	punch	賓治	B
184.	motor	摩打	D	224.	quart	骨	G
185.	mummy	媽咪	H	225.	queen	昆	F
186.	mummy	木乃伊	H	226.	quinine	見蓮	E
187.	mycin	咪仙	E	227.	radar	雷達	I
188.	Napoleon	拿破崙	H	228.	radium	鐳	I
189.	Nazi	納粹	H	229.	rayon	雷虹	A
190.	neon	霓虹	I	230.	rifle	來福	I
191.	Newton	牛頓	H	231.	rock and roll	樂與怒	F
192.	nicotine	尼古丁	E	232.	romance	浪漫史	I
193.	number	冧巴	I	233.	root beer	律啤	B
194.	number one	冧巴溫	H	234.	rum	冧	B

No.	English	Chinese	Sphere	No.	English	Chinese	Sphere
235.	rumba	倫巴	F	273.	tango	探戈	F
236.	rupee	盧比	G	274.	tank	坦克	D
237.	sago	西米	B	275.	tart	撻	B
238.	salad	沙律	B	276.	taxi	的士	D
239.	salmon	三文魚	B	277.	telephone	德律風	C
240.	salon	沙龍	I	278.	terylene	特麗紡	A
241.	sandwich	三文治	B	279.	thinner	天拿	I
242.	sardine	沙甸	B	280.	tie	呔	A
243.	sarsparilla	沙士	B	281.	tip	貼	I
244.	Satan	撒旦	H	282.	tire	呔	D
245.	satay	沙嗲	B	283.	toast	多士	B
246.	sauna	桑拿浴	F	284.	toffee	拖肥	B
247.	saxophone	色士風	F	285.	ton	噸	G
248.	science	蔡因斯	I	286.	totem	圖騰	I
249.	sergeant	沙展	H	287.	Tsar	沙皇	H
250.	set	恤	C	288.	tse tse fly	彩彩蠅	I
251.	sharkskin	沙士堅	A	289.	ultimatum	哀的美敦	I
252.	sherbet	些拔	B	290.	vanilla	雲厘那	B
253.	sherry	些厘	B	291.	varnish	凡立司	I
254.	shilling	先令	G	292.	vaseline	花士苓	E
255.	shirt	恤衫	A	293.	violin	梵奧玲	F
256.	sideboard	西砵	I	294.	vitamin	維他命	E
257.	sink	星	C	295.	vodka	伏特加	B
258.	sirloin	西冷	B	296.	voile	畏勞	A
259.	size	西士	I	297.	volt	伏特	G
260.	slick	士力	I	298.	wafer	威化	B
261.	soda	梳打	B	299.	waffle	華夫	B
262.	sofa	梳化	C	300.	waltz	華爾茲	F
263.	soft	疏扶	I	301.	waste	威士	I
264.	soufflé	疏乎利	B	302.	watt	瓦特	G
265.	spanner	士巴拿	I	303.	whisky	威士忌	B
266.	spare	士啤	I	304.	winner	溫拿	F
267.	spring	司必令	I	305.	wire	威吔	I
268.	stamp	士担	I	306.	X-ray	X光	E
269.	stick	士的	I	307.	yoga	瑜珈	F
270.	store	士多	I	308.	yoyo	搖搖	F
271.	strawberry	士多啤梨	B	309.	zinc	星	I
272.	switch	士域子	I	310.	zombie	桑比	B

A: Clothing; B: Food; C: Accommodation; D: Transportation; E: Medicine; F: Entertainment; G: Measure; H: People; I: Others.

Agricultural and Aquacultural Potential in Delta Areas

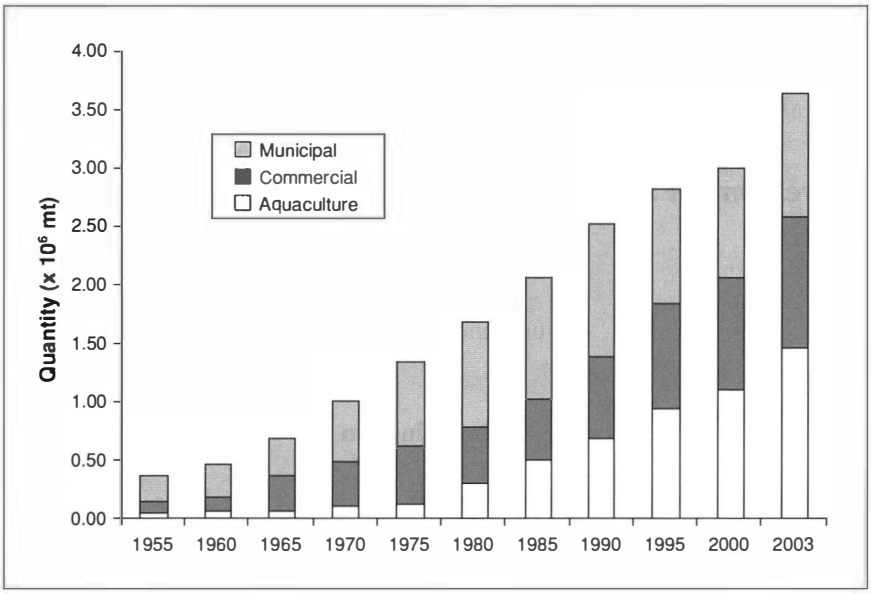

Fig. 1. — Philippine fisheries production by sector (municipal, commercial and aquaculture), 1955-2003 (BFAR 1965, 1975, 1985, 1991, 2003).

Table 1
Aquaculture systems in the Philippines (PRIMAVERA 2006).

Group	System	Method
Plants *Eucheuma, Kappaphycus, Gracilaria*	Rafts, longlines, beds	Extensive
Molluscs Oyster, mussel, cockle	Rafts, longlines, stakes	Extensive
Crustaceans Prawns/shrimps, Crabs	Ponds Pens	Extensive, semi-intensive, Intensive
Freshwater/marine/ brackish water fish Tilapia, milkfish, grouper, snapper	Ponds, pens, cages	Extensive, semi-intensive, intensive

seaweeds and bivalve mollusks, 22.5% by ponds, and 7.6% by pens and cages (tab. 2, fig. 2). Next to yields of 988,888 mt from marine seaweeds, aquaculture production was dominated by milkfish (236,468 mt) mainly from brackish water ponds, and tilapia (135,979 mt) mainly from freshwater ponds and pens/cages.

Table 2
2003 Aquaculture production (mt) in the Philippines by habitat and commodity and area covered in 1990 (BFAR 1991, 2003)

	Ponds	Pens/Cages	Others	Total
		12,644 ha		
A. Freshwater	14,531 ha			
Milkfish	—	21,681	—	21,681
Tilapia	68,056	58,386	—	126,442
Others	3,913	8,641	—	12,554
Subtotal	***71,969***	***88,708***	**—**	***160,677*** (11.0 %)
B. Brackish water	222,907 ha			
Milkfish	193,738	9,234	—	202,972
Tilapia	9,367	170	—	9,537
Prawns	37,032	—	—	37,032
Others	14,500	338	—	14,838
Subtotal	***254,637***	***9,742***	**—**	***264,379*** (18.2%)
C. Marine			8,398 ha	
Milkfish	—	11,815	—	11,815
Oysters	—	—	14,510	14,510
Mussels	—	—	13,490	13,490
Seaweeds	—	—	988,888	988,888
Others		305		305
Subtotal	**—**	***12,120***	***1,016,888***	***1,028,703*** (70.8 %)
TOTAL	**326,606** (22.5 %)	**110,570** (7.6%)	**1,016,888** (69.9 %)	**1,453,759** (100.0 %)

The beginnings of brackish water pond culture in Southeast Asia can be traced to Indonesia (SCHUSTER 1952) where a Javanese law codified in 1400 provided punishment for those who stole fish from saltwater ponds (HERRE & MENDOZA 1929). The first recorded fishpond in the Philippines was in Rizal province in 1863 (Philippine Census of 1921 in SIDDALL *et al.* 1985). From its early beginnings, Philippine aquaculture consisted wholly of milkfish farming in brackish water ponds (fig. 3) broken only in the mid-1970s, when the farming of tilapia, seaweeds and other commodities in freshwater

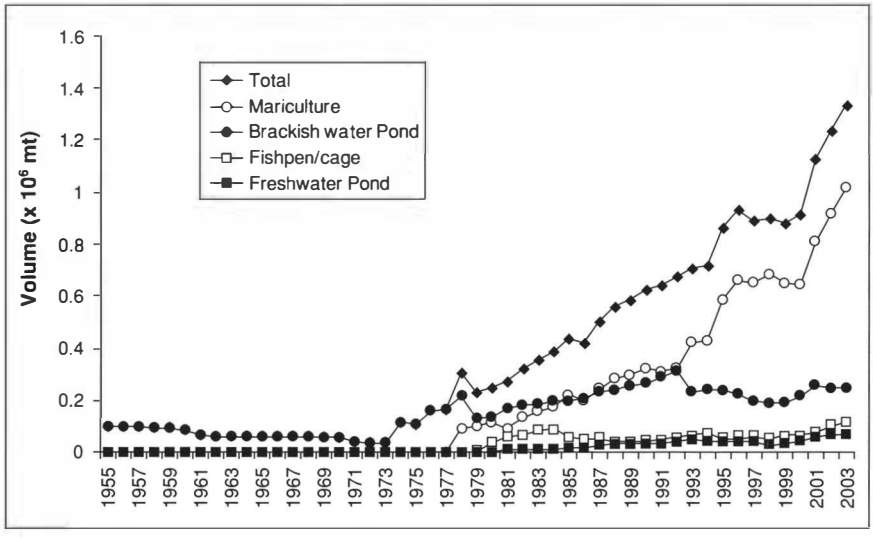

Fig. 2. — Philippine aquaculture production, total and habitat/culture system, 1955-2003 (BFAR 1965, 1975, 1985, 1995, 2003).

ponds, pens, cages, and floating/fixed lines appeared. This period coincides with the start of major aquaculture R&D programs by regional organizations like the Iloilo-based SEAFDEC Aquaculture Department, and national agencies and institutions such as the Philippine Council for Aquatic and Marine Resources Research and Development, Bureau of Fisheries, University of the Philippines in the Visayas, and Central Luzon State University.

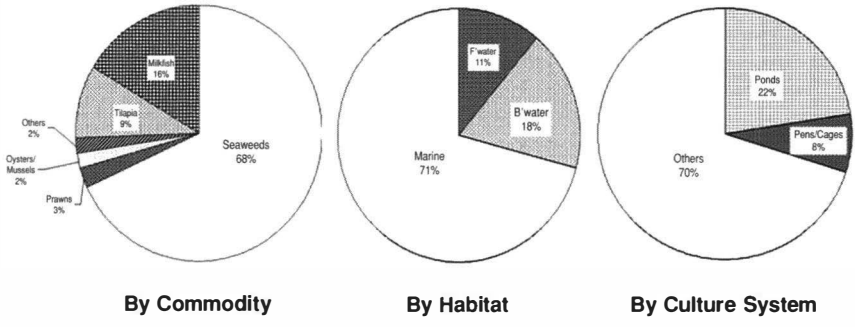

Fig. 3. — 2003 Philippine aquaculture production by commodity, habitat and culture system.

2.1. Milkfish

Even as production of milkfish *Chanos chanos* Forsskal from brackish water ponds steadily increased from 250 kg/ha/yr in 1940 to 760 kg/ha/yr in 1978 and 1,000 kg/ha/yr in 1982, the contribution of milkfish to total aquaculture production volume has declined from 100% in 1975 to only 17% in 2003. Successful milkfish culture can be traced to a large supply of wild seed, large domestic market, available manpower, and research and training support (Bagarinao 1998). The fast growth rate of *C. chanos* is related to its omnivorous diet, adaptation to crowding, resistance to disease, and wide tolerance to environmental conditions.

Pen culture of milkfish primarily in Laguna Lake started in the 1970s, covering up to 30,000 ha at its peak before it declined in the 1980s (Guerrero 1996). From brackish water ponds and freshwater lakes, milkfish was then introduced to pens and cages in subtidal marine waters in the 1990s.

2.2. Shrimp

From the cultivation of milkfish mostly as a single crop or sometimes in polyculture with shrimp, the profile of brackish water ponds in the Philippines has changed with the introduction of the giant or black tiger shrimp *Penaeus monodon* Fabricius. The phenomenal growth of shrimp culture has been driven by technology (making seed and feed available), high market demand, external development assistance from international organizations (*e.g.*, FAO-UNDP, Asian Development Bank and World Bank), active government support and private sector investment. Shrimp production steadily increased from one mt in 1975 to 47,600 mt in 1990, 90,000 mt in 1995, and back to 35,000 mt in 2003. Because of insurmountable bacterial and viral diseases which caused declines in *P. monodon* production, the tropical American species *Penaeus vannamei* Boone was introduced as a substitute, albeit illegally, into the country in the late 1990s. By late 2005, however, its pilot testing in accredited farms was approved in anticipation of a lifting of the government ban on this exotic species.

2.3. Tilapia

Experimental Laguna Lake cage and pen trials in 1973 tested Mozambique tilapia *Oreochromis mossambicus* Peters but Nile tilapia *Oreochromis niloticus* Linnaeus is now the primary species of culture. Dubbed the aquatic chicken, tilapia has since been introduced to freshwater ponds which now

yield 50% of total tilapia production while cages in lakes and reservoirs contribute another 30-40% (GUERRERO 1996).

2.4. SEAWEEDS

Commercial seaweeds of the genera *Eucheuma, Kappaphycus* and *Gracilaria* are cultured on fixed off-bottom and floating longlines in coral reef, seagrass and sediment habitats (GUERRERO 1996, HURTADO & LUHAN 2003) covering an estimated 10,000 ha. Their products, carrageenan and agar, are widely used in the food and pharmaceutical industries. The first plantation was set up in 1973, and the first exports of 90,000 mt were recorded in 1978. In 2003, seaweeds contributed 63% of total aquaculture volume but only 7% of total value.

2.5. OTHER COMMODITIES

In contrast, carnivorous groups including marine fish such as grouper and snapper (grown in cages) and pond-reared crustaceans, provided only 4% of total volume but 40% of total value (fig. 4). Other commodities are oysters and mussels on stakes and longlines in marine waters, and freshwater fish such as carps and catfish *Clarias* spp. in earthen ponds.

3. Environmental Impacts

As the bulk of production comes from marine and brackish water systems, the coastal zone bears most of the ecological consequences of aquaculture development. These include habitat loss/modification, effluent release into waterways, salinization of soil and water, loss of bycatch in wild seed and broodstock collection, introductions of exotic species, escapes of cultured animals, spread of diseases, misuse of chemicals and antibiotics, release of wastes, and dependence on fishmeal and fish oil (PRIMAVERA 1998, NAYLOR *et al.* 2000).

3.1. HABITAT LOSS

Coral reefs, seagrass beds and sediment communities have been degraded by the physical installation of seaweed longlines, fish pens and cages on these nearshore habitats (MSI 2001). But the most serious habitat loss is when intertidal mangroves are cleared for ponds. This transformation has

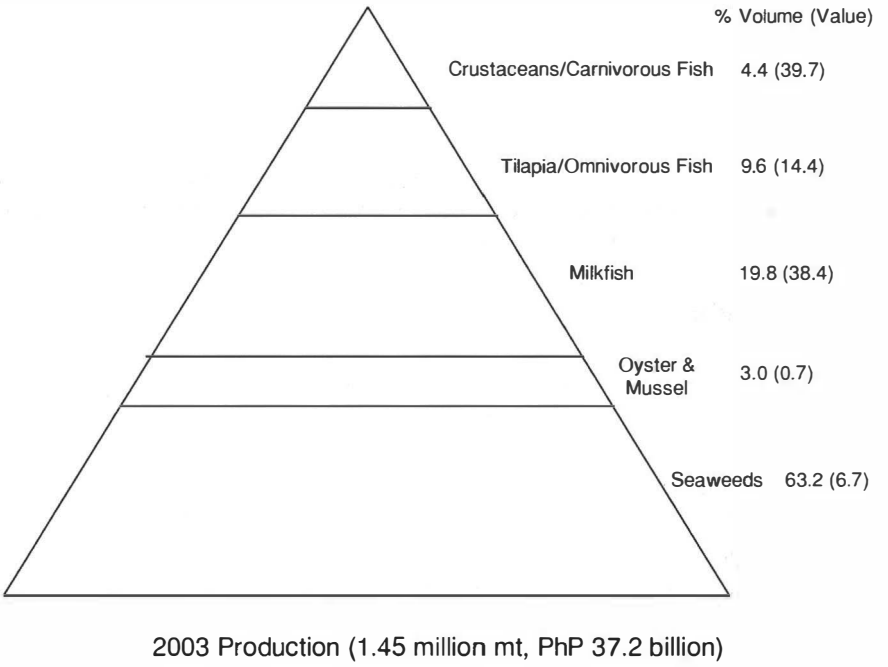

Fig. 4. — Contribution of different commodities to 2003 Philippine aquaculture production by volume and value, not drawn to scale (BFAR 2003).

resulted in the loss of essential ecosystem services generated by mangroves, including the provision of fish/crustacean nurseries, wildlife habitat, coastal protection, flood control, sediment trapping and water treatment. For a long time, the larger society has viewed mangroves and other wetlands as wastelands to be developed — the milkfish industry was considered important because it made use of "... otherwise practically valueless [mangrove] land" (CARBINE 1948) and mangroves were recommended as ideal aquaculture sites (ADAMS *et al.* 1932) with vast areas converted to earthen ponds for milkfish. Around half of the 279,000 ha of Philippine mangroves lost from 1951 to 1988 were developed into culture ponds; 95 % of Philippine brackish water ponds in 1952-1987 were derived from mangroves (PCAFNRRD 1991). The fishpond boom of the 1950s and 1960s (at 4,000-5,000 ha/yr) was fuelled by a loan of US$23.6 million for fishpond construction and operations from the International Bank for Reconstruction and Development (SIDDALL *et al.* 1985) released through such conduits as the Rehabilitation

Finance Corporation. These loans were intended "to accelerate... the conversion of vast areas of marshy lands [mangroves]... into productive fishponds" (VILLALUZ 1953). The Central Bank and the Development Bank of the Philippines provided assistance for pond construction, fish raising, processing and marketing through the Fishery Loan and Guarantee Fund and similar programs (KELLY 1996), and the Asian Development Bank made available $21.8 million in aquaculture loans for shrimp and fish hatcheries and ponds in 1984 (PRIMAVERA 1995).

3.2. WILD BYCATCH

Brackish water pond culture of milkfish and prawns depends mostly on collection of wild-caught seed and/or hatchery larvae from wild spawners or broodstock, with major consequences for wild fisheries. Wild juvenile milkfish collected for grow-out ponds constitute only 15% of total finfish fry from inshore seine net catches (BAGARINAO & TAKI 1986); the remaining 85% are discarded and left to die on the beach. The use of 1.7 billion wild milkfish fry stocked annually in culture ponds (BAGARINAO 1998) corresponds to a loss of about 10 billion fry of other finfish species. In shrimp culture, every fry of the favored tiger prawn *Penaeus monodon* means up to 330 other shrimp fry discarded in the Philippines (PRIMAVERA 1998).

3.3. SPECIES INTRODUCTIONS

Introductions of the tilapias, the third highest ranking aquaculture commodity, were all government-sponsored in the 1950s to the 1970s (FORTES 1992). Other exotic freshwater fish species such as carps and the catfish *Clarias batrachus* Linnaeus and *Clarias gariepinus* Burchell are likewise preferred because of the slow growth rate and/or small sizes of native species, *e.g., Clarias macrocephalus* Gunther. Among shrimps, *Penaeus stylirostris* Stimpson and *P. vannamei* were imported back in the 1970s but it was only in the 1990s that *P. vannamei* was grown widescale, covering some 700 ha in Luzon Island (OREJAS 2003). Instead of focusing on the longterm solution of changing unsustainable practices such as overly high densities of the stocked shrimp and the high concentration of farms, the industry has opted for the more convenient shortcut of changing species from the native *P. monodon* to *P. vannamei.*

The potential negative effects of such introductions include degradation of host environment, genetic degradation of host stock, and introduction of diseases and parasites. The White Spot Virus pandemic which has been

traced to the import into Japan of infected hatchery-produced *P. japonicus* from Chinese hatcheries in 1993 (MOMOYAMA *et al.* 1994) has subsequently spread to China, India, and Southeast Asia including the Philippines.

3.4. MISUSE OF CHEMICALS

Chemicals used in fish and shrimp culture include therapeutants, disinfectants, water and soil treatment compounds, algicides and pesticides (PRIMAVERA *et al.* 1993, ARTHUR *et al.* 2000). Excessive and unwanted use of such chemicals can result in toxicity to non-target populations (cultured species, human consumers, and wild biota), development of antibiotic resistance, and accumulation of residues (HOLSTROM *et al.* 2003). High rates of antibiotic resistance and widespread multiple resistance to tetracycline, oxytetracycline, oxolinic acid, furazolidone and chloramphenicol were observed in bacteria from shrimp ponds where antibiotics were routinely used (TENDENCIA & DELA PENA 2001). Organotin pesticides have long been used to control the snail *Cerithidea cingulata* that prevents growth of natural food in Philippine milkfish ponds. A government ban on these potentially harmful molluscicides has not stopped the backdoor smuggling from Indonesia and Malaysia where they remain legal. COLOSO & BORLONGAN (1999) found evidence of triphenyltin contamination of sediment and milkfish tissues collected from ponds previously treated with organotins.

3.5. AQUACULTURE WASTES AND COASTAL POLLUTION

As fish/shrimp biomass and feed inputs grow, the water quality in intensive ponds, pens and cages deteriorates over the cropping cycle. Sediment is the major sink accounting for 31% of N output, 84% of P, 63% of organic matter and 93% of solids, and accumulates in intensive shrimp ponds at the rate of 185-199 mt/ha/crop dry wt., while effluent water during regular flushing and at harvest accounts for 45% of nitrogen and 22% of organic matter output (BRIGGS & FUNGE-SMITH 1994). Quality of receiving waters deteriorates if the assimilative capacity of the environment is exceeded.

In early 2002, massive milkfish kills in pens and cages in Pangasinan, northern Philippines, of 110,000 mt valued at PhP800 million ($16 million) were traced to overstocking, overfeeding and low dissolved oxygen levels. Nutrient fluxes and organic matter levels were found to be higher inside fish pens compared to outside (HOLMER *et al.* 2002). Pens released 51-68% of total carbon and nitrogen inputs to the surroundings, and phosphorus was bound in the sediments, resulting in significant environmental impacts.

3.6. Salinization of Soil and Water

Pumping large volumes of underground water to achieve brackish water salinity led to the lowering of groundwater levels, and salinization of adjacent land and waterways in the Philippines and elsewhere in Southeast Asia (Primavera 1993, 1997). Even when fresh water is no longer pumped from aquifers, the discharge of salt water from shrimp farms located behind mangroves still causes salinization in adjoining rice and other agricultural lands (Dierberg *et al.* 1996).

3.7. Dependence on Wild Fisheries

Most of the milkfish and tilapia cultured in pens and cages are given formulated feeds although they are herbivores and omnivores; intensive pond culture also relies on pellets. The proportion of fish meal in aquaculture feeds is much higher than in poultry and livestock feeds, with one kilogram of carnivorous fish requiring up to 5 kg of wild fish (Tacon 2005). The demand for fish meal, fish oil and 'trash' (raw) fish is highest in aquaculture, growing from 10% in 1988 to 65-68% in 2002 (Naylor *et al.* 2000, Tacon 2005). This appropriation of aquatic productivity for fish feeds reduces wild fish supplies for low income communities. Philippine fisheries are so depleted and coastal communities so poor that even the smallest and cheapest fish are consumed by humans.

4. Socioeconomic Impacts

Negative socioeconomic impacts of aquaculture include loss of mangrove goods and services, blocked access to coastal resources, fisheries decline, food insecurity, rural unemployment, social disruption, and conflicts (Primavera 1993, 1995, 1997). Many of these impacts are related to income distribution. The contribution of aquaculture to total fisheries production increased from 10.1% in 1955 to 40.2% in 2003, while that of municipal fisheries decreased from 60% to 29% for the same period (fig. 1). This has negative implications for equity because municipal fishers number 2.6 times those employed in aquaculture — 675,000 vs 258,500 (BFAR 2003).

Fish and shrimp culture ponds spread over 232,000 ha of coastline (DENR 1996) represent a fourfold increase in pond area from 61,000 ha in 1940 (Rabanal 1961). Conversely, mangroves declined from some 500,000 ha in 1918 to around 120,000 ha in 1994 (Primavera 1995), mainly due to conversion to aquaculture, giving a 2:1 pond-to-mangrove ratio.

Another issue is the relative ease by which mangroves have been transformed from public forests to aquaculture ponds. The fishpond lease fee of PhP50/ha/yr (= US$1/ha/yr in the 1950s) charged for government-owned ponds was not commensurate to values of fish and wood harvests from Philippine mangroves estimated at $538/ha/yr and $42-156/ha/yr, respectively (SCHATZ 1991) and the economic rent of mangroves converted into culture ponds calculated at $20-130/ha/yr (EVANGELISTA 1992). Such low government fees encourage mangrove conversion to ponds by underpricing the rights to harvest public forests, but do not penalize low pond production (World Bank 1989).

5. Sustainable Aquaculture

Sustainable aquaculture can be promoted both on the farm level and within the wider context of coastal zone management. Grow-out systems need to reduce and mitigate negative impacts and improve sustainability through the development and wider dissemination of available onfarm technologies and integration of aquatic species (polyculture of tilapia/fish and shrimp in ponds).

5.1. FARM SITING

Criteria include such standard physical factors as water supply, tidal regime, topography, soil quality and climate and also the capacity of the environment to absorb effluents. More important than fish/shrimp density inside ponds is the farm density in a given area so that the (waste) absorbing or assimilative capacity of the environment is not exceeded.

5.2. FARM AND EFFLUENT MANAGEMENT

Closed and semiclosed systems that recycle water through a series of reservoirs, treatment ponds (with fish, bivalves and algae in what is called the greenwater technique) and canals back to production ponds serve to reduce the amount of discharged wastes and minimize the entry of disease organisms from natural waters. A fallowing period between crops will provide recovery time for ponds.

Pond sludge may be reduced by applying probiotics, holding a portion of harvest water in a settling pond, or tilling and drying the pond bottom. Alternatively, sludge may be collected and stored near the farm for mangrove planting or subsequent transfer to agricultural or forest land. Mangroves can

also be used to treat shrimp pond effluents with high levels of solids and nutrients (see below).

5.3. Disease Control

The control of diseases (and pests) through the use of chemicals should be a last resort only after environmental conditions, nutrition and hygiene have been optimized. Chemicals used should be safe to the environment, cultured species, farm workers, and consumers. Farmers should avoid prophylactic treatment, apply effective and narrow spectrum antibacterials, adopt withdrawal periods and avoid discharge of effluents with toxic chemical levels into natural water bodies (Arthur *et al.* 2000).

5.4. Native and Low Trophic Level Species

Introductions of exotic species should be minimized and strictly follow established protocols. There is a need to counter the market-driven trend towards carnivorous crustaceans and marine fish and focus on herbivorous species that do not require fishmeal-based pellets or raw fish. There is also need to reduce fishmeal/fish oil levels in feeds and N, P levels in effluents.

5.5. Mangrove-friendly Aquaculture

Mangroves and aquaculture are not necessarily incompatible. Seaweeds, bivalves and fish (seabass, grouper in cages) can be grown in subtidal mangrove waterways. More difficult is the integration of aquaculture and intertidal mangroves. Present-day examples of such integrated forestry-fisheries-aquaculture systems can be found in the traditional *gei wai* ponds in Hong Kong, mangrove-shrimp ponds in Vietnam, and silvofisheries in Indonesia (Primavera 2000). Guidelines for the responsible use of mangrove areas for aquaculture are discussed in Bagarinao & Primavera (2005).

Alternatively, mangroves can be used as mud crab farming sites and those adjacent to intensive ponds as biofilters for processing effluents. In one study, passing shrimp pond effluents through a natural mangrove stand for 6 h reduced levels of total solids, sulfide, ammonia, and nitrate by 18.7-64.2 %. Biomass increase of mangroves with effluents was 2.5 times greater compared to a control mangrove. Results show that 1.8-5.4 ha of mangroves are needed to assimilate nitrate wastes from one hectare of shrimp pond (Primavera *et al.*, in press).

Present mud crab *Scylla* spp. farming still depends on raw fish and wild seed. To lessen such dependence, another study compared the stocking of hatchery vs wild juveniles, and feeding of pellet+raw fish vs fish alone. Preliminary results show that low-cost pellets can reduce raw fish requirement in crab diets, but hatchery-reared crab juveniles need behavioral conditioning for foraging and predator avoidance before they can be released in mangrove pen sites.

6. Fishponds and the Coastal Zone

Coastal zones should be delineated for fisheries, forestry, aquaculture, tourism and other uses (fig. 5) through the process of Integrated Coastal Zone Management. Allocation of activities should be based on the carrying capacity of the environment for a given use, protection of community resources, rehabilitation of degraded habitats, stakeholder needs and mechanisms for conflict resolution.

To protect vulnerable Philippine coastlines from typhoons and tsunamis, there is need to enforce numerous greenbelt laws such as Presidential Decree

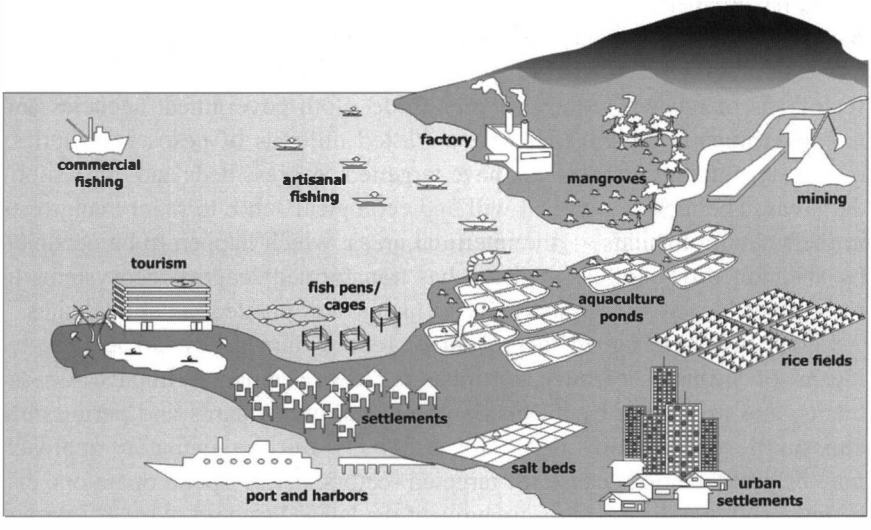

Fig. 5. — Multiple uses of the coastal zone in the Philippines and Southeast Asia.

(P. D.) 705 and P. D. 953 that require a buffer zone of 20-50 m wide along rivers and 50-100 m facing open seas (PRIMAVERA 1997). An aerial view of the Philippine coastline will show pond after fishpond in monotonous succession with hardly a relief of green. Mangrove-coastal forest greenbelts are necessary because 20-30 typhoons that visit the country yearly leave thousands dead, injured or missing, and damage to infrastructure and property in the millions of pesos. Tsunamis that appear every 20-50 years may be less common but more catastrophic.

The present 232,000 ha of fish/shrimp culture ponds and 120,000 ha of remaining mangroves give a 2:1 pond-to-mangrove ratio for the Philippines, which is way beyond the ideal 1:4 ratio. The Precautionary Principle as applied to mangroves states that no more than 20% of a discrete mangrove area should be converted to ponds (SAENGER *et al.* 1983).

Often single families own up to hundreds of hectares of pond area whereas Thai shrimp farms average only 2 ha or less. Most Filipino pond operators reside in towns and cities to practice law, medicine and other professions as primary source of income — and leave daily pond operations to a caretaker. In contrast, Thai and other Southeast Asian farmers live onsite, allowing 24-hour care of their stock. Therefore many Philippine ponds suffer from low productivity because they are poorly managed, underutilized or abandoned. By reducing farm sizes, Filipino pond operators can increase pond yields and afford to pay the rental fee of PhP1000/ha/yr (PRIMAVERA 2005).

Many, perhaps up to a third, of government-leased ponds have no associated legal papers — either the lease has expired or the application is pending. Such abandoned and illegal ponds should be reverted to mangroves (instead of being reactivated to increase fish production from the aquaculture sector), as mandated by the Fisheries Code. Both government agencies and nongovernmental organizations have wasted millions of pesos in countless mangrove planting projects that have targetted seagrass beds and other subtidal areas. The lack of political will and ecological sense to plant mangroves in their natural habitats — the intertidal areas, which happen to be occupied by abandoned or expired ponds — has transformed seagrass ecosystems to mangroves, or led to high mortality of mangroves planted in subtidal sites.

Legislation is designed to prevent or reduce damage by aquaculture by means of licenses, permits, certifications, Environmental Impact Assessments, and regulation by means of water quality standards and permissible emission levels programs (VAN HOUTTE 1995). But the regulatory approach may be problematic because the targeted sectors, *i.e.*, fishpond operators, can be powerful and disregard or circumvent the laws (BARRACLOUGH & FINGERSTICH 1996). Moreover, there is little will or ability to enforce legislation,

often because the delineation of the government agencies responsible for enforcement of specific laws, and the level of authority, whether local, state, provincial, regional or national, for enforcement remain vague. Developing countries should therefore adopt coastal zone management policies based on the local social and political economy instead of copying the model in developed countries designed for a politically stable middle class (MELTZOFF & LIPUMA 1986).

Green taxes can mitigate the environmental and socioeconomic damage of aquaculture by correcting water quality problems, financing alternative water supplies in salt-contaminated areas, rehabilitating mangroves and other damaged landscapes, and compensating local populations for the loss in livelihoods (BARRACLOUGH & FINGER-STICH 1996). Economic incentives and disincentives in the form of fees, taxes and penalties for effluent disposal, groundwater abstraction, chemical use, etc. may be more effective than regulatory approaches in promoting environmental protection and generating revenues to finance environmental policy programs (VAN HOUTTE 1995). Such fees should reflect the economic rent of the resource used, *e.g.*, ground water and mangrove area converted to pond and encourage efficient pond utilization.

For example, the relatively low fee for leasing ponds of PhP50/ha/yr was increased to PhP1,000/ha/yr (~$40/ha/yr) in 1991, but a lobby by the aquaculture industry postponed implementation indefinitely (PRIMAVERA 1993). The 1998 Fisheries Code mandated a yearly increase of PhP250/ha until the full PhP1,000/ha/yr was reached, with implementing guidelines embodied in Fisheries Administrative Order (F.A.O.) 197. In 2002, the Iloilo Fishpond Producers Association (IFPA) filed a complaint with the Regional Trial Court questioning the validity of F.A.O. 197 (PRIMAVERA 2005). After more than two years of hearings, the court dismissed the complaint because no evidence was presented that such rent increase would lead to bankruptcy of the plaintiff fishpond producers. The enforcement of such vital legislation a full 13 years after promulgation reflects lack of political will.

7. Conclusion

From the low-density monoculture of milkfish in brackish water ponds, Philippine aquaculture has expanded to cover many plant and animal crops grown in a variety of pond, pen, cage, and longline systems in all the major aquatic habitats. Hence it has become an important sector contributing 40% of total fisheries production in the country. Aquaculture sustainability can be

assured through onfarm improvements in feed, water, effluent and disease management, focus on native and low trophic level species, and integration with agriculture and silviculture, in particular mangroves. But aquaculture development must also address a number of negative environmental and socioeconomic impacts, so it can fulfill the promises of food security and poverty alleviation. For this, a paradigm shift is needed away from its sectoral promotion detached from traditional coastal activities to a more holistic approach requiring the participation of other stakeholders including fishers and local communities. For brackish water pond culture, this new paradigm shall mean pond operators giving up some hectarage for reversion back to mangroves and establishment of protective greenbelts, improving farm efficiency and productivity of their remaining farm areas, and paying increased pond lease fees commensurate to economic rent.

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Agricultural Potential of Delta Areas in Peninsular Malaysia with Particular Reference to Those in the Kelantan Plain

by

Jusop SHAMSHUDDIN*, Abdul Rahim ANUAR** & Syed Rastan SYED OMAR**

1. Introduction

The complex of deltas located in the northeast of the Malay Peninsula, otherwise referred to as the Kelantan plain, lies about 6° N of the Equator (fig. 1). The plain is in the tropical wet climatic zone, with mean temperature of 32 °C and mean annual rainfall varies from 2,290 to 2,540 mm (OOI 1964). The climate is influenced by the South China Sea during the Northeast Monsoon (November to January). The relative humidity is high; the main daily minimum is 60 % and the main daily maximum is 95 % (OOI 1964).

The 280 km long Kelantan River (fig. 1), which drains into the South China Sea, is the third longest river in the Malay Peninsula (DJIA 1973). This river system has evolved through the years, built up an extensive plain at its lower reaches. The characteristics of the major soil types found in the plain are in a way much related to riverine and marine erosion and deposition as a result of the sea level changes during the Quaternary.

The succession of sandy deposits forming ridges at some part of the coast of the northeast Kelantan indicates a recession of the sea and the lowering of the sea level for many meters. The formation of these beach ridges is the

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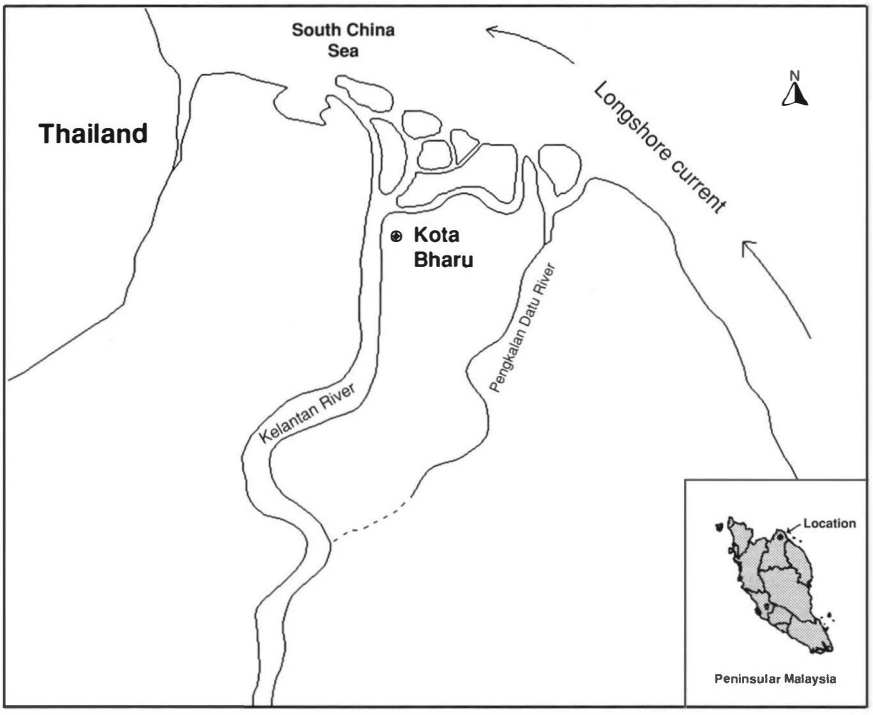

Fig. 1. — A map showing the location of Kelantan plain.

result of the falling sea level since Pleistocene. The ridge furthest inland has the maximum height of 7.5 m above the present sea level and their elevation decreases steadily towards the sea (NOSSIN 1961). The presence of these marine deposits is a clear evidence for Quaternary sea level changes (NOSSIN 1961, 1965). DJIA (1973) proposed from the available geological data that the highest sea level was 30-40 m above the present sea level.

When the sea level was at its highest, much of the present Kelantan plain was inundated. This somewhat influenced delta development in the area and the composition of the alluvial deposits forming the parent materials of the present soil types. The mouth of the Kelantan River was found to have shifted some 35 km towards NW or WNW due the influence of the longshore current prevailing in the area (DJIA 1973). This had, to a certain extent, changed the composition of the riverine deposits that become the parent materials of the soils in the plain.

The Kelantan plain have had settlements since immemorial. As far as we know, agriculture had been and still the main economic activity in the plain, with rice as the major crop, followed by fruit trees cultivation. In recent time, however, tobacco is being grown widely in the less fertile areas of the plain under strict government regulation so as to ensure high tobacco leaf productivity as well as quality.

The objectives of this paper are: a) to discuss the formation/occurrence of various soil types in the Kelantan plain; b) to describe the physico-chemical characteristics of those soils in relation to their crop productivity; and c) to evaluate or determine the potential of the Kelantan plain for agriculture production.

2. Soils in the Kelantan Plain

2.1. Soil Type

Soo (1975) had studied and produced a semi-detailed soil map of the Kelantan plain some thirty years ago. We studied this map carefully during the preparation of this paper and found interesting information, which is now discussed. On the riverine alluvial deposits, soils of the Tok Yong-Cempaka-Lundang Association are found extensively. On the other hand, those on the marine alluvial deposits are located soils of the Rudua-Rusila Association. Other soil type but of lesser acreage is the soil of Telemong Series. Peat and acid sulfate soils (with or without peat within their solum) are found in small pockets in areas close to or at some distant away from the coastal area. The soils in the Kelantan plain classified according to soil taxonomy (Soil Survey Staff 1999) are given in table 1.

Table 1
Major soil types in the Kelantan plain

Soil Series	Great Group
Tok Yong	Dystropepts
Cempaka	Tropudults
Lundang	Tropudults
Rudua	Troporthods
Rusila	Tropaquods
Telemong	Dystropepts

Source: Paramananthan (1983).

2.2. Soil Characteristics

The Tok Yong Series is the most widespread soil in the Kelantan plain (Soo 1975). According to Soo (1975), this free-drained soil is formed on recent riverine alluvial deposits. It has a yellowish brown color to a depth of about 50 cm. In the plain landscape, it is located at the highest elevation. At a slightly lower elevation occurs the soil of Cempaka Series, having fluctuation water table. This soil is identified by the presence of light red mottling about 40 cm below the surface. In the Lundang Series, this mottling is more pronounced, occurring near to the surface. The Lundang soil is also located at lower elevation than the Tok Yong soil. Also occurs in the Kelantan plain, but of less frequency, is a soil with loam, loamy sand and sandy clay loan texture, with weak structures and loose to friable consistence. This is the soil of Telemong Series. By and large, this Telemong soil is the least developed of all soils found in the plain. It has been used for growing cash crops like maize and groundnut just before the beginning of the Monsoon period, in the months of November-January.

The most important soils in terms of acreage and agricultural productivity are the soils of the Tok Yong and Cempaka Series. In reality, these two soils occur in close proximity, meaning occur in association. They are generally characterized by the presence of low organic carbon, and their cation exchange capacity is also low (tab. 2). The amount of clay content in the two soils is moderately high, fitting them into the clayey textural class.

Table 2
Physico-chemical properties of selected soils in the Kelantan plains

Soil	Depth cm	Organic Carbon %	Nitrogen	Clay	Cation Exchange Capacity $cmol_c/kg$
Tok Yong	0-20	1.27	0.16	36.9	11.7
	20-40	0.68	0.11	39.5	11.7
Cempaka	0-20	0.98	0.14	38.3	12.9
	20-40	0.06	0.11	47.5	10.1

Source: Aminuddin *et al.* (2003).

The soils of Tok Yong and Cempaka Series are normally planted to paddy with mixed success, but generally the yield is usually slightly below the national average of 3-4 t/ha. These paddy soils have all the properties common to soils intermittently flooded with water. For example, manganese concretions are found in the subsoil (Aminuddin & Fitzpatrick 1991).

Paddy is cultivated on these soils since immemorial times. Continuous paddy cultivation on these soils over many years had resulted in them being slightly physically and chemically degraded (AMINUDDIN *et al.* 2003).

2.3. SOIL SUITABILITY CLASSIFICATION

Based on the Soil-Crop Suitability Classification of WONG (1986), SOO (1975) grouped the Tok Yong-Cempaka-Lundang Association as a Class II soils. The reasons being the soils have unfavorable topography and micro-relief. Additionally, they have a slightly excessive internal drainage. This is due to the slightly sandy nature of the alluvial deposits forming these three soil series. This is presumably the reason why paddy yield in the areas on the Kelantan plain covered by these soils is not as good as that of the main granary areas in the Peninsula.

In Kedah, the main granary area of the country, for instance, the marine alluvial soils planted with paddy produce an average yield of 6-7 t/ha using farmer's practice. With the advent of the state-of-the-art technology in paddy production, the Ministry of Agriculture Malaysia envisages a paddy yield of up to 10 t/ha in not too distant future in this area. The same kind of yield is aimed at in the Kelantan plain, but we have to treat this with caution as the two areas have soils with different fertility status. Research is ongoing in the Kelantan plain by the research arm of the Ministry of Agriculture Malaysia, the Malaysian Agricultural Research and Development Institute (MARDI) towards achieving that kind of ideal paddy yield of 10 t/ha.

The Rudua-Rusila Association is classified as class V soils. The main reasons are low fertility due to sandy textural class, low storage capacity, unfavorable topography, excessive drainage and low organic matter contents.

3. The Agricultural Potential of the Kelantan Plain

Kelantan is a rural-based state with the majority of the population involved in agriculture-based economic activities such as paddy and tobacco cultivation. Some cash crops such as maize and groundnut are grown to supplement the meager income from the cultivation of paddy or tobacco. The people of Kelantan are mainly concentrated in this area. They are mostly poor farmers who get fertilizer and pesticide subsidy from the government. Unfortunately, farmers tend to follow the traditional farming practice, which produce paddy yield far below its potential yield. This is made worse by the comparatively

poor soils on which the crop is grown. Of late, however, the government is going all out to promote a new technology in paddy cultivation. As such, extension work by the Ministry of Agriculture is actively ongoing throughout the plain to explain to the farmers with a view of adopting it for their own good.

As it is now, the clay textured soils, the Tok Yong-Cempaka-Lundang Association, are planted to paddy with mixed yield level using farmer's practice. The sand textured ones, the Rudua-Rusila Association, occurring at or near the coast is suited to tobacco. The yield of tobacco grown on these soils is kept improving by the years, thanks to the good research work of MARDI in the last ten years or so.

As being known, on their own, the soils in the Kelantan plain are less fertile compared to those in Kedah or any other granary areas in the Peninsula. But with the availability of the new technology on paddy cultivation, soil productivity can be somewhat improved. For example studies conducted by MARDI showed that the Tok Yong and Cempaka soils could yield paddy up to 8 t/ha in one season (AZIZ BIDIN 2003). ISMAIL (2003) found also that rice grown on these soils would be increased by 30% to about 8 t/ha by proper management of organic matter in the field after harvest. These are far too good compared to farmer's practice of slightly less than 3-4 t/ha only.

It means here that the Kelantan plain can be made suitable for agriculture. It has great potential to be a new granary area for Malaysia. With fertilizer and pesticide subsidy and following the state-of-the-art paddy production technology, the paddy yield in the area can even reach the government target of 10 t/ha. This is yet to be achieved though. We believe sincerely it would be some time in the future once the farmers adopt the new technologies obtained from research that are being conducted now.

RAZAK *et al.* (2004) of MARDI had recently conducted a trial to test a new fertilizer recommendation termed as FERTO (Fertilizer Tool) for paddy cultivation in Malaysia. One of the sites is in the Kelantan plain. It was found that using this technique, the farmers could get yield as high as 8 t/ha, comparable to that of AZIZ BIDIN (2003). Other research trying to improve paddy yield had also been conducted (SUHAIMI *et al.* 2004). The researchers had tried to improve soil productivity for paddy cultivation using an expert system known as DREST-DSS (Crop Establishment — Decision Support System). The adoption of this expert system, as part of the precision agriculture program now being promoted in Malaysia, is being tested in the Kelantan plain too. Hopefully, it would increase farmer's income substantially by the increased paddy yield.

Even on the very infertile soils known as acid sulfate soils, paddy can be grown with comparable yield provided the farmers adopt the new information recently acquired through research on acid sulfate soil in that area. For this to happen, the acid sulfate soil has to be limed with ground magnesium limestone (GML) at appropriate rate (fig. 2). Results obtained by the authors given in table 3 showed that in 2nd season (about 18 months after liming) a paddy yield of >7 t/ha was obtained with application 4 t GML/ha in combination with a paddy husk-based organic fertilizer (fig. 3). In the trial, the seeds were treated with a newly formulated growth enhancer (Vitagrow). Work is ongoing to see how long the ameliorative effect of lime lasts. The farmers can reap big profit if the liming is effective for more than three years. Note that the paddy yield for the 1st season was not significantly improved with treatment. This was because the experimental plots were severely affected by the big flood of November 2002.

The good results from research conducted on soils of the Kelantan plain go to show that the area has great potential for agriculture. What the government needs to do now is to convince the farmers in the affected areas to

Fig. 2. — Liming an acid sulfate soil using a tractor.

adopt the newly acquired technologies in paddy cultivation. The types of crops to be grown on which soils have to be remained the same as currently practiced. By this we mean that the clayey soil types are for paddy cultivation, while the sandy types are for tobacco. This is to avoid the research data gathered so far in the targeted areas have not gone to waste. In so doing, the farmers in the Kelantan plain can make a living tilling their land and make agriculture a very important economic activity for the state.

Fig. 3. — Rice on the field.

Table 3
The potential of acid sulfate soil for paddy cultivation

Treatment	**Yield** (t/ha)	
	1st Season	**2nd Season**
Control	4.5	5.1
4 t GML/ha	3.5	6.3
8 t GML/ha	4.2	7.2
4 t GML/ha + JITU	3.7	7.5

Source: unpublished data from senior authors.

4. Land Pollution

The main crops grown in the Kelantan plain are paddy and tobacco, in order of importance in terms of area covered and income obtained. Relatively high fertilizers are used in the rice and tobacco agro-systems that this inputs could contaminate the shallow groundwater in the areas. Many farmers in the Kelatan plain are dependent on the shallow groundwater as the source for domestic and agricultural water supply.

In the paddy agro-system, the average level of ammonium ions in the drinking wells is generally below the permissible level (AHMAD *et al.* 1996). However, in the tobacco agro-system, AHMAD *et al.* (1996) found that the ammonium ions in the groundwater were high (1 mg/l) in June 1992. Drinking well data indicated that nitrate ions could get into the groundwater very quickly during the months of fertilizer applications (March-April). It was found also that nitrate ions increased again in August-October, with corresponding decrease in ammonium nitrogen.

In the vicinity of the acid sulfate soil areas, our preliminary investigation of the water in the canals and the drinking wells indicated that it was unsuitable for domestic purposes as the pH was low with value of about 5.7. It was also found that the water was contaminated with aluminium. The water has a bad small. The groundwater in such areas is thus unfit for drinking. This is an important chemical degradation of the land.

There is too much iron in the water of the paddy fields in the vicinity of the acid sulfate soils in the Kelantan plain. When the paddy fields are flooded after a spate of dry season, the water in the fields is reddish brown in color showing the presence of high amounts of Fe oxides/hydroxides (fig. 4). If these are not alleviated soon enough during the cropping season, they would greatly affect rice production on the field.

The state government of Kelantan has to be sensitive to the occurrence of this health hazard. Steps should be taken immediately to overcome it. The farmers should not be allowed to use groundwater in the areas contaminated with ammonium, nitrate, Al and Fe ions for domestic purposes unless it is assured that the water quality is fit for drinking.

5. Conclusion

The delta forming the extensive Kelantan plain has had settlements and has been cultivated with paddy since immemorial times. Later, tobacco became an

Fig. 4. — Fe and Al contamination in the paddy fields.

important economic crop in the area. Paddy yield was low using farmer's practice partly due to soil infertility. With the advent of the new technologies and their adoption for paddy production, the yield can be increased significantly. This would increase the income of poor farmers in the area. However, the farmers are facing the problem of land degradation, in the form of groundwater pollution, which needs to be looked into seriously by the government.

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Rice Production, Actual Soil Productivity and Agricultural Potential in the Mekong Delta, Vietnam

by

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Eric VAN RANST*** & NGUYEN VAN NHAN****

1. Introduction

1.1. General Information of the Mekong Delta

On the world map, Vietnam is located at the Eastern border of the Indochinese peninsular and belongs to the South-East-Asia region (fig. 1). The total area of natural land is about 33 million ha, and it extends between 23°22'N- 8°30'N latitude and 102°10'E — 109°24'E longitude (LE BA THAO 1997). Therefore, the climatic condition of Vietnam is somehow determined by continental influences, except in the North. About 2/3 of the territorial mainland is covered by hills and mountains. However, there are also large and rather fertile deltas, where annually fluvial materials of the Red river system (North) and the Mekong river system (South) are deposited. These deltas join with the narrow coastal plains along the central region. At present, about 55 % of the natural land area is being used for agriculture (about 7 millions ha), forestry and other specific purposes. In 2004, the national population was approximately 82 million.

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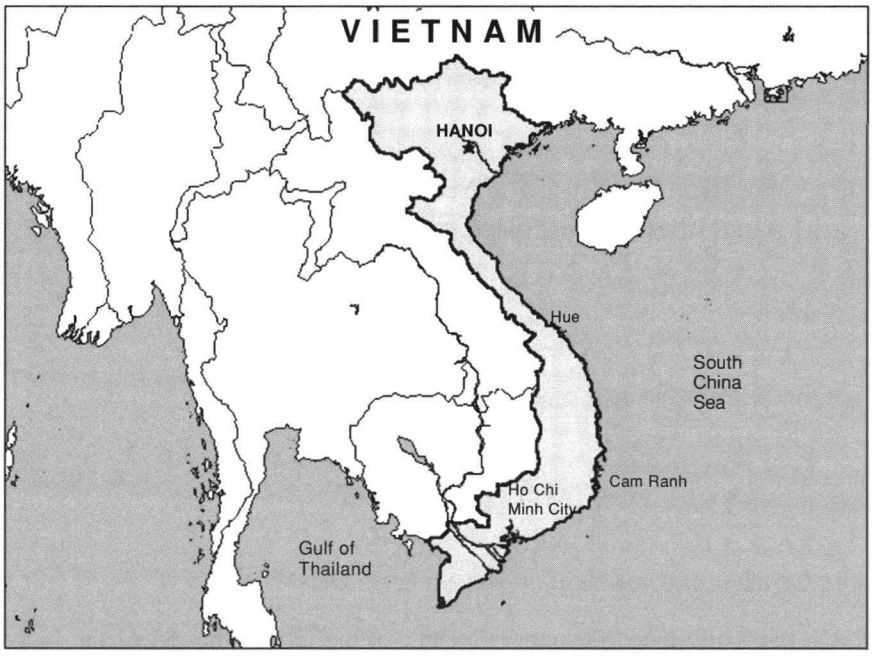

Fig. 1. — Map of Vietnam and the Mekong Delta in South East Asia.

The Mekong Delta is part of the Mekong river delta. It covers an area of 3.96 million ha (about 74% of the total area formed by the Mekong River and 12% compared to the total natural land area of Vietnam). It spreads from 11°N to 8°30'N, as the most Southern territory of the country. It occupies almost completely the down-stream area of the Mekong River and is with three sides connected to the sea. To the west, the delta borders the Gulf of Thailand; the eastern and southern parts join the Eastern Sea, and the northern and north-eastern part is bordering to Cambodia and the southeast part of Vietnam (fig. 2).

The eastern and northern parts of the delta are the areas consisting of old alluvial sedimentation with a relatively high elevation, varying from 4-5 m above sea level. The western and southern parts are gently sloping down to the sea. The main depression area is a plain of reeds in Dong Thap Muoi (Dong Thap province) with an average elevation ± 0.5 m. The elevation of sandy bridges and levees is about ± 3.5 m, while the mountainous areas in the northern (That Son district, An Giang province) and northwest direction (Ha Tien, Hon Dat district, Kien Giang province) are much higher. The highest point is the top of the Cam Mountain (+ 780 m). Generally, the average elevation of the Mekong Delta is ± 2 m and almost flat.

The Mekong Delta comprises 13 provinces, nowadays (fig. 2): Ca Mau, Bac Lieu, Soc Trang, Can Tho, Hau Giang, An Giang, Kien Giang, Dong Thap, Vinh Long, Tra Vinh, Tien Giang, Ben Tre and Long An. The regional population is about 17 million (about 20 % of the country). It has also been considered as a very important delta of the country, contributing about 47.4 % of national agricultural produce, 50 % of national rice produce and 60 % of national fruit produce (the brochure of Can Tho University 2004).

The typical characteristics of the Mekong Delta, influenced by soil forming processes are soil ripening, humus accumulation, leaching, acidification, gleyisation and plinthite-laterisation.

1.2. Major Soil Groups in the Mekong Delta

Based on the result of USDA soil taxonomy classification system, soils can be regionally grouped into the major soil groups as following (Le Van Khoa 2000):

1. Alluvial soils;
2. Acid Sulphate Soils;
3. Saline soils;
4. Saline-Acid Sulphate Soils;
5. Degraded Grey Soils;
6. Peaty soils;
7. Sand-ridge soils.

From these soil groups, alluvial soils and three other major soil groups (saline soils, degraded Grey Soils and Acid Sulphate Soils) are selected for this study. The alluvial soils occupy about 1 million ha of the total natural area of the Mekong Delta (approximately 3 million ha over the country) and they are distributed in the middle of the delta. The largest soil group is the acid sulphate soil group (occupying approximately 1.5 million ha) is located mainly in the northern and western part and the most southern area of the delta (Nguyen Bao Ve 1985-1990, Le Van Khoa 1993).

1.3. Development History of the Land Use Systems

From ancient times, the Mekong delta was considered and referred to as a region covered by very densely natural forest. The first Viet people (from the south-eastern part of Vietnam) came to reclaim this plain at the beginning of the 17th century (Huynh Lua 1987). They dug many artificial canals. Step by step, the land was cultivated by many methods, such as burning,

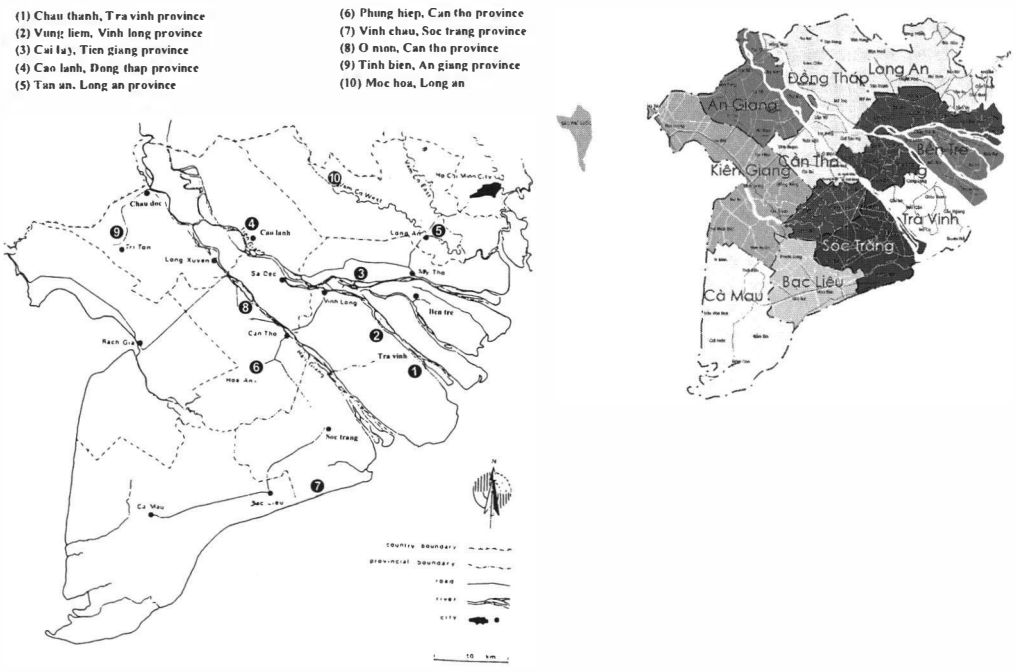

Fig. 2. — Map of the administrative boundary of the Mekong Delta and typical selected study locations.

ploughing (with buffaloes on low fields), making dikes in deep muddy fields, etc., for growing paddy rice.

As a result, in the middle of the 19th century, the Mekong Delta had become a large region of agricultural production, essentially rice production for marketing purposes. Along with land reclamation, an increasing number of immigrants came to the delta. So, the development of rice cultivation in the Mekong Delta evolved with people settlement, occurrence and construction of canal systems. Traditional rice cultivation was a mono-cropping culture which could only be adapted during the initial stage of land exploitation. However, depending on specific land characteristics, production methods and cropping names would be different from area to area, for instance: high (no ploughing) and low rice field (ploughed), etc. In 1930, with environmental violence and social events, two rice crops per year were produced on a small scale. Around 1980, a cropping system allowing three rice crops per year was developed. That system of multiple crops per year continued to grow with time, up to 7 rice crops per two years in several areas along the Tien and Hau River. An overview of the development of three rice crops per year in the Mekong Delta is listed in the table 1.

In some areas, land utilization types as two rice crops per year alternated with a cash crop (mainly soybean), have also been applied by local master farmers. Generally, rice cultivation has been intensive in the Mekong Delta, because of favourable conditions, more land rotation and a diversity in agricultural production (LE VAN KHOA 97-99).

Table 1
Development of three rice crops per year in the Mekong Delta, Vietnam

Year	Area (ha)	Cited source
1975-1980	Very few	LE VAN KHOA (1997-1999)
1985	1,108	TRAN AN PHONG (1986)
1990	10,237	NGUYEN AN TIEM (1993)
1993	95,634	NGUYEN AN TIEM (1993)
2000	230,000	General Statistical Office, Vietnam (2000)
2001	270,500	General Statistical Office, Vietnam (2001)
2002	278,180	General Statistical Office, Vietnam (2002)
2003	312,815	General Statistical Office, Vietnam (2003)
2004	362,543	General Statistical Office, Vietnam (2004)

1.4. CURRENT SITUATION OF AGRICULTURAL PRODUCTION

Although in comparison with other regions in Vietnam the Mekong Delta has the largest area of agricultural land, it does not mean that all soil types are fertile and favourable for production. The Mekong Delta has both water surplus (in the rainy season) and water shortage (in the dry season). This drastically influences the agricultural production and people's life.

Anyway, the agricultural land area in the delta (fig. 3) tends to increase slowly from 1990 up to the year 2004, while the rice land area tends to be stable and decreases. Generally, the total rice production still increases though gradually less quick in recent years, and the problem of stable production and yield decline occurred in some specific areas, essentially in areas of continuous mono-rice cultivation. The above obtained achievements can be explained by several reasons in which the application of science and technology in farming is one of the important factors (LE BA THAO 1997). Some areas of the Mekong Delta have been exploited and used intensively by many farmer generations, especially areas which are located along a main river system. In order to get high yields and production, many methods of land management have been applied, such as: manual soil preparation, machinery ploughing, acid sulphate soil leaching,

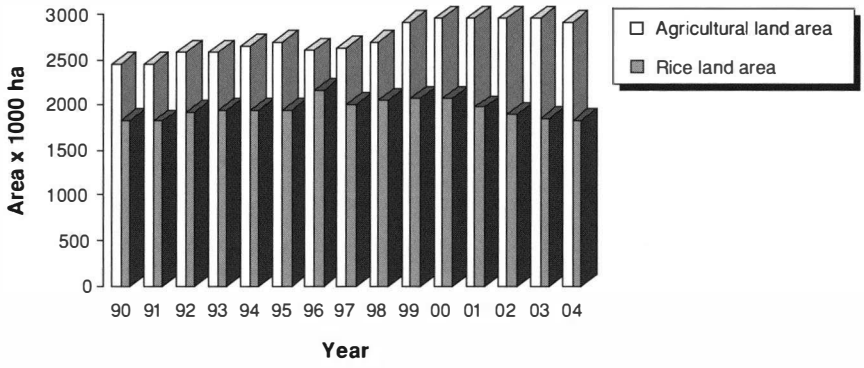

Fig. 3. — The changes of agricultural and rice land within the recent past 15 years.

fertilized or unfertilized cultivation in different soil areas (NGUYEN CONG BINH 1995).These methods of land management as well as natural soil processes finally can bring soils to complete degradation. This will lead to an unsustainable agricultural development in the area, if no research and agricultural extension work is carried out. At present, the paddy fields are gradually alternated and intercropped with cash or industrial crops, and have been tested for other perspective land utilization types in a spontaneous way by the local farmers and also by trials of scientists. This is included in the main strategies of agricultural production for the Mekong Delta development in the future.

In the future, up to the year of 2010 as estimated, the agricultural land area will be 2.8 M ha. Rice land area occupies about 1.8 M ha, with an average yield of 5.14 tons/ha/crop and a rice production of approximately 17.3 M tons (Ministry of Natural Resources and Environment 1999-2004).

So, the observation and evaluation of rice production, the actual soil productivity and agricultural potential in the Mekong Delta, Vietnam is very important and study is necessary. Using the results of this case study, we are able to limit some soil processes which cause soil physical degradation, to find the ways to restore and increase the potential productivity of soils in the area, to introduce new land use systems, to improve the socio-economic situation and to partly contribute to the strategic plan of agricultural production for the Mekong Delta development in the future.

1.5. The Scope of the Study

The study focuses on and evaluates mainly the area of intensive rice cultivation and problem soils which are strongly influenced by the rice production and agricultural potential in the Mekong Delta. Ten selected study locations spread over the delta were located:

- For recent alluvial sediments (Holocene epoch):
  nearby and far away from Hau and Tien river: Haplustepts, Dystrustepts Sulfaquepts, Epiaquepts, Endoaquepts and Halaquepts;
- For old alluvial sediments (Pleistocene epoch):
  Plinthaquults;
- For weathered soils in the mountainous areas:
  Haplustepts.

The results of this study can provide useful data and necessary documents for changing the land use systems in the sustainable agricultural development and for suitable soil management in the Mekong delta.

2. Methodology and Materials

2.1. Methodology

2.1.1. Pre-field Work

Based on the practical situation, an inventory study was minutely performed on secondary available data at the Department of Soil Science and Land Management, College of Agriculture, Cantho University. Also other organisations involved in Vietnam were contacted to identify, contour line and limit the study area (Le Van Khoa 1993-2002; Soil Science Department 1996-2000).

2.1.2. Field Work

In the selected study locations, the following activities were carried out:

2.1.2.1. Field Investigation for Collecting the Data and Information

Local owner-farmers of the study field and from surrounding areas were interviewed on the history of land exploitation, cultivation technique and land management, yield and limiting factors to crop yield and soil productivity.

2.1.2.2. Collection of Climatic Data

Climatic data as requested for quantitative land evaluation were collected at meteorological stations located nearby the study locations and the available documents, data measured and combined during the periods of 1930-1940, 1959-1971 and 1976-1190 (General Hydrology and Meteorology Service, Hanoi, Vietnam 1993) were used for calculations for each study location.

2.1.2.3. Typical Soil Profile Description

A representative field area in each study location was selected and a soil profile was dug. All the master soil horizons were described using the guidelines of FAO/Unesco (1990), updated with attribute conditions of the Mekong Delta and photographs were taken. The Munsell soil colour chart was used (KIC 1990) and other information was also recorded.

2.1.2.4. Soil Physical Measurements Directly in the Field

Soil consistency

The soil consistency was measured with the hand penetrometer, with three replications in vertical direction.

2.1.2.5. Soil Sampling for Soil Analyses in the Laboratory

Undisturbed soil sample rings with 98.125 cm^3 volume were taken with an undisturbed soil sampling kit. Also about 3 kg of disturbed soil sample was taken from each soil master horizon under study with the sampling plan (DIJKERMAN 1988).

2.1.2.6. Physical Soil Analyses and Laboratory Measurements

Soil bulk density, ρ_b (Mg/m^3)
Soil porosity, ϕ (%)

2.1.3. Data Analysis and Calculation

2.1.3.1. Land Evaluation

Quantitative land evaluation (VAN RANST 1991, 2000) is applied to find suitable crops which can partly improve the current land use system and recommend the adapted methods of land management for sustainable agricultural production in the Mekong delta, Vietnam. Selected crops: soybean, mungbean, maize and cotton.

2.1.3.2. Calculation of Production

The following calculations were made:

- Thermal-radiation production potential, RPP (the 3-level hierarchical crop growth model of FAO).
- Water limited production potential, WPP (VAN RANST 2000).
- Land production potential, LPP (SYS *et al.* 1993, VAN RANST 2000).

LPP was strongly affected by the limiting soil properties and management level. So, a reduction of the water-limited production potential, originated from those factors and which is conventionally expressed as a soil and management index, is the land production potential. The best-performing combination equation of the Penmann-Monteith approach was applied to calculate ETo (mm/month) and ETo (mm/decades).

2.1.3.3. Data Interpretation

Repeated statistical methods of the SPSS programme were used to calculate and evaluate all of the data involved.

2.2. MATERIALS

Data collection and calculation were done at the Laboratory of Soil Science and Land Management Department, College of Agriculture, Can Tho University, Vietnam and at the Laboratory of Soil Physics, Faculty of Bioscience Engineering, Geological Institute, Ghent University, Belgium.

3. Results and Discussions

3.1. ACTUAL SOIL PRODUCTIVITY

3.1.1. Physical Soil Fertility

3.1.1.1. Soil Compaction

This research mainly deals with some physical soil characteristics and qualities of soil compaction which strongly influence crop growth and crop development, and especially the root system. Most of the study locations are situated in intensive rice cultivation areas with a high soil rotation, so-called

fertile soils (or non-problem soils). The rest belongs to the problem soils characterizedby certain soil constraints.

Soil compaction refers to the packing effect of a mechanical force on the soil, that decreases the voids in the bulk soil volume and increases the density and strength of the soil mass. Therefore, it directly slows down both the rate of infiltration and the internal drainage. Rooting depth, soil water storage and also the water movement from the compacted soil horizon will be strongly influenced. In this case, plant roots must exert a greater force to penetrate the soils. If soil penetration resistance is greater than 3MPa (LAL & STEWART 1990) no plant roots can penetrate and the soil layer is considered as a limitation in the quantitative land evaluation. Yet, soil compaction can have both good and bad effects on plant growth and development. Soil bulk densities greater than 1.40 Mg/m^3 are usually considered as a limiting factor for mineral soils in terms of agricultural production (LAL & STEWART 1990). However, it also depends on the nature of the soils and the crop characteristics, whether crop yield will be affected or not. In the Mekong delta, a bulk density value of 1.35 g/cm^3 exerts a somewhat negative influence on rice yields. The strongest effects were found by using tractors compared to man or buffalo/hand-tractor (DUONG VAN NI 1995).

Environmental impacts and essentially the activities of land management play a very important role in terms of soil degradation. Soil compaction is one of the physical degradation types significantly related to crop production. Table 2 and table 3 below show all the soil physical data which were measured and analysed on the different study locations.

3.1.1.2. Plinthization and Cementation of Soil Surface and Subsoil Horizons

Plinthite defined as a soft-crystalised blocky compound is mainly formed by a high content of iron oxides (Fe_2O_3) and quartz (SiO_2), but is very poor in organic matter content. It is dark red coloured and commonly occurs with platy shapes and can still be cut with sharpers (LAL & STEWART 1990). The role of plinthite is specially considered in laterization. It will be transformed into petroplinthite under the impact of the soil ripening process in the soil profile.

Study location No. 10 (Moc Hoa, Long An) is selected as representative for plinthization in soils of the Mekong delta. It can mainly be found in areas of old alluvial soils (along the Cambodia and Vietnam border) and occasionally on high land of recent alluvial deposits. Plinthite already exists abundantly and is somewhat developed into petroplinthite (hard compound) in this soil profile, within the depth of 60-110 cm. This can be proved by a

Table 2
Physical soil characteristics related to soil compaction of A master soil horizons, spread over the study locations

No.	Study location	Soil depth (cm)	Physical soil characteristics					
			ρ_b (Mg/m^3)	ρ_p (Mg/m^3)	ϕ (%)	Ksat (m/s)	SPR* (Mpa)	SR (stage)
1	No. 1	**0-45**	1.55	2.44	36.7	1.98E-09	0.83	R
2	No. 2	**0-25**	1.32	2.50	47.3	3.89E-05	1.36	R
3	No. 3	**0-30**	1.13	2.44	53.8	3.62E-07	0.41	R
4	No. 4	**0-20**	1.23	2.52	51.1	9.53E-06	0.85	R
5	No. 5	**0-30**	1.43	2.48	42.5	1.77E-08	1.19	R
6	No. 6	**0-25**	0.86	2.21	61.1	1.63E-05	0.53	R
7	No. 7	**0-45**	1.33	2.44	46.6	6.58E-07	0.86	R
8	No. 8	**0-22**	1.14	2.21	48.4	4.74E-06	0.52	R
9	No. 9	**0-20**	1.65	2.55	35.1	4.80E-05	Very hard	R
10	No. 10	**0-15**	1.14	2.38	52.4	3.26E-09	1.02	R

(*): Average value of measured data with three replications.
ρ_b: Bulk density.
ρ_p: Particle density.
ϕ: Porosity; Ks: saturated hydraulic conductivity.
SPR: Soil Penetration Resistance; SR: Soil Ripening.

Table 3
Physical soil characteristics related to soil compaction of B master soil horizons, spread over the study locations

No.	Study location	Soil depth (cm)	Physical soil characteristics					
			ρ_b (Mg/m^3)	ρ_p (Mg/m^3)	ϕ (%)	Ksat (m/s)	SPR* (MPa)	SR (stage)
1	No. 1	45-85	1.42	2.37	40.0	1.81E-09	1.05	R
2	No. 2	25-67	1.72	2.58	33.3	2.91E-09	0.47	R
3	No. 3	30-70	1.34	2.46	45.5	2.33E-09	0.48	R
4	No. 4	20-70	1.47	2.55	42.5	5.95E-09	1.00	R
5	No. 5	40-75	1.37	2.55	46.4	2.41E-09	1.08	Rr
6	No. 6	25-90	1.03	2.43	57.6	2.34E-06	0.46	r
7	No. 7	45-95	1.07	2.43	56.0	1.33E-05	0.95	r
8	No. 8	22-60	1.10	2.25	51.0	1.00E-06	0.38	R
9	No. 9	20-85	1.63	2.61	37.5	6.13E-06	Very hard	Rr
10	No. 10	15-60	1.59	2.56	37.9	5.83E-09	1.12	R

(*): Average value of measured data.
ρ_b: Bulk density.
ρ_p: Particle density.
ϕ: Porosity; Ks: saturated hydraulic conductivity.
SPR: Soil Penetration Resistance; SR: Soil Ripening.

drastically increasing value of the soil penetration resistance at that soil depth. In practice, if not any proper soil management is applied, plinthite in the subsoil horizons will gradually be transformed into petroplinthite at a high rate during the dry season, when the lowest watertable level is reached. This is also the case for other areas having the same situation in the Mekong Delta, Vietnam.

Cementation refers to the cohesion between soil particles of medium-coarse textured soils under oxidative conditions. The soil surface and even subsoil horizons become extremely hard during the dry season. This was the case in study location No. 9 (Tinh Bien, An Giang). No penetrometer data could be obtained to measure the soil penetration resistance. In some other profiles in this area, also iron-manganese cemented angular blocky soil clods occur in the subsoil. The watertable level in these soil profiles is deeper than 200 cm. These profiles are vitally lacking water for cultivation and living. However, in the rainy season, surplus water occurs in the top soil and soil particles are lost. This situation is comparable with hardsetting, firstly termed by NORTHCOTE (1960, 1979) for Australian soils and by HEINONEN (1982) for Swedish soils and described as self-compaction.

3.1.2. Chemical Soil Fertility

The chemical soil fertility presented in this section only aims to qualify the present status of the fertility, using some basic chemical determinants which were mainly analyzed for soil classification, in combination with some physical problems. Table 4 shows partly a qualitative overview of the practical situation. The qualitative assessment is based on the classification of the laboratory of Soil Chemistry (Handbook of Soil analysis 2000), the Department of Soil Science and Land Management, College of Agriculture, Can Tho University in Vietnam for local rice production.

The data in table 4 show that in most of the study locations the soil is rather poor in nutrients in the subsoil horizons, even in the areas of intensive rice cultivation, the so-called non-problem soils. Specially, in the areas influenced by floods in the Mekong Delta, fluvial materials enriched with some nutrients are always deposited at the soil surface (study location No. 8: O Mon, Can Tho). However, this effect is only positive for winter-spring rice crop. Then these soil nutrients will be depleted during the following crop.

This chemical soil degradation links the soils under study to a situation of nutrient depletion which is classified as one of the soil degradation types. Only the cation exchange capacity can still support for "soil health", except

Table 4
Qualitative assessment of the analysed chemical soil determinants involved at the study locations

No.	Study location	Chemical soil characteristics*							
		EC(1/5) (S/m)	pH_{H20}	SOM (%)	Total N (%)	Avail. P (mg/kg)	P_2O_5 (%)	Al** (cmol(+)/kg soil)	CEC (cmol(+)/ kg soil)
1	No. 1	No saline	Slight to neutral	Moderate to poor	Moderate to poor	Moderate-very poor	Very poor to rich	–	Moderate to high
2	No. 2	No saline	Slight to neutral	Moderate to very poor	Moderate to very poor	Poor - moderate	Poor	–	Moderate
3	No. 3	No saline	Slight to neutral	Moderate to poor	Moderate to very poor	Very poor	Poor	–	High
4	No. 4	No saline	Slight to neutral	Moderate to very poor	Moderate to very poor	Very poor to moderate	Moderate to poor	–	Moderate
5	No. 5	No saline	Slight to neutral	Moderate to very poor	Moderate to very poor	Very poor	Moderate to poor	–	High to moderate
6	No. 6	Slightly saline	Extreme acidic	Rich to moderate	Rich to moderate	Moderate to poor	Rather rich to moderate	High to very high	Moderate to high
7	No. 7	Slightly saline	Neutral	Poor	Poor to very poor	Very poor to rich	Rather rich	–	High
8	No. 8	No saline	Moderate acidic	Rather rich-poor	Rather rich to poor	Very poor	Poor	–	Moderate
9	No. 9	No saline	Moderate acidic	Very poor	Very poor	Very poor	Very poor	–	Very low
10	No. 10	No saline	Moderate acidic	Rather rich-very poor	Rich-very poor	Rather rich to poor	Poor to very poor	–	Moderate

(*): Classified from top soil to subsoils.
(**): Soluble aluminum content; EC (1/5): Electric Conductivity unit (with soil/water ratio).
SOM: Soil Organic Matter.

in study location No. 9. However, the bulk soil volume and voids need to be optimum for plant roots to develop with an optimum of nutrient uptake.

Based on the data interpretation above, most of the soils of the study locations show physical problems and are also rather poor in chemical soil fertility. This is a main reason why local farmers have to use inputs at high capital level (mainly fertilizer) on their fields to get the expected rice yield.

3.2. Agricultural Production Potential

3.2.1. Land Suitability and Selected Alternative Crops with Rice Cultivation

Taking into consideration the market requirements, the technological-scientific level of farmers and in particular the agricultural development strategy from the State, land evaluation is only applied to some crops: (1) soybean, (2) mungbean and (3) maize. These crops have been planted by local farmers and can be sold on the local market and/or be exported. Soybean is selected prior to alternate or intercrop with rice. This land use system already existed in some places in the Mekong Delta, mainly at Cao Lanh, Dong Thap (study location No. 4), O Mon, Can Tho; Cai Lay, Tien Giang and Cau Ke, Tra Vinh. It was developed spontaneously by local farmers, because they felt and partly understood the positive effects of multiple agricultural production on soil productivity and their income . Yet, at the moment, the market for consumption of the products is one of the problems that need to be solved.

Cotton (4) is a new plant in the Mekong delta, and also selected for quantitative land evaluation for the areas with problem soils. The study will not focus on the inherent and current main crops which have been suitable and were applied on a large scale in the Mekong Delta already a long time ago, such as: the first rice crop (winter-spring) of the intensive cultivation area (location No. 2, No. 3, No. 4, No. 5 and No. 8) and the main rice crop (traditional rice or upland rice) of other study locations (location No. 1 and No. 9), and suitable land uses (pineapple, sugarcane, jam, ...) which have been recommended in the area of Acid Sulphate Soils (location No. 6). As land utilization types and with regard to the evolution of soil properties in the areas of intensive rice cultivation and problem soils, the growing cycle of selected crops is chosen at the second rice crop (spring-summer or early summer-autumn depending on the agro-ecological zone) which will be suitable to the cropping structure (fig. 5) and is adapted to the specific weather conditions. The selected crop for alternation with rice, will not influence the main rice crop in the delta (winter-spring rice), what is easily accepted by

the local farmers. Cotton is only studied in the locations No. 1, No. 7 and No. 9, due to soil properties and cropping requirements. Other selected crops can be grown in the study locations except for study location No. 7, which is an area of permanent saline intrusion.

3.2.1.1. Soybean

As discussed above, there are two crop growing cycles: (1) March 25 — June 25 for the study locations No. 9 and No. 10 and (2) March 05 — June 05 for the other areas of the study locations. Main limitations for soybean cultivation in the study locations are the acidity and soil organic matter. These soil constraints occur in recent alluvial soils, while lack of soil nutrients are the big problem and need to be improved in the area of degraded Grey Soil (study location No. 9 and No. 10).

3.2.1.2. Mungbean

Mungbean has the same crop growing period as the one applied for soybean cultivation. However, salinity and alkalinity become a serious problem in the study locations. Soil nutrients have also to be reclaimed in old alluvial soils.

3.2.1.3. Maize

In most of the study locations, maize is grown in the period of March 01 — June 06, except for study locations No. 7 (May 01 — August 10), No. 9 and No. 10 (March 20 — June 30). Soil nutrients and salinity are the main limiting factors for maize cultivation in the study locations.

3.2.1.4. Cotton

Nowadays, cotton is a new plant recommended to grow in the areas with non-fertile soils. In the scope of this study, land suitability assessment of cotton is applied in some study locations with different crop growing cycles:

Location No. 1: February 10 — July 30.
Location No. 7: May 10 — October 30;
November 01 — April 20.
Location No. 9: March 10 — August 30.

In order to improve the LPP of cotton in the study locations, salinity and alkalinity must be reclaimed in the saline area and soil nutrients in the degraded Grey Soil.

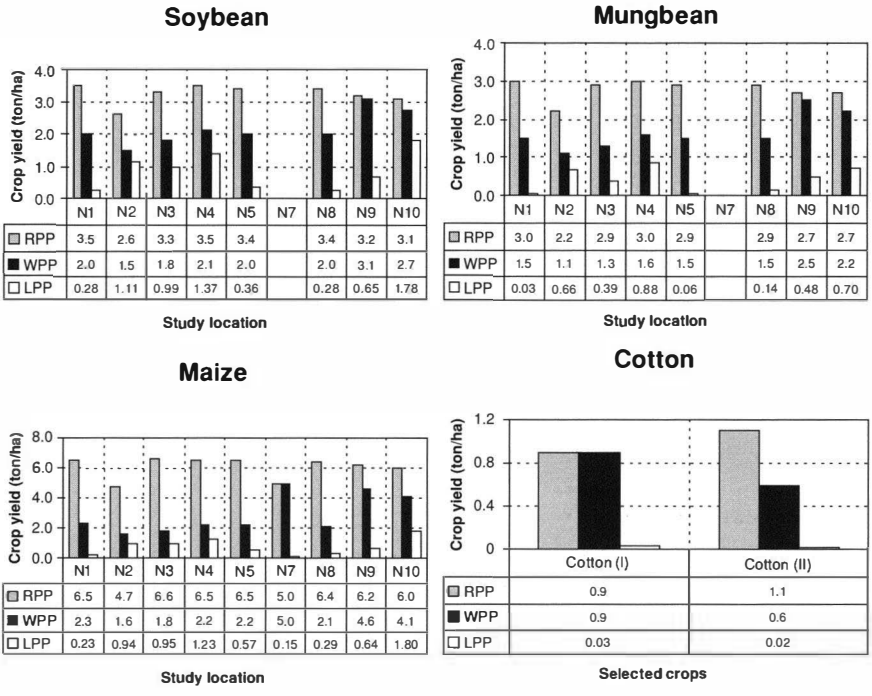

Fig. 5. — The yield gaps of selected crops at the different study locations.

4. Conclusion

4.1. Situation of Current Land Use System in the Study Locations

As known, the Mekong Delta Vietnam is considered as "the biggest rice basket" of the country, with large intensive rice cultivation areas, commonly three rice crops per year, developed more than 10 years ago on recent alluvial soils along the Tien and Hau River. Nowadays, rice production has become increasingly dependent on inorganic fertilizers, and less attention has been paid to the soil management. The local farmers have relied on the external factors (mainly fertilizer application) for their crop yield rather than on the soil capacity. Those activities are reducing soil productivity and are leading to soil degradation. Although the rice yield still somewhat improved during the past 5 years, it seems to start stagnating and some soil constraints occur. This has become a major agronomic concern over the delta. Therefore, it is

necessary and very important to introduce a new land use system to replace the mono-cultivation. In addition some adaptive soil managements for sustainable agricultural production are recommended. In a few rice cultivation areas, local farmers spontaneously started to alternate rice with some interesting cash crops (commonly soybean) in the Mekong Delta, to improve their economic situation and some soil properties.

4.2. Soil Problems

4.2.1. Physical Soil Fertility

Soil compaction, the so-called "plow pan", has essentially been formed and developed in the B master soil horizon in the intensive rice cultivation areas. The mean dry bulk density is 1.40 Mg/m^3, but in about 70% of the cases, it is greater than this value (max. 1.73 Mg/m^3). In 90% of the cases, the porosity is less than 50% (33.10% — 47.5%), with a very low saturated hydraulic conductivity (mean 1.57E-07 m/s).

The thickness of the compacted layer is highly variable from area to area, depending on an overlying cultivated soil horizon which abundantly exists between 20-40 cm depth and which is commonly 35-50 cm thick. In the 10 study locations, the soil bulk density of the B master soil horizons tends to be higher and differs significantly from the bulk density of the A master soil horizons. Soil compaction in the study locations in the Mekong delta mainly originates from: (1) illuvial soil processes; (2) mono-rice cultivation with high soil rotation; and (3) soil preparation under wet conditions. Surface hardsetting and the plinthization process in the subsoils only occur in degraded Grey Soils: soils derived from hard rock in the mountainous area (so called weathered soils) and in the old alluvial soils.

4.2.2. Chemical Soil Fertility

In the framework of this study, the evaluation of the chemical soil fertility is based on some basically chemical determinants which are related to soil classification and quantitative land evaluation. Therefore it only partly represents the soil nutrient status of the soils in the study locations. In most of the study locations, soil nutrients are rather poor in the subsoil horizons, even in the area of intensive rice cultivation, the so-called "non-problem soils". Fluvial materials from flooding, annually deposited on the field surface, enrich the topsoils with some nutrients, but its influence is only positive to the crop yield of winter-spring.

4.2.3. Actual Soil Productivity

Most of the soils in the Mekong Delta are formed and developed during the Holocene period. Therefore the soil problems mentioned above, mainly originate from land use and land exploitation. Human-induced soil degradation tends to increase, especially in the area with high soil rotation. At this moment, some types of soil degradation can be identified as (1) physical soil degradation (soil compaction) and (2) chemical soil degradation (nutrient depletion, acidification (oxidation of pyrite) and sodification). Soil compaction is a major problem in the intensive rice cultivation area. It has just started and it is gradually increasing. This is also the case for nutrient depletion. Acidification and sodification represent a more severe problem in the attribute problem soils under study. Nutrient depletion, cementation and plinthization are also heavy soil constraints on degraded Grey Soils.This study particularly alarms for the soil productivity at present in the intensive rice cultivation area, the so-called "non problem soils". It partly suggests some specific activities need to be carried out to conserve the soil resources in the near future.

4.3. Perspective Land Use System and Agricultural Production Potential

The results of quantitative land evaluation to determine which of a number of selected crops are most interesting to alternate with rice as second crop (spring-summer or early summer-autumn) in the intensive rice cultivation area, showed that soybean is the most suitable crop. Soybean has the best perspectives when compared to mungbean and maize. However, at present a few soil constraints limit the land production potential. The soils need to be reclaimed and improved, particularly the acidity (pH), soil organic matter and macro-nutrients (K, Ca and Mg). This new land use system will reduce the period of wetness in the field and produces an optimum condition to increase the formation of soil aggregates and finally soil development. It can serve for sustainable agricultural production. In order to improve the crop yield on degraded Grey Soils, in particular the weathered soils, inputs at high level are needed, to compensate for poor soil material. On old alluvial soils (humic accumulation), the cultivation of soybean, mungbean and maize is moderately suitable.

Maize and cotton can be planted in saline and alkaline soils, first of all in raised beds along the coastal area in the Mekong delta. ECe and ESP values must be reduced, because those limiting factors influence strongly the current

suitability, leading to low yields. Organic fertilizer and balanced use of inorganic fertilizer, proper soil preparation and crop alternation essentially with cash crop are the necessary activities to conserve soil resources, to improve rice yields and to develop a sustainable agricultural production in the Mekong delta, Vietnam.

Agricultural extension work also plays a very important role. It not only supports the scientific-technological knowledge, but also encourages the local farmers to apply new land utilization types. When new land use is recommended, capital input, good crop varieties, and specially a market for consumption should be taken into account. If this is not done, new crops will be difficult to accept. The suitability of the selected crops is quantified on the typical locations of the major soil groups under study. Therefore the result should be applied in the area with the same soil groups and weather condition. However, some soil properties should also be tested, especially the chemical soil determinants which vary spatially and temporally. Eventually, these results can partly document the agricultural development strategy in the Mekong delta, e.g. alternate or intercropping in rice field with fish, shrimp and cash crops where it is possible.

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Salinity Intrusion and Structural Change of Agriculture – Forestry – Aquaculture in Coastal Areas of the Mekong Delta, Vietnam

by

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1. Background

The Mekong Delta in Vietnam covers an area of 3.95 millions hectares extending over 12 provinces and one city, with a population of 17 millions. This is a large and flat delta with an average elevation of 0.5-1.5 m. Three main soil types occur: acid soils, saline soils and young alluvial soils, with a high potential natural fertility; in addition, heat, moisture and sunshine are natural potential power sources. Beside these advantages, the area faces many difficulties such as floods in the rainy season and droughts and fresh water shortage in the dry season, even as bank erosion, siltation, salinity intrusion from the sea etc. The Mekong delta is an open and low system affected by the semi-diurnal tide of the East Sea with high amplitudes (up to 3.5 m) and diurnal tides of the West Sea with small amplitude (0.4-1.2 m). It is located in the tropical monsoon area with two contrasting seasons: the rainy season and the dry season.

Over 300 years of development, especially in the recent years, the environment and ecology in the coastal areas of the Mekong delta have profoundly been changed and are conversing from a natural ecosystem to one controlled by man. The rapid crop pattern change from rice to aquaculture in many large regions is a proof of this process. However, the exploitation of these potential coastal areas is a complicated problem with high risks. It is therefore necessary to study the system in order to realise its potentialities

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and limitations with respect to the exploitation and to define the relationship between exploitation and environmental protection. In order to plan the socio-economical development many suggestions have been made recently for this area, concerning standards, balance threshold, assessment of the ecological system's effectiveness, etc.

This paper deals with a salinity intrusion research carried out from 1991 to 2000 and recently in 2004, 2005. Some suggestions for structural production changes in the coastal areas in the Mekong Delta, Vietnam will also be presented.

2. Salinity Intrusion Research in the Coastal Areas in the Mekong Delta

2.1. Salinity Intrusion Zoning

The salinity affected areas in the Mekong Delta occupy more than 50% of the delta, including 8 provinces: Long An, Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang. Based on the natural conditions of hydrology, topography, geology, meteorology, irrigation systems, etc., we divide the coastal areas into 4 sub zones for salinity monitoring and survey:

- The Mekong estuaries sub zone: Tien Giang, Ben Tre, Tra Vinh and one part of Soc Trang province;
- Sub zone of the two Vai Co rivers in Long An province;
- Sub zone of the West Sea: Kien Giang and one part of Ca Mau province;
- Sub zone of the Ca Mau peninsula: Soc Trang, Bac Lieu and Ca Mau provinces.

Salinity intrusion sources have been defined mainly in the coastal areas:

- The East Sea: from Long An province to Ca Mau cape (Ca Mau province) with 14 saline water sources intruded by tide to canal systems through Dong Tranh river, Xoai Rap, Tieu, Dai, Ham Luong, Co Chien, Cung Hau, Dinh An, Tran De, My Thanh, Ganh Hao estuaries, Bong Ket, Bo De river and Duong Keo ditch;
- The West Sea: from Ha Tien to Cua Lon river (Ca Mau) with 19 saline water sources intruded to inland through Dong Ho swamp, Rach Gia- Ha Tien canal, Tam Ban ditch, Ta Sang, Ba Hon, Khoe La, Vam Rang canals,

Kien, Cai San, Cai Be, Cai Lon, Trem Trem, Tieu Dua, Bien Nhi, Ong Doc, Cua Lon rivers, Bay Hap estuary, Cai Doi Vam ditch and Thi Tuong river.

A salinity monitoring network has been established in the 4 sub zones and salinity monitoring stations have been operating in the rivers and canals every year from January to June (see fig. 1).

2.2. Salinity Intrusion Process in the Period of 1991-2005 in the Mekong Delta

2.2.1. The Mekong Estuaries Sub Zone

The Mekong river runs to Vietnam through two branches: Tien and Hau rivers. At the Vam Nao tributary, the flow has been distributed from Tien to Hau river. At Vinh Long, Tra Vinh provinces, estuaries have been formed: Dai, Tieu, Balai, Ham Luong, Co Chien, Cung Hau and Tran De. The Ba Lai dam was built in the Balai estuary and became the regulate sluice. In the dry season, the limited flow of fresh water from upstream, the weak river slope and the low elevation cause salinity intrusion towards the inland. It occurs twice a day in relation with the tide.

For the study of salinity and acidity processes in the Mekong Delta, Le *et al.* (2001) measured from 1991 to 2000 and during the years 2004-2005 some parameters during the dry season (from January to June). They conclude that in the period 1991 to 2000 the salinity intrusion is serious in March and April and that at the same time the flow discharge is smallest (tab. 1A). According to Le *et al.* (2005), the salinity intrusion in 2004 and 2005 were normal compared to the other years with the highest value in April, decreasing in May. Salinity decreased in following order: April, May, March, February, June and January (tab. 1B).

2.2.2. Vai Co Rivers Sub Zone

The Vai Co West river is 325 km long and drains a basin area of 6,000 km^2. It originates in Cambodia to Long An province, link to Vai Co East river towards the sea through Xoai Rap estuary.

The Vai Co East river is 283 km long and originates in Cambodia, linked to the Vai Co West river at Tan Tru (Long An). Both are affected by the tide of the East Sea. Salinity intrusion depends on the Tien river flow to the Vai

Table 2A
Maximum monthly salinity (g/l) in Vai Co rivers (1991 ÷ 2000)

Station	Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cau Noi	March	12.1	13.5	16.8	19.4	13.1	12.7	12.3	17.9	14.0	9.5
	April	13.0	15.5	14.4	15.0	14.5	14.5	11.8	16.7	11.9	9.4
Tan An	March	5.8	7.0	10.2	9.3	6.7	7.0	3.2	8.3	5.6	1.2
	April	8.0	10.6	11.1	9.0	9.8	8.8	3.7	9.3	5.8	1.1
Tuyen Nhon	March	0.2	0.6	7.5	2.9	1.3	1.6	1.7	3.2	1.2	0
	April	3.0	1.9	6.9	2.8	5.8	3.3	3.4	6.5	1.9	0
Doi Ma sluice	March	11.0	10.5	12.4	11.0	7.0	9.1	4.5	9.5	6.0	1.5
	April	13.0	12.3	12.8	12.5	7.5	10.2	3.9	8.8	5.8	1.7
Ben Luc	March	7.0	8.2	11.9	10.6	6.4	8.7	5.0	9.3	5.8	2.6
	April	10.4	11.0	12.0	10.8	6.9	9.9	5.0	10.7	5.5	3.0
An Ha bridge	March	1.0	2.0	3.0	2.5	2.2	4.5	1.0	0.8	0	0
	April	1.4	2.5	2.0	1.2	5.5	6.2	1.1	4.5	0	0

Sources: Southern Institute of Water Resource Research 2001.

Table 2B
Maximum monthly salinity (g/l) in Vai Co rivers (2004 ÷ 2005)

No.	Station	Time (month)									
		February		March		April		May		June	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
1	Cau Noi	11.9	8.5	11.8	10.4	11.2	13.8	14.0	12.3	9.2	4.3
2	Tan An	0.9	1.0	2.5	3.3	6.5	4.9	5.8	5.1	3.1	0.7
3	Doi Ma sluice	4.2	2.7	4.7	5.0	7.3	6.0	7.8	5.9	3.7	0.8
4	Ben Luc	2.9	2.3	3.2	4.6	8.9	5.6	6.3	5.6	3.1	0.5
5	An Ha bridge	0.6	1.1	0.6	3.5	0.8	5.2	0.7	5.4	0.4	1.0

Sources: Southern Institute of Water Resources Research 2005.

2.2.3. Ca Mau Peninsula Sub Zone

The hydrological regime of the Ca Mau peninsula is controlled by the tide of the East and the West Sea, the rainfall and water use. Main salinity intrusion sources come from the East Sea to My Thanh, Ganh Hao rivers and from West Sea to Ong Doc, Cai Lon, Cai Be rivers.

From 1994 until now, the Quan Lo—Phung Hiep hydraulic work has operated basically to prevent salinity from the East Sea and one part of the West sea. In recent years, the combination of rice and shrimp growing has caused problems in the water environment especially the salinity intrusion

has changed significantly and uncontrollably. The maximum monthly salinity in 1991-2000 is presented in table 3A. In 2004 and 2005 Ca Mau peninsula had the same average salinity as in the period 1991-2000 with a highest values in April and late March and some days in the beginning of May. The salinity has decreased in following order: April, May, March, February, January and June (tab. 3B).

Table 3A
Maximum monthly salinity (g/l) in Ca Mau peninsula (1991 ÷ 2000)

Station	Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cai Xe sluice	March	3.0	3.5	3.7	4.6	5.2	2.5	1.3	4.5	6.4	4.0
	April	3.5	4.0	4.2	3.2	4.0	4.6	2.4	7.3	7.5	9.6
Tiep Nhat sluice	March	5.0	6.4	7.0	6.5	10.3	10.7	7.0	7.6	5.6	5.5
	April	5.8	9.0	8.2	10.0	12.8	18.8	7.0	8.8	6.1	4.1
Soc Trang town	March	1.8	2.2	2.5	2.4	3.0	2.9	1.3	4.5	6.1	1.4
	April	2.5	3.1	3.3	3.5	5.3	4.2	2.0	6.8	7.0	4.4
Ngan Dua	March	20.2	19.5	22.0	21.0	37.6	23.2	1.6	8.8	1.3	0.6
	April	21.1	20.3	23.4	20.5	34.7	28.3	1.6	8.9	1.2	0.6
Cong Hoa	March	30.0	27.2	28.4	27.7	29.3	21.5	2.6	13.0	6.2	1.9
	April	32.2	33.1	34.6	30.6	36.6	20.0	14.0	14.5	2.8	1.9
Canh Den - Pho Sinh	March	28.6	29.1	30.1	29.4	30.0	26.2	2.9	8.2	11.1	7.0
	April	29.7	30.5	32.0	31.3	30.0	23.7	10.2	15.3	5.1	15.1

Sources: Southern Institute of Water Resources Research 2001.

Table 3B
Maximum monthly salinity (g/l) in Ca Mau peninsula (2004 ÷ 2005)

No.	Station	Time (month)									
		February		March		April		May		June	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
1	Cai Xe sluice	4.8	4.4	7.4	7.8	7.5	8.2	4.4	5.0	6.1	7.0
2	Tiep Nhat sluice	1.3	2.0	1.5	2.0	2.7	3.6	3.0	3.5	0.6	1.2
3	Soc Trang town	1.4	2.2	3.1	3.3	2.6	3.2	2.3	3.1	1.0	1.5
4	Ngan Dua	1.3	0.0	1.3	0.0	1.7	0.5	2.0	0.1	1.4	0.0
5	Cong Hoa	2.3	0.0	2.5	0.0	5.5	0.7	5.7	0.0	4.1	0.0
6	Dai Ngai	3.6	4.0	6.8	8.2	7.0	7.2	4.2	3.9	2.1	1.0
7	Ca Mau	24.2	25.8	25.6	29.5	28.4	32.6	30.0	35.1	22.8	24.3

Sources: Southern Institute of Water Resources Research 2005.

Based on salinity data of 10 years (1991-2000) and 2 recent years (2004 and 2005) in the Mekong Delta, the highest salinity is observed in April (tab. 4). During the period 1991-2005 the average affected area was up to 1,305,550 ha (33.2 % of the total areas of the Mekong Delta).

Table 4
Saline affected areas (ha) in April (average estimation 1991 ÷ 2005)

No.	Location	Sub zone areas (ha)				Total areas (ha)	Proportional to the Mekong delta
		Estuaries	Vai Co rivers	West Sea	Ca Mau peninsula		
1	Non saline affected areas	Total areas				1,773,365	45.1
2	Fresh water improvement areas	358,203	72,956	160,449	260,777	852,385	21.7
3	Saline areas with 6-18g/I	136,120	57,746	382,977	468,707	1,045,550	26.6
4	Saline areas with >18g/l	64,126	0.0	51,070	144,804	260,000	6.6
Total						**3,931,300**	**100**

Sources: Southern Institute of Water Resources Research 2005.

2.3. Salinity Intrusion Mechanism to Canal Networks in the Coastal Areas of the Mekong Delta

Salinity is an attribute of sea estuaries with two aspects: the disadvantageous aspect is that it limits agriculture and the opposite aspect is the formation of an abundant brackish area with high biological yield. By the interaction of river dynamics and sea flow, during flood, disturbance occurs and the saline water discharge during the low tide forms salinisation of estuaries and seashore. Salinity intrusion occurs annually in the dry season by the impacts of some basic factors: upstream discharge and tide flow, Northeast wind, rainfall, water use, surface evaporation in canal networks.

The areas affected by saline water are located in 8 provinces: Long An, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau. The areas affected in April are estimated to occupy 2,126,635 ha (54.5 % of the natural areas in the Mekong delta) in the period of 1991 to 2005.

Generally, salinity intrusion is controlled by many factors:

— Upstream flow;
— Tide of East and West Sea;

— Internal factors: river topography and canals systems, irrigation systems, transportation, water use and transfer with other basins, etc.;
— Climate and weather.

According to Le (2003, p. 157), salinity in estuaries changes from Smin = 0 (river) to Smax (sea) based on the general salinity level as follows:

Extreme saline:	S ≥ 30 g/l (or 30 ‰)
Saline:	S = 18-30g/l
Brackish:	S = 0.4-18g/l
Fresh:	S ≤ 0.4g/l

In the dry season, saline water is pushed towards the river by tide. The saline isograph 0.4-1 g/l shows that salinity intrudes to 95-100 km (Vinh Long province) in the Tien river and 90 km (Can Tho province) in the Hau river.

Salinity intrusion is variable and complex every year. The salinity concentration changes depending on the Mekong river upstream flow as well as climate, hydrology and tide in the Mekong delta in terms of time and quantity.

3. Structural Production Change in the Coastal Areas of the Mekong Delta

3.1. Real Condition

In the Mekong Delta the total natural areas (January 2000) cover 2,860,723 ha of the coastal area, including the natural areas of 8 provinces, in which agricultural land occupies 74.7 % of the total areas (tab. 5).

In some recent years, the resource exploitation in the coastal areas of the Mekong delta is good and successful. However, from the point of view of sustainable development, it has faced following problems:

— Based on statistical data from 2001, unused land covers about 121,000 ha from which 50,000 ha have a potential to be developed.
— Water resource is limited for irrigation since in the dry season water flow decreases, water leakage happens in the field and saline water intrudes in many areas.
— Some issues related to socio-economical factors are: infrastructure building, market condition improvement, new technology application, related policy to land, trade, funding, etc. If these problems are not

Table 5
Land use condition in the coastal areas in the Mekong delta

Land use	Coastal areas		Long An	Tien Giang	Ben Tre	Tra Vinh	Kien Giang	Soc Trang	Bac Lieu	Ca Mau
	ha	%								
Total areas	***2,860,723***	***100,00***	***449,187***	***236,663***	***231,502***	***222,567***	***626,904***	***322,330***	***252,063***	***519,507***
I. Agriculture land	*2,138,547*	*74.76*	*329,595*	*185,489*	*170,013*	*179,701*	*444,686*	*264,641*	*209,976*	*354,446*
1. *Annual trees*	***1,286,735***	44.98	299,513	112,390	69,151	109,164	342,833	182,958	95,591	75,135
1.1. 1 rice, 1 rice — crop	***1,179,671***	41.24	275,496	106,199	52,634	99,807	315,452	167,539	92,973	69,571
a. 3 rice-crop	***179,425***	6.27	21,324	81,500	9,031	3,418	19,271	30,486	14,395	0
- 3 rice	***173,925***	6.08	16,824	81,000	9,031	3,418	18,771	30,486	14,395	
- 2 rice + 1 crop	***4,000***	0.14	3,000	500			500			
- 1 rice + 2 crops	***1,500***	0.05	1,500							
b. 2 rice-1 crop	***805,648***	28.16	188,776	22,241	29,500	69,134	254,681	116,923	70,205	54,188
- 2 rice	***802,648***	28.06	185,776	22,241	29,500	69,134	254,681	116,923	70,205	54,188
- 1 rice-1 crop	***3,000***	0.10	3,000							
c. 1 rice	***194,597***	6.80	65,396	2,458	14,103	27,255	41,500	20,130	8,372	15,383
1.2. Milpa	***8***	0.00					8		0	0
1.3. Annual plants	***107,057***	3.74	24,017	6,191	16,517	9,357	27,373	15,419	2,619	5,564
2. Garden land	***106,760***	3.73	18,918	8,491	1,640	2,035	29,271	22,955	16,189	7,260
3. Perennial land	***291,093***	10.18	6,193	57,505	71,612	37,796	37,101	21,257	14,930	44,699
a. industrial trees	***94,929***	3.32	3,000	10,300	33,600	11,000	8,200	3,429	4,500	20,900
b. fruit trees	***130,023***	4.55	2,900	39,600	31,700	12,700	11,500	13,823	7,000	10,800
c. other perennials	***66,141***	2.31	293	7,605	6,312	14,096	17,401	4,005	3,430	12,999
4. *grass for breeding*	***0***	0.00							0	
5. *Aquaculture land.*	***453,959***	15.87	4,971	7,102	27,610	30,706	35,481	37,471	83,266	227,352
a. for shrimp	***377,902***	13.21	3,285	2,425	26,107	10,274	20,300	32,050	81,308	202,153
- Shrimp	***274,969***	9.61	549	2,393	20,926	8,413	12,450	7,610	49,230	173,398
- Rice- shrimp	***102,933***	3.60	2,736	32	5,181	1,861	7,850	24,440	32,078	28,755
b. For fish	***76,057***	2.66	1,686	4,677	1,503	20,432	15,181	5,421	1,958	25,199
- pond growing	***8,832***	0.31	1,614	3,527	673	1,430	500	756	283	49
- rice- fish	***67,225***	2.35	72	1,150	830	19,002	14,681	4,665	1,675	25,150
6. *Other agriculture land*	***0***	0.00								
II. Forestry	***260,202***	9.10	*47,047*	*4,282*	*3,451*	*8,019*	*80,732*	*8,477*	*6,480*	*101,714*
1. *Natural*	***57,563***	2.01	1,553	368	994	1,794	40,637	1,686	778	9,753
2. *Planting*	***202,639***	7.08	45,494	3,914	2,457	6,225	40,095	6,791	5,702	91,961
III. Special land use	***150,243***	5.25	*28,574*	*15,887*	*11,389*	*8,986*	*35,412*	*19,611*	*13,312*	*17,072*
IV. Building land	***52,664***	1.84	*10,968*	*7,646*	*7,005*	*3,213*	*10,090*	*4,725*	*3,514*	*5,502*
V. Unused land	***121,332***	4.24	*2,051*	*4,402*	*2,854*	*1,383*	*49,939*	*3,604*	*13,340*	*25,311*
VI. Rivers	***137,735***	4.81	*12,502*	*18,958*	*36,791*	*21,265*	*6,045*	*21,272*	*5,441*	*15,462*

Sources: General Department of Land Survey 2000.

solved thoroughly, the coastal areas remain an agricultural zone with the least stable production of the Mekong delta.
- Important land use changes occurred in the coastal areas of the Mekong delta with the conversion of land from rice to shrimp growing.
- Mangrove deforestation for aquaculture caused serious damage affecting seashore and environment safety.
- The conversion of land use from rice to shrimp was carried out uncontrolled and unplanned causing environmental degradation and increasing salinity intrusion far towards the inland areas.
- Most of the aquaculture ponds with extensive and improved extensive production have lack of hydraulic technology, basic principle of ecology and preservation as well as diversified and sustainable development that causes a decrease of the efficiency investment and environmental pollution, especially of soil and water.
- Irrigation systems have not met the requirement of water supply and the water quality has not met the requirement of aquaculture.

Based on the assessment of the real condition of salinity intrusion change and cultivation systems in the coastal areas of the Mekong Delta, suitable alternatives for structural production change are suggested.

Change principle is suggested based on the salinity concentration:

- Salinity < 4g/l (4‰), affected time < 3 months: rice and crop;
- Salinity > 4-8g/l, affected time < 6 months: rice-shrimp;
- Salinity > 8g/l affected time > 6 months: aquaculture growing.

Specific recommendations

- The Mekong estuaries: Tien Giang, Ben Tre, Tra Vinh provinces
  - There is a need to converse crop type and time: aquaculture growing; 1 high yield rice; 2 rice (summer-autumn-winter crop); 1 winter rice + 1 crop; fruit trees in sand dune; 1 winter rice + 1 shrimp in dry season; sea shrimp, shrimp + rice growing.
  - Besides specialised shrimp-fish growing, it is necessary to develop aquaculture and to breed oyster and clams in tidal mud flats, combined with planting garden trees.
- Two Vai Co rivers: Long An province
  - Decrease 3 rice productions and replace them by fish and shrimp aquaculture in some unstable production condition areas.
  - Convert rice growing to melaleuca planting, yam and pineapple in some low affected alkalinity areas.
  - Structural plants and crop: 2 rice + crop; short term plants (sugar cane, pineapple, etc.); melaleuca, melaleuca + fish.

— West Sea: Kien Giang, Ca Mau provinces
  — Continue to develop the uncultivated land for shrimp growing, convert some ineffective land for rice to brackish water shrimp growing (Tiger shrimp).
  — Convert partly 3 rice cultivated land to 2 rice — fresh water fish, shrimp growing to increase the land use efficiency.
  — Melaleuca has to be planted in the heavy affected acid land and low areas.
  — It is necessary to shift crop time and type: 2 rice (Winter-Spring and Summer—Autum); 1 rice + aquaculture growing (Winter crop - shrimp-fish); 1 rice + 1 crop (Winter rice-water melon, potatoes or vegetable); specialised crop (pumpkin, yam, sesame, etc.); specialised sugar cane; melaleuca planting and fish growing.
— Ca Mau peninsula: Soc Trang, Ca Mau, Bac Lieu provinces
  This area is not affected by flood but the land is affected by high salinity and alkalinity. Aquaculture and artificial forests for protection have to be established here. The advantageous areas of the Quan Lo—Phung Hiep irrigation system have to be organised for 1 high yield rice, 2 rice (Winter-Spring and Summer-Autumn) and 2 rice (Summer-Autumn — crop); 1 crop +1 shrimp; specialised vegetables and beans, fruit trees in sand dune; shrimp combined rice growing, sea shrimp growing, rice variety with high quality to meet the requirement of export and consumption.

3.2. Suitable Structural Production Change Tendency in the Coastal Areas in the Mekong Delta (fig. 2)

Based on his research for socio-economical development of salinity intrusion in the coastal areas in the Mekong delta, Le *et al.* (2004) formulated some proposals concerning suitable structural production changes.

3.2.1. Agriculture Development

Rice is a strategic plant that has been developed significantly and occupies 90-95 %. Rice production is still the main food supply for local areas, but also contributes to the national export. Besides, it is necessary to diversify in order to get the maximum of the saline- brackish ecology and mitigate possible bad environmental impacts.

3.2.2. Forestry Development

Forests in the coastal areas of the Mekong delta mostly occur on saline and alkaline soils on the border line. Natural and artificial forest areas cover about 260,000 ha (January 2000). There is a need to develop mangrove forests as national parks, conservation areas and protection of coastal areas and estuaries.

3.2.3. Aquaculture Production Development

In the Mekong delta, aquaculture areas and yield production occupy about 60 % and 65 % respectively and the export turn-over is 51 % compared to the nation-wide one. In recent years aquaculture strongly developed, especially shrimp growing, for export. In 2001, the total area used for Tiger shrimp growing was 410,500 ha (76.9 % of the total areas) producing 123,000 tons, compared to 38,700 tons in 1996; it means that the yearly average yield increased by 36.3 %. This is a highly profitable production and export though it takes high risks due to water environment, diseases, etc. and market price control. Therefore, some conflicts happen between using land for rice or for aquaculture, using saline water for shrimp or keeping fresh water for rice. For aquaculture development it is necessary to modify existing irrigation systems and infrastructures; to establish irrigation systems for cultivating rice-shrimp for intensive, semi intensive and specialising cultivation in some coastal areas in terms of conversion areas, suitable sub zones with ecology and water resources.

3.2.4. Salt Production Development

The salt production area is not large, with a total area of 4,700 ha and a yield of 150,000 tons. In Tien Giang, Ben Tre, Tra Vinh, Soc Trang provinces salt ponds are located in Go Cong, Binh Dai and Ba Tri, Duyen Hai and Vinh Chau respectively. In Bac Lieu, they are located in Bac Lieu town, Vinh Loi and Dong Hai districts. Salt industry mainly supplies to the Mekong Delta area and the export market. In order to extend, the industry has to exploit the mangrove forest to take land for salt production although the forest land is not suitable as drying ground and it causes land degradation in some places.

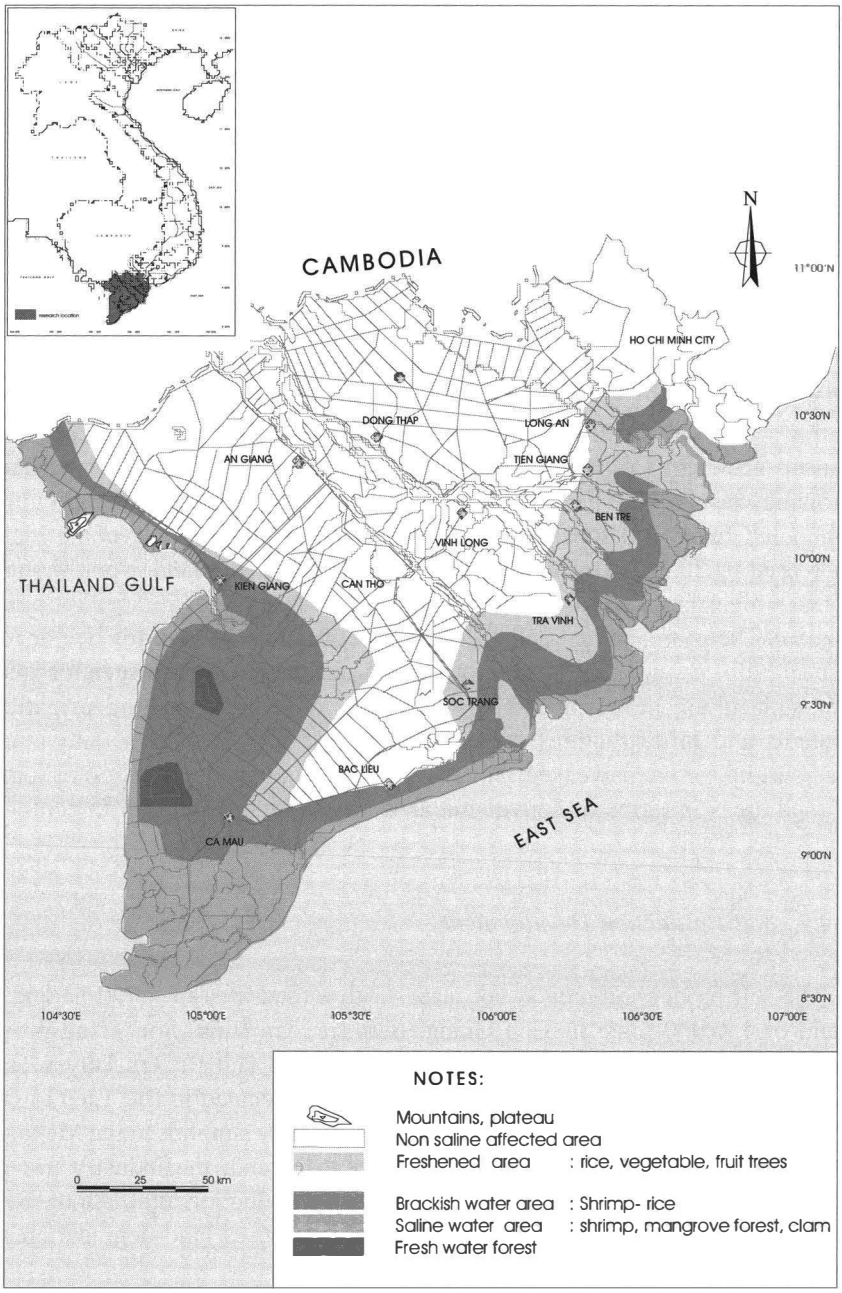

Fig. 2. — Alternative Suggestions of Structural Productivity Change in the Coastal Areas of the Mekong Delta.

4. Conclusion

Based on the research of salinity assessment in the dry season in the coastal areas of the Mekong Delta, the paper clarifies a process rule and impact of salinity intrusion to human life and production based on the analysis of the saline limit zoning, water quality ecology – water environment and cultivation system. Besides, it is a data base for water and soil resource application and ecological environment protection in the coastal provinces in the Mekong Delta.

Apart from the existing results, it is necessary to continue further research in order to suggest a strategy with high priority to control and develop effectively more than 2 million ha of saline land in the Mekong Delta.

In the coastal areas, a multipurpose agriculture developed, based on favourable natural conditions such as topography, land quality and climate, and especially the existing saline water resources with different concentration in the canal systems and fields during the year.

The understanding of saline intrusion during 10 years of research, reveals that its impacts were disadvantageous for the basin development. Our research will continue in order to propose alternatives for each zone in the Mekong Delta in terms of water supply for households, irrigation, aquacultur and forestry for a sustainable development.

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Utilisation of Cassava Top Meal for Local Duck Feeding

by

CHHUM PHITH LOAN* & KOA PHAL**

1. Introduction

Cambodia is an agricultural country. About 85 % of the population is working in agriculture. The main crop is rice, followed by animal production that plays a very important role for the family income of the farmer. Amongst the poultry production duck is especially popular in Asia asduck meat is highly appreciated. Moreover ducks grow very fast in short time and their eggs can be used for consumption to prepare several kinds of food.

To improve the performance of duck production one has to provide good quality of feed, but protein rich components, such as fish meal and soy bean are very expensive, and are therefore not available for feeding. It is thus necessary to find an alternative feed component with high protein content in future. At present cassava leave is very popular for animal feeding. According to DEVENDRA (1997) cassava leave contain 23.2 % protein, 21.90 % crude fibre, 0.37 % calcium and 0.58 % phosphorus but is poor in amino acid.

A proportional decrease of the performance of non ruminant animal with an increasing amount of cassava leave meal (CTM) was found by AKINFALA (2002) for chicken and MAHENDRANATHAN (1971) and ALHASSAN & ODOI (1982) for pig.

CTM contains high amounts of hydrocyanic acid but MENER (1973) and TEWE (1992) reported that sun drying for few days is sufficient to remove this toxicity from cassava.

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2. Material and Methodology

2.1. Material

The research was carried out at the Animal Experimental station of RUA. 300 local ducklings of the Angkam race of one day old were prepared for this research. Cassava leave tops were collected from different districts in the country.

2.2. Methodology

— The testing of duck performance took 12 weeks, according to an experiment by completely randomisation design as shown below:

$T_{0\ 25}$	$T_{1\ 25}$	$T_{2\ 25}$	$T_{3\ 25}$
$T_{3\ 25}$	$T_{2\ 25}$	$T_{1\ 25}$	$T_{0\ 25}$
$T_{2\ 25}$	$T_{1\ 25}$	$T_{0\ 25}$	$T_{3\ 25}$

— Each group consists of 25 ducklings. Following treatments are defined:

To = control treatment
T_1 = 10 % CLT
T_2 = 20 % CLT
T_3 = 30 % CLT

The composition of the feed was changed in function of the age of the ducklings. Three periods were considered:

- From 0 to 6 weeks (tab. 1);
- From 6 to 8 weeks (tab. 2);
- From 8 to 12 weeks (tab. 3).

Table 1
Feed ingredients for ducklings from 0-6 weeks old

Group / Raw material	T0	T1	T2	T3
Maize	40.25	34.50	28.00	23.50
Rice bran	9.75	9.00	8.00	6.00
Dry fish	21.50	19.50	17.00	13.00
Soy bean	26.50	23.00	20.50	19.00

Group / Raw material	T0	T1	T2	T3
CLT	00.00	10.00	20.00	30.00
Premix	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
DCP	1.00	1.00	1.00	1.00
Oil	0.00	2.00	4.50	6.50
Total	100.00	100.00	100.00	100.00
Chemical Composition				
CP%	22.08	22.00	22.07	22.02
ME (Kcal/ Kg)	2819.00	2804.00	2821.00	2812.00
Ca%	1.24	1.29	1.09	0.95
P%	0.89	0.96	0.84	0.78

Table 2
Feed ingredients for ducklings from 6-8 weeks old

Group / Raw material	T0	T1	T2	T3
Maize	37.00	32.50	31.00	24.50
Rice bran	20.00	17.00	12.00	12.00
Dry fish	18.50	16.00	14.00	10.00
Soy bean	22.50	20.00	16.50	15.00
CLT	0.00	10.00	20.00	30.00
Premix	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
DCP	1.00	1.00	1.00	1.00
Oil	0.00	2.50	4.50	6.50
Total	100.00	100.00	100.00	100.00
Chemical Composition				
CP%	20.06	20.10	20.06	20.00
ME (Kcal/ Kg)	2800.00	2822.00	2816.00	2803.00
Ca%	1.11	1.02	0.96	0.81
P%	0.82	0.79	0.77	0.71

Table 3
Feed ingredients for ducklings from 8-12 weeks old

Group / Raw material	T0	T1	T2	T3
Maize	44.50	40.00	33.50	31.50
Rice bran	23.00	20.25	20.00	15.25
Dry fish	13.75	11.75	9.50	5.50
Soy bean	16.75	13.50	10.50	9.25
CLT	0.00	10.00	20.00	30.00
Premix	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50
DCP	1.00	1.00	1.00	1.00
Oil	0.00	2.50	4.50	6.50
Total	100.00	100.00	100.00	100.00
Chemical Composition				
CP%	17.04	17.02	17.04	17.06
ME (Kcal/ Kg)	2800.00	2820.00	2805.00	2802.00
Ca %	0.89	0.82	0.75	0.60
P%	0.71	0.69	0.66	0.60

3. Result and Discussion

3.1. Live Weight of Ducks Until 12 weeks

Table 4
Average body weight weekly (g/head)

Group	T_o		T_1		T_2		T_3		P.
Live weight	mean	S±	mean	S±	mean	S±	mean	S±	
1 day old	37.40^{a}	3.11	36.82^{b}	3.94	37.00^{b}	4.1	38.60^{a}	3.81	0.019
week									
1	10.06^{ns}	14.33	104.80^{ns}	13.08	106.00^{ns}	13.10	105.80^{ns}	14.09	0.939
2	200.73^{a}	21.60	197.80^{a}	22.01	176.86^{b}	21.09	171.66^{b}	17.86	0.000
3	290.60^{a}	28.48	293.33^{a}	36.33	245.93^{b}	31.93	232.60^{c}	26.99	0.000
4	385.16^{b}	32.38	388.25^{a}	33.88	323.45^{b}	32.73	316.57^{b}	24.50	0.000
5	489.94^{b}	19.54	501.50^{a}	23.26	413.65^{c}	19.70	408.37^{c}	14.19	0.000
6	619.32^{b}	40.48	685.21^{a}	79.53	528.38^{c}	31.92	510.78^{d}	20.32	0.000

Group	T_0		T_1		T_2		T_3		P.
Live weight	mean	S±	mean	S±	mean	S±	mean	S±	
7	748.32[b]	19.73	802.66[a]	17.16	664.08[c]	18.04	615.21[d]	18.91	0.000
8	866.10[b]	28.86	924.06[a]	28.07	782.41[c]	17.13	722.09[d]	18.26	0.000
9	972.89[b]	33.36	1073.90[a]	63.86	886.77[c]	24.15	811.91[d]	24.28	0.000
10	1100.31[b]	58.13	1199.68[a]	71.64	989.25[c]	54.97	916.31[d]	41.24	0.000
11	1237.88[b]	31.51	1318.22[a]	34.84	1109.90[c]	69.66	1027.13[d]	51.13	0.000
12	1396.48[b]	27.90	1492.14[a]	24.17	1235.98[c]	18.48	1127.38[d]	28.42	0.000

a, b, c, d significantly difference a>b>c>d and P probability.

From the results in table 4 it can be deduced that the average body weight of treatment two (T2) is significantly higher (P< 0.001) than that of other treatments. This result is quite similar to the findings of LOAN (2002).

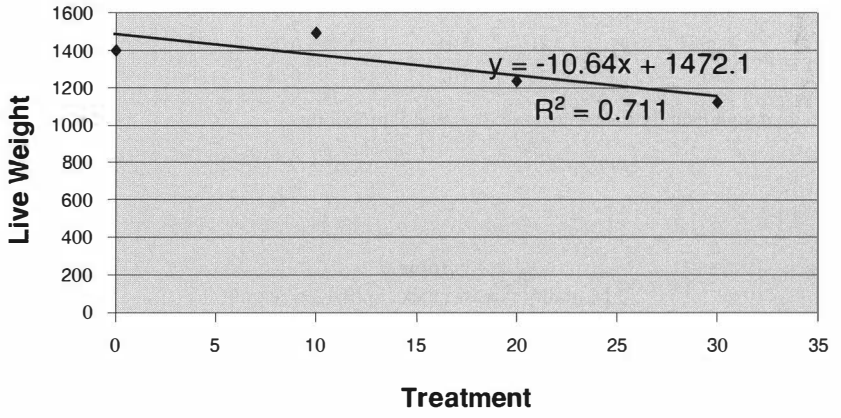

Fig. 1. — Relationship between live weight and treatments. This graphic shows that the relationship between live weight of local duck and treatments is negative.

The data in table 5 indicate that the feed conversion ratio of T2 and T3 is significantly lower than that of T1 and T2 although the difference between both treatments is not significant. It is clear that when using high amounts of CTM the digestibility becomes very low due to the high content of crude fibre in Cassava leave.

The mortality in the test group T2 and T3 (tab. 6) is very high compared to the other treatments because of the high toxicity of hydrocyanic acid. This result confirms the findings of LOAN (2002).

Table 5
Feed Conversion Ratio

Group	T_o		T_1		T_2		T_3		P.
Live weight	mean	S±	mean	S±	mean	S±	mean	S±	
week									
1	1.70^{sn}	0.06	1.78^{ns}	0.07	1.74^{ns}	0.09	1.83^{sn}	0.04	0.289
2	2.10^{b}	0.11	2.21^{b}	0.13	2.81^{a}	0.05	2.63^{a}	0.14	0.000
3	2.30^{b}	0.17	2.43^{ab}	0.12	2.50^{ab}	0.07	2.59^{a}	0.04	0.082
4	1.71^{c}	0.01	2.46^{a}	0.01	2.57^{a}	0.13	2.02^{b}	0.09	0.000
5	2.73^{a}	0.15	2.49^{a}	0.11	2.66^{a}	0.23	2.36^{b}	0.09	0.072
6	2.44^{b}	0.06	1.87^{c}	0.29	3.02^{a}	0.36	3.17^{a}	0.09	0.001
7	2.70^{ns}	0.26	3.2^{ns}	0.62	2.78^{ns}	0.22	3.40^{ns}	0.16	0.129
8	3.40^{c}	0.15	3.45^{c}	0.05	4.01^{b}	0.11	4.34^{a}	0.13	0.000
9	3.89^{b}	0.01	2.91^{c}	0.16	4.00^{b}	0.10	4.68^{a}	0.05	0.000
10	3.37^{d}	0.04	3.21^{c}	0.04	3.99^{a}	0.03	3.91^{a}	0.07	0.000
11	3.42^{b}	0.08	3.86^{a}	0.15	3.45^{b}	0.04	3.74^{a}	0.13	0.003
12	3.35^{c}	0.07	2.81^{d}	0.02	3.45^{b}	0.08	4.33^{a}	0.05	0.000
Total	2.85^{c}	0.03	2.76^{d}	0.02	3.17^{b}	0.04	3.36^{a}	0.01	0.000

a, b, c, d significantly difference a>b>c>d and P probability.

Table 6
Mortality rate of Ducks until 12 week old

Group	T_o	T_1	T_2	T_3
No	5	4	10	15
Mortality rate (%)	6.67	5.33	13.33	20.00

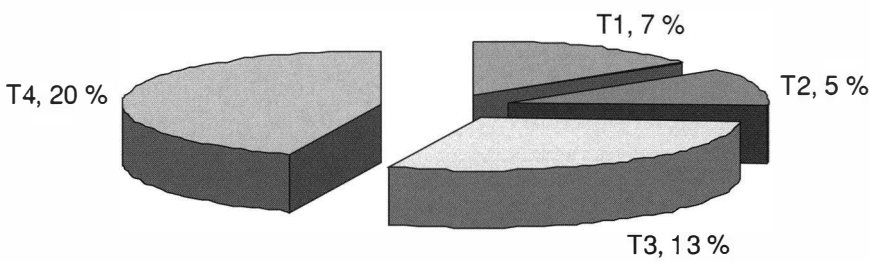

Fig. 2. — Mortality by different treatments.

4. Conclusion

The utilisation of CTM as feed needs to be limited, an addition of 10 % can improve the performance of ducks such as live weight, feed conversion ratio and low mortality.

By using more than 10 % of CTM there is a tendency of decreasing performance due to its higher HCN and crude fibre content. It is therefore recommended that more attention should be paid to the use of lysine and methionine as additive to the feed.

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First Results of Vegetables Trials of Khmer Effective Microorganisms (E.M.)

by

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1. Introduction

1.1. WHAT ARE E.M. (EFFECTIVE MICROORGANISMS)?

A multi-culture of major indigenous microorganisms such as Photosynthetic bacteria, Yeast and Actinomycetes, Lactic-acid bacteria who coexist together and with other microorganisms. They are not genetically modified organisms.

Photosynthetic bacteria synthesizes useful substances from secretions of roots, organic matter by using sunlight and the heat of soil as sources of energy: amino acids, nucleic acids, bioactive substances and sugars. These metabolites promote plant growth and development, beneficial microorganism (yeast, lactic-acid bacteria,...) increase.

Lactic-acid bacteria produce lactic acid from sugars and other carbohydrates, developed by yeast and photosynthetic bacteria. Lactic acid acts as sterilizing compound and limits harmful microorganisms (Fusarium,...) development and enhances decomposition of organic matter.

Yeasts produces antimicrobial and other useful substances for plant growth from amino-acid and sugar synthesized by photosynthetic bacteria organic matter and plant roots. The useful substances (hormones and enzymes) secreted by yeast favor active cell division and root growth, promote also lactic acid bacteria and actinomycetes development.

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The incorporation of the 3 species of microorganisms in the soil enhances the development of the existing beneficial soil microorganisms. This results in better plant growth, greater yield and healthier nutritious plants. Therefore, we could reduce and even give up chemical fertilizers and pesticides in vegetables areas, especially around Phnom Penh, which residues are toxic for consumers according to Health Ministry.

E.M. are known and used with success in more than 90 countries over the world, in agriculture, swine, chicken, fish rearing and in environment management.

1.2. How to make Khmer E.M.?

We applied the formula kindly offered by Rosukon, Director of Health Farm at Rayong (Thailand):

Fresh organic matter : 3 parts
Sugar : 1 part
Water : 10 parts

As we used Cambodian raw materials, we called our product "Khmer E.M.".

Fresh organic matter: mixed local vegetables.

Local sugar palm.

Purified water bought at the market.

Inoculum: natural microorganisms in Cambodian environment.

This is the first E.M. made in Cambodia. Until now, some people imported it from Thailand.

We have confidence in Rosukon formula.

2. Objective

To test the efficiency of Khmer E.M. on vegetable growth.

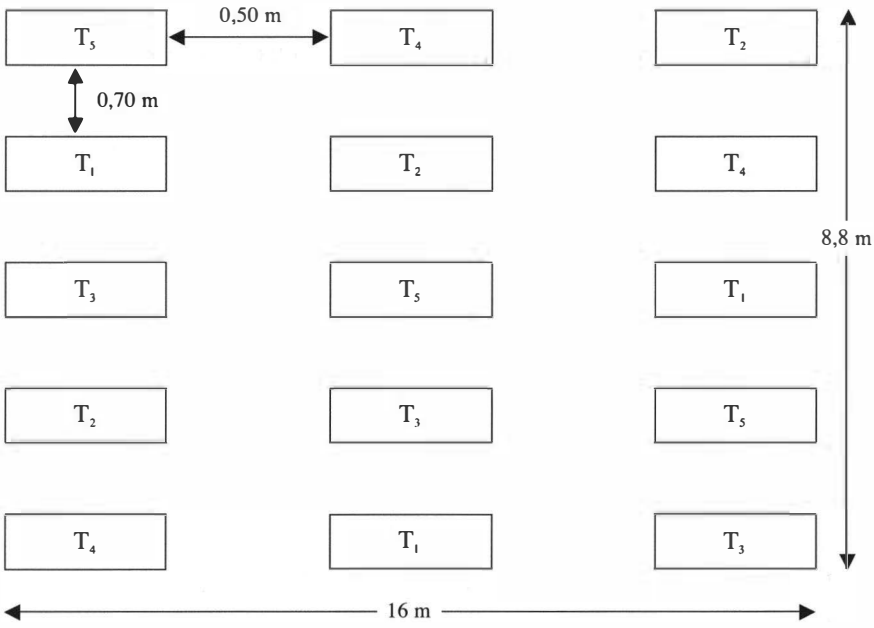
3. Materials and Methods

The first experimented vegetable is tomato.

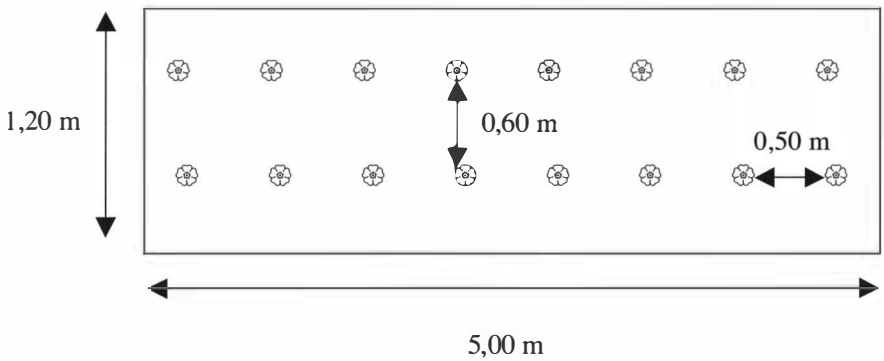
Variety: TMK_1 from Kbal Koh station.

Period of trial: 4th January to 2nd April 2005.

Experimental plot: Randomized Complete Blocs Design (RCBD) with 5 treatments and 3 replications.



Size of each plot: 1.2 m × 5.0 m.
Space between seedlings: 0.5 m × 0.6 m.



3.1. Treatments

T1:	Compost	: 15	T/ha
T2:	Cow Dung	: 15	T/ha
T3:	EM Bokashi	: 6	T/ha
T4:	Chicken Dung	: 15	T/ha
T5: Khmer E.M. (10 %) +	Cow Dung	: 7,5	T/ha

3.2. Cropping Calendar

01 January 2005	1st plough
04 "	sowing
15 "	2nd plough
25 "	incorporation of organic matter (compost, cow dung,...) in each treatment
26 "	transplantation of seedlings
03 February 2005	1st watering with Khmer E.M. (10 %) on T_5
10 "	2nd watering with Khmer E.M. (10 %) on T_5
11 "	hoeing
13 "	staking
17 "	3rd watering with Khmer E.M. (10 %) on T_5
24 "	4th watering with Khmer E.M. (10 %) on T_5
03 March 2005	5th watering with Khmer E.M. (10 %) on T_5
05 "	hoeing
10 "	hoeing
19 "	1st harvest
27 "	2nd harvest
04 April 2005	3rd harvest

4. Results

4.1. Flowering

50 % between 20 - 23 days after transplantation.
100 % between 26 -31 days after transplantation.

4.2. YIELDS (T/HA)

Treatment (Tr)	Replication (Re)	Commercial Yield	Non commercial Yield	Total Yield
T1	I	12.83	5.00	17.83
	II	11.50	3.66	15.16
	III	10.50	3.58	14.08
	Total	34.83	12.24	47.07
T2	I	14.50	8.30	22.80
	II	17.50	3.83	21.33
	III	13.33	1.75	15.08
	Total	45.33	13.88	59.21
T3	I	16.83	6.50	23.33
	II	14.16	6.50	20.66
	III	12.33	3.00	15.33
	Total	43.32	16.00	59.32
T4	I	14.50	7.00	21.50
	II	12.83	4.91	17.74
	III	13.08	3.33	16.41
	Total	40.41	15.24	55.65
T5	I	16.66	4.50	21.16
	II	18.16	5.75	23.91
	III	18.33	3.66	21.99
	Total	53.15	13.91	67.06

Non commercial yield

Tr \ Re	Yield T /ha			Total of Tr	Average of Tr
	I	II	III		
T1	5.00	3.66	3.58	12.24	4.08
T2	8.30	3.83	1.75	13.88	4.62
T3	6.50	6.50	3.00	16.00	5.33
T4	7.00	4.91	3.33	15.24	5.08
T5	4.50	5.75	3.66	13.91	4.63
Total Bloc	31.30	24.65	15.32		
Grand Total				71.27	
Average					4.74

SV	Df	SS	MS	FC	F theoric	
					5 %	1 %
Replication	2	25.77	12.88	6.85*	4.46	8.65
Treatment	4	2.77	0.69	0.36ns	3.84	7.01
Error	8	15.05	1.88			
Total	12					

There is no significative difference between the treatments.

Commercial yield

Tr \ Re	Yield T/ha			Total of Tr	Average of Tr
	I	II	III		
T1	12.83	11.50	10.50	34.83	11.61
T2	14.50	17.50	13.33	45.33	15.11
T3	16.83	14.16	12.33	43.32	14.44
T4	14.50	12.83	13.08	40.41	13.47
T5	16.66	18.16	18.33	53.15	17.71
Total Bloc	75.32	74.15	67.57		
Grand Total				217.04	
Average					14.46

SV	Df	SS	MS	FC	F theoric	
					5 %	1 %
Replication	2	6.98	3.49	1.51ns	4.46	8.65
Treatment	4	60.39	15.09	6.53*	3.48	7.01
Error	8	18.55	2.31			
Total	12					

There is significative difference between the treatments.

Total yield

Re / Tr	Yield T/ha			TrT	TrM
	I	II	III		
T1	17.83	15.16	14.08	47.07	15.69
T2	22.80	21.33	15.08	59.21	19.73
T3	23.33	20.66	15.33	59.32	19.77
T4	21.50	17.74	16.41	55.65	18.55
T5	21.16	23.91	21.99	67.06	22.35
Total Bloc	106.62	98.80	82.89		
GrandTotal				288.31	
Average					19.21

SV	Df	SS	MS	FC	F theoric	
					5 %	1 %
Replication	2	58.49	29.24	6.96*	4.46	8.65
Treatment	4	69.90	17.47	4.15*	3.84	7.01
Error	8	33.66	4.20			
Total	14					

SV: Sources of variation.
Df: Degree of freedom.
SS: Sum of square.
MS: Mean of square.
FC: F calculated.
CV: Coefficient of variation.

DMRT: Duncan's Multiple Rang Test

$RP_{5\%}$	$RP_{1\%}$	TrM5	TrM2	TrM3	TrM4	TrM1
		17.71	15.11	14.44	13.47	11.61
4.04	5.87	2.06^{ns}	0.67^{ns}	0.97^{ns}	1.86^{ns}	
4.20	6.20	3.27^{ns}	1.64^{ns}	2.83^{ns}		
4.30	6.37	4.24^{ns}	3.50^{ns}			
4.36	6.59	6.10*				

There is significative difference between TrM5 (KEM + Cow Dung) and TrM4 (Chicken Dung) and TrM5 and TrM1 (control).

5. Conclusion

As regards tomato, the treatment KEM (mixed fruits) + Cow Dung gives the highest total yield, with significative difference with the treatments Chicken Dung and Compost.

We summarize in the tables below the results of experimentations (Randomized Complete Blocks Design) achieved by 8 students of Royal University of Agriculture (Chamcar Daung) and an APSARA Authority officer dealing with salad, chinese kale, green mustard, chilli pepper and tomato trials.

Comparison between:

—	KEM + Cow Dung	(7.5T/ha)
—	E.M. Bokashi (Thai)	(3-6T/ha)
—	Chicken Dung	(15T/ha)
—	Cow Dung	(15T/ha)
—	Compost (Stung Meanchey)	(15T/ha)

By students:

— Vay Soeung	(2 Dec., 04 — 24 Jan., 05) on Chinese Kale (Brassica oleeracea) EM Bokashi 3T/ha , KEM 5 % (mixed vegetables)
— San Phirum	(4 Jan. — 2 April, 05) on Tomato (Lycopersicum esculentum) EM Bokashi 6T/ha, KEM 10 % (mixed fruit)

Conclusion:

KEM + Cow Dung is the best (KEM made from mixed vegetables, mixed fruits)

Comparison between

The rates KEM (aged from 7 to 10 months) 2 % 5 % 8 %

By students:

— Nget Bunthoeun	on Green Mustard (1) (Brassica juncea)
— Tan Setha	on Chinese Kale (2)(Brassica oleracea)
— Teoun	on Tomato (2)(Lycopersicum esculentum)
— Sakun Pida	on Chilli Pepper (1) (Capsicum frutescens)

(1) KEM mixed vegetables

(2) KEM mixed fruits

Conclusion:

The rate 2 % is the best efficient concentration for all crops.

Comparison between:
Different sources of KEM: mixed vegetables, Eupatorium odoratum, Eichhornia crassipes

By:

—	Aing Sochenda	on Salad in pot	KEM (18 months) 0.5 % (Lactuca sativa)
—	Kor Tong Seng	on Salad in pot	KEM (8 months) 5 % (Lactuca sativa)
—	Chhoeurn Sila	on Chinese Kale	KEM (8 months) 5 % (Brassica oleracea)
—	Kong Nay	on Green Mustard	KEM (8 months) 5 % (Brassica juncea)

Conclusion:
KEM mixed vegetables>KEM Eupatorium odoratum>
KEM Eichhornia crassipes>Control

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Effect of Fertilisers and Crop Residue on Soil Fertility and Crop Yield of some Cropping Systems on Bac Giang Degraded Soil

by

HOANG THI MINH*

1. Introduction

Degraded soils occupy an area of 1,791,021 ha, mainly derived from sandstone and old alluvium. They are poor in nutrients, have a very low cation exchange capacity and are poor in organic matter. The soil texture is sandy loam to silty loam, with a very low clay content in the upper horizons, but increasing in depth.

Because the area for cultivation is narrowing day by day, with a demand for food continuously increasing, it is necessary to increase crop yields and number of crops per year.

Recently, requirement for agricultural products changed under the influence of the market economy. Many crop systems are cultivated with a different input, which have an impact on soil fertility. For a sustainable agriculture and healthy environment, it is necessary to investigate the change on soil fertility by different agricultural practices.

This study is based on long-term farm experiments to evaluate the effect of fertilisers and crop residue on soil fertility and crop yield of some cropping systems on degraded soils.

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2. Materials and Methods

Soil samples were collected from the fields of three crop - patterns:

1. Spring rice — Summer soybean — Late Summer rice.
2. Spring soybean — Early Summer rice — Winter maize.
3. Spring rice — Early Summer rice — Winter maize.

The experiments included 4 treatments on residues incorporated in the soil and residues non-incorporated in the soil:

1. Without fertiliser (control).
2. Inorganic fertiliser NPK.
3. Inorganic fertiliser NPK + farmyard manure (FYM).
4. Farmyard manure (FYM).

Following levels of fertiliser were applied for each crop per ha:

Spring rice: 10 ton FYM + 100 kg N + 70 kg P_2O_5 + 100 kg K_2O.
Spring soybean: 8 ton FYM + 45 kg N + 60 kg P_2O_5 + 60 kg K_2O.
Summer soybean: 8 ton FYM + 30 kg N + 60 kg P_2O_5 + 60 kg K_2O.
Early summer rice: 10 ton FYM + 80 kg N + 60 kg P_2O_5 + 60 kg K_2O.
Late summer rice: 8 ton FYM + 60 kg N + 40 kg P_2O_5 + 60 kg K_2O.
Winter maize: 10 ton FYM + 180 kg N + 120 kg P_2O_5 + 150 kg K_2O.

Soils were sampled at 0-10 cm depth to determine soil properties after the fifth year of the experiment.

For crop-pattern 1, soil samples were taken after harvest of late summer rice, for crop-patterns 2 and 3 soil samples were taken after harvest of winter maize.

Microbial biomass was measured on fresh soil samples by direct counts.

Air dry soil samples were used to determine soil chemical properties. The pH was measured with pH meter, total soil organic matter and nitrogen by the Walkley and Black and the Kjeldahl method respectively, available P by Bray — II extraction, available K extracted by neutral 1M ammonium acetate, CEC by neutral 1M ammonium acetate.

Soil physical properties such as bulk density, field water capacity and water stable aggregates were determined by the methods applied at the laboratory of NISF.

All results are averages of 3 replicate plots, expressed on an oven dry soil basis. Data are treated by statistical methods.

3. Results and Discussion

3.1. Soil Properties

3.1.1. Bulk Density (tab. 1)

Bulk density of the analysed samples ranged from 1.27 to 1.45 g. cm^{-3}. In treatments with inorganic NPK the bulk density was highest. Application of FYM as well as crop residue decreased bulk density values.

A very close correlation between total organic matter (OM) and bulk density ($r = - 0.73$) was noticed.

Table 1
Soil bulk density (g cm^{-3}) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	1.38	1.38	1.45	1.41	1.38	1.35
NPK	1.41	1.36	1.42	1.33	1.36	1.28
NPK+ FYM	1.37	1.30	1.31	1.30	1.31	1.27
FYM	1.32	1.31	1.3	1.28	1.30	1.27

3.1.2. Field Water Capacity (tab. 2)

Soils treated with NPK had a low field water capacity (FWC), whereas treatments with FYM increased the FWC. Comparing NPK + FYM with NPK treatments, the field water capacity of CS1; CS2 and CS3 were: 110.5; 106.7; and 121.7 % respectively. Incorporation of crop residue increased the field water capacity in almost all cases. A good correlation between total OM and FWC ($r= 0.34$ ($p<0.01$)) is noticed.

Table 2
Field water capacity (%) related to cropping systems

Treatments	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	36.7	39.4	30.7	33	34.5	35.5
NPK	36.3	40.2	34.5	35.3	33.7	37.6
NPK+ FYM	40.1	45.7	36.8	37.7	41	40.1
FYM	39.7	41.2	34.8	35.3	38.7	39

3.1.3. Water Stable Aggregates (tab. 3)

On degraded soils, the capacity to form aggregates larger than 1 mm is limited due to low clay and OM contents. Larger aggregates play an important role in structure formation, optimal air regime and good nutrient content for crops. Treatments without organic matter application had low proportion of >1 mm aggregates.

Application of farmyard manure as well as incorporation of crop residue increased the amount of > 1 mm aggregates. On average, treatments with incorporation of crop residue in CS1, CS2 and CS3 yielded respectively 155.1 %; 197.4 % and 174.1 % of aggregates > 1 mm, in comparison with non incorporation crop residue.

According to MINAMI & MAIEDA (1971) the continuous addition of straw improves the physical properties of soils.

The correlation between soil organic matter and amount of > 1 mm aggregates is good (r = 0.48).

Table 3
Water stable aggregates (%) related to cropping systems

Treatments	System 1		System 2		System 3	
	>1 mm	< 0.25 mm	>1 mm	< 0.25 mm	>1 mm	< 0.25 mm
Control	5.8	47.5	0.7	58.3	9.4	54.6
NPK	7.0	51.4	4.5	52.1	6.3	57.7
NPK+ FYM	10.0	47.5	8.4	60.6	16.8	48.3
FYM	8.8	43.0	20.6	52.1	17.4	38.2
Control + residue	10.7	42.4	8.6	58.8	10.3	54.1
NPK + residue	8.2	43.1	13.1	49.2	31.9	35.7
NPK+ FYM+ residue	10.9	40.7	15.2	48.8	20.1	44.8
FYM + residue	19.2	36.5	30.6	46.9	24.6	46.2

3.1.4. Soil Acidity (tab. 4)

The pH of CS1 varied from 5.4 to 5.8. When only NPK was applied, the soil became more acid, whereas the combination of inorganic and FYM made the soil less acid. Comparison by Duncan shows that the differences of pH depending upon the fertiliser treatments were significant. Using only NPK and not applying fertilisers resulted in a lower pH (a level) whereas by applying NPK + FYM and FYM the pH increased (b level). Incorporation of crop residue did not affect soil acidity. Variation between incorporated and non incorporated treatments was non significant.

In CS2 the pH varied from 5.1 to 5.5, this is slightly more acid than in CS1 but the tendency of variation was the same. The treatment with FYM and FYM + NPK makes the soils less acid than with NPK and control soils, the difference being significant. (Duncan's new multiple test were control: a; NPK: a; NPK + FYM: b and FYM: b. Incorporation of crop residue: a; non incorporation: a).

Table 4
pH_{KCL} related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	5.5 (a)	5.6	5.3 (a)	5.3	5.4 (b)	5.3
NPK	5.4 (a)	5.5	5.1 (a)	5.2	5.0 (a)	5.2
NPK+ FYM	5.7 (b)	5.8	5.3 (b)	5.4	5.3 (b)	5.7
FYM	5.7 (b)	5.7	5.4 (b)	5.5	5.6 (c)	5.8

Note: Values followed by different letters are significantly different among rates fertiliser and between incorporation and non incorporation crop residue.

In CS3 the tendency of pH variation was somewhat different compared to CS1 and CS2. Treatments with NPK show the lowest pH values, whereas treatments with FYM the highest.

Incorporation of crop residues made the soils less acid. Difference between incorporation and non-corporation was significant.

3.1.5. Soil Organic Matter Content (tab. 5)

There was a difference in soil organic matter (SOM) content between fertiliser treatments on these degraded soils. In the control soils, the total SOM content was lowest whereas it was highest in NPK + FYM and FYM treatments.

According to YAMASITA (1967) long term experiments in Japan with the application of farmyard manure increased the humus content by 0.8-3 %.

The amount of SOM increased by application of FYM in CS1, CS2 and CS3 to 47%, 27% and 50% respectively in comparison with the control soils.

Crop residue returned into the soil increased the SOM content average between 15 and 24% compared to the control soils. Combined with mineral fertiliser application, crop residue incorporation resulted in a higher amount of SOM.

POWLSON *et al.* (1987) reported that 18 years of straw incorporation in Danish soils increased the biomass carbon about a 40-50 % whereas the total soil organic carbon increased only by 5 %.

Table 5
Total soil organic matter (%) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	0.771 (a)	1.193	1.085 (a)	1.259	1.313 (a)	1.378
NPK	0.934 (a)	1.140	1.334 (b)	1.444	1.411 (b)	1.606
NPK+ FYM	1.258 (c)	1.628	1.432 (d)	1.910	1.561 (c)	1.975
FYM	1.227 (b)	1.248	1.443 (c)	1.541	1.801 (d)	2.062

Comparing the 3 cropping systems, soil organic matter was lowest in CS1, increased with 18-26 % in CS2 and 30-40 % in CS3 compared to CS1 and 10-14 % in CS3 compared to CS2. These was relation to fertiliser rate applied in 3 cropping system was different. The lowest rate was applied to CS 1, the highest to CS3.

Organic matter actively influences soil fertility, increasing soil humus and improving soil physical properties such as soil porosity, field water capacity, increasing formation of aggregates leading to better structure. Increase of OM also increases cation exchange capacity.

3.1.6. Total Nitrogen Content (tab. 6)

The total nitrogen content varied between 0.051 to 0.109 %. In the three cropping systems the same tendency is noticed: the total N value was lowest in the control soils compared to the NPK + FYM treatments of CS1, CS2 and CS3 which yield 124 %, 170.5 % and 134 % respectively.

Treatments with incorporation of crop residue increased the total N content of the soil about 4-15 %.

Table 6
Total soil nitrogen (%) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	0.059	0.063	0.051	0.06	0.074	0.078
NPK	0.065	0.064	0.068	0.069	0.092	0.107
NPK + FYM	0.073	0.075	0.087	0.098	0.099	0.109
FYM	0.064	0.069	0.091	0.089	0.083	0.106

3.1.7. Available Phosphorous Content (tab. 7)

The available phosphorous content in the degraded soils was high, the average content varying between 33.5 to 67.6 mg P_2O_5 100^{-1}g soil. In three cropping systems this variation followed the same tendency: in the control soils the values of available phosphorous were lowest.

Table 7
Available phosphorous (mg $P_2O_5$100 $^{-1}$g soil) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	34.4 (a)	38.7	25.7 (a)	26.0	37.4 (a)	37.1
NPK	51.6 (b)	51.6	55.1 (c)	52.2	67.6 (b)	59.0
NPK + FYM	52.4 (b)	59.0	59.6 (c)	50.4	66.5 (b)	57.5
FYM	50.2 (b)	51.3	33.5 (b)	34.5	36.9 (a)	36.1

In NPK+ FYM treatments of CS1, CS2 and CS3 the available phosphorous content increased 52.3 %, 77.0 % and 77.8 % respectively, in comparison with the control soils.

Residue incorporation in the soils did generally not increase the available phosphorous content, and sometimes even a negative effect was noticed.

3.1.8. Available Potassium Content (tab. 8)

The degraded soils have a low available potassium content, a factor constraining crop yield. According to TRAN THUC SON (1999) crop yield increased on degraded soils with 1.11 ton ha^{-1} and 3.76 ton ha^{-1} when potassium fertiliser was applied on rice and maize respectively (comparing NP and NPK treatments).

Fertiliser application and crop residue incorporation increased the available potassium content in the soil. In NPK + FYM treatment available potassium content was highest.

The available potassium increased with 40 % when residue was incorporated in CS1, with 24 % in CS 2 and 42.5 % in CS3. This is probably also related to the rate of fertiliser application in the soil.

There was a close relation between total soil organic matter content and available potassium content ($r = 0.63$), showing that crop residue incorporation in the soil could solve partly the K requirement for crops.

Table 8
Available potassium (mg K_2O 100 $^{-1}$g) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	1.2	1.4	1.2	1.2	1.6	1.8
NPK	1.6	2.6	4.6	5.1	3.8	5.4
NPK + FYM	3.0	5.0	5.4	6.4	6.4	11.3
FYM	1.6	1.8	1.6	3.2	4.2	4.2

3.1.9. Cation Exchange Capacity (CEC) and Exchangeable Cations (tab. 9)

The degraded soils under study have a low CEC due to a low clay and OM content and the fact that the main clay mineral is kaolinite.

Table 9
Cation exchange capacity(CEC) (meq100^{-1} g soil) related to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	2.25 (a)	2.26	1.99 (a)	2.21	2.1 (a)	2.42
NPK	2.11 (a)	2.43	2.36 (b)	2.61	2.11 (a)	2.52
NPK + FYM	2.6 (b)	2.73	2.6 (c)	3.03	2.75 (c)	3.09
FYM	2.65 (b)	2.68	2.39 (b)	2.66	2.58 (b)	2.74

In treatments where only NPK was applied, the CEC was lower than that in the NPK +FYM treatments as well as the FYM application, with a significant difference.

According to YAMASHITA (1967) long-term application of farmyard manure increases CEC and exchangeable bases, particularly calcium and potassium.

Increase of CEC by incorporating residue of CS1, CS2 and CS3 were 5 %; 12 and 13 % respectively. The difference was significant.

Exchangeable Ca^{++} varies from 1.06 to 2.34 meq 100g^{-1} (tab. 10) and occupies a large part of the CEC.

In CS1 treatments with fertilisers resulted in a 20 to 70 % higher Ca^{++} content than in the control soils, whereas the incorporation of cropping residue increased the exchangeable Ca^{++} by about 15 %. The difference between incorporation and non incorporation of crop residue was significant.

In CS2 the exchangeable Ca^{++} content increased from 15-40 % when fertilisers were applied, but the difference between incorporation and non incorporation of crop residue was not significant.

Table 10
Exchangeable Ca^{++} related (meq100^{-1} g soil) to cropping systems

Treatment	System 1		System 2		System 3	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	1.06 (a)	1.48	1.33 (a)	1.29	1.37 (a)	1.41
NPK	1.28 (b)	1.67	1.87 (b)	1.84	1.52 (b)	1.71
NPK + FYM	1.75 (c)	1.86	1.63 (b)	2.03	1.88 (d)	2.34
FYM	1.82 (c)	1.75	1.53 (a)	1.71	1.71 (c)	2.08

In CS3 NPK +FYM and FYM treatments resulted in an increase of exchangeable Ca^{++} content from 37 to 52 % compared to the control soils, but the difference between incorporation of crop residue was not significant.

There was a close correlation between CEC and exchangeable Ca^{++} content ($r = 0.65$).

3.1.10. Soil Biological Properties (tab. 11)

Micro-organisms play an important role in soil fertility, by nutrient exchange and they form an organic resource supply for soils. On average about 5 % of biomass consists of living mass (INUBUSHI & WANTANABE 1986). Microbial biomass can be used as an early indicator of changes in total soil organic matter in submerged rice soil (YOSHIKAWA 1995).

Table 11
Microbial biomass (10^7 CFU/g soil) related to the crop systems

Treatments	System 1	System 2	System 3
No fertiliser	1.4	1.3	0.7
NPK	4.2	1.6	1.2
NPK +FYM	4.9	2.1	0.8
FYM	8.4	1.2	0.9
No fertiliser + Residue	1.0	1.0	0.8
NPK + Residue	3.9	2.1	3.6
NPK + FYM+ Residue	5.6	2.3	1.9
FYM + Residue	2.7	2.2	1.3

The results of table 11 show that on the degraded soil, fertiliser treatments strongly influenced the microbial biomass, which increased 3 to 6 times compared to control soils. Also between incorporation and non incorporation of residue a difference is observed.

In CS1 and CS2, the application of mineral fertiliser and farmyard manure resulted in a higher microbial biomass than when only mineral fertilisers were applied. In CS3, the NPK treatment had the highest microbial biomass.

3.1.11. The Influence of Fertiliser and Residues on Crop Yield (tab. 12)

On the degraded soil in Bac Giang both fertiliser and residue application increased crop yield. For almost all crops a sufficient supply of mineral fertiliser and farmyard manure (NPK and NPK + FYM) showed the highest increase of crop yield, and NPK treatment gave higher yields than farmyard manure only.

For winter-maize, the yield obtained by applying only farmyard manure was very low compared to mineral fertiliser treatment (about 3.3 ton ha^{-1}). For soybean NPK increased the yield more than farmyard manure by 30-50 %. For spring rice, the NPK increased the yield about 1.3 ton/ha compared to manure use (over-yielded 45 %).

Residue incorporation contributed to an increase in organic matter and available nutrients and created a favourable environment for plant growth, leading to increasing yields for all crops.

According to PATNAIK (1978) rice straw from one normally fertilised hectare, contains 45 kg nitrogen, 7.5 kg phosphorous, 104 kg potassium, 20 kg calcium, 32 kg magnesium, 3 kg iron, 11 kg manganese and 235 kg silicon.

Incorporation of residue in the cropping systems lead to following over-yields:

— CS 1: Over-yield of Spring rice, Summer soybean and late Summer rice were 8.5; 20.6 and 7.1 % respectively.
— CS 2: Over-yield of Spring soybean, early Summer rice and Winter maize were 21.6; 27.1 and 45.8 % respectively.
— CS 3: Over-yield of Spring rice, early Summer rice and Winter maize were 6,5; 25.7 and 49.1 % respectively.

The average higher yield by incorporation of residue for each crop was as follows: the increased yield for spring rice was 7.5 %, for soybean 21 %, for early summer rice was 26 % and for winter maize 47 %.

Table 12
Influence of fertilisers and crop residue on crop yield for some cropping systems (kg/ha, mean of 5 years, 1998-2002)

System 1 Treatment	Spring rice		Soybean		Late Summer rice	
	no Residue	+Residue	no Residue	+Residue	no Residue	+Residue
Control	1,980	2,280	360	490	1,740	2,040
NPK	4,000	4,250	1,130	1,390	3,090	3,310
NPK + FYM	4,400	4,650	1,440	1,560	3,340	3,670
FYM	2,690	2,900	750	890	2,490	2,590
System 2 Treatment	**Soybean**		**Summer rice**		**Winter maize**	
	no Residue	**+Residue**	**no Residue**	**+Residue**	**no Residue**	**+Residue**
Control	440	620	2,120	2,580	430	600
NPK	1,200	1,420	4,240	4,590	3,970	4,390
NPK + FYM	1,490	1,690	4,470	4,900	4,780	4,960
FYM	950	1,110	3,260	3,500	880	1,110
System 3 Treatment	**Spring rice**		**Summer rice**		**Winter maize**	
	no Residue	**+Residue**	**no Residue**	**+Residue**	**no Residue**	**+Residue**
Control	1,930	2,070	2,020	2,410	500	570
NPK	3,900	4,170	4,000	4,310	3,960	4,440
NPK + FYM	4,350	4,550	4,450	4,610	4,710	4,950
FYM	2,650	2,840	3,220	3,430	780	1,000

4. Conclusion

Without the application of fertilisers, the degraded soil in Bac Giang supporting 3 crops would become depleted, poor in organic matter and nitrogen and with a low CEC and poor base saturation.

If only inorganic fertilisers were applied, the soil properties changed in a negative sense in the 3 systems, as soils became compact, low in moisture content, less soil aggregates being formed. Soil acidity increased and soil organic matter and CEC decreased.

The combination of mineral fertiliser and farmyard manure influenced actively soil fertility, created favourable conditions for plant growth and gave high yields.

On the degraded soil the crop residue incorporation increased soil organic matter, improved soil physical properties, increased CEC and exchangeable K^+, contributed to increase of crop yield between 7.5 to 47 %.

Soil organic matter played an important role in soil fertility, had a negative correlation with density soil (r =-0.73), had proportional correlation with exchangeable K^+ (r = 0.63) and CEC (r = 0.67).

On the degraded soils the combined application of NPK and farmyard manure gave the highest yields. When only inorganic fertiliser were applied, the crop yield achieved higher results than the farmyard manure application; crop yields were lowest if no fertilisers were applied, particularly for maize that demands large amounts of nutrients.

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Aquaculture Development in the Mekong Delta, Vietnam

by

NGUYEN THANH PHUONG*

1. Introduction

The Mekong river meets the Eastern Sea through nice branches. It forms one of Asia's largest deltas that is about 5 million hectares, of which 80 % lie in Vietnam and known as Mekong river delta. The Mekong river delta is characterized as a flat and low-lying region and crossed by an extensive network of canals and rivers of over 5,000 km in length. It possesses about 1.37 million ha coastal areas and 1.77 million ha inland areas (LE 2001, TRAN & NGUYEN 2001). The inland areas are suffered by annual floods so the freshwater bodies change greatly between seasons. The flood in rainy season may cover 8 of 12 provinces of the delta or about 1.4-1.9 million hectares. Flood water level varies from 1-4 m deep for about 2-6 months depending on locations. Freshwater aquaculture is operated in relation to the flood conditions. Vietnam has a long coastline of over 3,200 km spreading from the North to the South with about 226,000 km^2 territorial water and over 1 million km^2 of Exclusive Economic Zone (CHU *et al.* 2003). The Mekong river delta has over 350 km coastline and about 600,000 ha of brackish water areas. This is a large and an excellent region for coastal aquaculture development. Shrimps, mollusks and marine finfishes are all possible to farm in this area.

The aquaculture development plan for the period from 1999-2010, which was approved by the Vietnamese Government indicated that the Mekong river delta will be a main region for aquaculture sector of Vietnam (Decree

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No. 224/1999/QD-TTg 1999). The growth of the aquaculture in the Mekong delta has shown a remarkable level during the last decade (fig. 1). Marine shrimp (*Penaeus monodon*) and catfishes (*Pangasius bocourti* and *P. hypophthalmus*) are major culture species of the Mekong river delta and their growth is the greatest. The total production of catfishes and marine shrimp was approximately 515,000 m.t out of 744,442 m.t of aquaculture production of the delta in 2004 (Ministry of Fisheries 2005). The production of catfishes and marine shrimp increased 4.0 and 3.6 times during the 5-year period from 1999 and 2004, respectively (Ministry of Fisheries 2005).

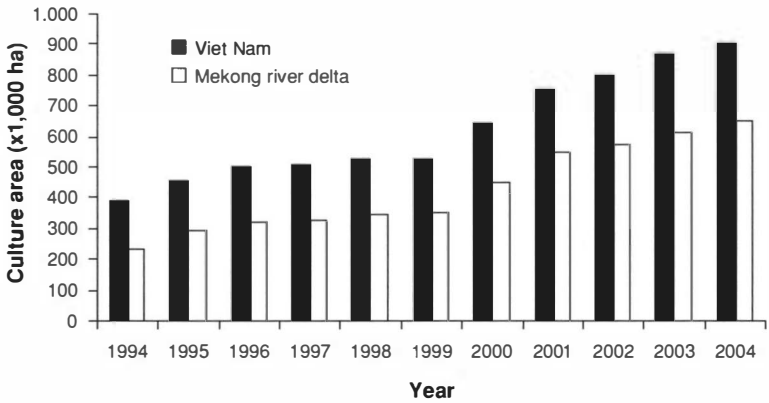

Fig. 1. — Growth of aquaculture areas of Vietnam and the Mekong river delta since 1994-2004 (Ministry of Fisheries 2002, 2003, 2004, 2005).

2. Aquaculture Development in the Mekong River Delta

Aquaculture in the Mekong delta was defined at high level of importance of the aquaculture sector development of Vietnam for the period from 1999-2010 (Decree No. 224/1999/QD-TTg. 1999). It has been shown as true that the production of main important cultured species such as shrimp and catfishes have increased continuously during the last few years (figs. 2, 3). The reason of the increase of both production and culture area has resulted from the improvement and development of technologies of grow-out and seed production.

2.1. Brackish Water Aquaculture Development in the Mekong Delta

With a total brackish water area of 600,000 ha and diversified ecological conditions, the Mekong river delta has a great potential for coastal aquaculture development in term of culture species, culture system and culture area. However, the existing coastal aquaculture of this delta is limited to few species such as marine shrimp (*Penaeus monodon*), mud crab (*Scylla* spp) and some brackish water fishes. Shrimp is a front runner and the most important of the coastal aquaculture.

The shrimp production was 200,000 m.t and it shared up to 70 % of total shrimp export turnover of Vietnam in 2004 (Ministry of Fisheries 2005). The growth of shrimp production in the delta from 1999 to 2004 is shown in figure 2 and its rapid growth happened since the beginning of this decade. The growth of shrimp is resulting from the seed production techniques that established since the beginning of 1990s. Twenty six billions of post-larvae were produced in Vietnam in 2004, of which 7 billions were from the Mekong river delta. The shrimp culture comprises intensive, semi-intensive, improved extensive and extensive cultures. The low intensification cultures such as improved extensive and extensive cultures (alternative rice-shrimp and integrated mangrove-shrimp) share about 90 % and 60 % of total culture area and production, respectively (Ministry of Fisheries 2004, 2005). During the last five years, more than one hundred thousand hectares of rice land in the seasonal saline water intrusion areas of coastal provinces of the Mekong river delta have been converted to shrimp farming according the national policy (Decree No. 09/2000/NQ-CP 2000). This adds up the change

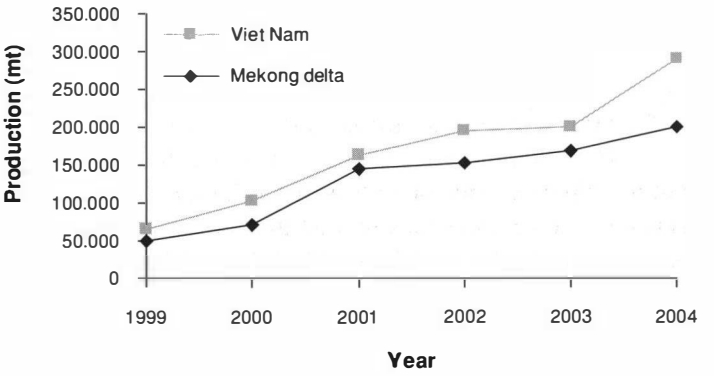

Fig. 2. — Increase of shrimp production in the Mekong delta and Vietnam during the period from 1999 to 2004 (Ministry of Fisheries 2002, 2003, 2004, 2005)

of shrimp culture area from 250,000 ha in 2000 to 500,000 ha in 2004. The culture of other species such as mud crab and brackish water finfishes is at a very preliminary stage and depends on wild collected seeds.

The shrimp culture will keep its important role and will move forward intensive and semi-intensive cultures in the coming period due to the improvement of management, infrastructures, culture technologies and technological knowledge of shrimp farmers. However, the diversification of coastal aquaculture will be difficult to implement in the short coming period due to technologies for the culture and seed production of species such as mud crab, marine finfishes which are not established yet.

2.2. Freshwater Aquaculture Development in the Mekong Delta

The inland area of the Mekong river delta has diverse habitats that are suited for various types of freshwater aquaculture. The freshwater aquaculture is therefore playing an increasingly important role in the economic development of the delta. The production of freshwater aquaculture is about 500,000 m.t or about 70 % of the total aquaculture production of the delta in 2004 (Ministry of Fisheries 2005). Culture species for freshwater bodies are rather diversified such as indigenous fishes (catfishes, *Pangasius bocourti* and *P. hypophthalmus;* snakeheads, *Channa micropeltes* and *Channa striata;* climbing perch, *Annabas testudineus*; snakeskin gourami, *Trichogaster pectoralis;* silver barb, *Puntius gonionotus*), exotic fishes (Tilapia, *Oreochromis niloticus*; Common carp, *Cyprinus carpio)* and prawns (*Macrobrachium rosenbergii*). The freshwater aquaculture is operated with two main forms including intensive and extensive.

The intensive culture is operated with species such as catfishes, snakeheads and climbing perch and is conducted not only in cages and ponds but also in pens. The culture of catfishes, especially *Pangasius hypophthalmus*, is a leading of the freshwater aquaculture sector. The production of catfishes alone was 315,000 m.t, 3.6 times as much that of year 1999, export value of 300 million USD, covering around 60 % of the total freshwater aquaculture of the delta in 2004 (Ministry of Fisheries 2005). The production growth of catfish is shown in figure 3. Catfishes culture in cage along the Mekong river branches have been developed since the beginning of 1960s (Nguyen 1998), while pond and pen cultures are newly formed. Pond culture has become a main culture form and shared up to 70 % of total catfish production. The culture of catfishes has started to grow rapidly since 2000, where the induced spawning technique was widely applied. The productivity of catfish cultures are at high level if compared to other species. It is greater than 100 kg/m^3/

crop for cage, 183-582 m.t/ha/crop depending on stocking density for pond and 345 m.t/ha/crop for pen (NGUYEN *et al.* 2004, LE 2005). However, the production of other intensive culture species like snakeheads and climbing perch has not been summed up officially yet, but these species performed a potential growth in the future.

The extensive cultures are mainly operated on rice paddy and garden ponds. Recently, fish and giant freshwater prawn (*Macrobracium rosenbergii)* is a main culture species on rice paddy either in forms of integration or alternation. Tilapia (*Oreochromus niloticus*), common carp (*Cyprinus carpio*), silver barb (*Puntius gonionotus*),... are commonly stocked in ponds in the form of polyculture. The culture of giant freshwater prawn on rice paddy has performed as a way to improve total profit from rice paddy production. This type of culture has started since the beginning of 2000, when hatchery-reared seeds was available. There are about 1,000 ha of rice paddy which have been converted to this form of culture. The productivity of the rice-cum-prawn culture varied from 100-887 kg/ha/crop and of rice alternated with prawn was 384-1,681 kg/ha/crop (NGUYEN *et al.* 2005). Fish culture on rice paddy is a traditional form of production in Vietnam, and it still remains in many places. The yield from rice-cum-fish culture varied from 482-808 kg/ha (NGUYEN *et al.* 2005). The livestock-fish polyculture has not been operated as a commercial way but it functioned as a household protein source and minor income. The productivity of this culture form varied 467-1,456 kg/ha depending on stocking densities (NGUYEN *et al.* 2005).

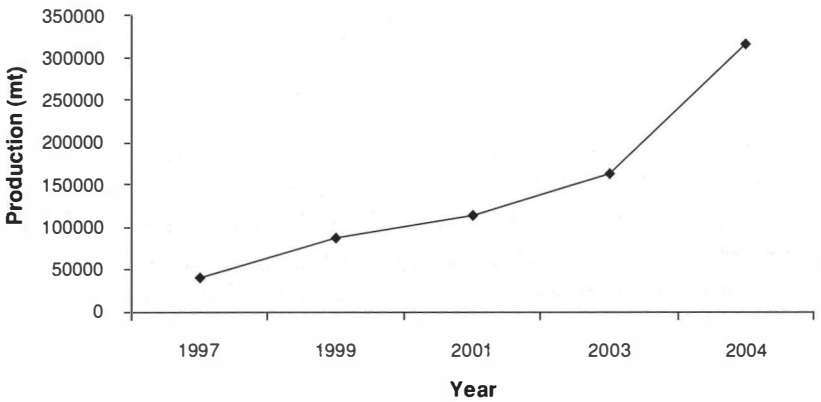

Fig. 3. — Increase of catfish production of the Mekong river delta during the period from 1997 to 2004 (TRAN 2004, DO 2004).

3. Constraints

The aquaculture of the Mekong delta has faced a number of technical, environmental, managerial and market challenges for sustainable development. They are: (i) lack of high quality shrimp seed supply due to the dependence on the wild collected broodstocks; (ii) unavailability of technologies for induced breeding of marine finfishes and mollusk leading to limited development of these species; (iii) improper planning and weak management of coastal aquaculture development, especially shrimp farming; (iv) disease outbreak at a large scale causing heavy losses, especially viral diseases in shrimp farming; (v) mis-use of chemicals and drugs in shrimp and catfish farming leading to chemical and drug residue contamination in products; and (vi) environmental pollution due to overgrowth of shrimp and catfish in certain areas. Moreover, the market for products, *i.e.* shrimp and catfish has become high level of competition with other countries in term of quality control and tariff.

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Eco-friendly Prawn Farming – cum – Pokkali Cultivation: Suitable for Wetland Conservation and Coastal Management

by

Joseph PAIMPILLIL*

1. Introduction

Man-made impacts in the coastal ocean and in estuaries have increased rapidly over the past decades, affecting the natural dynamic equilibrium and the biotic composition of the respective ecosystems. The main causes for such changes are the introduction of untreated and partially treated sewage rich in organic substances and plant nutrients from human settlements, urban areas and certain industries, the leaching of nutrients from soils and agricultural fields and animal husbandry.

The west coast of India is environmentally more sensitive than the east coast, primarily because it borders one of the most sensitive ecosystems in the world, the Arabian Sea. The environmental property of the northern Arabian Sea is unique and manifests itself in rich biological production throughout the year through different processes thereby explaining the Arabian Sea 'Paradox' (MATHUPRATAP *et al.* 1996). The symptoms are there to show the considerable impact of deterioration of estuarine waters on the coastal ecosystem (NAIR *et al.* 1991, NAQVI *et al.* 2000, JAYAKUMAR *et al.* 2001). The emerging industrial establishments and human settlements along the west coast of India thus necessitate a critical evaluation of the nature and quantum of inputs to the Arabian sea, as well as their regional assimilative capacities. If there is a possible threat to the well-being of the living resources of EEZ of India, then the coastal waters of southwest India, and in particular

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the Cochin region, are the prime location prone to trigger this. The booming city of Cochin has a population of nearly 1.5 million (Anonymous 1998) and 60 % of the chemical industries of Kerala are situated in this area. Cochin backwaters are the largest of their kind on the west coast of India with an area of 256 km. The 16 major and several minor industries situated in the upstream region of the backwaters discharge nearly 0.105 Mm^3d^{-1} of effluents (Anonymous 1996). The industrial typology includes fertilizer, pesticide, radio active mineral processing, chemical and allied industries, petroleum refining and heavy metal processing, and fish processing. The fertilizer consumption in the Kuttanad region (the main agricultural field draining to Cochin backwater) alone is reported to be 20,239 t y^{-1} (Anonymous 1998). The backwater receives organic wastes (~ 260 t d^{-1}, Anonymous 1998) and an annual dredge spoil from the harbor area to the tune of 10^7 m^3.

2. Investigation Results and Discussion

The objective of the present study is to evaluate the ecological benefits of pokkali paddy cum shrimp cultivation on the ecology of wetlands and of the potential economic advantages to the local farmers from the practice. It is in our scheme of things that only after we lose something do we sing praises to it and make great lamentations about how good it was.... Pokkali cultivation is no different. Even as scientists sing paens to this cultivation and newer varieties of Pokkali paddy like Vytiia 1, Vytilla 2, 3, 4 and Vytilla 5 were developed at the Rice Research station, Vytilla, India to give better yields, the Pokkali paddy fields seem to be shrinking rapidly.

Of the 26,400 hectares of potential Pokkali area in Thrissur, Ernakulam, Alleppy and Kannur districts only 8,000 to 10,000 hectares are actually used for Pokkali cultivation. The other areas are left unattended citing high labour wages or that these are reclaimed to build houses. Even if pure seed material of the new varieties is provided to the farmers they do not bother to retain the seed. When compared to the paddy fields of Kuttanad, these farmers have less expenditure because of the low incidence of diseases due to the high salinity, but the farmers seem to be disinterested in cultivating Pokkali. People are of the opinion that there is no market for the Pokkali rice, largely because people are unaware that it is eco-friendly and organically grown.

The other paddy varieties require several rounds of pesticides, fungicide, weed killers and fertilizer spraying before the grain gets to the market, while the Pokkali paddy is organically grown. But curiously there seem to be no

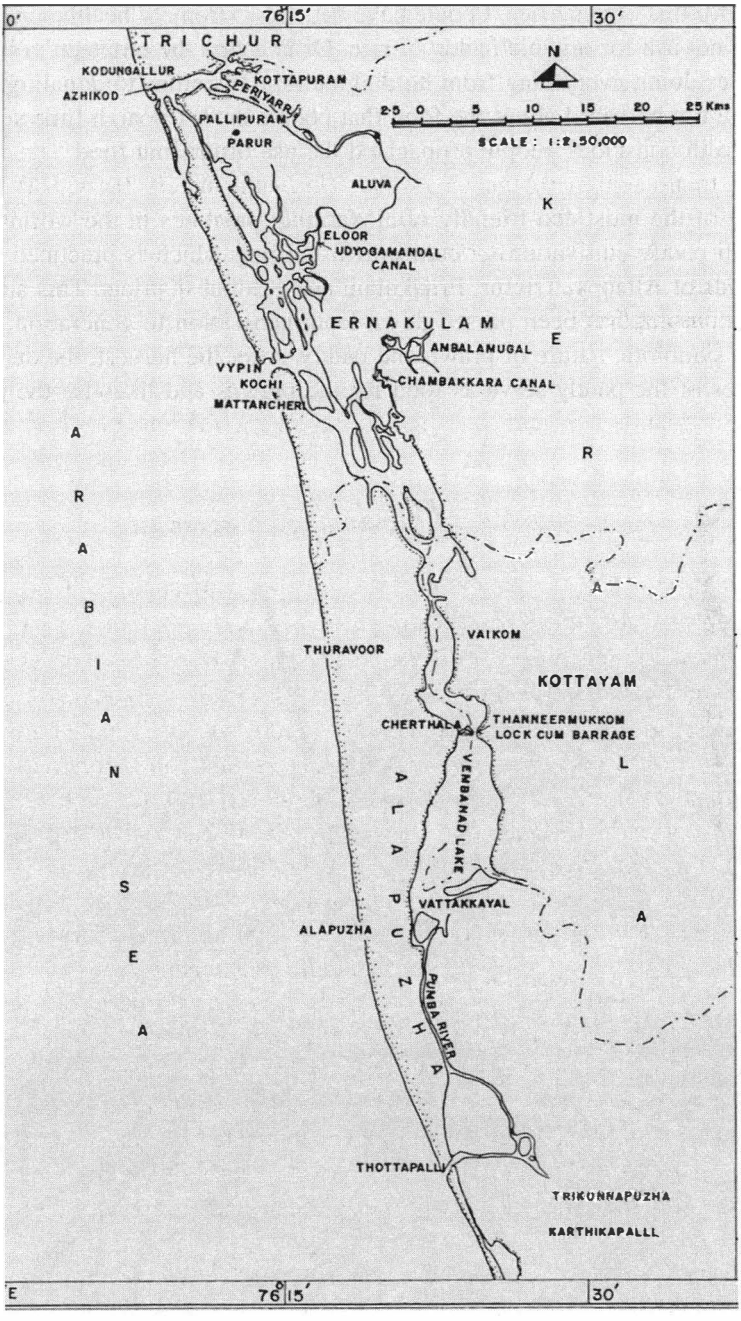

Fig. 1. — Vembanadu Lake and wetlands of Kerala State, South India.

takers for this organic rice. People have become extremely health conscious, yet do not ask for organic paddy or rice. Or is it that the umpteen voluntary agencies doing everything from holding cultural evenings to donating tricycles are not bothered about the food that people eat? It is high time socially and health conscious people propagated the use of organic food.

One of the most eco-friendly of all farming practices in the world is the Pokkali paddy cultivation — cum prawn farming which is practiced in the wetlands of Alleppy, Trissur, Ernakulam and Kannur districts. This singular method, which has been passed down from generation to generation, relies on the symbiotic nature of prawn and paddy. After the harvest, the decaying stubbles of the paddy serve as food for the prawns and likewise the prawn

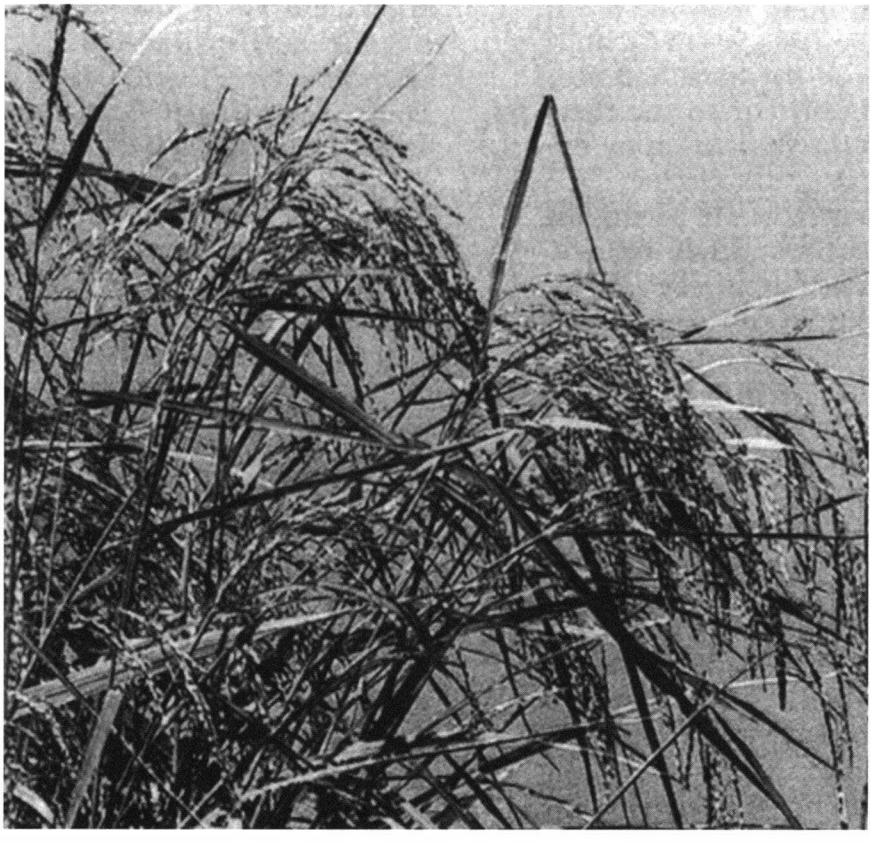

Fig. 2. — Pokkali rice ready for harvesting.

excreta make the field fertile. What is really interesting here is that absolutely no pesticide or fertilizers are used in the fields, making it vastly different from the other prevalent farming practices.

In the coastal districts of Kerala, vast areas are marshy and water-logged. These marshy tracks lie near the mouth of rivers and are prone to flooding and salinity. The nature of the soil is also highly acidic and has elemental toxic content, making the area unsuitable for paddy cultivation. But the Pokkali paddy, which to an extent, is saline, flood and acid resistant, is the wonder crop which is cultivated in these parts. In the International Plant breeding labs, the gene of the Pokkali paddy is used as the parent gene to culture saline and flood-resistant paddy.

In Pokkali fields only one crop is cultivated during the monsoons (June - October), which is the low saline phase, and subsequently during the high saline phase the fields are used for prawn filtration (November to April). Even Pokkali cannot withstand very high salinity. In the months of April /May the water-logged fields are prepared by making mounds and in June, with the onset of monsoons, the grains are sown on top of the mounds. This traditional method has been proved by scientists as the best method to prepare the fields

Fig. 3. — A Pokkali rice field in Ernakulam, Kerala India.

because of the larger surface area and it enhances the leaching of the toxic contents of the soil with rainwater. But curiously this method is the least practised and the farmers resort to the easier method of preparing the fields — bed formation. Though Pokkali paddy is comparatively less labour intensive than other varieties of paddy, the farmers are disinterested in Pokkali and do it just for the sake of feeding the prawns, which is by far more lucrative. The white prawn P. indicus or the Tiger prawn Penaeus monodon are cultured in these fields. While the farmer may get 1.2-to 1.5 tons/hectare of Pokkali he will harvest about 400 to 500 kilos/ha of prawns during one season. The Pokkali will fetch about Rs. 12 to Rs. 13 in the market while a kilo of prawns, anywhere between Rs. 450 to 800/kg ($10 to $17.75/kg), depending on the size and variety.

In October when the paddy is mature, only the panicles are cut off, leaving the stubble in the field to decay and this forms the natural feed for the prawns. Adjacent to the paddy fields lie the prawn fields where the waters from the backwaters are regulated through the sluice gates. From November onwards, prawn seedlings gravitate towards the fields in search of food. The farmers take advantage of the situation and at night, place lamps near the sluice gate to attract the prawn. During the high tide the prawn seedlings are swept into the fields and they remain there. The farmers then place nets at the mouth of the sluice gate to prevent the seedlings from leaving the fields during low tide. During the high tide the net is removed to let in more prawn seedlings. The prawn seedlings gorge on the decaying stubble. The prawns are periodically harvested 2-3 days before the new and full moons till the middle of April.

It seems beneficial for the juvenile prawns to feed on the decaying stubbles as this keeps the incidences of disease low. Without Pokkali, the entire area will be flooded, acidity will be more, and toxicity will be high and there will be less oxygen and more hydrogen sulphide, which can kill the prawn larvae. All this is effectively removed by the farming operation, which ensures good drainage. It is also cost effective because artificial feed is expensive and prawns are more prone to diseases. Whereas in the pokkali fields, the natural feed needs to be supplemented with artificial feed only in the last phase just before the prawns are harvested. The prawns require high protein feed, which costs approximately Rs. 25/Kilo and the requirement is 2 kilo for one kilo of prawn. The constant movement of prawn larvae aerates the field and keeps it clear of weeds and the prawn excreta is a good natural fertilizer. The high investment towards feed cost rendered prawn farming always a loss — making venture.

Fig. 4. — Pokkali rice harvesting practice followed in Ernakulam.

In the case of the rice bowl of Kerala (Kuttanadu), 54,000 hectares of polders had been traditionally yielding two annual rice crops — the Virippu or the monsoon crop and the Punja or the summer crop, the total extent of paddy field lying idle increased alarmingly during the past decade as farmers abandoned rice cultivation due to diminishing and ever-increasing cost of production. An ecologically sustainable and economically viable farming practice for the giant freshwater prawn (Macrobrachium rosenbergil) developed on the basis of a data base generated from 122 prawn farms in Kuttanadu (KURUP *et al.* 2003) representing both mono and poly culture with and without integration of rice and had also revealed that it was necessary to carry out paddy cultivation as a follow-up to prawn farming.

3. Pokkali Cultivation and Wetland Water Quality

A comparison of the environmental parameters collected presently with the earlier data can indicate the estuarine system behavior over the years. The available data from the bar mouth region are used as several workers had sampled this region since 1965 and this is the point where the pollutants are

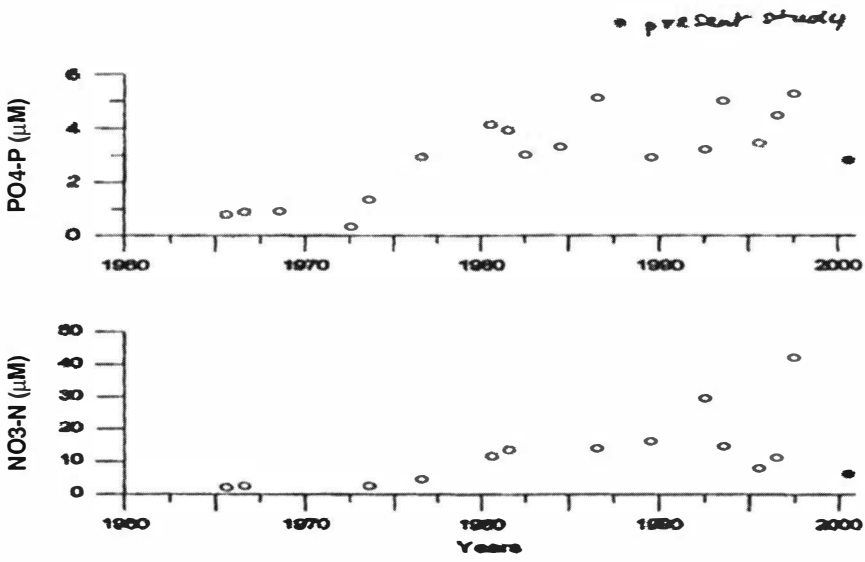

Fig. 5. — Long term trends in nutrient levels at Cochin bar mouth.

brought down to the minimum by dilution before being exported to the coastal waters. The phosphate and nitrates were present in very low levels up to the mid 70s from where, due to the combined effect of increased industrial and agricultural activities, the levels increased during the 80s and 90s.

During 1965, the surface phosphate and nitrate were 0.75 and 2.0 μmol, which has increased to 2.9 and 6 μmol respectively by 2000 even though, between the years it shows still higher levels. The trend also shows a build up of nitrogen and phosphorus fractions after 1975 and from 1980 onwards the concentrations remained high. Enrichment of phosphorus with respect to nitrogen is leading more to mesotrophic waters. However, this enhanced nutrient levels have not led to any oxygen depletion in the environment, possibly because the river discharge and tidal exchange may be sufficient enough to renew the estuarine waters and prevent deoxygenating even during the lean discharge period. But the maximum nutrient levels reported for the upstream regions were quite alarming. The build-up for inorganic phosphate had started after 1973, and the subsequent increase in waste discharge had ultimately resulted in extreme levels of ammonia, phosphate and nitrate in the estuarine region. During 1980-81, the study region had nitrate and

phosphate levels up to 40 and 12 μmol with its upstream peaks of 108 μmol and 186 μmol (SARALADEVI 1986). SANKARANARAYAN *et al.* (1986) have reported phosphate levels up to 88 μmol during 1982-83 in the northern upstream stations. The present study recorded phosphate levels from 5 to 40 μmol for the same region. During 1990, the nutrient maximum reported from this estuarine region was 98.48 for nitrate and 15.11 μmol for phosphate (KUNJIKRISHA PILLAI 1991). SHEEBA (2000) had also reported nutrient enrichment in this system and recorded nitrate up to 451 μmol and phosphate up to 33 μmol at the bar mouth alone.

The deterioration of the environmental quality of Cochin backwaters seems to depend on several factors, all related to human interventions. One of the recent estimates shows that in spite of receiving 42.4×10^3 mol.d^{-1} of inorganic phosphate and 37.6×10^3 mol.d^{-1} of inorganic nitrate from the Periyar side of the estuary, the export to the coastal waters is only 28.2×10^3 mol.d^{-1} of inorganic phosphate and 24×10^3 mol.d^{-1} of inorganic nitrate (HEMA NAIK 2000). Thus, the estuary acts as a sink for the nutrients, flushing out only a portion of the pollution load that it receives. The enhancement with respect to these nutrients in Cochin Backwaters shows the signs of eutrophication.

4. Conclusion

The studies revealed that the best combination of eco-friendly sustainable aquaculture for the wetlands of south India would be a rotational system between rice and prawn. Instead of filling up land and creating monstrosities in concrete, will not some agency encourage this kind of farming which is indeed healthier and sensible money-wise? The symbiotic relationship of pokkali paddy with shrimp farming contributes towards a deduction in nutrient loading of the wetlands. From the adaptation of this practice to the entire Kuttanadu paddy fields considerable improvement on the overall water quality of the wetland can be expected.

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The Role of Irrigation Systems in Sustainable Aquaculture Growing for the Mekong Delta, Vietnam

by

NGUYEN DINH VUONG* & TRAN THI XUAN MY*

1. Background

Vietnam with a coast 3,260 km long is a tropical littoral nation having hundreds of rivers and canals carrying sediment to the sea. Tidal flats, lagoon, and many large mangrove forests are the place where aquaculture has been significantly developed. The Mekong delta in Vietnam is located at the end of the Mekong basin with an area of 3.95 million hectares. This is an area with high potential and its development plays an important role in the national food safety and security programme and enjoys the biggest export turn-over for agriculture and aquaculture in the nation. Total output for this area is about 55 % of total national output, among which aquaculture takes up 50 % of national output and exports cover 61 % nationwide.

The Mekong delta is an open, low system adjacent to the large delta silted by the Mekong river sediment; there are tidal flats containing the largest mangrove forests nationwide, and it is the place where shrimp larvae have come to live (Kien Giang, Ca Mau, Bac Lieu, Soc Trang, Tra Vinh, Ben Tre province....). The area has two seasons: the dry season from November to April and the rainy season from May to October. The tidal regime of the East Sea is an irregular semi-diurnal tide with large amplitude (2.5 ÷ 3.5) m, and in the coastal areas of the West and South West there is an irregular diurnal tide with small amplitude (0.4 ÷ 1.2) m. Due to suitable natural conditions along the 700 km long coastline, there are many different sub-climate areas, many tidal

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zones with large brackish water and a biodiversity of coastal ecological systems, so that we have advantageous conditions to develop aquaculture.

Aquaculture has developed significantly in recent years. Beside the increase of growing areas and yields, infrastructure works have developed rapidly. However, the improvement of technology of these hydraulic works leave much to be desired. In order to develop the coastal ecological areas effectively for multifunctionality, the initial step is to study and plan the hydraulic systems based on the logical building of models and estimation of the systems specifications. Aquaculture has only developed significantly where hydraulic systems are suitable to the cultivation projects to meet the requirement of a sufficient saline and fresh water supply of top quality. Therefore, hydraulic systems play an important and essential role for sustainable aquaculture development in the Mekong delta of Vietnam.

2. Introduction: Aquaculture in the Coastal Areas of the Mekong Delta

2.1. General

In the Mekong delta, aquaculture development in brackish, saline water, especially shrimp cultivation, has developed rapidly during the past ten years. With lagoons, tidal flats, mangrove forests, natural and favourable conditions compared to other areas, this area plays an important role in aquaculture development in Vietnam. It is increasing strongly as a significant proportion of main commodity exports of Vietnam. However, productivity is still low compared to other countries in the Southeast Asia.

From the late 1980s the Vietnamese economy changed into a market economy with the development of multisectors, and aquaculture has developed significantly with highly increasing yields. Some areas in the surrounding dikes had only grown rice or rushes with low productivity; but today they have changed to aquaculture development. By getting high income from shrimp growing and with a lack of control from the local authorities people have rapidly improved and enlarged growing ponds. This causes the deforestation of mangrove forests for growing areas and causes environmental degradation, and threatens the ecological balance of many large coastal areas.

Extensive farming has been applied in some places where people have grown shrimps without prompting and although the yield is very high in early years it gradually reduces, and many ponds were faced with a high rate

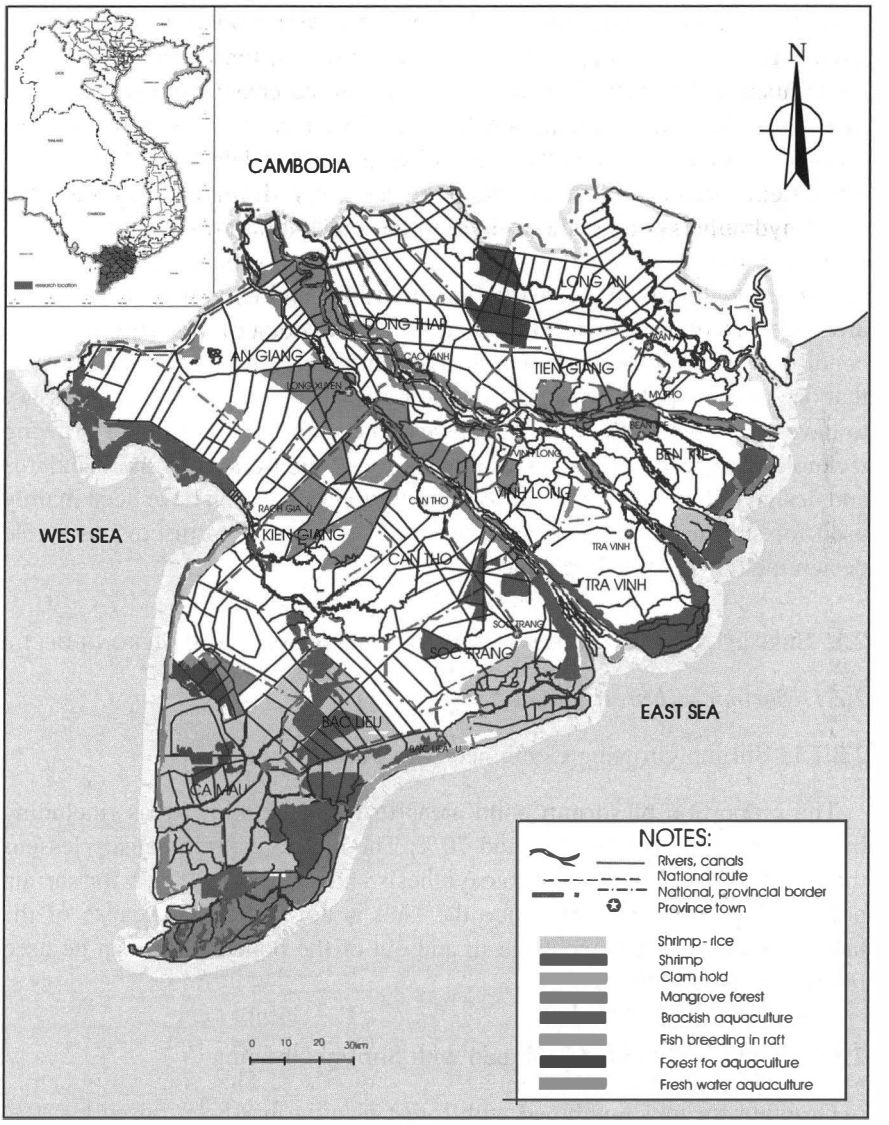


Fig. 1. — Aquaculture growing zones planned in the Mekong delta by 2010.

of shrimp mortality due to disease or an unsuitable water environment for shrimp physiology. Pilot intensive and semi-intensive shrimp farming models have been applied to some local coastal areas, but these must have infrastructure facilities with good conditions and efficient irrigation systems in order to be able to control the water regime in the systems, depending on the requirement of the growing process. The construction of infrastructure facilities for complete irrigation systems requires heavy investment. Consequently, to ensure the sustainability of growing systems in terms of technology and economics, irrigation requires the design of appropriate structures and construction to meet the technological, economic and efficient requirements for operation.

At present, design and construction guides for hydraulic works for shrimp areas are not yet available. Moreover, such works depend mainly on natural conditions like rainfall patterns, tides and the scale of the growing areas so that one cannot apply the same model for all systems. Instead, it is necessary to have a suitable method for designs based on the water regime of growing technology procedures which can apply to all areas. So far, the standards and design of hydraulic systems for agricultural production have been mainly used for shrimp growing areas. Therefore, it is urgent to discover suitable design methods for shrimp areas.

2.1. Shrimp growing models in the coastal areas in the Mekong delta

2.2.1. Shrimp — Forest Model

2.2.1.1. Shrimp Growing Combined with Forest Planting

The proportion of shrimp pond areas to forest planting areas (including borders and trenches) is 30 % and 70 %. The low forest tree density lessens the forest canopy that helps photosynthesis and produces oxygen for shrimp ponds. This model is good since the land is not degraded because of the large amount of water exchange in and out of the ponds and it can be used for seven years or more.

2.2.1.2. Forest Planting Combined with Shrimp Growing

Growing shrimps combined with forest planting has been raised by 30 % of the adjacent areas of the river separately from the forest. This model has given benefit in the first 5 ÷ 6 years, then it ceased, due to the large canopy of the forest that makes water pollution by the organic pollutants from leaves (Ngo 2003).

2.2.2. Shrimp Growing — Fruit Garden Model

This model has utilized fruit garden land to get saline water into trenches so as to raise shrimps in the dry season and fresh fish in the rainy season. The growing areas are not big (in Ca Mau, they represent about 10,000 ha). In the coastal areas of the Mekong delta, the elevation is flat, 0.5 ÷ 0.7 m high, so people must use bamboo screens for fruit growing. In some previous years these trenches were used for fresh water aquaculture and now they are used for saline Su shrimp. This model is effective and produces high profits with low investment for the households.

2.2.3. Extensive Aquaculture Growing

In this model, aquaculture growing is based on native shrimp and food in water ponds that are regulated by sluice gates 0.7 ÷ 0.9 m wide. Sluice gates are opened twice a month on the rising tide for 3 ÷ 4 days and shrimps are kept and taken from the net; at the same time, postlarvae (seedstock) and food is taken and raised for the following harvestable time. Since the rising time in trenches is short (10 ÷ 12 days), shrimps are not big in size: 'Bac''Dat'and 'The' are 48 mm, 49 ÷ 53 mm and 65 mm long respectively. In the late 1980s yield capacity was 250 ÷ 300 kg/ha/year because of the available native resources of shrimp, however, nowadays it is reduced to 100 ÷ 150 kg/ha/year.

For some researchers the reasons why the yield capacity is reduced are the limitations of native shrimps due to over-development and mangrove deforestation; the water level is too shallow (30 ÷ 50 cm) due to seepage and silting (20 ÷ 30 cm for one crop), high turbidity, poor food sources, and the condition of water exchange is limited due to the dual function of sluices producing organic pollution in ponds.

2.2.4. Improved Extensive Aquaculture Growing

This model combines both native shrimp sources and food and artificial post larvae to improve the yield capacity. Generally they are raised in ponds with a density of 1 shrimp/m^2 and grown by natural food in the first month, then fed with coconut fruit, minced fish, mash and manioc. After two months some 'Su' shrimps (or Tiger prawn) are big enough to harvest with native shrimps. Though it is difficult to get 'Su' shrimps and their survival rate is fairly low from the farmers'experience, 'Su' shrimps fetch a higher price than other native ones like 'Dat', 'The', 'Bac' shrimp. People prefer to use this model rather than extensive aquaculture growing. Native shrimps are

harvested twice a month, 'Su' shrimps are grown in the second month and harvested with native shrimps. 'Su' shrimps growing in trenches have a high rate of mortality, but their value is high due to some improvements such as keeping the water level at about 0.7 ÷ 1.2 m, using concrete slabs for seepage protection, increasing the density of postlarvae and supplementing processing food, as well as changing 10 ÷ 20% of the water amount when it is of bad quality and harvesting in part when they are at least 45 ÷ 50 days old.

2.2.5. Semi-intensive and Intensive Growing Model

Semi-intensive and intensive growing models (where tides are high) are better than extensive growing models in terms of technology as when the pond is 1.1 ÷ 1.2 m deep with a cleansing pond and ventilator systems and a distinctive water supply. The density is 6-7 post larvae/m^2 with a size of 2 ÷ 3 cm/post larvae, and the yield is 1.6 ÷ 1.8 tons/ha/year. The breeding period is 5 months per crop (150 days/crop) from June to October and from December to April (semi-intensive growing is applied only in the coastal areas).

2.2.6. Rotational Rice-Shrimp Growing Model

This model combines both extensive shrimp growing —rice crop and rotational Su shrimp growing after the shrimp crop. It is applied in the brackish water areas with 20 ÷ 25% of the rice field areas. With a distinct water supply, 10 ÷ 15% of the water amount is changed everyday. The yield capacity is 0.25 ÷ 0.35 tons/ha/crop. The breeding period is 4 months from January to April. These models are applied in Soc Trang, Ben Tre, especially in My Xuyen, Vinh Chau, Gia Rai districts, Bac Lieu province. This model is good and yields high benefits with small risk of infection (NGUYEN 2004).

3. Likely Areas for Aquaculture in the Coastal Areas of the Mekong Delta by 2010

3.1. SALINE-BRACKISH WATER LIKELY AREAS

Based on [5] the likely areas for aquaculture growth in saline and brackish waters are very large. The largest areas are Ca Mau and Bac Lieu provinces and Long An and Tien Giang have the smallest ones (tab. 1).

Table 1
Saline-brackish water likely areas for aquaculture growth in some coastal provinces in the Mekong delta

No.	Provinces	Natural total areas (ha)	Potentials forecast (ha)	Probability growing (ha)
1	Long An	444,866	15,650	10,000
2	Tien Giang	232,609	18,860	7,150
3	Ben Tre	230,000	65,870	65,000
4	Tra Vinh	235,351	21,560	40,000
5	Soc Trang	322,230	88,650	60,000
6	Bac Lieu	241,813	187,500	187,500
7	Ca Mau	521,000	320,000	320,000
8	Kien Giang	624,560	86,650	64,000
	Total	**2,852,429**	**804,740**	**753,650**

Sources: Institute of Economics and Aquaculture Planning — Vietnam Ministry of Aquaculture, 2002.

3.2. Fresh Water Likely Areas

Due to the fresh water from the Tien and Hau rivers, there are favourable conditions for aquaculture cultivation in many places in the Mekong delta (fig. 2). However, it is difficult to estimate the adequate areas, but the possible areas have been presented in table 2.

Table 2
Freshwater likely areas for aquaculture growth

No	Provinces	Natural total areas (ha)	Areas (ha)	Proportion (%)
1	Long An	444,866	12,050	2.71
2	Tien Giang	232,609	12,000	5.16
3	Ben Tre	230,000	20,000	8.70
4	Tra Vinh	235,351	36,000	15.30
5	Soc Trang	322,230	23,000	7.14
6	Bac Lieu	241,813	4,000	1.65
7	Ca Mau	521,000	100,000	19.19
8	Kien Giang	624,560	77,000	12.33
	Total	**2,852,429**	**284,050**	**9.96**

Sources: Institute of Economics and Aquaculture Planning — Vietnam Ministry of Aquaculture, 2002.

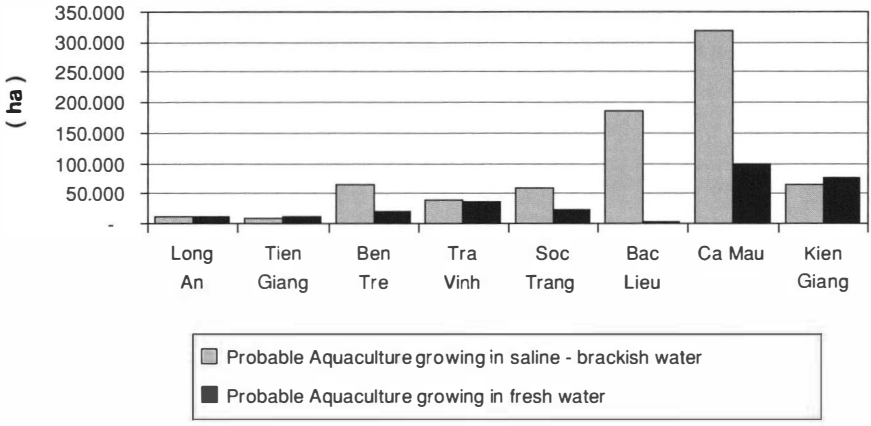


Fig. 2. — Likely aquaculture cultivation of coastal provinces in the Mekong delta, Vietnam (*sources:* Institute of Economics and Aquaculture Planning — Vietnam Ministry of Aquaculture, 2002).

4. Limitations of Hydraulic Systems for Aquaculture Cultivation in the Coastal Areas of the Mekong Delta

Through two decades, especially from the 1990s onwards, hydraulic works have rapidly developed with hundred of thousands of km of canals, sea dikes and large and small sized sluices. Especially in Quan Lo Phung Hiep, Tiep Nhat, Go Cong... there are complete hydraulic works. Hence, salinity control, fresh water supply, waste water drainage for agriculture have been managed.

However, in order to serve aquaculture development, hydraulic works have not met up to the technical and infrastructure requirements.

The regulation of sluice systems is small and has not ensured the water supply and drainage. They have often one way energy dissipation and eroded easily when operating on two sides. Some temporary sluices are very primitive.

In general hydraulic systems for aquaculture have improved but not completely and in synchrony with casual plot planning, a lack of waste water treatment systems and pump stations, with saline intake sluices that have not followed the safety norms for dikes.

5. Hydraulic Works and their Importance for Aquaculture in the Mekong Delta

5.1. Function of Hydraulic Works

— To build and enhance hydraulic works to prevent inundation due to high tides;
— To ensure sufficient water supply and drainage for aquaculture growth requirements in the dry season and for rice in the rainy season;
— To develop navigation and improve residential areas.

Hydraulic works will control the saline water supply and fresh water, so their main functions are:

a) Salinity prevention, fresh water supply, drainage, saline water supply, waste water drainage for shrimp-rice areas:
   — To prevent salinity from the rivers in the dry season when water has been affected by salt;
   — To conduct fresh water and supply for irrigation through canals;
   — To prevent flooding and drainage;
   — To supply clean saline water and waste water drainage for aquaculture growing.
b) Transportation and navigation development:

Hydraulic works provide infrastructure development such as roads, dikes that create an interdistrict transportation line in order to develop residential areas.

c) Disaster and environment protection:

Hydraulic works have prevented disasters and enabled production protection in cases of heavy storms by sea dykes to sustainably develop the natural resources and production, protect the ecological environment and improve the people's lives.

5.2. Importance of Hydraulic Works for Aquaculture

Aquaculture in general, and shrimp growing in saline and brackish water in particular, are based mainly on land and water. The best selection of land is very important. However, a sufficient good quality water supply by hydraulic works is the essential factor for aquaculture development. It has only developed well when it has proper and synchronous hydraulic works.

The function of hydraulic works is to supply sufficient clean saline water, to drain rapidly waste and rainy water, disaster prevention, together with production and environmental protection.

It brings about effective land use and stimulates the potentiality of each zone for production development, including changes in exclusive rice planting, high economic value species and stable markets. To utilize ponds or uncultivated land for production creates jobs for farmers and improves their standard of living.

It enables aquaculture in sound and sustainable development in terms of ecological environmental protection, risk mitigation, production development and stable life-styles for the people involved.

It helps to set up a structure for sustainable aquaculture growing suitable for 3 ecological zones: fresh, saline and brackish water. It also encourages the effective models especially shrimp- rice models in intensive and semi intensive cultivation.

6. Hydraulic Methods for Aquaculture Development in Coastal Areas in the Mekong Delta

6.1. Hydraulic Planning for Shrimp Growing

6.1.1. Immediate Methods

— To utilize hydraulic works from up-dated projects for aquaculture development.
— To invest in dredging, enlarging and digging canals based on the estimation of water supply and drainage for each model that ensures the general plan for each sub zone (for example, providing some new canals to take saline water to supplement My Xuyen, Vinh Chau, Soc Trang, south national route No. 1A in Bac Lieu province, An Minh, An Bien in Kien Giang province...).
— To enlarge drainage systems, build separate works for agriculture and brackish aquaculture zones, to complete in-field works and plots. To build a close dike and border systems to ensure the water intake, disaster prevention and production protection.

6.1.2. Long Term Orientation

— To define areas and build complete hydraulic works such as dyke systems.
— To separate border ponds for each sub zone.
— To establish inland hydraulic systems suitable for each model in terms of multipurpose functions to use saline water in the dry season, fresh water in the rainy season with water quality and quantity control.
— To regulate sluices and operate water supply and drainage.

6.2. Hydraulic Systems for Aquaculture

6.2.1. Main Hydraulic Works

To ensure the procedure and growing areas to meet the requirements of a growing circle, water control conveniences which are safe from pollution and for the health of shrimps, main hydraulic works are:

— Main works: Dykes and dyke borders, sluices, pump stations.
— Pond systems: growing pond, storage pond, waste treatment pond, intake and drainage sluice systems.
— Saline water supply: main canal for intake water and tributaries, gates at the beginning of canals.
— Drainage system for waste water: main drainage canals and tributary drainage works at the end of canals.
— Fresh water supply to dilute the salinity when needed.
— Power system and management.

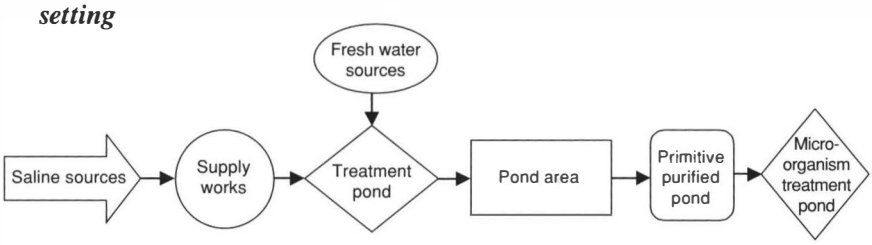
6.2.2. Some Considerations

— For the turbid and polluted areas there is a need to have ponds for storing and cleansing water before taking water to growth ponds. Ponds must have a depth bigger than 0.8 m.
— There is a need to plant mangrove trees along intake and drainage canals as well as in some adjacent places to let water have biological treatment.
— In some places affected by heavy acidity land or without completely disintegrated organic humus and sandy land, weak alluvial land, there is a need to use geotextile at the bottom and around pond borders and leave a land layer 25 ÷ 30 cm thick.
— In some high elevation land, pumps have been applied to take water to ponds.

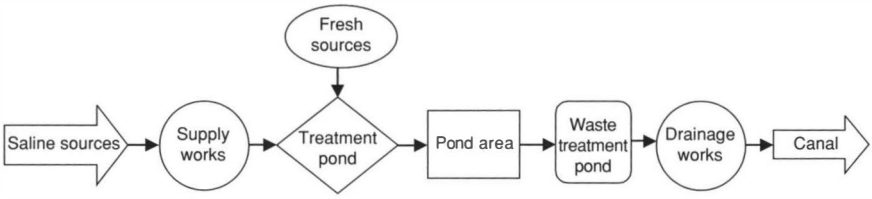
6.3. Schematic Setting of Hydraulic Works in Shrimp Areas

6.3.1. According to Le et al. *(2003, pp. 25-33):*

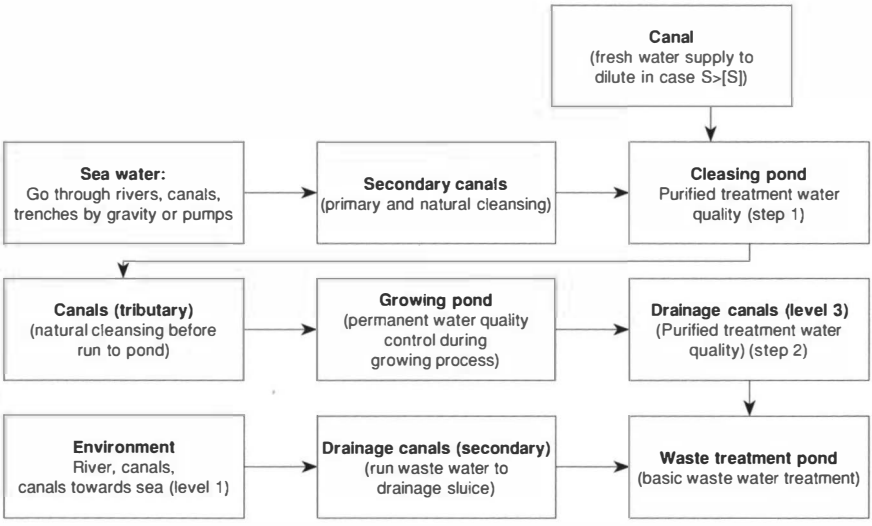
a. Close and circulated semi and intensive growing model schematic setting



b. Non-circulated semi and intensive growing model schematic setting



c. Water supply procedure



6.3.2. Shrimp Combined with Rice Growing System

The most suitable cultivated model in the structural change areas from 1 and 2 rice to shrimp growing is the shrimp-rice model. This model has been applied largely in the coastal zones of the Mekong delta for the future, such as shrimp growing in the dry season and rice growing in the rainy season will improve the environment for both shrimp and rice as well as create sustainable and complete ecology. It is considered as a typical model and encouraged for broad application.

Recently, growing ponds (fig. 3) have areas from 0.2 ÷ 1.0 ha, their shapes depend on land location and people's taste. However, growing ponds should be rectangular with the width equal to 1/3 ÷ 1/4 of the length.

According to NGUYEN *et al.* (2003, pp. 131-142), trenches must be set along the ponds and occupy 25 ÷ 30 % of pond areas. The dimension of the trench is a 3 ÷ 4 m bed width, a slope of m = 2, and a bed elevation = 0.3 ÷ 0.5 m. The total length of trench for 1 ha is 400 ÷ 500 m. The pond borders require firmness and must be watertight and are higher than the water level in pond 0.5 m.

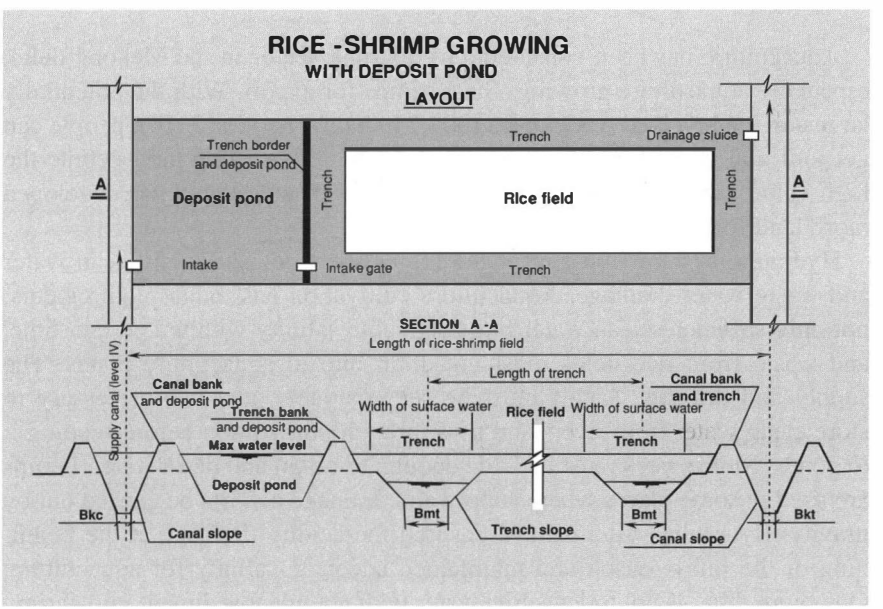


Fig. 3. — Scheme of hydraulic works for growing pond (rice-shrimp model).

6.3.3. Sluices for Growing Ponds

6.3.3.1. Intake Sluice

The bed elevation of the sluice is 0.1 m higher than that of ponds, it must be designed properly and meet the requirements of sufficient water supply depending on pond areas (15% of the water amount/day). In some urgent cases intake sluices can drain part of the surface water, like heavy rainfall, to ensure the water quality is good and not to cause banks to overflow.

6.3.3.2. Drainage Sluice

To take water out properly the bed elevation of a drainage sluice is 0.1 m lower than that of ponds; it must be appropriately designed not only to meet the requirements of water drainage depending on the pond areas (15% of the water amount/day) but also to drain out by the tide not longer than 3 days in order to harvest and reclaim ponds. Sluices must be in good condition, easy to operate and have gate water-tightness.

7. Conclusion

Aquaculture has been considered as a strong sector in the Mekong delta, especially aquaculture growing 'Su' shrimps for export. With the potentially large surface brackish water areas (804,740 ha by the year 2010), people can get jobs and profit from 'Su' shrimp growing. 'Su' shrimp has become the high value export product, especially since 1995 and people has developed more land for aquaculture cultivation.

Hydraulic systems must meet the requirements of sufficient clean water and waste water drainage. Aquaculture cultivation has tough requirements; not only sufficient clean water but also stable salinity within a certain time, and waste from rice fields must not drain into to aquaculture ponds. The supply and drainage canals must be set separately, and it is necessary to store clean water from rivers and seas through purification before sending it to ponds. Sluice gates must be wide enough to retain and drain water. Pumps are used in some places where supply and drainage can not be carried out by gravity. Hydraulic systems have ensured the acidity drainage at the beginning of the rainy season and maintained adequate salinity for aquaculture. One more thing is not to let saline water with abundant sediment into shrimp ponds since it creates a risk for shrimp and causes silting.

The strategy development for hydraulic systems in the Mekong delta in the next stage is to build a complete multipurpose system for different ecological zones. Moreover, it will be necessary to select appropriate models for each sub zone so as to develop and manage them effectively. Therefore, to develop hydraulic systems for aquaculture in the coastal areas of the Mekong delta means finding suitable models for sustainable agriculture and aquaculture development.

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Comparison of Freshwater Prawn (*Macrobrachium rosenbergii*) Production in Integrated and Rotational Rice Prawn Systems in the Mekong Delta of Vietnam

by

LAM MY LAN*, LONG DUONG NHUT*,
PHAM YEN TRUONG** & Jean-Claude MICHA***

1. Introduction

Freshwater prawns are one of the most recently cultured animals in freshwater in Asia such as Bangladesh, China, India, Malaysia, Taiwan, Thailand, and Vietnam (SINGHOLKA *et al.* 1980, NEW 2000, WEIMIN & XIANPING 2002, NAIR & SALIN 2003). The Mekong Delta of Vietnam has a great potential for aquaculture development with more than 600,000 ha of water area. In recent years, aquaculture has been considered as an important sector for economic improvement of local people. Giant freshwater prawn, *Macrobrachium rosenbergii* (DE MAN 1879) is one of the most promising cultured species for integrated farming system in the flooded areas. The rotational rice-prawn system has been applied because of higher net profit than summer - autumn rice crop (YEN 2000). National strategy for aquaculture development has been set up in which prawn production is target for 60,000 tons using 32,000 ha by the year 2010 (MOF 1999). However, the rotational rice-prawn system is just starting and developing since a few years. According to WEIMIN & XIANPING (2002) freshwater prawn culture is a relatively new aquaculture practice.

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Therefore, there are few studies on the culture techniques and the present practice is mainly based on farmers' empirical trials. On the other hand, most of previous studies for *M. rosenbergii* culture techniques were conducted in ponds (NEW & SINGHOLKA 1985, D'ABRAMO *et al.* 1989, TRIPATHI 1992, TIDWELL 1999, NEW 2000). LAN *et al.* (2006) also conducted a research on integrated and rotational rice-prawn culture systems with stocking postlarvae of *M. rosenbergii*. This study is conducted to assess the effects of stocking density of juveniles in both integrated and rotational prawn-rice farming systems, on prawn yield and on economical aspects in order to develop the best sustainable prawn farming systems in the rice field of the Mekong Delta, Vietnam.

2. Materials and Methods

2.1. EXPERIMENTAL DESIGN

This study was carried out in O Mon District, Cantho City, Vietnam. A 1-ha rice field was divided into 36 plots (0.01 ha per plot with an L-shaped ditch), inlets and outlets canal. The ditch area of each plot was 21.25% of the total area. In this experiment, 18 plots were used. Three replicate plots were randomly design for each culture system (integration and rotation) and each density (1, 2, and 3 juvenile/m^2) (3 × 2 × 3) (tab. 1).

Table 1
The treatments of *Macrobrachium rosenbergii* culture in the rice field under integrated and rotational systems at different juveniles' stocking density

Culture system	**Stocking density** (juveniles/m^2)			**Replication**
Integration	1 (1I)	2 (2I)	3 (3I)	3
Rotation	1 (1R)	2 (2R)	3 (3R)	3

Young seedlings of rice variety OM 3536 at 22 days old were transplanted for summer — autumn rice crop in 9 plots which applied the integrated rice — prawn system. Before stocking prawns, rice fields were drained for cleaning. Limestone was applied to the ditch at the rate of 10 kg/100 m^2. After 3 days, the ditch was filled with water. Post larvae (PL) of *Macrobrachium rosenbergii* at 25 days (0.033 g/PL) were nursed in one month to get the juveniles (1.4 g). PL of the same batch was stocked for both this study and the other study of LAN *et al.* (2006). During nursing phase, PL was fed by pellet (35% of crude protein). Juveniles were hand-counted and stocked into

18 experimental plots and cultured for 140 days (from the middle of June to the beginning of November, 2003). The prawns were fed with commercial pellet (25 - 30 % of crude protein) (tab. 2). Feeding rate was adjusted monthly based on sample by cast net.

Table 2
Feeding schedule for *M. rosenbergii* culture in the experimental rice plots

Culture period (month)	**Feeding rate** (% of body weight)	**Crude protein** (%)	**Feeding frequency** (time/day)
1	10	30	2
2	8	30	2
3	5	25	2
4	3	25	2
5	2	25	2

The water level in the ditch (16 m + 5.25 m in length (L shape) and 1 m in wide) was maintained at 0.8 - 1.0 m. In the rice fields, water was kept as high as possible in accordance with rice growth (15 - 40 cm). Rice was harvested 75 days after transplantation. After harvesting rice, water in the rice plots was increased up to 60 cm. During rice cultivation, pesticide was not used in the rice plots.

2.2. Sampling

Water temperature and dissolved oxygen (DO) of experimental plots were monitored monthly using an YSI Model oxygen meter (Yellow Springs, Ohio). Water pH was determined monthly using a pH meter. Total ammonia nitrogen ($N\text{-}NH_4^+$), soluble reactive phosphorus ($P\text{-}PO_4^{-3}$) and hydrogen sulfide (H_2S) were determined monthly using a spectrophotometer in accordance with the phenate-hypochlorite method, the ascorbic acid reduction method and the methylene blue method, respectively. Level of precision for the measure of the DO was 0.01 mg/l and pH was 0.1, while $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$ and H_2S were 0.001 mg/l.

Prawns were monthly collected by cast net for estimation of mean weight. At harvest, the water was drained and prawns were collected. All prawns in each plot were graded into different groups (tab. 3) and counted. Survival rate (%), gross prawn yield (kg/ha), production (kg/ha/year), marketable prawn yield (%) — percentage of prawn weight of more than 15 g and Food Conversion Rate (FCR) were calculated.

Table 3
Farm prices of *Macrobrachium rosenbergii* at different sizes based on the local market in Cantho City, Vietnam (November, 2003) (1 USD = 15,660 VND)

Group	Prawn size (g/prawn)	Price (VND/kg)	Price (USD/kg)
1	> 110	125,000	7.98
2	> 60	102,000	6.51
3	> 30	75,000	4.79
4	> 15	45,000	2.87
5	< 15	15,000	0.96

The variable costs included rice field preparation, seed, materials, feed, fuel for pumping water and labor of prawn culture. The labor for harvest was not counted because it was paid through selling other species of fish harvested in the culture systems. Depreciation (ditch construction, a 2-HP water pump (All Jet, Taiwan) and net, interest and maintenance were generated to fixed costs. Cost of rice field was not included as initial investment in this study. Total operating cost, gross revenue, net profit, return on labor and management (RoLM) and cost benefit ratio of treatments were compared.

The data was statistically analyzed using two factors ANOVA and following by Tukey's HSD (Tukey's Honestly Significant Difference Test) through SPSS 11.5 for Windows. The significant difference was considered at $P < 0.05$.

3. Results and Discussion

3.1. Water Quality in Cultured Systems

The mean range of water temperature was 25.3 ± 0.1 °C to 28.6 ± 0.1 °C during the culture period. The lowest and highest water temperature was in July and September, respectively. Due to the effect of a storm, it was raining during sampling time, so water temperature went down in July. According to Boyd & Zimmermann (2000) the ideal range of water temperature for grow-out phase of *Macrobrachium rosenbergii* is 25-32 °C. Water pH fluctuated from 6.0 to 7.0. These pH values were lower than the optimal range for prawn farming. The low pH of water resulted in new construction of experimental plots. Therefore, lime was regularly applied for experiments to increase pH value to ideal range: 7.0 - 8.5 (Boyd & Zimmermann 2000).

The fluctuations of dissolved oxygen ranged from 2.06 — 4.84 mg/l. The high value of oxygen was from the treatment of the lowest stocking density.

The concentration of oxygen in integrated system was lower than that in rotational system due to decomposition of rice stubble after harvesting rice. The concentration of H_2S, $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$ ranged 0.003 - 0.104 mg/l, 0.07 - 1.89 mg/l, 0.006 - 0.345 mg/l, respectively. JAYACHANDRAN (2001) mentioned that, hydrogen sulfide for prawn growth should be lower than 0.25 mg/l. Most of water quality values were in suitable ranges for optimal growth of the prawn (fig. 1). At the end of the culture period, total ammonia nitrogen and phosphorus increased.

3.2. PRAWN GROWTH PERFORMANCE

The growth curves of *Macrobrachium rosenbergii* cultured in the rice fields with and without rice cultivation were different between male and female (figs. 2, 3). Male grew faster than female. At harvest, the mean weights of the males 30 g and 40 g were higher than those of the female 20 g and 25 g in integrated and rotational system, respectively. At the same stocking density, the growth of prawn under integrated system was slower than in rotational system.

3.3. SURVIVAL, YIELD, FOOD CONVERSION RATE, MARKETABLE YIELD, FINAL MEAN WEIGHT AND PRODUCTION OF PRAWNS

For two factors such stocking density and culture system, there was no interaction on production (tab. 4). At low stocking density, mean final weight and survival rate were significantly highest at higher density ($P < 0.05$). There were no significant differences in mean final weight, survival rate and FOOD CONVERSION RATE (FCR) at stocking densities of 2 and 3 juveniles/m^2 ($P > 0.05$). Density of 1 juvenile/m^2 gave the lowest result on FCR. Although the yield of prawns stocked at 3 juveniles/m^2 was significantly the highest ($P < 0.05$), its marketable profit was significantly the lowest ($P < 0.05$). There were no significant differences in survival rate and FCR between integrated and rotational systems of prawns cultured in the rice fields. The mean weight at harvest and the yield in rotational system were significantly higher than those in integrated system. The results showed that rotational system significantly offered better production than integrated system.

The yields of prawn ranged from 251 to 430 kg/ha for integrated system and from 297 to 486 kg/ha for rotational system and were similar to the reports from HIEN *et al.* (1998), HAI *et al.* (2001) and PHUONG *et al.* (2002). However, the yields with stocking juveniles in the present study were much

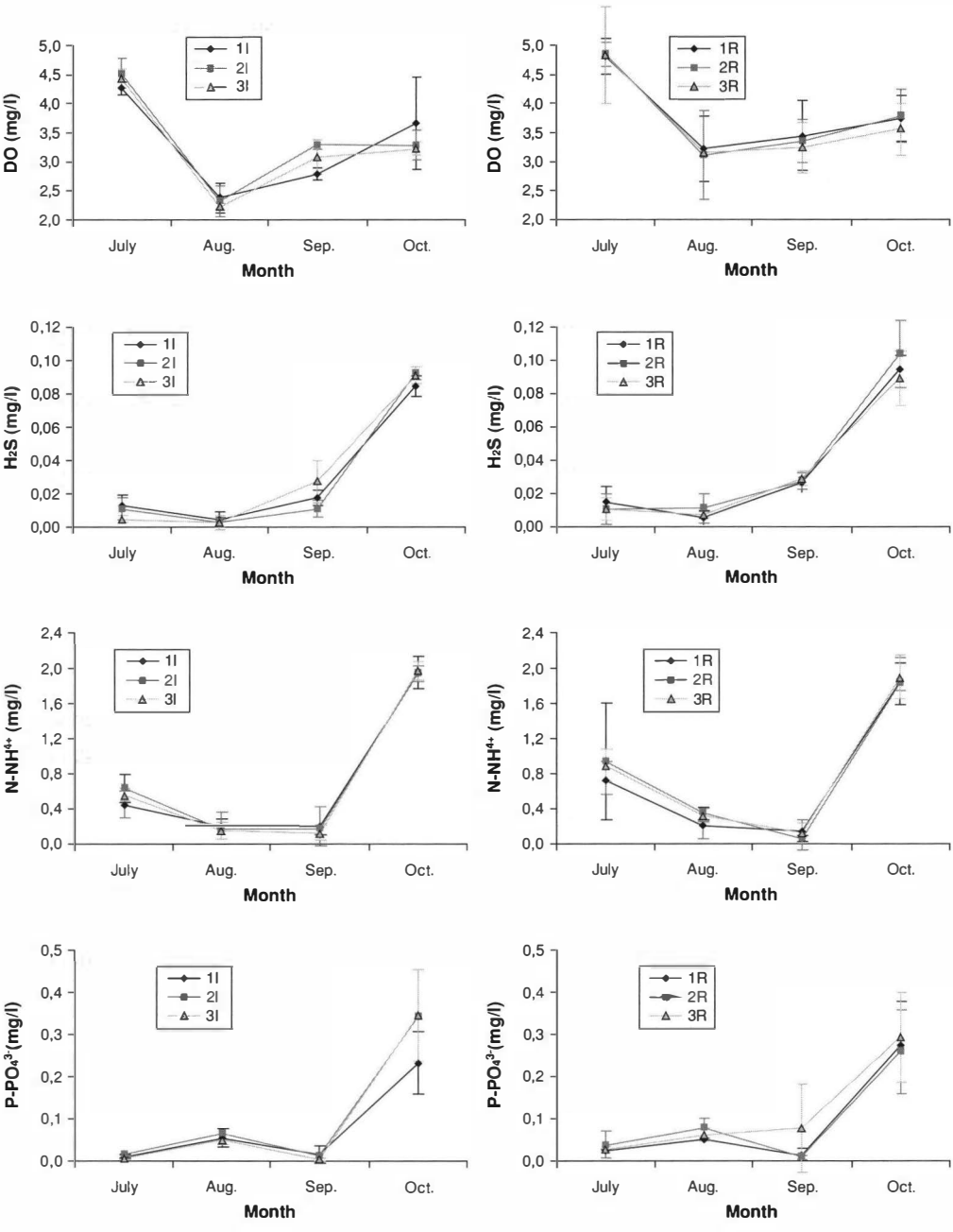

Fig. 1. — Fluctuations of some water quality parameters in integrated (I) and rotational (R) rice prawn systems at different stocking densities (1, 2 and 3 juveniles/m^2).

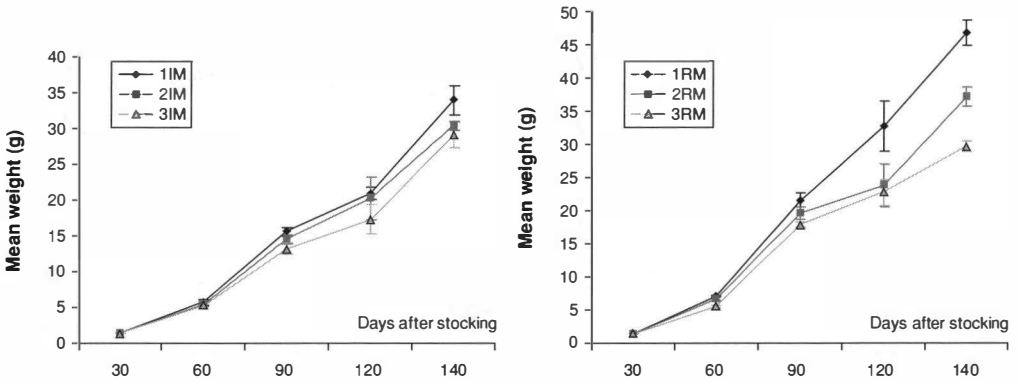

Fig. 2. — Growth curves of male *M. rosenbergii* cultured in integrated (I) and rotational (R) rice — prawn systems at different stocking densities (1, 2 and 3 juveniles/m²).

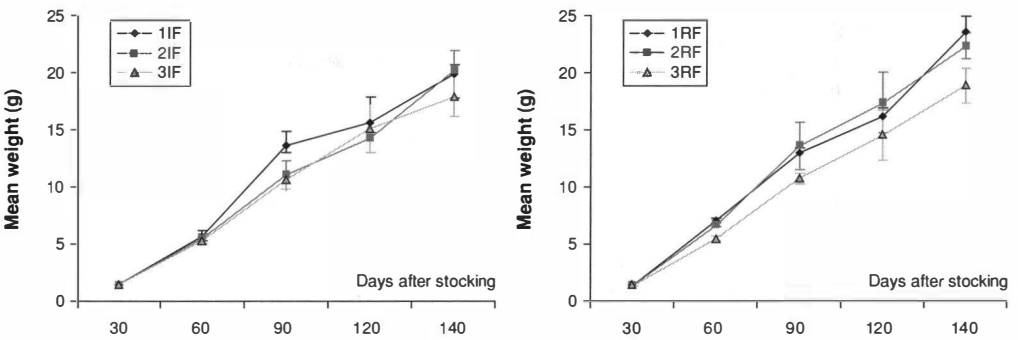

Fig. 3. — Growth curves of female *M. rosenbergii* cultured in integrated (I) and rotational (R) rice — prawn systems at different stocking densities (1, 2 and 3 juveniles/m²).

lower being 286 to 516 kg/ha and 412 to 584 kg/ha in integrated and rotational systems than the results from LAN *et al.* (2005) with stocking postlarvae of *M. rosenbergii*. The yield of prawn in this present study significantly increases with the increasing of density ($P < 0.05$). In integrated system (tab. 5), final mean weight, survival rate and FCR at density of 1 juvenile/m² was significantly better than at 2 juveniles/m² (treatment 2I) and 3 juveniles/m² (treatment 3I) ($P > 0.05$), but the yield was lower. In treatment 3I, the yield and FCR were significantly higher (430 kg/ha). Marketable profits of the three treatments were not significantly different ($P > 0.05$). In rotational system, the final mean weight of prawn in treatment 1R was higher than in 3R but was not different with 2R ($P < 0.05$) (tab. 6). Yields of prawn signif-

Table 4

Main effect of *M. rosenbergii* cultured in integrated and rotational rice — prawn system at different stocking densities of juveniles. Mean in a column within a main effect followed by different letters are significantly different ($P < 0.05$)

Main effects	Final weight (g/prawn)	Survival rate (%)	Yield (kg/ha)	FCR	Marketable yield (%)
Densities					
- 1 juvenile/m^2	34.8 ± 4.3^b	83.7 ± 3.5^b	274 ± 33^a	2.08 ± 0.14^a	96.4 ± 3.6^b
- 2 juvenile/m^2	26.4 ± 4.7^{ab}	75.3 ± 7.13^a	394 ± 35^b	2.38 ± 0.21^b	94.8 ± 1.5^b
- 3 juvenile/m^2	23.1 ± 2.0^a	65.9 ± 4.8^a	485 ± 40^c	2.56 ± 0.21^c	82.7 ± 8.8^a
Culture system					
- Integration	24.8 ± 4.3^a	77.0 ± 9.8	350 ± 91^a	2.39 ± 0.26	92.5 ± 3.2
- Rotation	31.4 ± 7.9^b	73.0 ± 8.6	401 ± 96^b	2.28 ± 0.28	90.1 ± 12.0
Density (1)	*	*	*	*	*
System (2)	*	ns	*	ns	ns
(1) × (2)	ns	ns	ns	ns	ns

* Significant difference.
ns: non-significant difference.

Table 5

Production parameters of *Macrobrachium rosenbergii* culture in integrated rice — prawn system. Mean in a row followed by different letters are significantly different at $P < 0.05$

Treatment	1I	2I	3I
Mean weight (g/prawn)	29.6 ± 2.3^b	23.0 ± 3.0^a	21.7 ± 1.3^a
Survival rate (%)	84.7 ± 1.5^b	80.3 ± 5.5^a	65.9 ± 4.7^a
Yield (kg/ha)	251 ± 16^a	369 ± 50^b	430 ± 54^c
FCR	2.14 ± 0.14^a	2.40 ± 0.19^b	2.63 ± 0.21^c
Marketable yield (%)	93.9 ± 2.2	94.7 ± 1.0	88.9 ± 7.6

Table 6

Production parameters of *Macrobrachium rosenbergii* culture in rotational rice — prawn system. Mean in a row followed by different letters are significantly different at $P < 0.05$

Treatment	1R	2R	3R
Mean weight (g/prawn)	35.9 ± 2.1^b	29.7 ± 1.3^{ab}	24.6 ± 0.4^a
Survival rate (%)	82.7 ± 5.0^b	70.3 ± 5.3^a	66.0 ± 4.4^a
Yield (kg/ha)	297 ± 24^a	418 ± 38^b	486 ± 38^c
FCR	2.01 ± 0.13^a	2.35 ± 0.28^b	2.49 ± 0.22^b
Marketable yield (%)	98.9 ± 0.4^b	95.0 ± 5.2^b	76.5 ± 0.9^a

icantly increased (from the densities of 1 to 2 and 3 juveniles/m^2. The FCR values of treatment 2R and 3R were not different, but were lower than in treatment 1R. Marketable yield in the treatment 3R was lower than in the treatment 1R and 2R. The final mean weight of prawns was the highest in experiment 1I and 1R ($P < 0.05$).

3.4. Size Distribution of Prawns at Harvest

The size of the prawns determines the price and gross revenue (Yen 2000, Phuong 2002). Most of the large size *Macrobrachium rosenbergii* in the present study (> 60 g/prawn) were males. The size of the females was in the range of 15 - 35 g per individual. Ranjeet & Kurup (2002) found that the size of females in the population is rather small and the different growth patterns in males are a major bottleneck confronting the profitability of farming *Macrobrachium rosenbergii*. Prawns at density of 1 juvenile/m^2 reached a large size (up to 90 g/prawn). In integrated system, the treatment 3 juveniles/m^2 had the highest percentage of the smallest prawns. A few prawns which were smaller than 15 g were found in the treatments of 1 juvenile/m^2 in rotational system (fig. 4). At the same stocking density, prawns cultured in integrated system were smaller than in rotational system. In addition, prawn cultured with rice had more fungus disease than prawn cultured alone in the rice field.

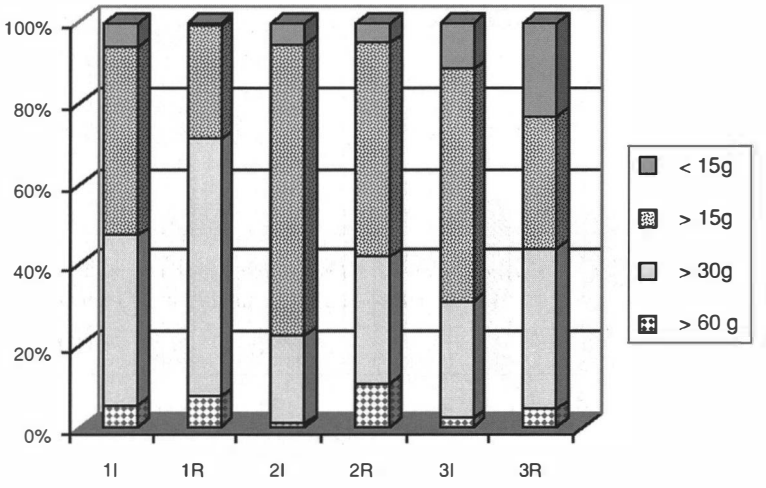

Fig. 4. — Size distribution of *M. rosenbergii* cultured in integrated (I) and rotational (R) rice — prawn systems at different stocking densities (1, 2 and 3 juveniles/m^2).

3.5. Economical Analysis

Due to the use of available rice field where a canal must be enlarged, the fixed costs are a small amount in operating costs (fig. 5). These costs ranged from 870 - 1,637 USD/ha. For both integrated and rotational systems in this study, the costs for seed, materials, pumping water and labor were the same at the same stocking density. Only the cost of feed was different. The relationship between yield of prawn and gross revenue was not always good (fig. 6). Yield in the treatment 2R was higher than in 3R, but gross returns of both treatments were not significantly different. Yield of prawn increased with the increase of stocking density. The gross revenue in the rotational treatment(s) (were) was higher than in the integrated system.

Between both factors, density and culture system, there was no interaction. The total costs were significantly increased with the stocking density, but gross revenues for the densities of 2 and 3 juveniles/m^2 were not different ($P < 0.05$) (tab. 7). However, the net profit, RoLM and cost benefit ratio at the density of 3 juveniles/m^2 were significantly the lowest (negative value). There was no significant difference in profit for the treatment 1 and

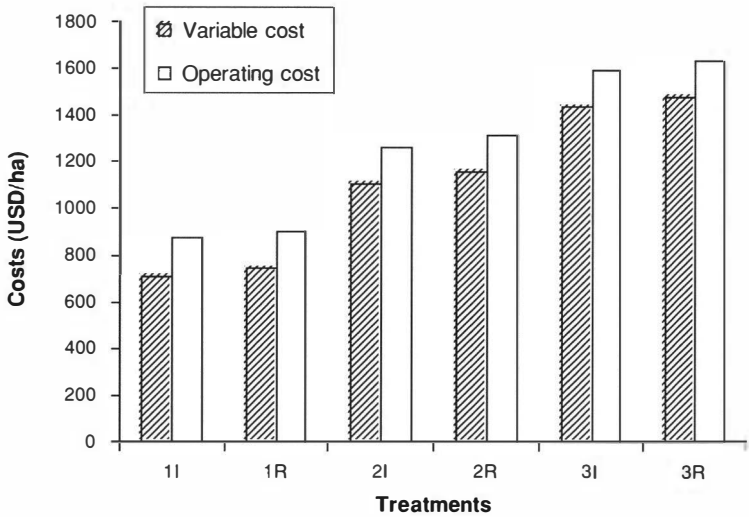

Fig. 5. — Variable and operating costs (USD/ha) for *Macrobrachium rosenbergii* in integated (I) and rotational (R) rice — prawn systems at different stocking densities (1, 2 and 3 juveniles/m^2).

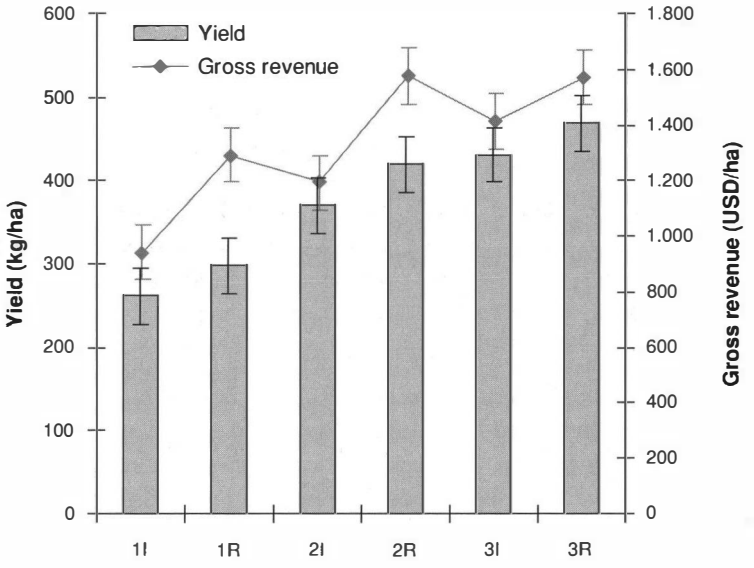

Fig. 6. — The relationship between yield and gross revenue in integrated (I) and rotational (R) rice — prawn systems at different densities (1, 2 and 3 juveniles/m^2).

Table 7

Economical analysis of different *Macrobrachium rosenbergii* culture systems. Mean in a column within a main effect followed by different letters are significantly different at $P < 0.05$

Culture systems	Operating costs	Gross revenues	Net profit	RoLM	Cost benefit ratio
Density					
- 1 Juvenile/m^2	887 ± 20^a	1117 ± 225^a	230 ± 206^b	389 ± 206^b	1.26 ± 0.23^c
- 2 Juvenile/m^2	1288 ± 43^b	1384 ± 272^b	96 ± 240^b	256 ± 240^b	1.07 ± 0.19^b
- 3 Juvenile/m^2	1614 ± 33^c	1493 ± 141^b	-122 ± 125^a	38 ± 125^a	0.92 ± 0.08^a
System					
- Integration	1240 ± 314^a	1118 ± 229^a	-59 ± 146^a	100 ± 146^a	0.97^a
- Rotation	1286 ± 319^b	1481 ± 165^b	295 ± 222^b	355 ± 221^b	1.20^b
Density (1)	*	*	*	*	*
System (2)	*	*	*	*	*
(1) × (2)	ns	ns	ns	ns	ns

* Significant difference.
ns: non-significant difference.

2 juvenile/m^2 ($P < 0.05$). Production of prawns stocked under integrated system could need less investment than in rotational system, but the later get significantly higher profit and cost benefit ratio ($P < 0.05$). The result of net profit from prawn culture in integrated system was negative. PHUONG (2002) also mentioned less profit in integrated system caused by low price of prawn of small sizes. LAN *et al.* (2006) reported that farmers could get more net profit than in this present study because prawns can be fed with low cost feed, as natural fresh food (snails, trash fish, crabs, etc.).

In rice — prawn integrated system, only the treatment of 1 juvenile/m^2 gave good economic — lower investment cost and better net profit than the treatment with 2 and 3 juveniles/m^2 (tab. 8). Cost benefit ratio from summer — autumn rice crop ranged from 1.32 — 1.40 and these values were higher than that in prawn system. In rice — prawn rotational system, operating cost, net profit and cost — benefit ratio at 1 and 2 juveniles/m^2 offered good

Table 8

Economical analysis of integrated rice — *M. rosenbergii* culture system (USD/ha). Mean in a row followed by different letters are significantly different at $P < 0.05$

Treatment	1I	2I	3I
Prawn subsystem			
- Operating costs	870 ± 9^a	1260 ± 29^b	1592 ± 29^c
- Gross revenues	941 ± 94^a	1192 ± 158^{ab}	1411 ± 99^b
- Net profit	72 ± 91	-68 ± 131	-181 ± 107
- RoLM	231 ± 91	92 ± 131	-21 ± 107
- Cost benefit ratio	1.08 ± 0.10	0.94 ± 0.10	0.88 ± 0.07
Rice subsystem			
- Operating costs	180	180	180
- Gross revenues	252 ± 6	238 ± 6	249 ± 6
- Net profit	72 ± 6	58 ± 6	68 ± 6
- RoLM	148 ± 6	135 ± 6	145 ± 6
- Cost benefit ratio	1.40 ± 0.03	1.32 ± 0.03	1.38 ± 0.03
Whole system			
- Total costs	1050 ± 9^a	1440 ± 28^b	1772 ± 29^c
- Gross revenues	1193 ± 90^a	1430 ± 164^{ab}	1659 ± 105^b
- Net profit	144 ± 88	-10 ± 137	-113 ± 113
- RoLM	380 ± 87	226 ± 137	124 ± 113
- Cost benefit ratio	1.14 ± 0.08^b	0.99 ± 0.09^{ab}	0.94 ± 0.06^a

values (tab. 9). Although the cost benefit ratio between both culture systems: with and without summer — autumn rice crop were not much different, RoLM in the later model was much higher. This was one of the most important reasons why farmers in the Mekong delta, especially in flooded areas are applying rice — prawn rotational system more and more and we encourage them to do it.

Table 9

Economical analysis of stocking juveniles in rotational rice — prawn system (USD/ha). Mean in a row followed by different letters are significantly different at $P < 0.05$

Treatment	1R	2R	3R
- Operating costs	904 ± 8^a	1316 ± 22^b	1637 ± 25^c
- Gross revenues	1292 ± 82^a	1576 ± 110^b	1574 ± 101^b
- Net profit	388 ± 76^b	261 ± 132^b	-62 ± 107^a
- Cost — benefit ratio	1.43 ± 0.08^c	1.20 ± 0.10^b	0.96 ± 0.07^a
- RoLM	547 ± 76^b	420 ± 132^b	97 ± 107^a

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Integrated Coastal Resources Management through the Existing Natural Resources and Environmental Action Plans: Case Study from Pak Phanang Delta in Southern Thailand

by

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1. Introduction

The Pak Phanang delta is located in the southern part of Thailand in the province of Nakhon Si Thammarat (fig. 1). It is known for its biodiversity and economic potential. Once it was a very productive rice area and thus gained the surname of, "a land of milk and honey". This fame also spoke of its rich natural resources that ensured an abundance of rice, fish and fresh water (BOROMTHANARAT 1991). However, the situation has changed over the years. Due to the unique topography of the delta, flooding, saltwater intrusion and lack of freshwater became major problems. Land elevation in the delta is about 0.5 m above MSL while water level in the river during the dry season is about 0.7 m above MSL (ANDONG 2004). Without water control structures, salty water will naturally flow upstream affecting thousands of hectares of agricultural land. The rice farming area in the province that once exceeded 200,000 hectares has decreased by half due to the degradation of soil and lack of freshwater supply (Chaipattana Foundation 1996). Many rice farmers shifted to shrimp farming. This switchover has resulted in serious environmental problems due to the indiscriminate discharging of untreated wastewater aside from the fact that agricultural lands have been converted and mangroves have been cut. The boom in shrimp farming that

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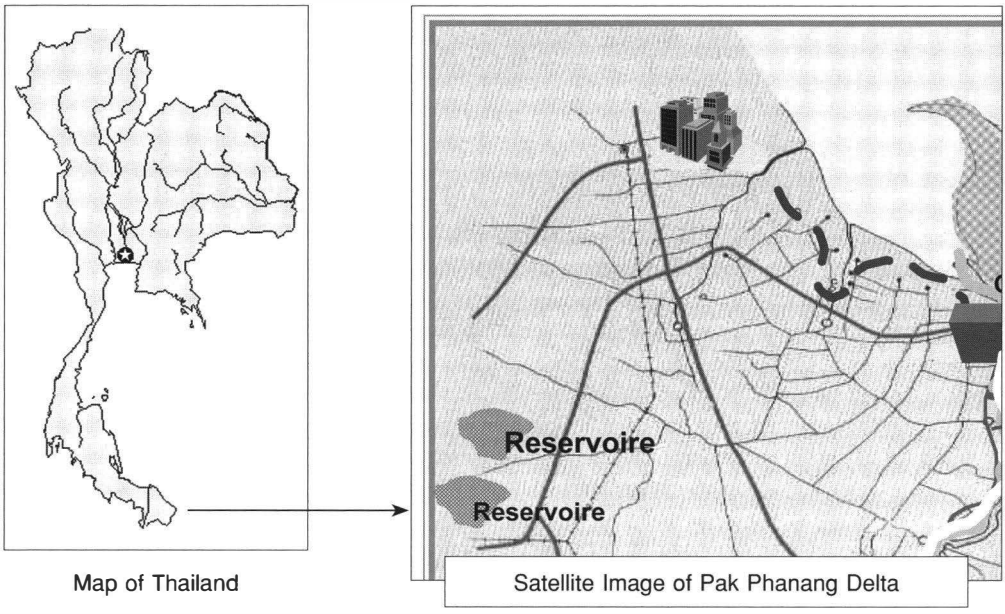

Fig. 1. — Location of Pak Phanang Delta.

was caused by the high international market demand was not sustained. The fishing port stopped operation because it was already difficult for fishing boats to navigate in the bay and to reach the port due to sedimentation.

2. Uses of the Delta

The delta has been a very important area not only within the province but also of the southern part of Thailand and the country as a whole. It serves as a port for rice granary because rice has been exported to other regions like China, Malaysia and other neighboring countries. It was also a lucrative fishing port where commercial fishing boats unload their catch. Thus, rice as well as fish trading use to be major and traditional economic activities in the delta. In the late 1980s to the early 1990s, the boom in shrimp farming due to high international market demand caused a major change in the delta as large areas of mangrove lands and rice fields were converted into shrimp farms. The delta saw the expansion of shrimp farms landward. Another important livelihood activity in the area is bay fishery. Futhermore, there is

an abundance of fish catch for maintaining fishermen until lately when the river flow was altered due to the introduction of water structures in the main river of Pak Phanang. Furthermore, through the years, the delta witnessed agricultural development in various forms. The traditional farming systems using local variety of rice eventually gave way to the use of hybrid varieties and modern technology, as government policy was geared up in order to intensify rice production.

3. Government's Response

The government has the assignment to respond to the various issues arising from the dynamism and changes produced by both natural occurrences and human activities. The major approaches of the government occur through the formulation of policies and infrastructure development. In the delta, development of the agriculture sector for livelihood is one of the main aims. In the past few decades, the delta was the rice production bowl of Southern Thailand and the foodstaff was being exported. This activity was evidenced by the proliferation of rice mills (both big- and small-scaled) along the river banks. Today, only the chimneys remain as the visible proof of this loss. The major strategies to support the policy mentioned above are through (*i*) the construction of water control structures such as gates and canals (figs 2, 3) (RID 2003); (*ii*) zoning to separate freshwater and salt water areas (fig. 4) (DoF 2003); and (*iii*) install a wastewater treatment plant to maintain water quality. The building of water control structures was primarily intended to provide sufficient supply of freshwater to the agriculture sector. The zoning policy aimed at creating the optimum conditions and use of water resources appropriated for agriculture, shrimp farming and other livelihood activities.

4. Issues within the Pak Phanang Delta

The dynamism in the delta is influenced by several natural phenomena like stream flow, sediment transport, flooding, and other impacts from the river basin as well as by human activities like shrimp farming and modern agriculture. In the same manner, the dynamism of the delta also affects the river basin through tide, storm surges and coastal sedimentation. As a result, the delta is dynamic and so with the way several interactions are taking

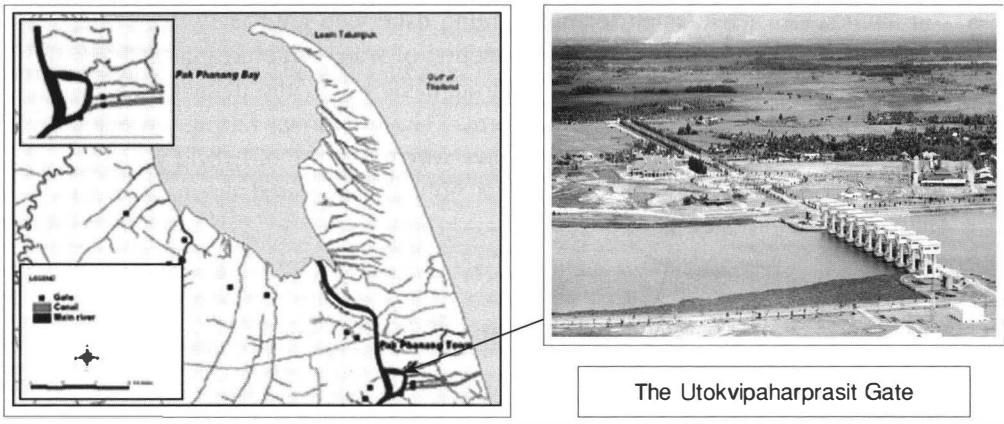

Fig. 2. — Water control structures as part of the government's response to the need for water and other resources management in Pak Phanang Delta.

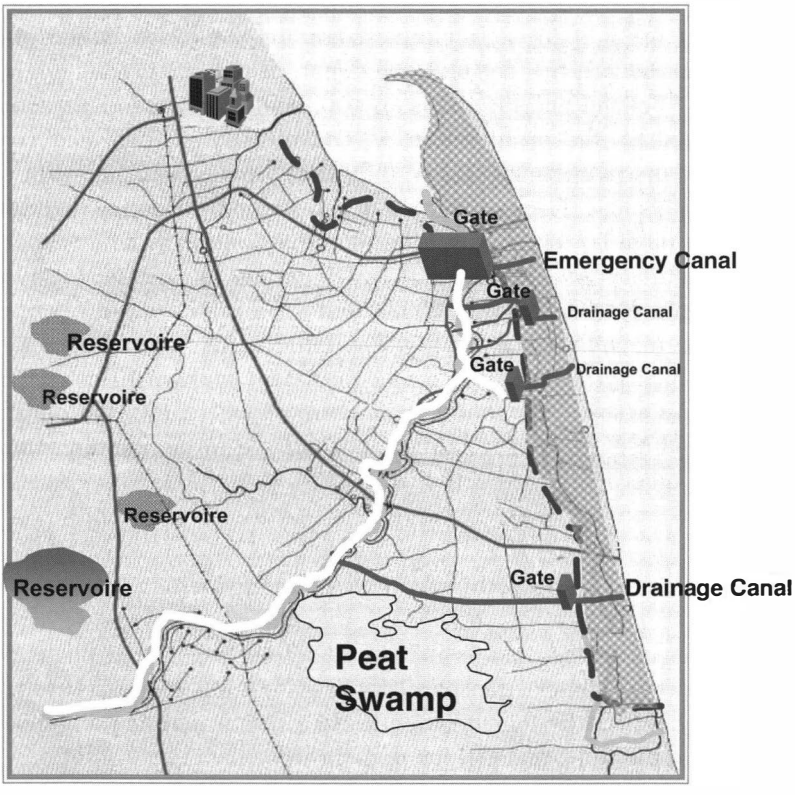

Fig. 3. — Gates and canals constructed for freshwater storage during dry season and drained during flood season.

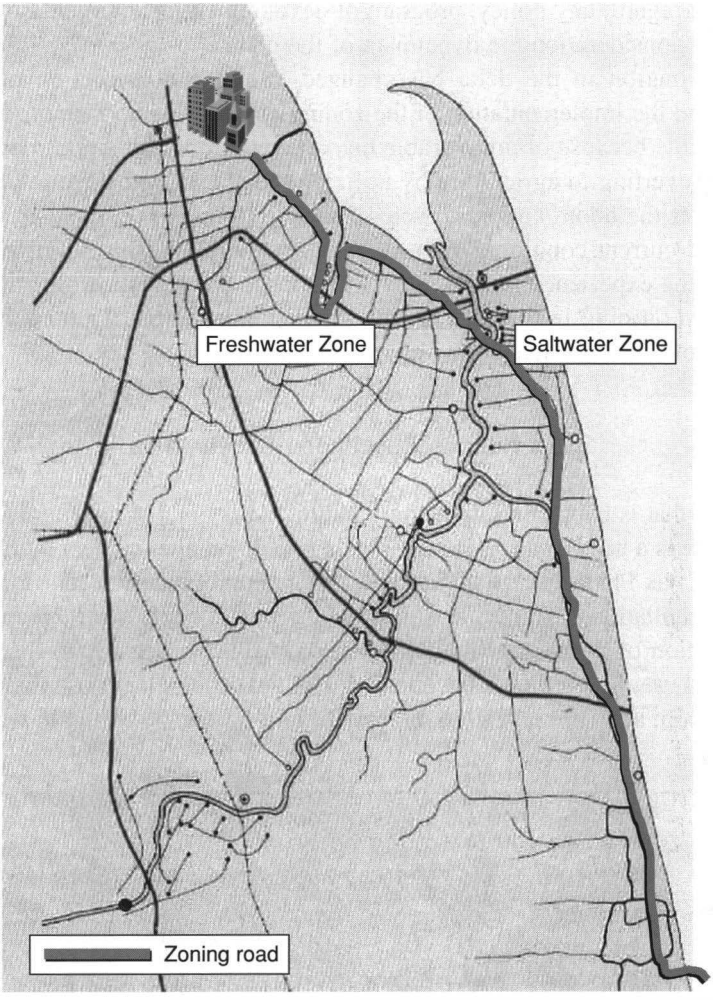

Fig. 4. — Physical zoning and division of freshwater and saltwater zones.

place. The major effects can be summarized into three main issues: (*i*) too little water; (*ii*) too much water; and (*iii*) dirty water.

The above-mentioned issues know a temporal variation depending on the season and time of the year. The handicap of lacking water occurs during the dry periods while the problem of too much water occurs during rainy season and flooding. The trouble of dirty water is caused by human activities, *i.e.* by shrimp farming and the closing off of main waterways through artificial structures like gates.

In this regard, any policy, program of development or intervention should take into consideration the dynamism of the delta.

The situation in the delta has changed after the construction of water works and the implementation of the zoning policy. Shrimp farming became unprofitable because of unfavorable market conditions and a poor pond condition. Reverting to agriculture by utilizing the abandoned shrimp farms for crops after the boom and bust cycle of shrimp farming is no longer feasible given the current conditions (tab. 1). A case example of this boom and bust cycle is the experience in Bang Pra Sub-district. Table 2 shows the timeline of shrimp farming in this sub-district. Figure 5 shows the fluctuation in the number of farmers engaged in shrimp cultivation.

5. Sustainable Livelihood Development

With what is happening in the agriculture, fishery and shrimp farming sectors, there is a need to develop sustainable livelihood alternatives. In the experience of Pak Phanang Delta, this can be more appropriately reached through: (*i*) the installation of a mechanism for an effective people's participation, (*ii*) the adoption of multi-stakeholders' decision-making process, (*iii*) the availability and use of appropriate technology; (*iv*) the development of micro-entrepreneurship; and (v) realization of capital-build-up for the community.

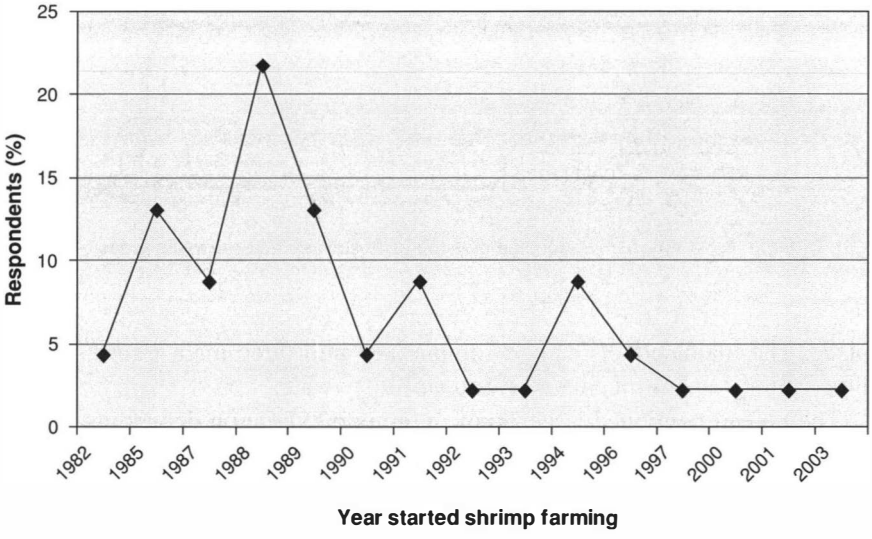

Fig. 5. — Fluctuation in the number of farmers engaged in shrimp cultivation.

Table 1
Economic feasibility of reverting to agriculture

Items		Planting: Rice-Kor-Khor7	Planting: Chinese Kale	Planting: Lettuce	Planting: Water Spinach
Cost for preparation of land (Baht/Rai)		5,136	8,420	8,42 0	8,420
Cost for preparation of soil quality (Baht/Rai)		2,112	3,450	3,450	3,450
Fix cost (Baht/Rai)		219	219	219	219
Variable cost (Baht/Rai)		1,289	7,354	7,219	5,607
Income (Baht/Rai)		1,062	3,543	9,647	3,311
Net income (Baht/Rai)	Including cost for preparation of land and soil quality	-7,695	-15,900	-9,661	-14,385
	Excluding cost for preparation of land and soil quality	-446	-4,030	2,209	-2,515
Average production (Kg/Rai): Soil quality as in abandoned shrimp pond		259	373	804	736
Average production (Kg/Rai): Soil quality as in normal condition		759	440	1,413	2,056
Financial feasibility (To gain profit, the B/C Ratio must be more than 1)	Including cost for preparation of land and soil quality	0.44	0.45	1.26	0.56
	Excluding cost for preparation of land and soil quality	0.70	0.48	1.33	0.59
Sensitivity analysis of capital decision (To gain profit, the B/C Ratio must be more than 1)	Including cost for preparation of land and soil quality	0.26	0.27	0.76	0.543
	Excluding cost for preparation of land and soil quality	0.42	0.29	0.80	0.35

The implementation of the above mentioned components led to the formation of clusters based on resource potentials and livelihood opportunities such as: (*i*) proliferation of water hyacinth; (*ii*) conversion of peat swamp; (*iii*) irrigated agricultural mainland; (*iv*) former brackish water area; (*v*) salt-water zone; and (*vi*) area downstream of the biggest water gate. These issues were considered as opportunities by the different groups. Thus, what first

Table 2
Boom and bust in shrimp farming
illustrated by the case example of Bang Pra sub-district in Pak Phanag Delta

Year	Event
Before 1982	➢ The golden period of rice farming (1982-peak)
1986-1988	➢ The Krisada Company started shrimp farming (16 ha.) ➢ Conflict in the use of resources between rice farming and shrimp farming ➢ Farmers converted paddy fields into shrimp ponds because of high market demand
1992-1994	➢ The whole area of paddy fields were converted into shrimp ponds ➢ Outside capitalists invested in shrimp farming in the area ➢ The peak period of shrimp farming
1995-1996	➢ Outbreak of shrimp disease ➢ Losses incurred ➢ Shrimp farming stopped ➢ Small-time shrimp farmers heavily indebted
1997-1998	➢ Price of shrimp went up (primarily due to inflation rate) ➢ Shrimp farming restored
1999	➢ Royal Development Project (Operation of water major water gate) ➢ Ecosystem is changed ➢ Diseases affected shrimp farming ➢ Shrimp farmers stopped to exploit shrimp farms with great losses
2004-2005	➢ Shrimp price is very low ➢ Abandoned shrimp ponds increase

seemed to be a problem was gradually turned into livelihood opportunities and making optimal use of the resource potential of the area. As a result of these initiatives by the local communities themselves and through the effective facilitation by an academic and research institution, 8 units of occupational excellence were established to effectively implement the mechanism being developed in the process.

The eight units of excellence based on the resource potential of the area are as follows: mangrove and bay fisheries unit; waste management unit; organic fertilizer production unit; river and floodplain fishery unit; integrated irrigation management unit; peat swamp conservation and palm oil production unit; nipa palm production and processing unit; and the coastal small-scale fishery unit. A co-management center is being established to coordinate the activities, to exchange information and experiences, and to facilitate the marketing of products.

6. Management Framework of Pak Phanang Delta

In order to support the livelihood activities and the utilization of resources in the delta, a management framework suitable to the local context was developed and is being implemented. The latter is done in close coordination with local authorities and government agencies and with the assistance of an academic institution. Figure 6 shows the structure of this management framework.

7. Institutional Arrangement

In order to effectively implement the mechanism for sustainable livelihood development, there is a need to network with other institutions and groups. This is considered as a vital component of sustainability as it involves both the communities and local authorities as well as government agencies. The units of excellence provide a forum for partnership and cooperation among various stakeholders. The co-management center facilitates better

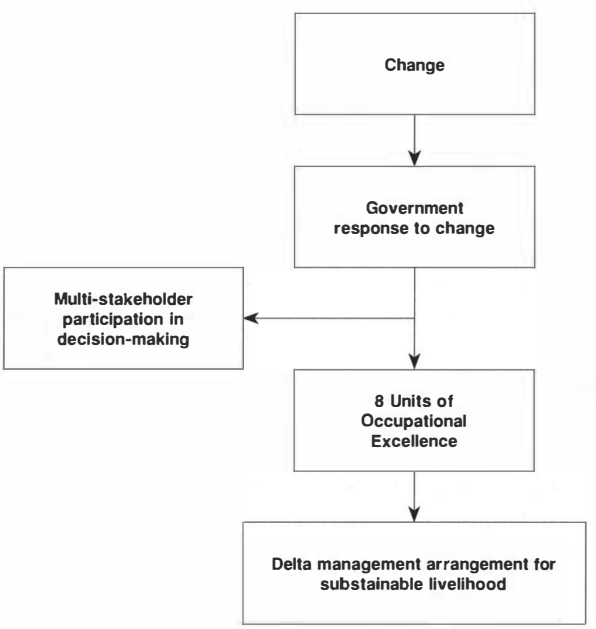

Fig. 6. — Pak Phanang Delta Management Framework.

networking and sharing of information and experience among the various units of excellence as well as with external organizations. Figure 7 illustrates this arrangement.

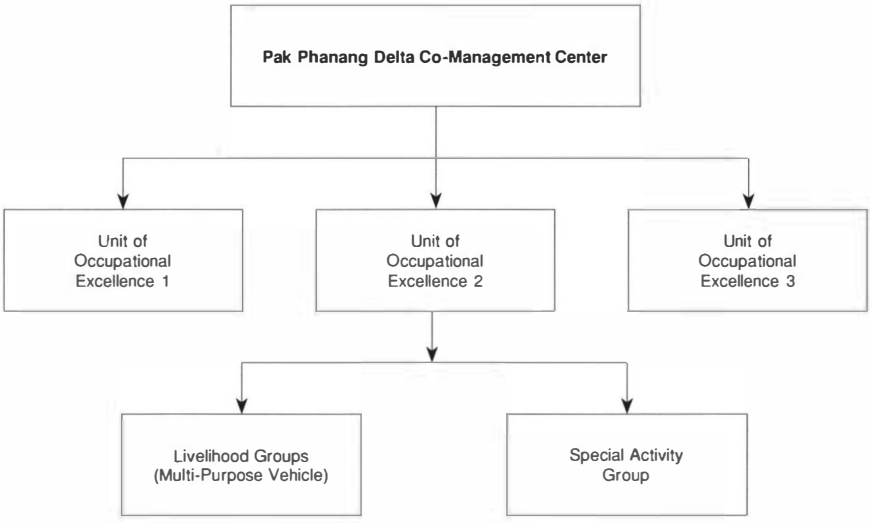

Fig. 7. — Institutional Frame in Pak Phanang Delta.

8. Management Arrangement

A mechanism for the management of the Pak Phanang Delta is very important. Indeed, an effective management arrangement ensures proper functioning of each unit and every aspect of interaction among various groups and organizations.

The management at the local level is linked to the national government strategy of resource management through the Co-management Center. This center facilitates and coordinates the various activities in which the various units of livelihood excellence may be involved. Activities may be in terms of processing, marketing, providing capital or realizing civic programs. It also serves as a contact center for other organizations and institutions who are interested in learning and being involved in the activities within the established mechanism of resource management in the delta. Figure 8 shows the management frame for the delta.

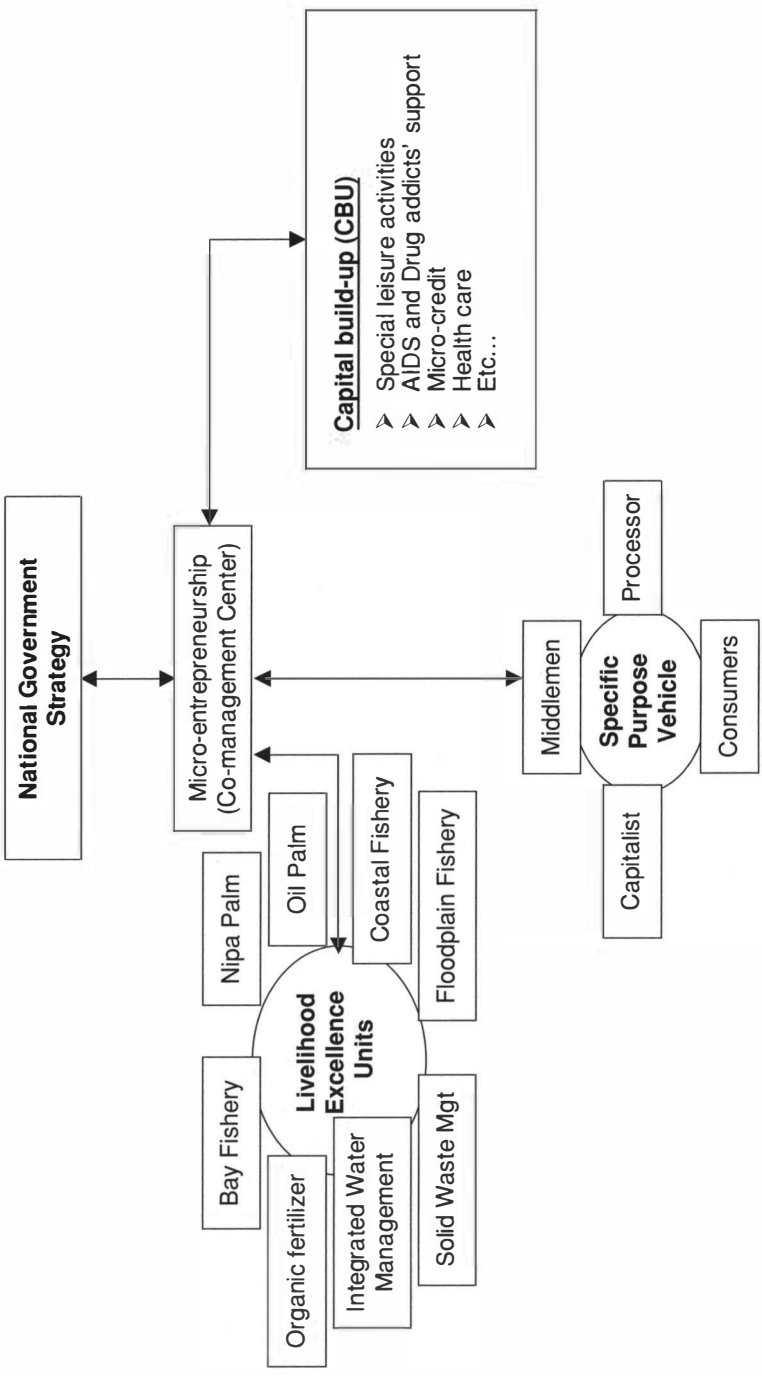

Fig. 8. — Management arrangement for Pak Phanang Delta (adapted from CORIN 2005).

9. Conclusion

From the experiences in the Pak Phanang Delta as discussed in this paper, the following conclusions can be deduced: (*i*) a mechanism for participation is needed to strengthen both the government and the grass root levels; (*ii*) development of sustainable occupation is a tool to improve develop delta management and institutional arrangements; (*iii*) a self-sufficient economy should be established to promote specific local products for the outside market; and (*iv*) to realize the above, enumerated goals there is a need for a neutral facilitator with the capacity to make use of tools for an iterative process.

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The Changing Physical Environment of Southeast Asian Deltas: a Case Study on the Mekong

by

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Introduction

The collision between the Indian and the Eurasian Plates formed the Himalaya Mountains. The associated extrusion tectonics created structural lows in the southeastern direction. The major rivers basins of Southeast Asia occupy such tectonic depressions (TAPPONIER *et al.* 1982, 1986, FENTON *et al.* 2003). Trunk streams draining river basins in mainland Southeast Asia are directed by structural lineations over long distances. For example, the Chao Praya locally follows north-trending normal faults, several of which probably are still active (SINSAKUL 2000). The Sông Hóng (Red) is an excellent example, flowing southeastward along the Red River Fault. The Mekong also is structurally controlled with a rock-cut channel for at least the first 4,000 km of its 4,800 km long course.

The South China Sea is a shallow continental sea over the Sunda Shelf. A very large area of the current sea floor was converted to dry land during the last glacial stage in the Quaternary. The present coastline is about 300 km inland from the past one in places (BISWAS 1973; see GUPTA *et al.* 1987 for a list of relevant references). The rivers of Southeast Asia had to adjust, flowing into the sea at locations different from the present ones.

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Geologically, the current world deltas are very young features. STANLEY & WARNE (1994) have shown that between 8,500 and 6,500 years ago deltas started to form, mainly due to the deceleration of the glacial-melting driven rise in sea level. This declining rate allowed sediment arriving at river mouths to extend beyond the accommodation space created by the waning sea level rise and to form deltas. The stratigraphy, age, and details of formation of a number of Southeast Asian deltas are now much better known. For example, subsurface cores indicate that the Mekong Delta was built in the last 6,000 years following the mid-Holocene sea-level high. Development of this delta extended the shoreline for more than 250 km (NGUYEN *et al.* 2000).

Given the hot and humid characteristics of the region, the deltas of Southeast Asia used to be extensive coastal wetlands primarily under mangroves or peat. A pattern in mangrove speciation is not always clearly perceived but a broad zonation has been suggested (MACNAE 1968). *Avicennia* and *Sonneratia* occur near the sea. *Rhizophora*, *Bruguieria*, and *Ceriops* are found landward in higher parts. *Avicennia* is also found inland. The zonation is controlled by three factors: the frequency and duration of tidal flooding, the amount of freshwater present, the nature of the subsurface material (CORLETT 2005). If present, mangroves play an important role in delta-building. The root system of the established stands slows down the silt-laden water and allows sedimentation on the landward side of the mangroves, thereby providing shore protection with the extension of deltas. Pioneer species move seaward, followed by other successions, ensuring coastal stability. Wetlands in deltas are vegetated also by species other than mangroves. *Nypa fruticans*, an extremely versatile plant, is usually found in extensive stands at the upper tidal limit of deltas behind sandbars. Casuarinas grow on beach ridges.

The deltas of Southeast Asia, at least parts of them, have been settled for long periods replacing the mangroves and other types of swamp vegetation. The surface of the deltas has been extensively transformed by the clearance of vegetation, draining of wetlands, modification of soils, and establishment of irrigation systems. These were followed by large-scale rice production and high density population. The delta surfaces have been changed to an anthropogenic landscape of rice cultivation for at least a millenium, and since the 1980s, the expansion of shrimp and fish farming and salt production has modified the land near the sea. About three-quarters of the world production of farmed shrimp comes from Southeast Asia. The practice, however, is usually short-lived, and the abandoned farm areas are not ecologically restored (SPENCER & SPALDING 2005). Such intense occupation has led to a

set of common environmental problems: floods, coastal erosion, saline water intrusions, acid sulphate soils, deforestation including destruction of mangroves. The modification of the main river and its basin upstream has also contributed to the changing of the deltaic environment, leading to alterations in discharge and sediment flux, and in certain cases, an increase in pollution. Ecological monitoring of deltas therefore has become necessary. The changing physical landscape of the Mekong Delta is examined in this paper along with projected possible changes.

The Mekong River and its Basin

The Mekong, the largest river in Southeast Asia, has built the biggest delta. It flows through a pan-shaped basin. The handle of the pan is in China and the rest of the basin covers parts of Myanmar, Thailand, Lao People's Democratic Republic (PDR), Cambodia and Vietnam (fig. 1). For the first 4,000 km of its course, the Mekong flows either directly on rocks or over a thin veneer of alluvium overlying rocks. On rock, the Mekong is structure-guided, geology controlling both its location and channel morphology. The river as a result changes its form and behaviour several times along its course and its sediment sits loosely on rocks in the channel (GUPTA & LIEW 2007). The Mekong is on thicker alluvium for the last 600 km of its course, and begins to move freely across the valley flat with lateral sediment deposition only from 50 km upstream of Phnom Penh. The delta starts at Phnom Penh where the Bassac separates from the Mekong.

For most of its course, the Mekong flows through steep-sided hills or mountains, through a valley flat only 1-10 km wide. The valley widens between Vientiane and Savannakhet but the hills close in again between the Annamite Mountains and the Korat Plateau. Only inside Cambodia the Mekong begins to flow through a wide flat structural basin. Unlike many large river basins of Asia, the basin of the Mekong is still in a fairly natural state in spite of continuing low-scale shifting cultivation and recent deforestation on slopes of the upper basin. However, both the river and the slopes are currently being subjected to development-related anthropogenic modifications, the most direct of these being a cascade of impoundments on the main river in Yunnan, China.

The average discharge at the river mouth is 15,000 m^3s^{-1} according to the Mekong River Commission. Before the construction of the dams on the upper Mekong, about 18 percent of its total water used to come from Yunnan. Almost all of the other 82 percent comes from four sources: (1) the

Fig. 1. — Location map of the Mekong River Basin.

hills of northern Lao PDR via a number of small steep tributaries, (2) the southern Annamite Mountains along the rivers San, Kong and Sre Pok, (3) a comparatively small fraction contributed by the Mun-Chi system draining the Korat Plateau, and (4) the drainage from the Tonlé Sap during the dry season. The sediment data are sparse, but about 150-170 million t is the standard estimated figure at the river mouth. About half of it arrives from China, which probably includes a higher proportion of Mekong's bedload. The sediment is primarily sand, but coarser material ranging up to boulders is seen in the channel. Finer material, such as fine sand, silt and clay reach the delta and the river mouth (MRC, various years).

The Mekong Delta

The Mekong Delta starts near Phnom Penh, where the Bassac as the first distributary leaves the main channel 330 km from the sea (fig. 2). The delta is commonly defined as the slightly curved triangular piece of land between Phnom Penh at the north, the mouth of the Saigon River to the southeast, and the southwestern cape of the Ca Mau Peninsula to the west (Ta *et al.* 2002a). Subsurface cores indicate that the Mekong Delta was formed in the last 6,000 years, mostly after the mid-Holocene high sea level. It is one of the largest deltas in the world, although the determination of its size varies between about 62,000 to 93,000 km^2 (Ta *et al.* 2001). A number of recent borehole-based studies carried out by the Sub-Institute of Geography, Vietnam National Center for Natural Science and Technology; the Department of Geology, Niigata University, Japan; and the Geological Survey of Japan, AIST have expanded our knowledge regarding the origin and formation of the delta.

Over the last 6,000 years, the delta has prograded more than 250 km from a shoreline near the Cambodia-Vietnam border to its present coastline (Nguyen *et al.* 2000). The regression of the South China Sea and exposure of the Sunda Shelf during the Last Glacial Maximum was followed by a sea-level rise during the Late Pleistocene and the Early Holocene. The sea level rose rapidly resulting in the deposition inland of a relatively thin layer of estuarine to marine sediment over the interfluves and filling of former river valleys to greater thickness. The large sediment load from the river formed a progressively outward-building delta after the sea-level highstand and continued with the subsequent fall in sea level. The present Mekong Delta was built with two types of sedimentary succession. The inner zone was formed as a tide-dominated delta and the outer one as a wave- and tide- dominated delta.

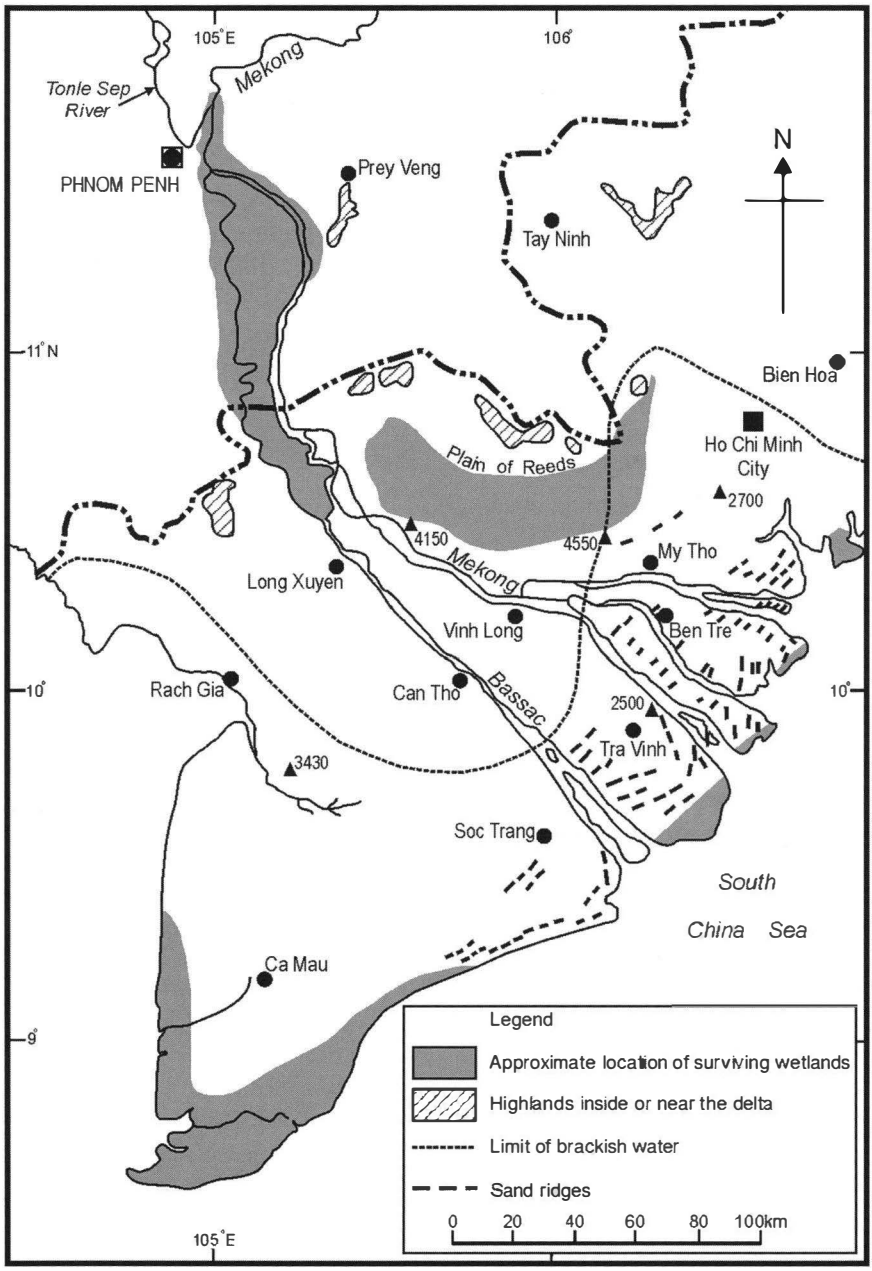

Fig. 2. — The Mekong Delta.

This change has been attributed to the extension of the delta about 3,000 years ago beyond a headland east of Ho Chi Minh City, exposing the delta to stronger wave action. The sediment and topography reflect the change. The upper delta is a land of channels, levees and backswamps, interrupted by a few scattered small rocky hills. The advance of the delta into the South China Sea and stronger wave action led to the formation of beach ridges, longshore sediment movement and steepening of the delta front. Over the last 3,000 years, the Mekong Delta prograded at rates that slightly fluctuated below 20 km per thousand years. The average annual rate of deltaic sedimentation has been determined as 144 ± 36 million t, which is very close to the present rate of sediment discharge (150-170 million t) at the mouth of the Mekong. This implies that the sediment discharge of the Mekong River has not really changed over the last 3,000 years, indicating a lack of significant anthropogenic alteration in its basin. This is unlike almost all major rivers of South, Southeast and East Asia (TA *et al.* 2001, 2002a, 2002b).

The two major channels, the Mekong and the Bassac, flow southeast, almost in a linear fashion, through the delta. The Mekong later separates into three main channels. These channels are bounded by continuous levees on both sides. Sand and silt bars occur midstream. The major channels are not particularly mobile, their positions have not changed much over the last two to three thousand years (TA *et al.* 2002a). Backswamps and depressions, where floodwater accumulates during the wet southwestern monsoon, occur between the major channels and between them and the western and eastern edge of the delta. A large swamp to the northeast is known as the Plain of Reeds. Not many interconnecting channels are seen in the delta. For example, the Bassac flows for about 200 km after separating from the Mekong at Phnom Penh, before the first interconnecting channel appears at Cho Moi.

The outer delta is different. The Ca Mau Peninsula to the west is a coastal plain with tidal channels and marshes. The western edge of the peninsula is remarkably straight, probably due to structural control although wave and current effects have been mentioned (TA *et al.* 2000a). Towards east, wave action has resulted in a beach ridge and salt marsh topography through which the major channels flow out to the sea, forming bars and islands in their channels. The outer delta is edged by a coastal wetland that, in general, changes from mangrove swamps to tidal flats towards the coast. The tidal range at the mouth of the Mekong exceeds 3 m (DOUGLAS 2005).

The Mekong River Commission maintains a gauging network on the Mekong and its tributaries, although only staff gauge readings have been reported from the delta. The river discharge shows a seasonal pattern, most of the rainfall arriving in the southwest monsoon between June and October

extensively flooding the low areas for months. The large floods of the lower basin are usually generated by tropical storms and cyclones approaching the Annamite Mountains during the wet period when the river is already high and the ground is wet. The time of occurrence of flood peaks changes in the downstream direction. The biggest floods of the year tend to arrive in August in Thailand and the upper Lao PDR. In Cambodia, the relevant month is September. In the delta in Vietnam it is most likely to be October (MRC 1997). It is difficult to determine the recurrence interval of big floods in the delta due to absence of discharge measurements. The last station on the Mekong where discharge is regularly measured is Stung Treng in Cambodia, where the flood of 2000 that extensively flooded the upper delta for months, had a recurrence interval of 4.7 years. At Phnom Penh and other stations where only staff gauges are read, this flood has been attributed recurrence intervals between 20 and 60 years. This discrepancy may be due to floodwaters in the delta moving upstream into the Tonlé Sap before entering the delta, escaping overbank into depressions, or flowing into a large number of canals. The natural drainage in the delta has been modified by a set of canals, constructed over the last 300 years. As a result floodwaters inundate the upper delta but instead of continuing overland down the delta, dissipate through the distributaries and canals or flow westwards to the sea. This pattern has been seen in satellite images for all floods between 1997 and 2002 (fig. 3). except 1998, which was an El Niño year. In such floods large-scale sediment transfers occur both overbank into topographic lows and the South China Sea. The overbank sediment deposition is indicated in the satellite images by the change in colour in water covering the backswamps when observed over a period of weeks. Regular sediment data are not acquired, but sediment plumes (fig. 4) derived from backscattering using MODIS images indicate a peak late in the wet season (October-November) and a general drift southwestward across the face of the delta towards Ca Mau Peninsula that forms a circulatory pattern past the cape. This has been suspected earlier by TA *et al* (2002a).

The delta, at least parts of it, has been settled, modified, and utilised for about two thousand years. Oc-èo, the site of which is now located 24 km inland, was once an important port with a dense population that lived within rectilinear ramparts and ditches. Roman coins and Indian artefacts found at the site indicate the importance of Oc-èo at that time. A visiting Chinese envoy reported shipping of iron and tin in the Ca Mau Peninsula probably around 250 AD. In the early first millennium AD a population nuclei seemed to have grown between Oc-èo and the inland Angkor Borei that later declined and disappeared (MIKSIC 1999, 2003). Historical narratives of several kingdoms

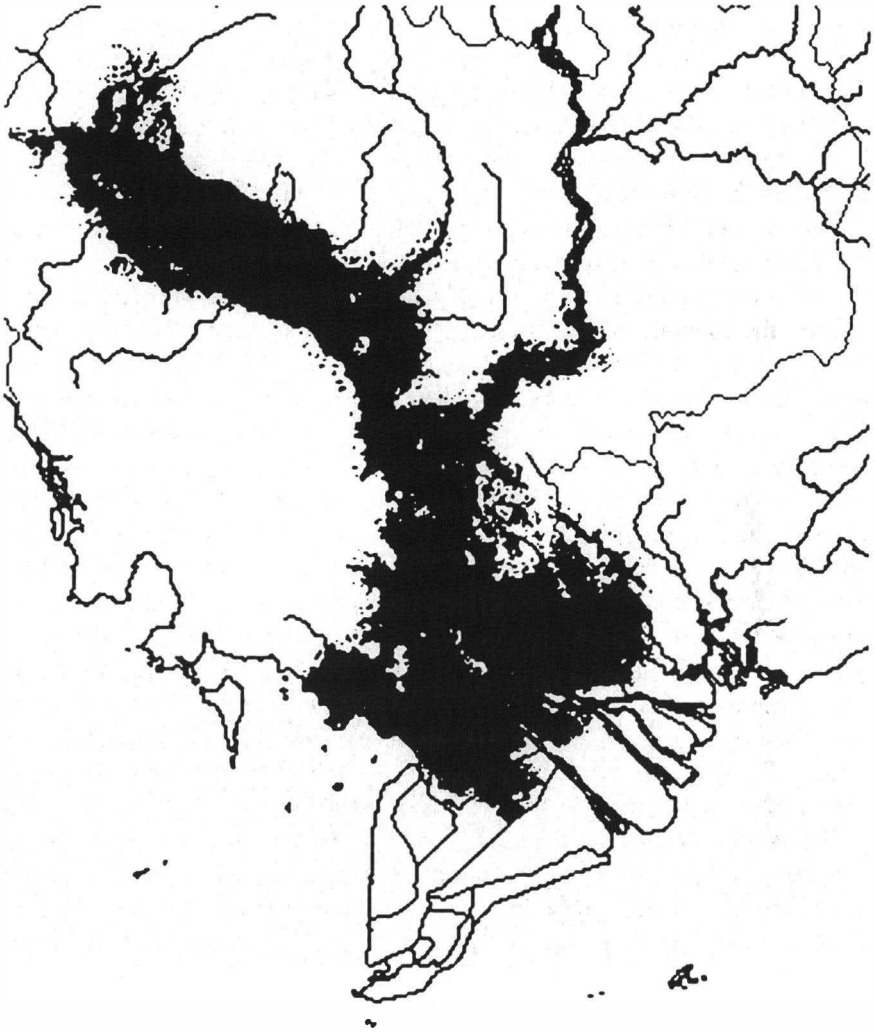

Fig. 3. — Flood of 2002 mapped from MODIS images at CRISP, Singapore, illustrating the pattern of flooding in the Mekong Delta.

in the delta area are available, although we do not know the level of past anthropogenic modification across the delta. The delta of the Mekong probably remained as a coastal wetland growing paddy in suitable locations for a very long time, until canal systems start to control its hydrology about three hundred years ago.

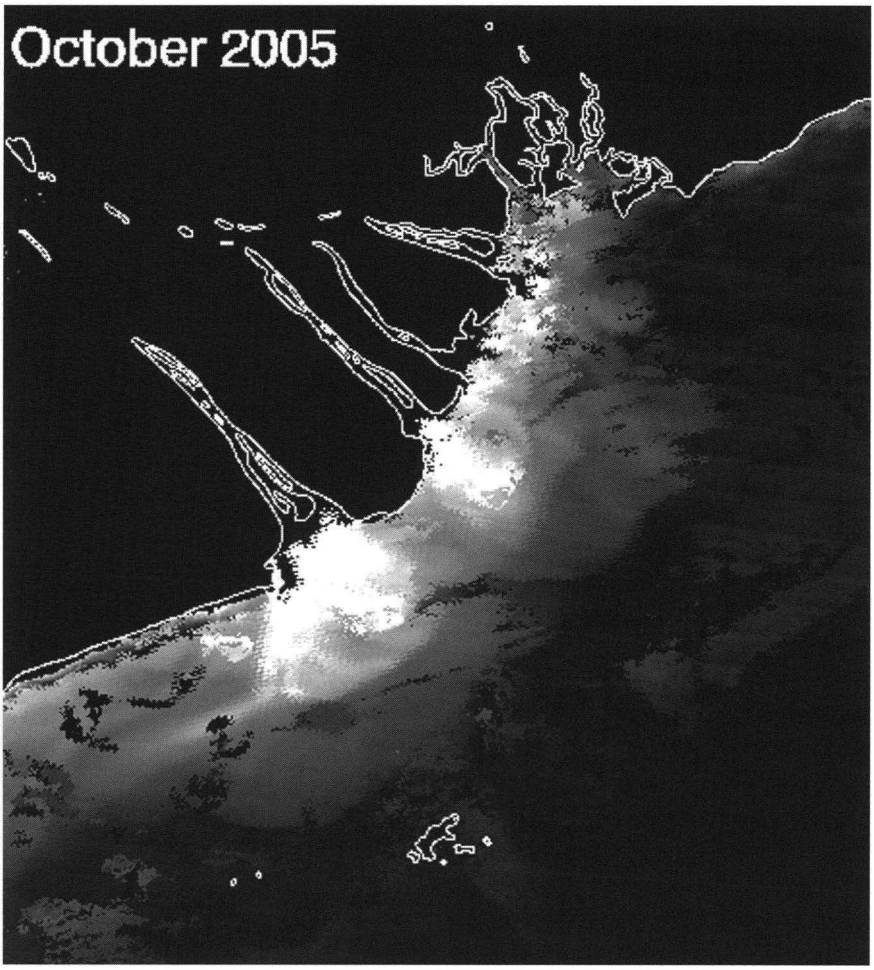

Fig. 4. — Example of a sediment plume off the mouth of the Mekong, October 2005 (previously published in GUPTA *et al.* 2006).

The current land use pattern in the delta can be summarised as settlements and roads on levees and canal embankments; paddy in the depressions that are usually inundated by overbank flows in the wet season (fig. 5); depleted *melaleuca* forestry in certain areas (particularly in Ca Mau Peninsula, Long Xuyen Quadrangle and the Plain of Reeds); mangroves near the coast being depleted for various reasons such as aquaculture, casuarinas, oil palms and settlements on the beach ridges near the southeast coast (fig. 6);

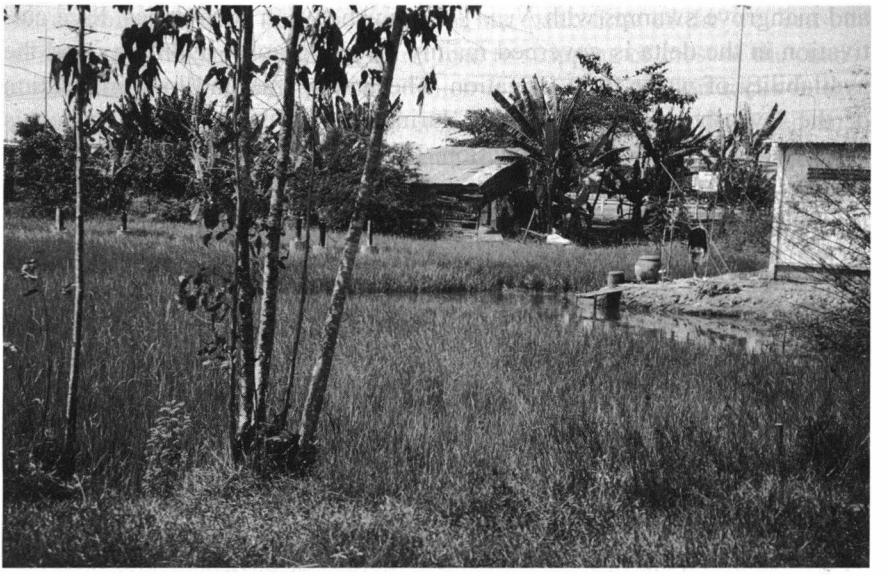

Fig. 5. — Paddy landscape in the inner delta.

Fig. 6. — Sandy beach ridges, outer delta.

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Some Physical and Community Characteristics of the Mangrove in a North Part of Mahakam Delta, East Kalimantan, Indonesia

by

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I. RIDWANSYAH* & S. NOMOSATRIO*

1. Introduction

Delta is a part of an estuary ecosystem, a very dynamic area that is controlled by hydrological regime, combination between high salinity fluctuations and high water mass moving. Variation of estuaries will reflect their temporal and spatial water regime variability. Temporal variability exists on short-time scale coinciding with diurnal tide. On longer time scale it coincides with the neap and spring tide cycle and with fresh water supplies variation from river and runoff (WILSON 1988). Spatial variability exists because of delta system, which enables to form unique water regime pattern on their channels, resulting in variation on material trapping. The different estuary types consequently have different sedimentation regimes (DYER 1986).

In East Kalimantan — Indonesia, Mahakam Delta extends to Makasar Straits, spread from north, Muara (Mouth) Berau, to south, Muara (Mouth) Jawa. Mangrove community develop on those areas, where various environmental conditions influence to their growth. According to LUKMAN *et al.* (2004), there were differences of mangrove conditions between both mouths. Based on dominance of pioneer species, such as *Soneratia* and *Avicenia*, the mangrove community shows a succession level, but regeneration level in Muara Berau seems better than Muara Jawa. That is why the area of Muara Berau was chosen for this research.

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According to THOM (1967), the most important ecological factor in deltaic environment is the microtopographic control over mangrove distribution. So the natural conditions' variations in delta channel of Mahakam River are supposed to influence the mangrove productivity. Therefore the study of the characteristics of the delta Mahakam system and the mangrove productivity is needed as management tool of deltas areas.

2. Methodology

Muara Berau was chosen for this study based on the consideration as stated before. The research was conducted on three stations, namely Muara Saliki (Station Ia, Ib), Muara Berau (Station IIa, IIb), and Muara Kaeli (Station III) (fig. 1).

Water regime was derived from the salinity temporal pattern and water fluctuation in the delta channel for 24 hours, based on three-hour periodically observations. The surface water (0 — 50 cm) salinity was measured using WQC (Water Quality Checker) HORIBA U-10, vertical salinity distribution on specific time was measured by data logger YSI 6000. Water fluctuation was measured using stick manual and compared to tide table in Sungai Kutei (P. Nubi) (Geographical Position: 00°7'S and 117°5'E) (Dinas Hidro-Oseanografi 2005). Sediment sampling, in delta area, was taken by coring the sediment, for determining vertical distribution of sediment fraction. Fraction of sediment was analyzed using *test sieve* and pipette methods (HIDAYAT 1988) for separating and grading the sand, silt and clay.

Mangrove productivity was considered from density of tree, propagation rate and organic (detritus) production from mangrove community. Density of mangrove community counted by line transects method, and the standing divided by density of tree (∅ trunk > 10 cm), belt (∅ trunk between 2 — 10 cm) and seedling (∅ trunk < 2 cm) of mangrove (PUDJOARINTO 1982). Propagation rate was evaluated from distribution of belt and seedling. Organic production counted by trapping detritus production on mangrove community in specific delta areas by using net (2×2 m^2) was set in 24 hours. Detritus was dried on temperature 100 °C to get constant dry weight. Organic sediment was sampled on the same location with sediment sampling. Organic content was determined by ash methods using *muffle furnace* at temperature 600 °C (BUCHANAN & KAIN 1984).

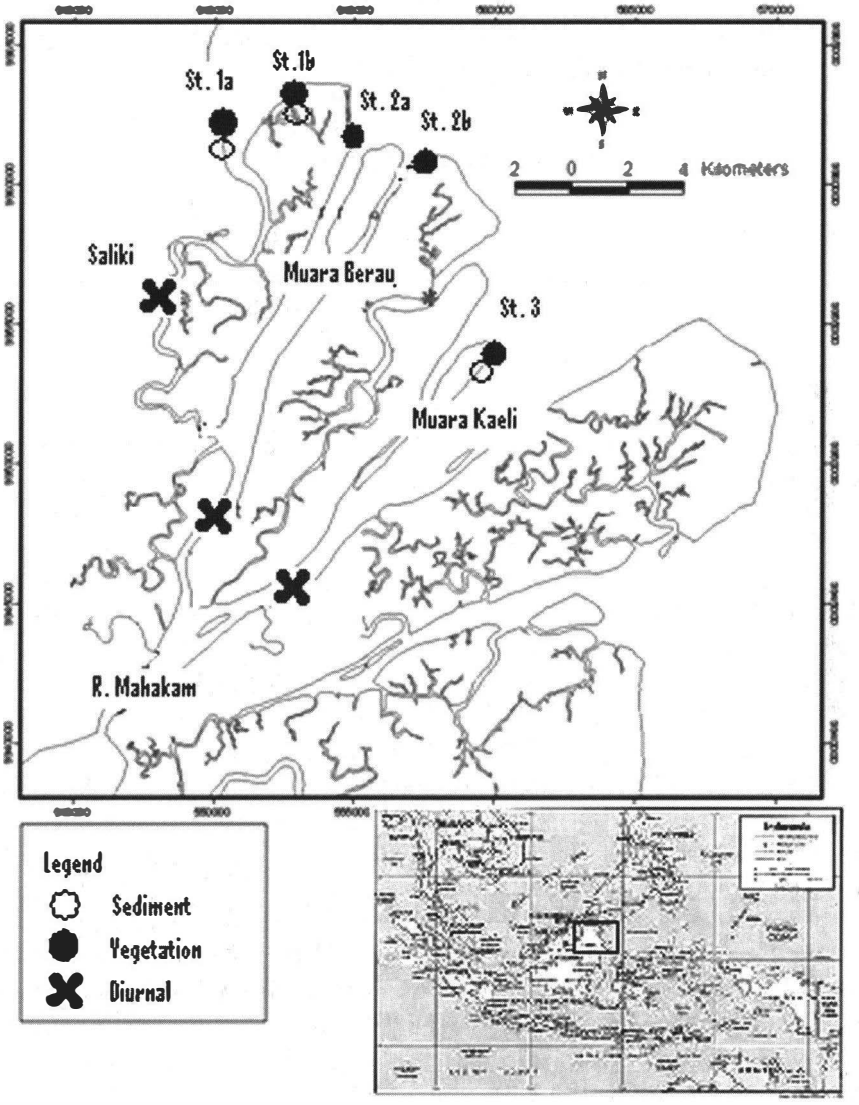


Fig. 1. — Map of Observation Sites in Mahakam Delta.

3. Results and Discussion

3.1. Physical Characteristic of Delta Channel

Maximum diurnal water level fluctuation on three delta channels was ± 2 metres (fig. 2) and depends on tidal pattern in these areas (fig. 3). There were no differences on water level fluctuation among the delta channels. Channel physical condition and river discharge indicate no influence on water level fluctuation.

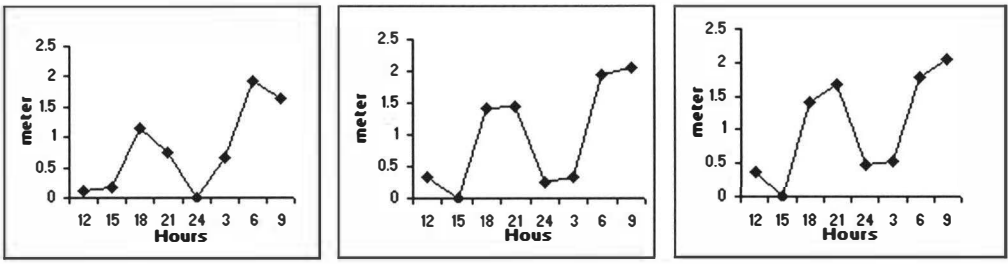


Fig. 2. — Diurnal water level fluctuation based on direct measuring in Muara Kaeli, Muara Berau, and Muara Saliki.

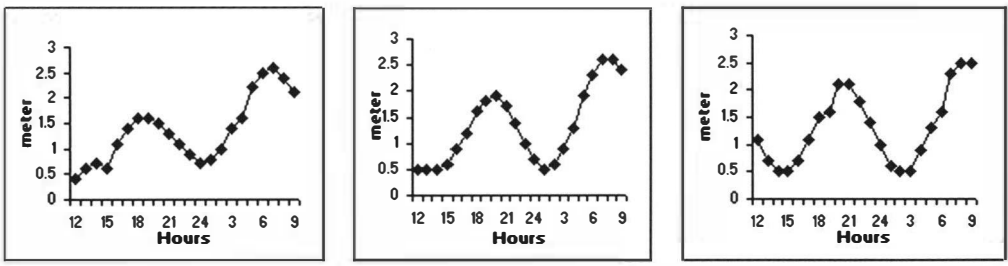
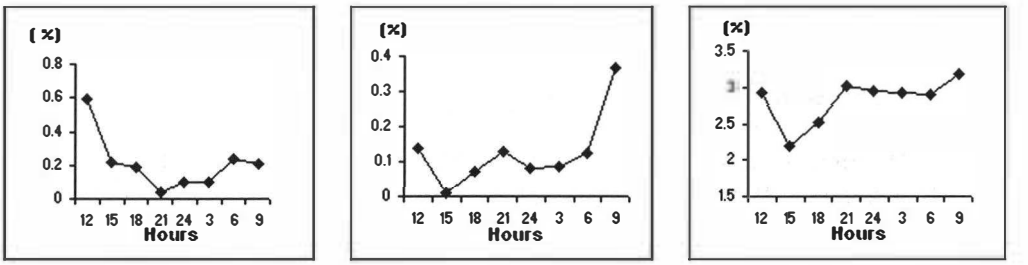


Fig. 3. — Diurnal water level fluctuation at different times in Mahakam Delta based on Tide Tables Indonesian Archipelago, in S. Kutei (Dinas Hidro-Oseanografi 2005).

Although water level fluctuations were similar in three delta channels, the salinity fluctuations of surface water were different (fig. 4). It was clear that salinity fluctuations were between 0,04 — 0,59 %, 0,01 — 0,37 %, and 2,18

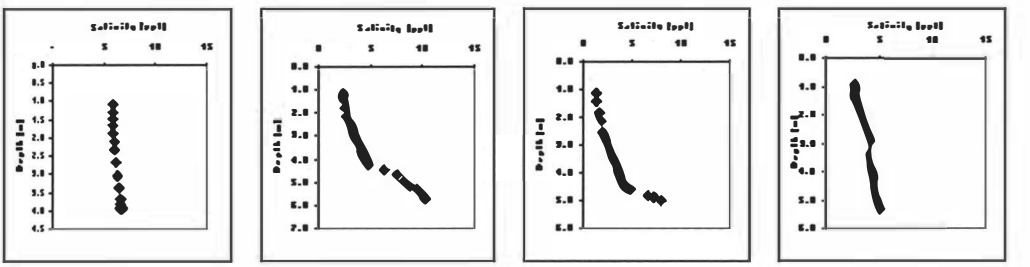


Muara Kaeli Muara Berau Muara Saliki

Fig. 4. — Diurnal salinity fluctuations of surface water in Muara Kaeli, Muara Berau, and Muara Saliki.

— 3,17% in Muara Kaeli, Muara Berau, and Saliki, respectively. Muara Berau and Muara Kaeli are main channels of northern part of Delta Mahakam, where the freshwater masses are dominant; therefore their salinity is low, while Saliki is the tidal river indicated by higher salinity.

Phenomenon of salinity fluctuation in three delta channels was an indication of three types of estuarine. According to PRITCHARD (1965) in SCHUBEL & KENNEDY (1984) the mixing sequence between freshwater and salt water forms a density gradient that results in different estuarine circulation patterns. In Muara Kaeli, the fluctuation of salinity did not depend on water level fluctuation. Therefore Muara Kaeli reflected the estuary type B, the water mass is partially mixed because the river water discharge is well balanced with the tide flow. When the tide flow came, salt water flew to the channel in the bottom part of the channel, while the freshwater from the river tended to lift up to surface (fig. 5).



12.00 18.00 24.00 06.00

Fig. 5. — Vertical salinity distribution at specific times in Muara Kaeli.

Salinity and water level fluctuations in Muara Berau have the same pattern as in Muara Kaeli, however tide rising in Berau did not influence salinity rising. Muara Berau is type A estuary; the river water discharge was dominant and higher than the tide flow. In this type, vertical water mass mixing was very limited which was indicated by high stratification (fig. 6). It was indicated that the freshwater discharge in this channel is higher than at Muara Kaeli, however freshwater mixed well with sea water when the tide came on 21.00 (09.00 pm).

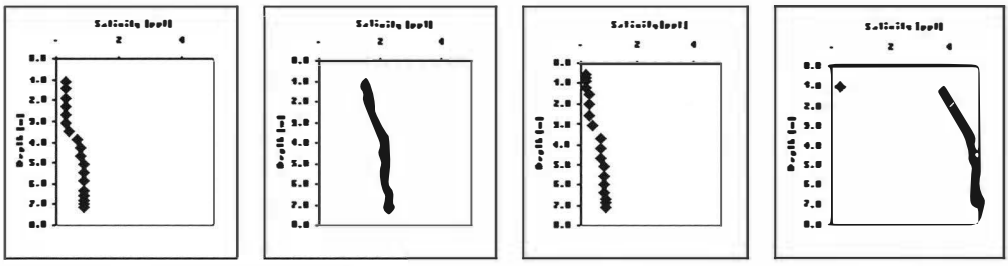


Fig. 6. — Vertical salinity distribution at specific times in Muara Berau.

In Muara Saliki, tide influences salinity fluctuations. Muara Saliki was type C of estuarine as marked by vertically homogeneous water mass, indicated by surface water salinity always at high level. It occurred when the tide flow was higher than the river flow. It was indicated that both at low tide (at 15.00 or 03.00 pm) and at high tide (on 21.00 or 09.00 pm), vertical salinity distribution was relatively homogeneous (fig. 7).

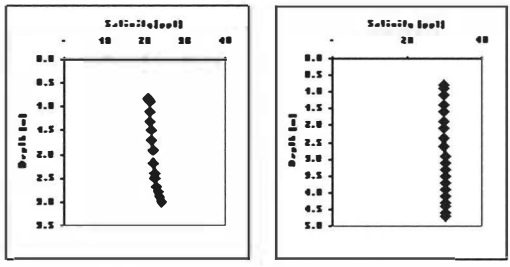


Fig. 7. — Vertical salinity distribution at specific times in Muara Saliki.

Water turbidity fluctuation at the surface in each channel showed different patterns, however in Muara Berau and Muara Kaeli the patterns were similar (fig. 8). Turbidity level in Muara Berau showed the highest fluctuation (45.6 — 361.6 NTU), followed by Muara Kaeli (31.2 — 238.6 NTU), and the lowest was in Muara Saliki (12.0 — 36.4 NTU). Maximum turbidity in Muara Berau and Muara Kaeli happened on the first moving of the tide, but decreased later on. When the tidewater flew to the channel and moved rapidly, then the mixing processes occurred intensively. This is related to river water mass, which was significantly large, especially in Muara Berau. The lower river water mass in Saliki was not influenced by water mass mixing, the level being too low.

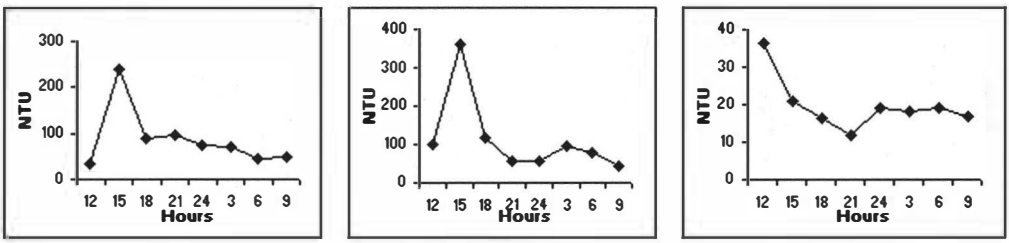


Fig. 8. — Diurnal turbidity fluctuation in Muara Kaeli, Muara Berau and Muara Saliki.

According to LIN & KUO (2003) the bottom resuspension is an important source of total suspended solids in estuary turbidity (maximum), and turbidity (maximum) is mainly generated by tidal pumping.

Sediment characteristics on three locations were representative of the channel delta conditions. Station Kaeli, Berau and Saliki are representative of the Muara Kaeli, Muara Berau and Muara Saliki, respectively (fig. 8).

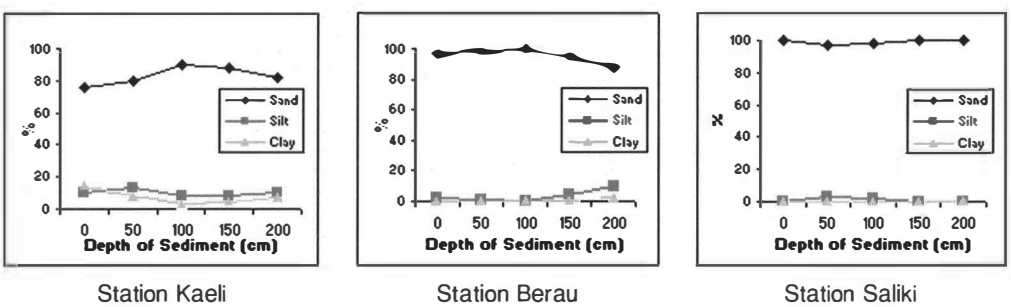


Fig. 9. — Vertical distribution of sediments in three locations of Delta.

Sand in three stations was the dominant fraction, however silt and clay fractions tend to increase from station Saliki to station Kaeli. Minimum river water flow in Muara Saliki, as indicated by the low turbidity level, affected the lower fraction of silt and clay there. Trapping of silt and clay was more effective in Station Kaeli, even if compared to the station Berau, as indicated by higher content of silt and clay fraction than in other stations. It was related to the condition of Muara Kaeli channel, which was influenced by the river flow but the flowing rate seems lower than Muara Berau.

According to BLAKE *et al.* (2002) the transport and trapping of fine-grained sediments are controlled by tidal dynamic, rivers discharges, salinity stratification, flow pattern and particle dynamics throughout the estuarine system. Based on observation in ACE Basin, South Carolina, flocculation processes may play a significant role in trapping fine-grained sediments, and rapid deposition and accumulation of flocculated material is associated with areas of decreased bottom stress (MILLIGAN 2002). It can explain why silt and clay are effectively more trapped in Station Kaeli than in Station Saliki or even in Berau.

3.2. MANGROVE COMMUNITY CHARACTERISTICS

Domination of *Sonneratia* and *Avicenia* in Muara Saliki, Muara Berau, and Muara Kaeli (tab. 1) indicated a young stage of mangrove community in that area. There were found *S. alba* (Station Ia, Ib, IIb, III), *S. ovata* (Station IIa), S. *caseolaris* (Station III), *A. maritima* (Station IIb, III), and the other species was *Bruguiera parviflora* (Station III).

Table 1
Mangrove species in different research stations

Delta Channel	Station	Dominant species	Other species
Muara Saliki	Ia	*S. alba*	*Nypa sp.*
	Ib	*S. alba*	
Muara Berau	IIa	*S. ovata*	
	IIb	*S. alba, A. maritima*	
Muara Kaeli	III	*S. alba, S. caseolaris, A. maritima*	

According to SUKARDJO (1984), *S. caseolaris*, *A. marina* and A. *alba* represent a pioneer community and grow on soft mud of coastal edge or delta. The lower salinity level in Muara Kaeli is suitable for *Bruguiera parviflora*. *Bruguiera* is able to grow on salinity level range up to 25‰ (SUKARDJO 1984).

Mangrove tends to increase from Saliki to Kaeli. It indicated that Kaeli had better condition or higher variation than Saliki.

Based on tree and seeding density of mangrove community it showed that all locations had good conditions, which were 225-567 trunk/ha and 3867-19600 trunk/ha, for tree and seed respectively, but belt density was low (183-675 trunk/ha) (tab. 2). According to WOUTHUYZEN *et al.* (2002), in good mangrove ecosystem, the minimum density of tree, belt and seedling are 260 trunk/ha, 2516 trunk/ha, and 3116 trunk/ha, respectively.

Table 2

Characteristics of mangrove community:
density, detritus production and organic sediments content in Delta Mahakam

Area	Station	Trunk Density			Detritus production (Ton_{DW}/ha/yr)*	Organic sediment content (%)
		Tree (trunk/ha)	Belt (trunk/ha)	Seeding (trunk/ha)		
Muara Saliki	Ia	567	183	3.867	4.18	17.08
Muara Saliki	Ib	458	617	2.133	nd	15.00
Muara Berau	IIa	325	675	10.933	3.94	13.76
Muara Berau	IIb	258	425	10.933	2.82	9.24
Muara Kaeli	III	225	250	19.600	3.05	11.01

* DW: Dry Weight.
nd: no data.

Although the revegetation level is still high, which was marked by high seedling density, the mangrove regeneration rate was degraded, it was indicated by low belt density. The worst condition was shown in station Ia and Ib marked by the lowest seeding density. Characteristics of sediment may influence the revegetation rate, as clay and silt contents were high in Kaeli, it was suitable for mangrove seeding to grow. The observations in Cimanuk delta, Indonesia, showed that seedling of *A. alba* and *A. marina* commonly occur, supported by labile conditions due to high rate of mud sedimentation (SUKARDJO 1982). Both kinds of mangrove have a root system supporting broad stabilization and adapted to extreme salinity fluctuations.

The mangrove conditions also indicated that ecosystem disturbance, in Muara Kaeli, was low while in Muara Saliki it was high. Muara Saliki is near to Muara Badak city where the people activity is high. Besides that, in Saliki village, in upper part of Ia and Ib stations there was a gas port construction.

Detritus production of mangrove community ranges between 2.8 — 4.2 ton dw (*dry weight*)/ha/year, and organic sediment content between 9,2 — 17,1 %

(tab. 2). Mangrove ecosystem is known as a supplier of organic and nutrient to surrounding ecosystem, and density of mangrove trees will support the detritus production. According to SOENARJO (1999) mangrove ecosystem in Kaliuntu, Central Java, supplied the detritus 7.06 — 7.61 ton dw/ha/yr., and the age and species of mangrove vegetation influenced the detritus production. Our data show that the detritus production in north part of Delta Mahakam was lower than in Kaliuntu. From our observations the density of tree influences the detritus production. There was a good correlation ($r^2 = 0.69$) between mangrove tree (∅ trunk >10 cm) density and detritus production (fig. 9). That is why the density of mangrove has to be maintained in order to assure productivity in surrounding area.

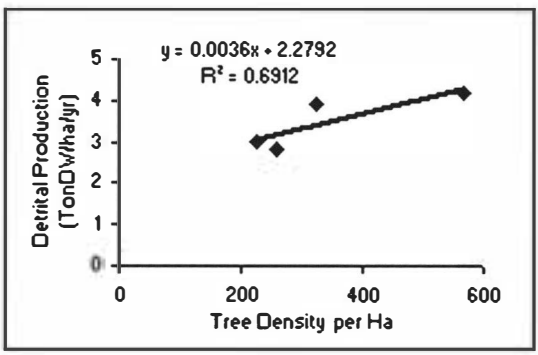


Fig. 10. — Correlation pattern between mangrove trees' (∅ trunk >10 cm) density and detritus production.

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Monitoring Soil Water Logging in the Mekong Delta using Multi-Temporal Radar Satellite Imagery

by

Morgan De Dapper*, Beata De Vliegher** & Christian De Meyer***

1. Introduction

All over the world it is a fact that estuary and delta regions are extremely vulnerable ecosystems. In general, these regions are very fertile and, as a consequence, subject to a high population pressure. Furthermore, this threat is imminent in some developing countries that must expand and intensify the agricultural production because of development and of increasing population. Due to excessive irrigation, this can lead to problems such as saline water intrusion.

The development of the Mekong delta is an urgent matter for the Vietnamese authorities. It is aimed to improve the cultivation of rice in order to meet the food supply for the increasing population and to stimulate the export facilities for rice. The coastal plain of the Mekong Delta is subject to a severe degree of salt penetration through the major rivers (Mekong, Bassac,...) and creeks that infiltrates in the soil. These salty intrusions form a limiting factor for the development of the rice cultivation (from 1 time a year to 2-3 times a year).

In the near future, the Mekong delta will be subject to large infrastructure works, such as deepening and embankment of the river with the aim to: (1) promote navigation (increase tonnage of ships), (2) increase the production of rice, (3) protection against flooding, and (4) creation of employment.

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Important to know is what impacts these infrastructure works and the intensification of the agricultural production will have on the different ecosystems occurring in the Mekong delta.

This paper deals with some of the results of a pilot Project "Study of salt water intrusion, land use and rice production in the coastal plain of the Mekong delta (Vietnam), based upon field work, remote sensing and GIS" financed by the Belgian Federal Science Policy Office. In this project, two partners were involved: a scientific partner being the Ghent University, Department of Geography, and a user partner, HAECON n.v. (Drongen, Belgium).

In the frame of this paper, the results will be discussed for the monitoring of soil water logging using multi temporal satellite data. In areas where flooding is a recurrent hazard, the need is high to simulate in a rather short time the possible impact of environmental changes. This implies the selection of good quality satellite imagery in a minimum time limit. Attention should be paid to the geographical, qualitative and technical suitability of the images.

Information about flooding and land cover changes is obtained through the digital interpretation of ERS [1]* SAR [2] data, in combination with field work.

Two campaigns of field work were carried out: one in the dry season (January-February 1998) and one in the rainy season (September 1998). The first campaign aimed to collect data about water logging and soil salinity, to search for the relation between the occurrence of waterlogged soils and their geomorphologic position in the landscape, and to collect data about land use and land cover. This campaign was mainly focused on three subregions of the delta, more precisely: the area to the northeast of Can Tho, the transect Can Tho — Vin Long and the surroundings of Soc Trang. The second field campaign aimed to collect information for the interpretation of SAR-images and data about water logging, soil salinity, land use and their relationship with the geomorphology.

2. Description of the Study Area

The Mekong delta was subject to several environmental studies: ANON 1993; GAGLIANO *et al.* 1968; NEDECO 1991, 1992, 1993.

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* The numbers in brackets [ ] refer to the notes p. 504.

The present study area is located in the coastal plain of the Mekong, between the rivers Bassac and Mekong (going from Soc Trang to My Tho) (fig. 1).

The entire Mekong delta occupies an area of $\pm 5.9 \times 10^6$ ha, of which one third is located in Cambodia and two thirds in Vietnam. Phnom Penh, the capital of Cambodia, lies near the apex of the delta, 340 km off the coast at an altitude of about 12 m above mean sea level. The Mekong delta is extremely flat with average altitude of 0.8 m a.m.s.l., except for the levees, the coastal ridges and some parts of the *U-Minh* forest. Variations in micro topography largely influence the drainage conditions. Backswamps are located in between the natural levees and are used as basins for excess water during periods of floods.

The Mekong delta is under the influence of the monsoon, with a very pronounced seasonal variation for wind, rainfall and cloudiness. Winds for summer and winter blow from opposite directions: from the NE during the winter and from the SW during summer. Rainfall varies between 1,270 mm to more than 2,030 mm.

The climatic regime in the Mekong is characterized by a regular yearly cycle, with a dry season lasting from November to the beginning of June, followed by a period of flooding. The onset of the Southwest-monsoon takes place in May-June and the peak is reached in September-October. The lowest water levels are observed during the months of April-May.

The *Grand Lac* (Great Lake), approximately 70 km to the NW of Phnom Penh acts as a buffer that controls the flood of the Mekong River. The volume of the Great Lake is about $\pm 40{,}000 \times 10^6$ m^3, corresponding to nearly one tenth of the yearly water supply of the Mekong river. The *Tonle Sap* branches off the Mekong River, diverting the water to the Great Lake in periods of high discharge, and subtracting water from the Great Lake when discharges are diminished.

The Mekong delta is built up of:

— Alluvial soils with a high natural fertility and no limitations.
— Acid sulphate soils with toxic elements, such as S, Al^{3+}, Fe^{2+} and Fe^{3+}. These soils mainly occur in depressions near to the Plain of Reeds, in the vicinity of Long Xuyen and in some parts of the Ca Mau peninsula.
— Saline soils.
— Others: peat soils (*U Minh* forest), Greysols and soils developed on weathered granite.

The delta is known as the rice-bowl of Southeast-Asia. The main rice seasons in the delta are listed in table 1.

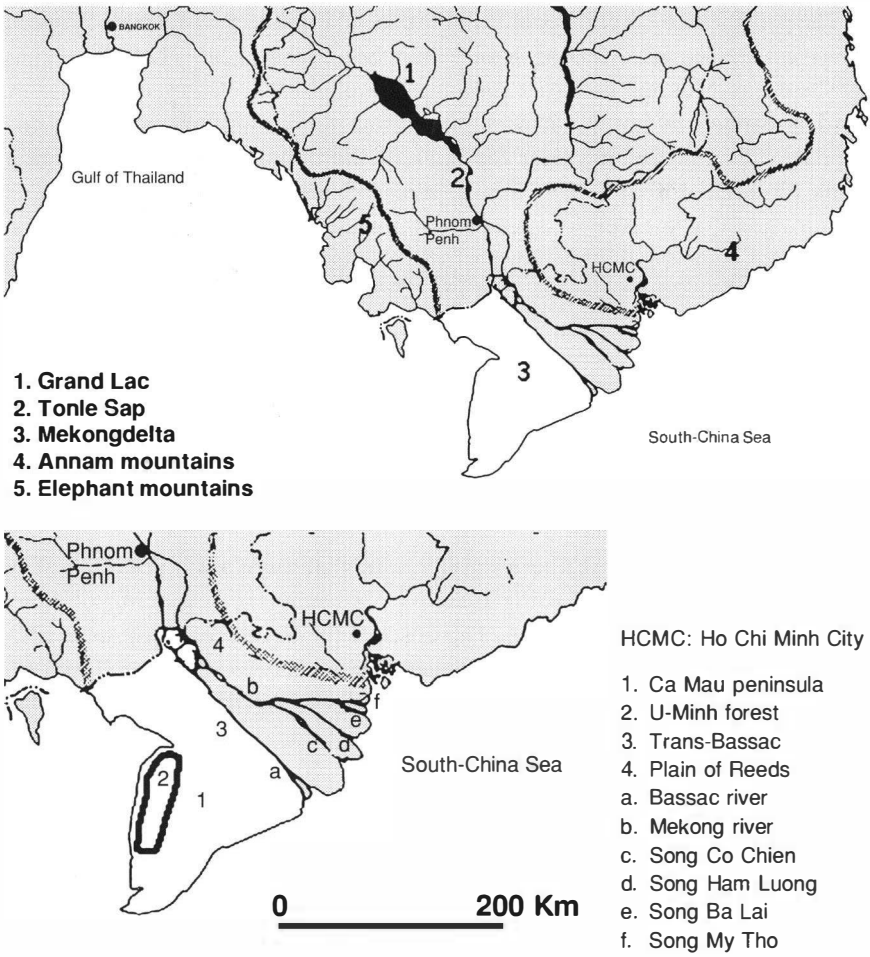

Fig. 1. — Overview of the Lower Mekong-basin.

Table 1
Main rice seasons in the Mekong delta (LIEW *et al.* 1998)

Rice Crop	Local Name	Variety	Planting Method	Planting	Harvest
Winter-spring	Dong Xuan (DX)	Modern	Direct seeding	Nov/Dec	Feb/Mar
Summer-autumn	He Thu (HT)	Modern	Direct seeding	May/Jun	Aug/Sep
Rainy season	Mua (M)	Traditional	Transplanting	Jul/Aug	Dec/Jan
	Thu Dong (TD)	Modern	Direct seeding or transplanting	Sep/Oct	Nov/Dec

The rice-based cropping systems vary according to local differences in hydrology, soil, rainfall pattern and the application of irrigation. The main rice-based cropping systems are: single rainfed rice, double rainfed rice, double irrigated rice, triple irrigated rice and a combined system rice-shrimp. One harvest per year is practiced in the coastal fringes where saline water intrudes at the end of the dry season or in areas where soils are permanently saline. A triple harvest can be obtained in areas with favorable hydrological condition and where irrigation is possible.

3. Benefit of Radar Images for Monitoring Waterlogging and Flooding

To study hydro-sedimentation, remote sensing documents can be of great use. The large variety of documents is very appropriate for different applications. It is thus of high importance to make the right choice in order to meet the aims of the research and take into account the regional aspect.

In the case of optical data, studies in humid tropical regions are often limited by the high degree of cloudiness — especially in the rainy season. This project aimed to develop an operational procedure and therefore cannot depend on "cloud free" days. In this case, radar images, with their capacity to penetrate the clouds and to obtain information over cloud covered areas day and night, can help. Although radar images are strongly influenced by the topography (*lay-over* and *foreshortening*), this factor can be neglected for the Mekong delta.

Pixels in SAR images have an intensity that represents the proportion of microwave that has been backscattered by the object. This backscattering depends on different factors, such as type, size, orientation of the objects in the target area, the moisture condition, the frequency and polarization of the radar pulses and the incident angle. In general it can be said, that the higher the intensity of backscattering, the rougher the surface is. The incident radar pulse can be reflected in different ways according to the type of surface:

— In the case of smooth surfaces, the radar pulse will be reflected specular and very little energy is scattered back to the radar sensor.
— Rough surfaces will reflect the radar pulse in different directions (diffused reflection), and part of the energy will be scattered back to the radar sensor. The amount of backscattering will depend on the characteristics of the surface.

The amount of water present in the soil will affect the backscattering: moist soil will result in higher backscattering as compared to dry soils where

part of the radar energy can penetrate into the soil surface. In the case of submerged soils, the surface acts as a specular reflector.

Changes in humidity and land cover can be monitored using a multi-temporal dataset of SAR images.

ERS SAR PRI data were used by NGUYEN THANH LONG & BUI DOAN TRONG (2001) to monitor the 1996 flooding in the Mekong delta. They selected a five-image data set covering the period before, during the flooding. The images were combined into a multi-temporal color composite, where changes on the earth surface are reflected into different colors. Two components of color were interpreted, the hue as an indicator of the period when change occurred and the intensity of the color as a reflection of the degree of change.

IMAZATO *et al.* (1998) selected a time series of Radarsat [3] data for the inundation mapping. The advantage of these images is the capability of the Radarsat satellite to observe at short time intervals (two to five days), as for the SAR that has a temporal resolution of 35 days. They suggest an observation during at least three different times for the mapping of inundation: (a) at the peak of inundation, (b) when the inundation has shrunk to a minimum and (c) the dry period in order to have an idea about the normal extent of the water body.

CHEN *et al.* (1999) used a multi temporal and multi sensor data set, comprising Radarsat images, ERS-2 PRI images and SPOT [4] multi spectral images. The radar images (Radarsat and ERS-2 PRI) were used to delineate the flooding; the optical data of SPOT were used to evaluate the results. They mention the restricted availability of ERS-2 data (35 days repeat cycle) as a drawback for near time monitoring.

Multi temporal ERS SAR data were used by LIEW *et al.* (1997) to delineate rice cropping systems. They created change index maps out of each pair of consecutive images. Applying a threshold of 3 dB, the change index maps were classified into three categories: increasing, decreasing or constant backscattering. A combination of five change index maps generated a composite map with 35 possible change classes that could be translated into classes of rice cropping systems. An analogue procedure has been described by BALABABA *et al.* (1997).

For this study, four images are selected that were recorded:

— At the end of the dry season / beginning of the rainy season: May 25, 1997;
— In the rainy season: August 3, 1997;
— At the end of the rainy season — with maximum extend of inundation in the lower delta: October 12, 1997;
— At the beginning of the dry season: December 21, 1997.

4. Methodology and Discussion

The calibration of the four radar images is done according to the procedure described in the *ESA-publication, document n° ES-TN-RS-PM-HL09, Issue 2, Rev. 4 (May 1997), using the formula*

$$\sigma^o = \left(\frac{1}{N} \sum_{i,j=1}^{i,j=N} DN_{ij}^2 \right) \times \frac{1}{K} \times \frac{\sin \alpha}{\sin \alpha_{ref}} \times C \times \frac{\text{Product Replica Power}}{\text{Reference Replica Power}} \times \text{Powerloss}$$

with

$\sigma°$: a measure for the backscatter coefficient for all pixels DN_{ij},
α_i: the average incident angle,
K: the calibration constant, specific for the type of product and processing station (in this case K = 944000),
α_{ref}: the reference incident angle (23°), and
C: the antenna-height (For the Esrin station, with processing datum later than 16 October 1995: C=1).

The Power Loss is due to the analogue to digital conversion. This varies between 0.97 en 1.03. Because of the needs to adapt the program and the necessary calculation time, this term has been neglected and put to 1. Herewith, errors are inserted with magnitude of ± 0.1-0.2 dB.

The backscatter coefficient is expressed in decibels:

$$\sigma^o{}_{(dB)} = 10 \log 10 \sigma^o$$

After the calibration, the SAR images are geo-referenced into the UTM [5] co-ordinate system — zone 48 (eastings/northings), horizontal datum: Indian 60, ellipsoid: Everest. The images are resampled with a resolution of 30 m, using a second degree transformation (resampling: Nearest Neighbour, rectification type: Polynomial, polynomial order: Quadratic).

The four selected SAR-images are shown in figures 2 to 5. At the end of the dry season-beginning of the rainy season, the backscatter of the various land surfaces is moderate to high. Exceptions to this are the mangroves with their reduced backscatter of the incident radar pulse. These mangroves are represented as a black, thick line at the edge land/sea. The massive, dark grey patch to the southwest of Soc Trang is a depression. With time, the backscatter coefficient reduces for most of the study area: at first (August), near to the coast and in a later stage (October) more inland. The bright spur in the Bassac River indicate the high turbidity in the water.

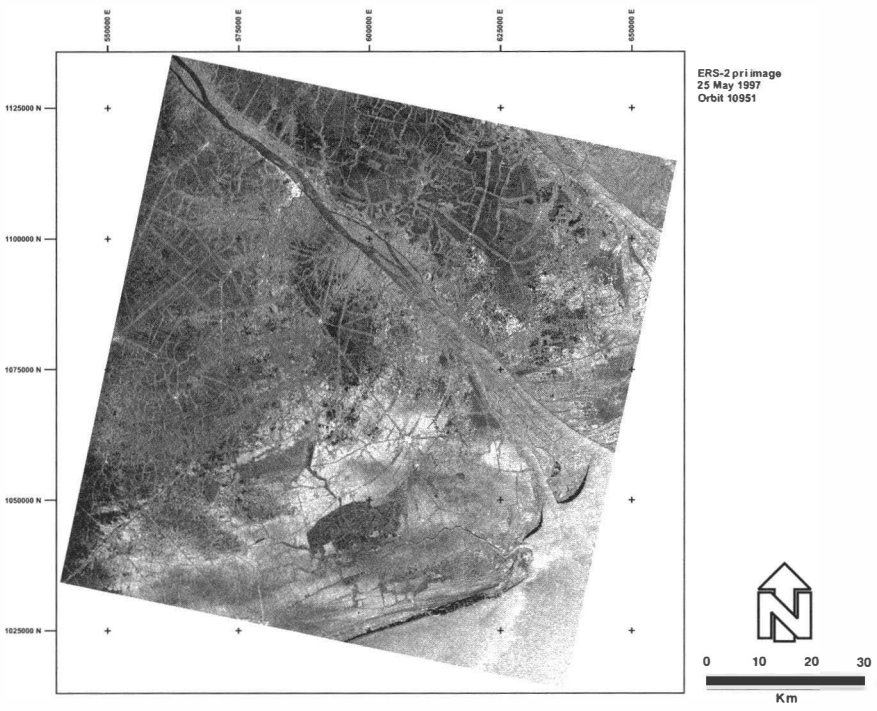

Fig. 2. — End dry / beginning rainy season.

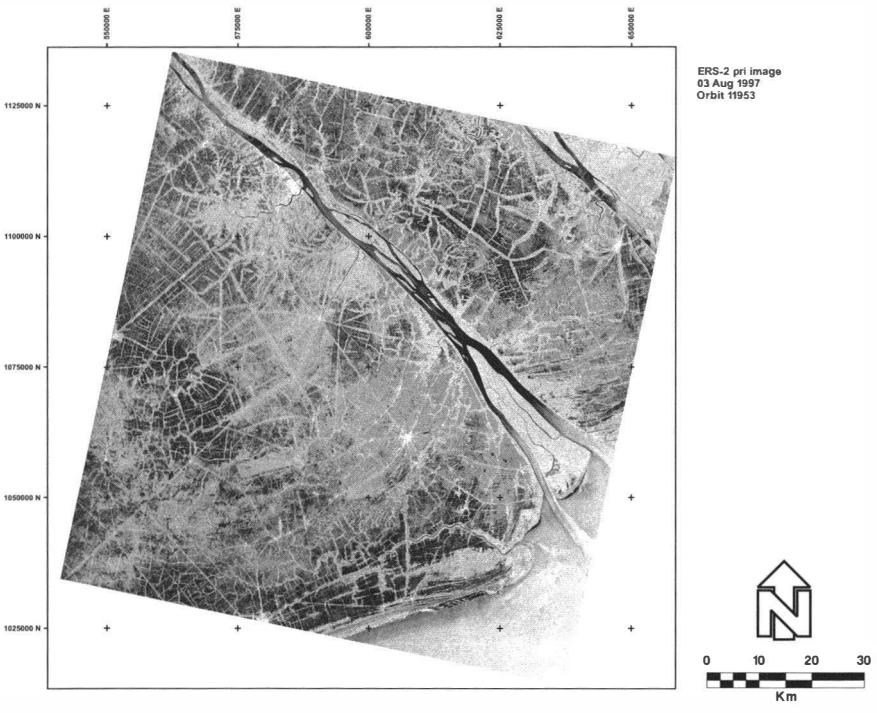

Fig. 3. — Rainy season.

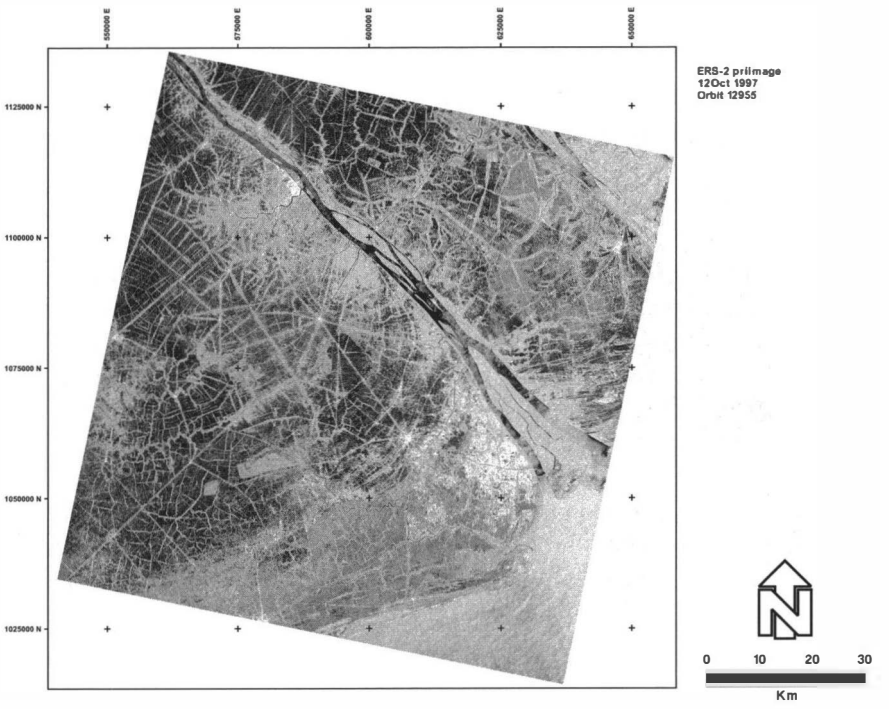

Fig. 4. — End rainy season.

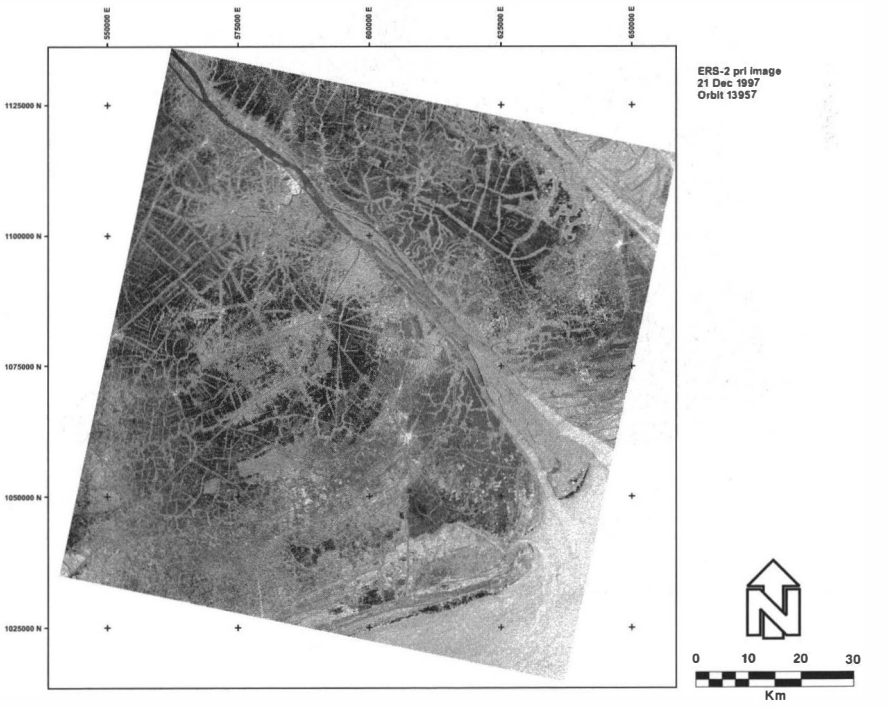

Fig. 5. — Beginning dry season.

As an example, three SAR-images are combined into a color composite, where the August image is rendered in red, the October image in green and the December image in blue. The resulting composite is shown in figure 6*. The different colors indicate different stages of land inundations and/or different land cover types. As mentioned earlier, the Mekong delta is a prime supplier of rice; different cropping systems are applied. The primary colors in this image indicate the period with the highest backscatter. Areas where no change in land cover is observed are given in grey color. Zones with high backscatter throughout the period of observation appear as white patches, as it is the case for the towns of Can Tho and Soc Trang. These patches can easily be distinguished on the four B&W images.

Using the multi temporal ERS-2 data set, changes in humidity and land cover can be monitored through (1) a *density slicing* or (2) calculation of *change indices* for consecutive pairs of images (LIEW *et al.* 1997, 1998).

Figure 6

* Color figures: cf. power point presentation on CD-ROM.

4.1. Density Slicing of ERS-Images

Based upon the σ_o-values, 10 classes are distinguished with equal interval (interval of 3 dB) (tab. 2). For each image, an identical slicing is applied.

The resulting images are shown in figures 7 to 10. It is clear that the image of May is dominated by classes represented in green and orange, *i.e.* σ_o values varying between -12 and -3 dB. With time, a considerable extent of the class in blue color (σ_o values between -18 and -12 dB) is present and indicate situations where conditions are more humid. In August, this increase in humidity is observed near to the coast and more upstream in October. The October-image illustrates the period of maximum extent of water logging. Areas that are situated more inland become wetter or are inundated (see following paragraph). Drying of soils can be seen in the December image.

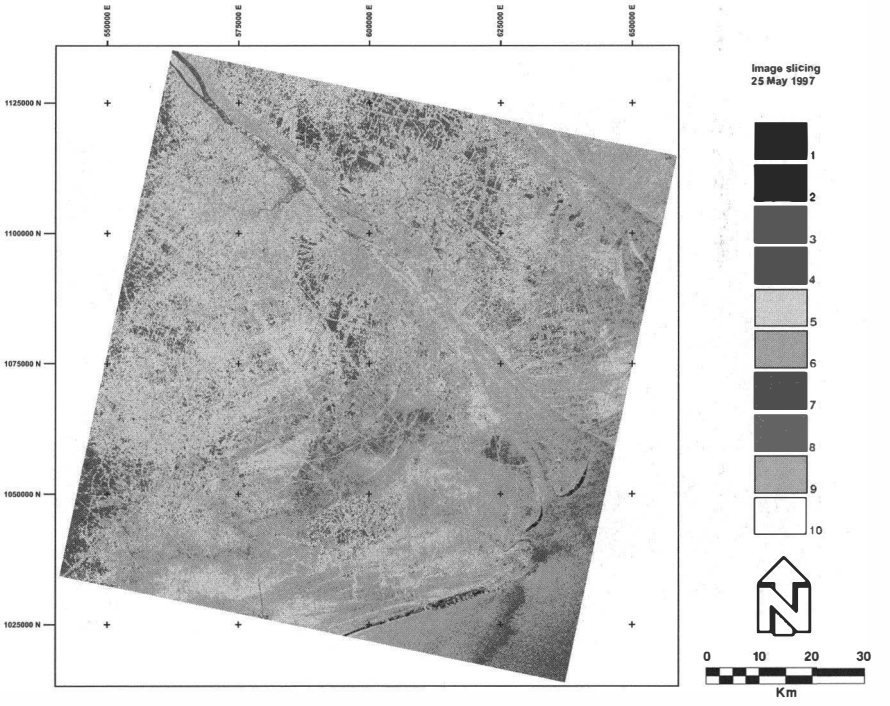

Figure 7

Table 2
Classification of σ_o-values (ERS-2 images)

Class	**Interval** (dB)
1	< -18
2	-18 — -5
3	-15 — -12
4	-12 — -9
5	-9 — -6
6	-6 — -3
7	-3 — 0
8	0 — 3
9	3 — 6
10	> 6

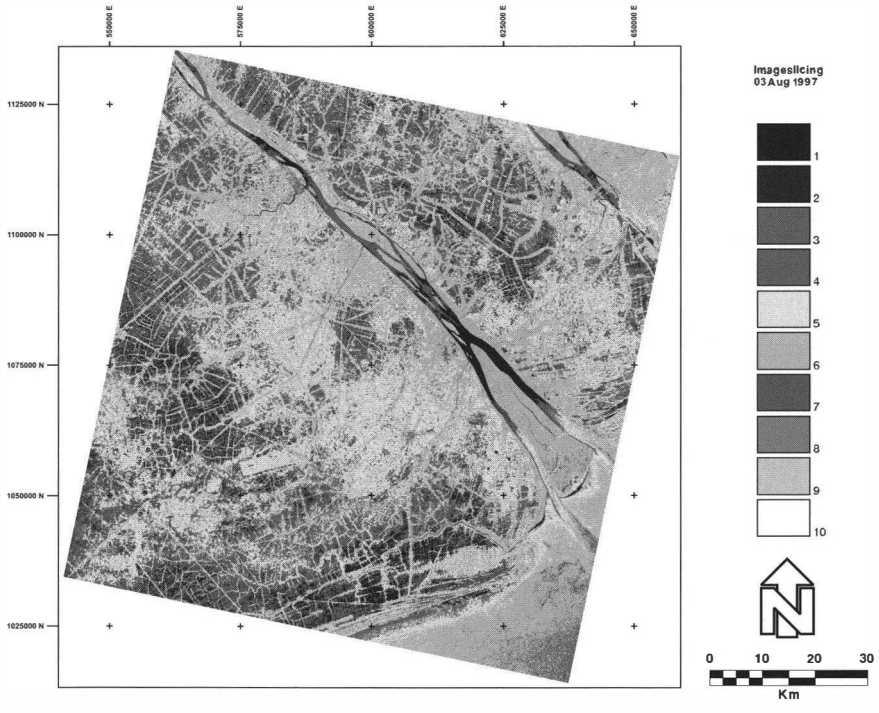

Figure 8

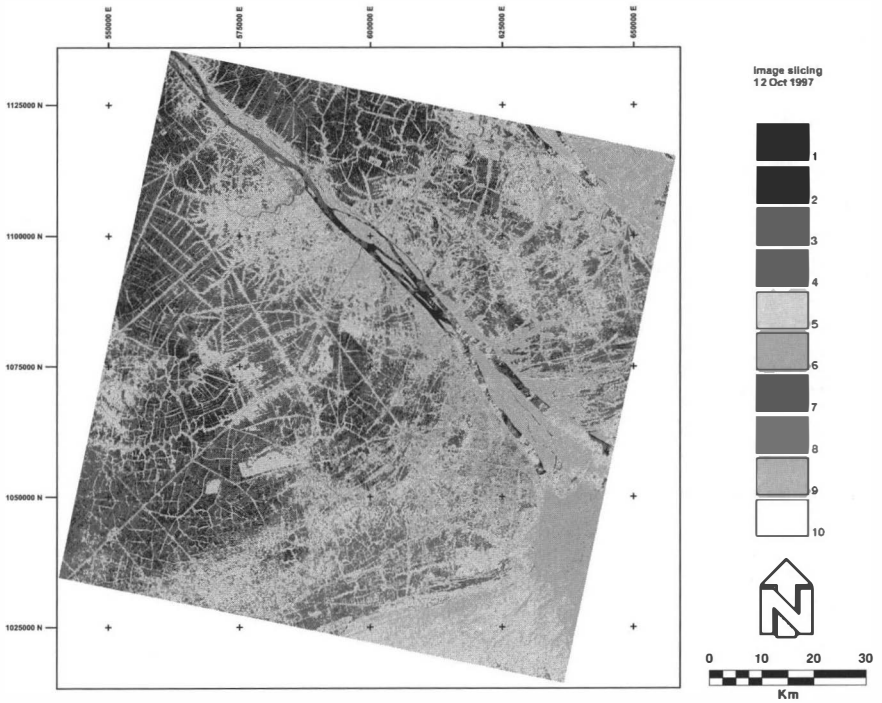

Fig. 9. — End rainy season.

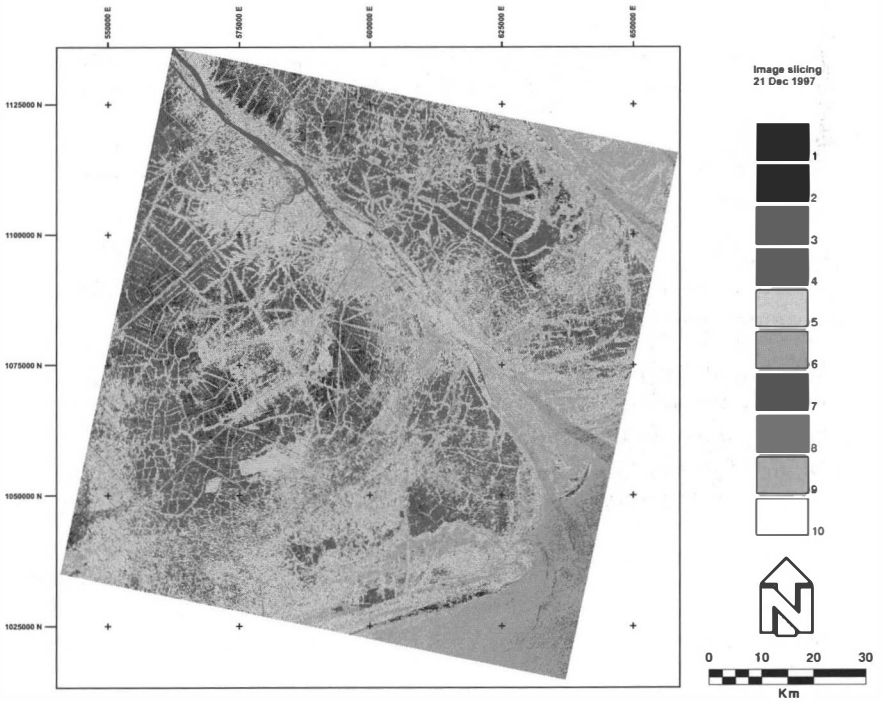

Figure 10

4.2. Calculation of Change Indices

To emphasize the difference between two consecutive images, it is recommended to calculate change indices (Liew *et al.* 1997, 1998). The change index (CI) is defined as the change in the backscattering coefficient expressed in dB. To calculate the change index, following formula is used:

$$CI\ (dB) = 10 \times \log (DN2/DN1)$$

or

$$CI\ (dB) = 10 \times \log DN2 - 10 \times \log DN1$$

with:

DN1: digital value for period 1, and
DN2: digital value for period 2.

In case that DN1 < DN2, thus period 1 is more humid than period 2, than CI is positive: it becomes drier.

In case that DN1 = DN2, thus comparable conditions of humidity, than $CI \approx 0$

In case that DN1 > DN2, thus period 2 is more humid than period 1, than CI is negative: it becomes wetter.

To define changes in humidity, a threshold of 1.5 dB is taken. This means that for

— CI < -1.5	?	becomes wetter in period 2. Values are reclassified as 1.
— -1.5 < CI < 1.5	?	status quo. Values are reclassified as 128.
— CI > 1.5	—	becomes drier in period 2. Values are reclassified as 255.

A change index is calculated for August/May, October/August and December/October. The change index maps are given in figures 11 to 13. The three classes are shown in:

— Black: referring to an increase in humidity for period 2 compared to period 1,
— Grey: referring to comparable conditions,
— White: referring to a decrease in humidity for period 2 compared to period 1.

It can be concluded that:

— For the index August/May (fig. 11): covering the first part of the rainy period, a general decrease in backscatter and thus a strong increase in

more humid areas can be observed. This is especially the case in the area near Soc Trang. It are only linear features corresponding to the canals, the along side roads, adjacent settlements and associated trees that show similar backscatter coefficients for both periods. These lines appear in grey.

— For the index October/August (fig. 12): both images are recorded in the rainy period. A strong increase of humid areas is observed for the inland regions. This is due to the flow pattern in Tonle Sap (fig. 14). This makes that the period of maximum flooding extent in the lower delta is post-poned and highest water levels are measured during the months October/ November.

— For the index December/October (fig. 13): in general, drier conditions.

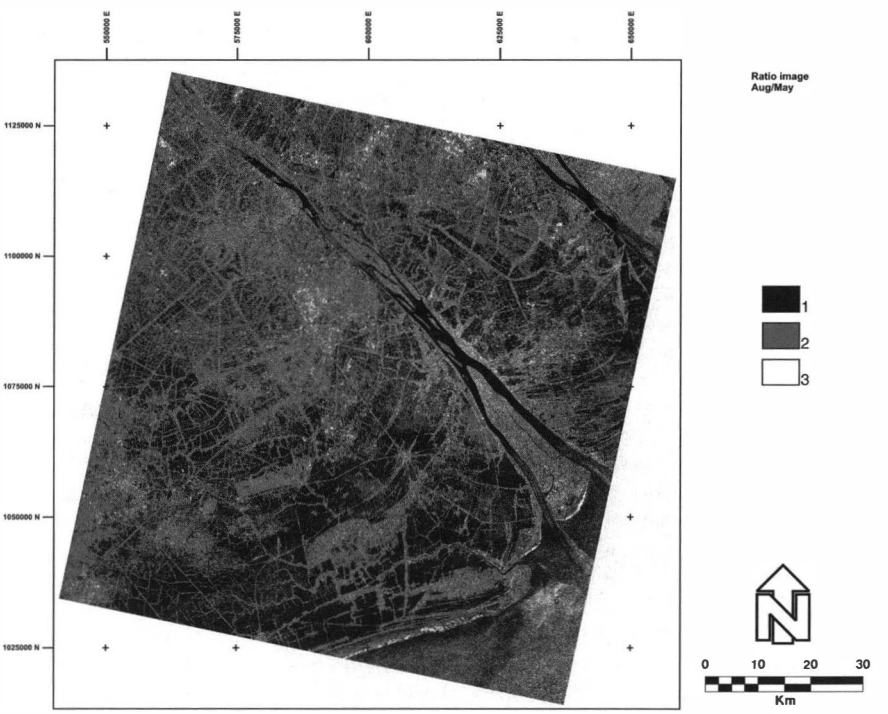

Figure 11

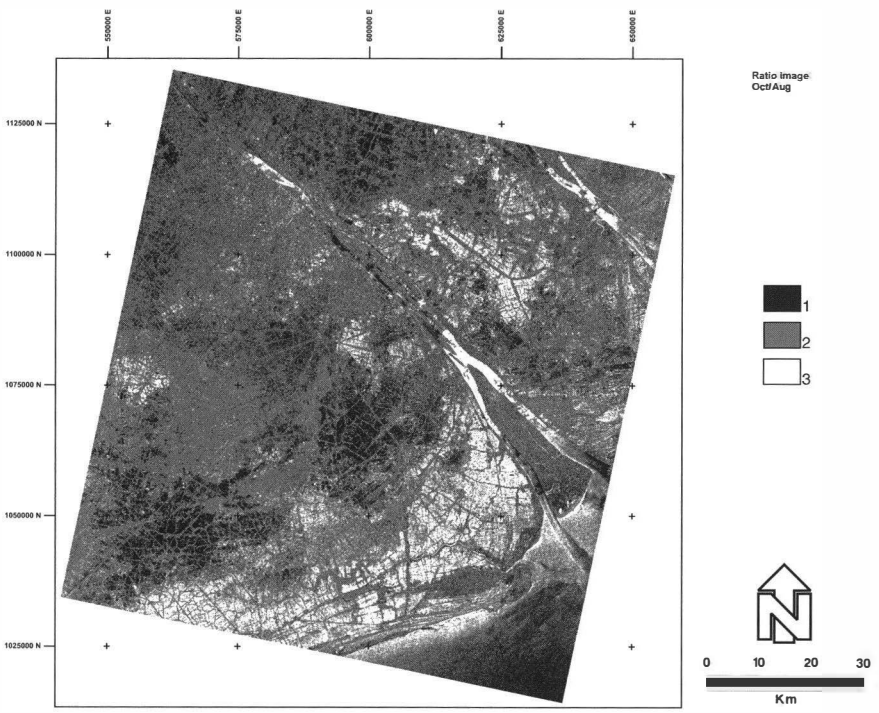

Figure 12

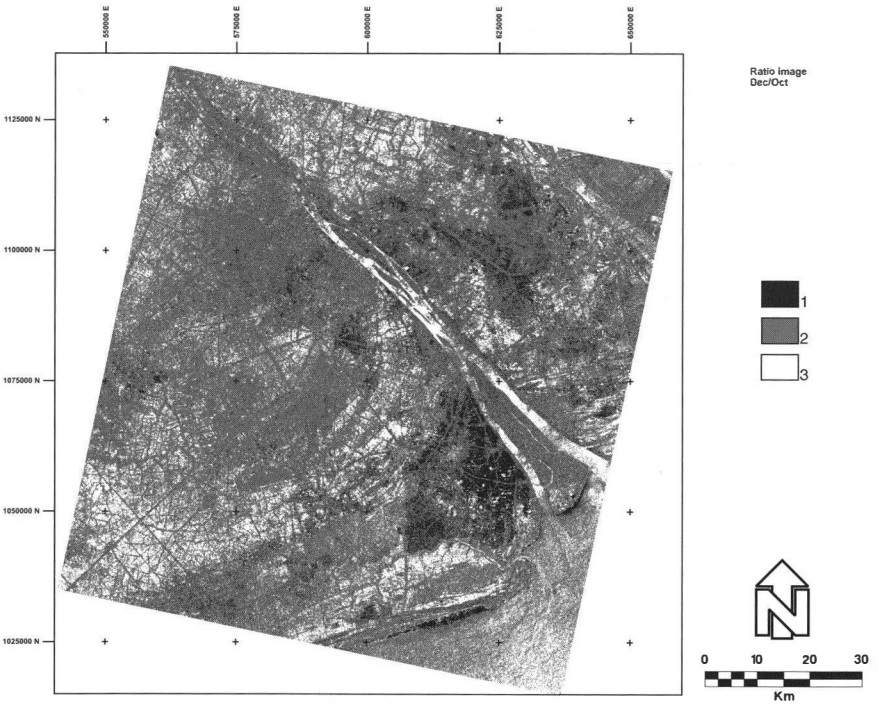

Figure 13

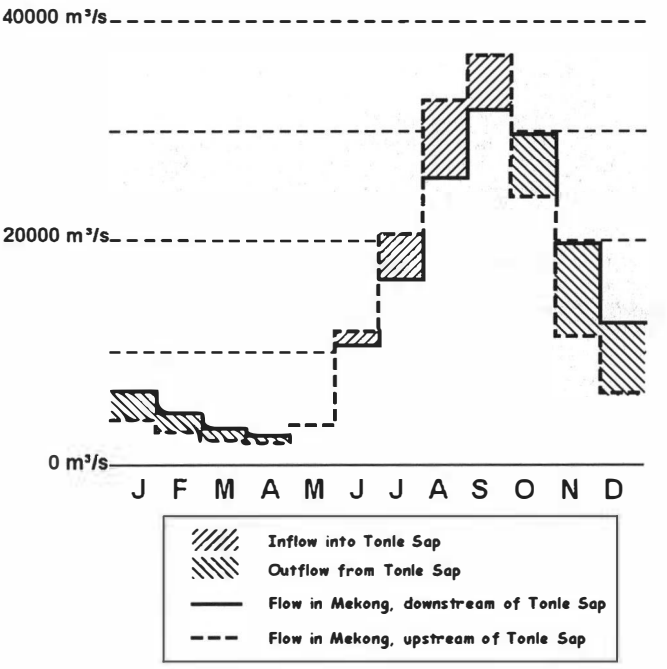

Fig. 14. — Influence of the Tonle Sap (Kampuchea) on the downstream flow of the Mekong River (NIELSEN 2000).

4.3. MONITORING OF INUNDATIONS AND SOIL WATER LOGGING (MAY-DECEMBER 1997) RELATED TO LAND USE AND LAND COVER

The different change indices can be combined into one color composite, holding the information of four images in one single image. This composite image as shown in figure 15 includes:

— the change index for August/May rendered in blue,
— the change index for October/August rendered in green, and
— the change index for December/October rendered in red.

As mentioned above, a threshold of 1.5 dB is taken as change indicator. The combination of the three change index images results in maximum 27 (= 3^3) change classes. Each class is characterized by its unique backscatter signature with time.

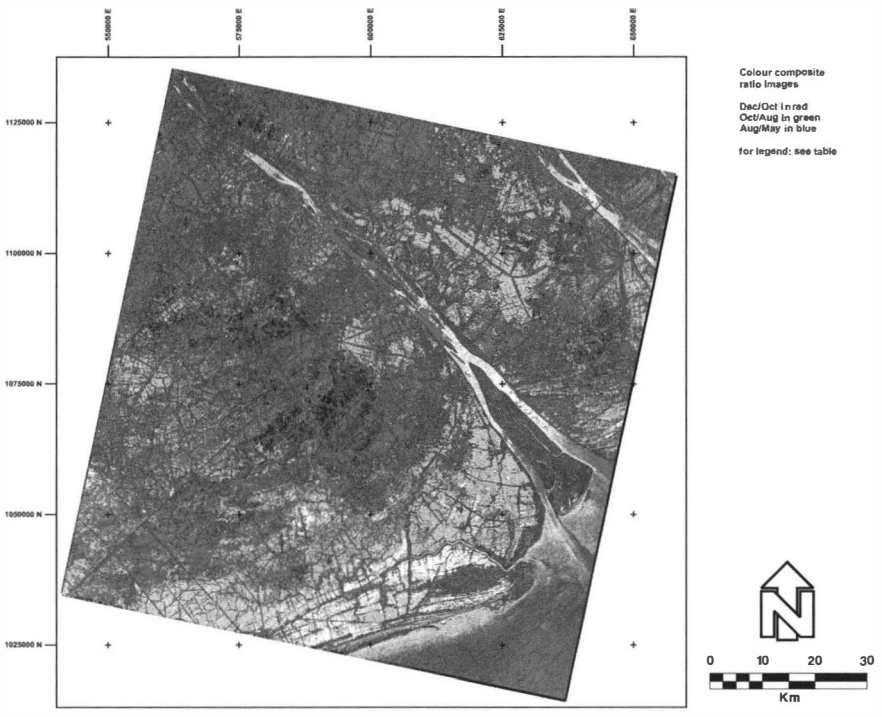

Figure 15

The interpretation of the colors can be made using a color cube, describing each color as a combination of the three primary colors: red, green and blue. With reference to the color cube (fig. 16), the colors in figure 15 are translated in terms of the change index code (▼: CI negative/becomes more humid, ≈: CI status quo, ▲: CI positive/becomes drier) (tab. 3). The triple values in the change index code correspond with the portion of red, green and blue in the RGB color model on a 255-scale.

For the interpretation of the colors in terms of flooding, soil water logging and land cover/land use, three sources are consulted, which are: the field information, LIEW *et al.* (1997, 1998) and the land use map (1995) [6]. The most important classes on the land will be discussed.

Class 5, limited to the coastal fringe and indicates the areas covered with mangrove.

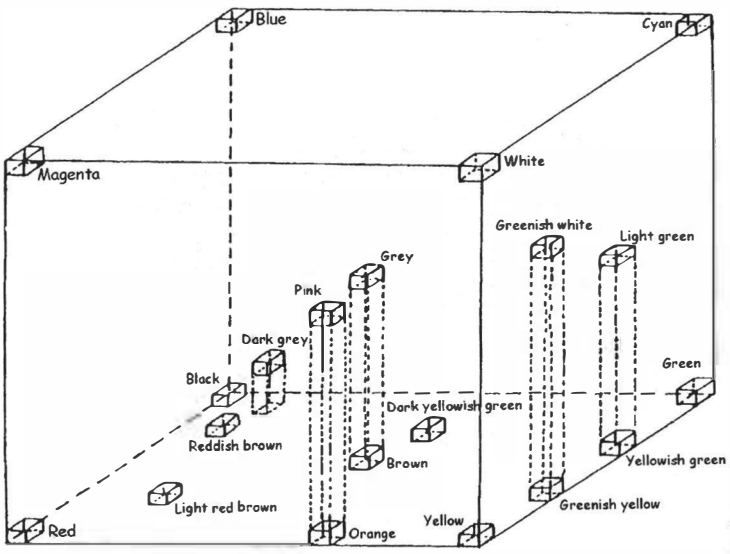

Fig. 16. — Color cube.

Class 6 and Class 23. Both classes indicate areas with a mixed cropping system in the region of Soc Trang. Near to Vinh Long, the green color represents areas with a triple rice cropping system.

Class 9, characterized by a drop in backscatter for the period May-August and an increase for the period August-October. This class indicates areas with a double rainfed cropping system (Summer-Autumn, Mua).

Class 11 and Class 25: Irrigated double crop (Winter-Spring and Summer-Autumn). The areas are low lying and subjected to flooding at the end of October. The second crop is planted in early April and harvested in July. The fields remain fallow till the beginning of December.

Class 13, also related to the linear structures. This class shows a similar backscatter profile as for the class 16, except for the period October-December when a drop in backscattering is noted indicating more humid conditions.

Class 14, characterized by a reduction in backscatter during the period August-October. The lands are not severely affected by flooding during the rainy season and are used for a mixed cropping system. The Summer-Autumn rice is planted in May/June, so that it takes maximal benefit from the rains. The drop in backscatter for the period August-October indicates the flood peak. This class is also found near to the linear structures (settlements), where a combination of sugarcane and rice is cultivated.

Table 3
Interpretation of CI-values

Color number (Class)	Change index code			Humidity			Number of pixels
	Dec/Oct (Red)	Oct/Aug (Green)	Aug/May (Blue)	Dec/Oct	Oct/Aug	Aug/May	
0	0	0	0	▼	▼	▼	53470
1	128	255	128	≈	▲	≈	15850
2	255	128	128	▲	≈	≈	71748
3	128	0	255	≈	▼	▲	211216
4	128	0	0	≈	▼	▼	140720
5	0	255	255	▼	▲	▲	16270
6	0	255	0	▼	▲	▼	1177516
7	255	0	128	▲	▼	≈	1206775
8	128	255	255	≈	▲	▲	4121
9	128	255	0	≈	▲	▼	813476
10	255	128	255	▲	≈	▲	3565
11	255	128	0	▲	≈	▼	585875
12	255	255	128	▲	▲	≈	4717
13	0	128	128	▼	≈	≈	315831
14	255	0	255	▲	▼	▲	213779
15	255	0	0	▲	▼	▼	1862234
16	128	128	128	≈	≈	≈	2492176
17	0	0	128	▼	▼	≈	22453
18	128	0	128	≈	▼	≈	381642
19	255	255	255	▲	▲	▲	1494
20	255	255	0	▲	▲	▼	630594
21	0	128	255	▼	≈	▲	60378
22	0	128	0	▼	≈	▼	109870
23	0	255	128	▼	▲	≈	100363
24	128	128	255	≈	≈	▲	59054
25	128	128	0	≈	≈	▼	582692
26	0	0	255	▼	▼	▲	29218

▼ — decrease in backscatter (wetter conditions); ▲ — increase in backscatter (drier conditions); ≈ - status quo.

Class 15. Close to Soc Trang and to the WSW of Phung Hiep, this class indicates areas with a double crop system: rainfed summer-autumn rice and Mua. The backscatter profile shows two drops during the period May till

October. These areas are low lying and the fields are flooded in June. The increase in backscatter during the period October-December is due to the Mua crop.

Class 16, shown in grey color. Typical for this class is that the backscattering is nearly constant throughout the year, indicating areas that have a rather homogeneous land cover in time. This class comprises areas with a dense tree canopy, such as forests, mixed orchards, or towns and settlements. The grey color is frequently found as linear structures, indicating the canals, the alongside roads and linear settlements and adjacent gardens.

Class 20, found in areas where a single crop (rainfed Mua) is practiced. The backscatter time series shows a sharp drop during the period May-August that corresponds with the start of the Mua crop. This is followed by an increase in backscatter.

5. Conclusions

A multi temporal data set of ERS SAR images is proved to be a useful instrument for the monitoring of inundations, soil water logging and land use/land cover.

Because of their synoptic characteristics and high temporal resolution, satellite images are important documents for the environmental studies. The high degree of cloudiness in rainy periods limits, however, the use of optical data, such as Landsat TM and SPOT, especially in areas with a humid tropical hydrology. Therefore it is recommended to use radar imagery, such as ERS SAR.

Differences in soil water logging and land use/land cover for the period of May till December 1997 have been delineated by calculating the change index for consecutive pairs of images and applying a 1.5 dB threshold. The resulting change index maps were combined in a color composite differentiating 27 ($= 3^3$) classes. The different classes are identified based upon the profile of backscattering during the months May — December. The backscattering characteristics were explained according to the rice cropping system applied and to the land cover characteristics.

It should be mentioned that for the interpretation of multi temporal satellite data, it is recommended to collect data in the field for different seasons (different meteorological conditions). It is advised that the period of field work and the date of image acquisition are coinciding as much as possible. In case this is not possible, the field work should be done during the season in which the image has been recorded.

NOTES

[1] European Remote Sensing Satellite.
[2] Synthetic Aperture Radar.
[3] http://www.rsi.ca/
[4] Système Pour l'Observation de la Terre; Spot Image, Toulouse (France) http://.spotimage.fr/
[5] Universal Transverse Mercator.
[6] Compiled by the Integrated Resource Mapping Centre (IRMC), Ho Chi Minh City (Vietnam) and made available by the Can Tho University, College of Agriculture.

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Mekong River Bank Erosion in Cambodia. A Case Study at Koh Choram (Chrouy Taek Village, Kandal Province)

by

MEN NARETH*

1. Introduction

The Department of Rural Engineering of the Institute of Technology and the Polytechnic School of Hô Chi Minh City were involved in an interuniversity project (PCSIU-2004) financed by the Academic Agency of French-speaking Countries. This project is studying the mechanism of Mekong bank erosion at Koh Choram in Cambodia.

2. Hydrology of the Mekong River

The Mekong River flows over a distance of 4,880 km from the Tibetan Plateau into the South China Sea. The Mekong River Basin (MRB) is situated in different countries: the Yunnan province of China, Myanmar, Laos, Thailand, Cambodia and Vietnam (fig. 1). On a world scale it ranks the 12th for it's length and the 21st for it's basin surface. The annual flow of the Mekong is about 475×10^9 m^3; the main sources are presented in table 1. During the rainy season, the water level rises from June/ July to November/ December; the discharge of that period comprises 85 % to 90 % of the annual flow. Surveys show that the natural resources in the MRB are still in good condition, except for some regions.

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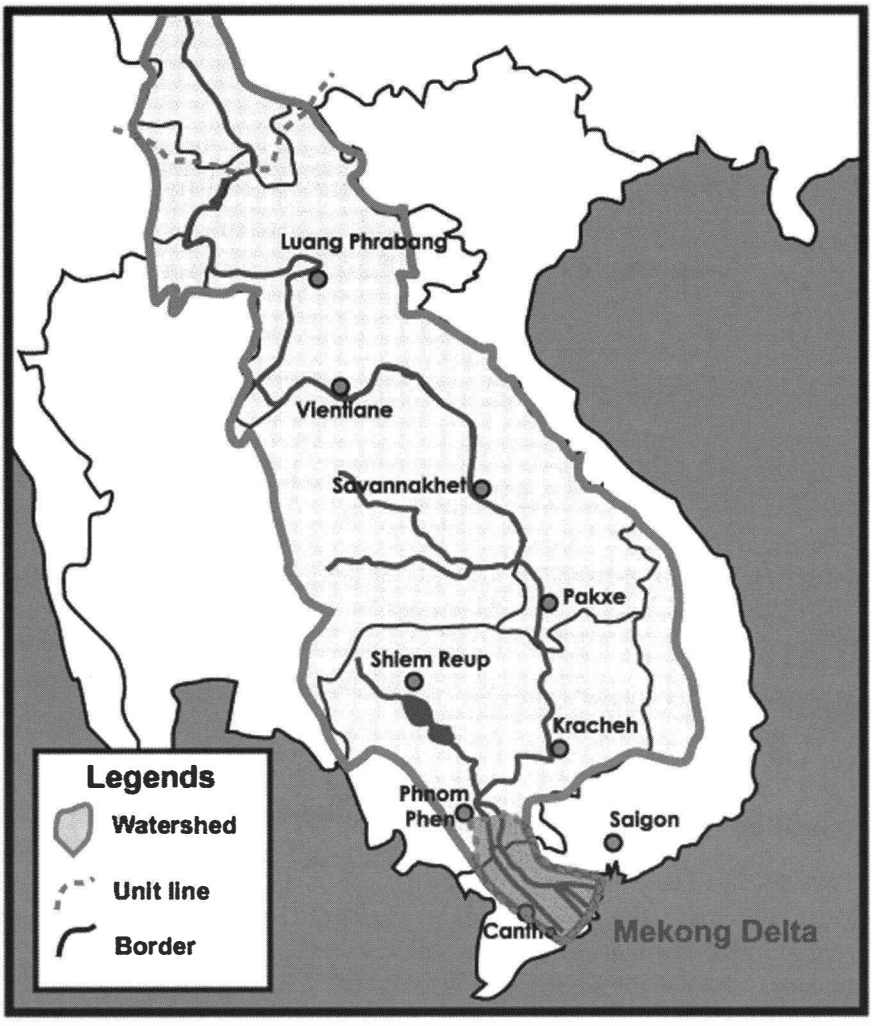


Fig. 1. — The Mekong River Basin (MRB).

The Mekong River crosses Cambodia from the North to the South over a distance of 480 km; the Cambodian MRB, comprises 86 % of the surface of the country. The annual discharge of the Mekong River in Cambodia is about 800×10^9 m^3: about 300×10^9 m^3 is distributed in land reservoirs, about 500×10^9 m^3 flows in the South China Sea (fig. 2). Every year, during the rainy season, about 450×10^9 m^3 streams into the plain and the Tonle Sap reservoir before entering into the South China Sea.

Table 1
Approximate distribution of the MRB water parameters by country or province

	Yunnan Province China	Myanmar	Laos	Thailand	Cambodia	Vietnam	MRB
Catchment Area as % of MRB	22	3	25	23	19	8	100
Average flow (m^3/sec)	2,410	300	5,270	2,560	2,860	1,660	15,060
Average flow as % of total	16	2	35	18	18	11	100

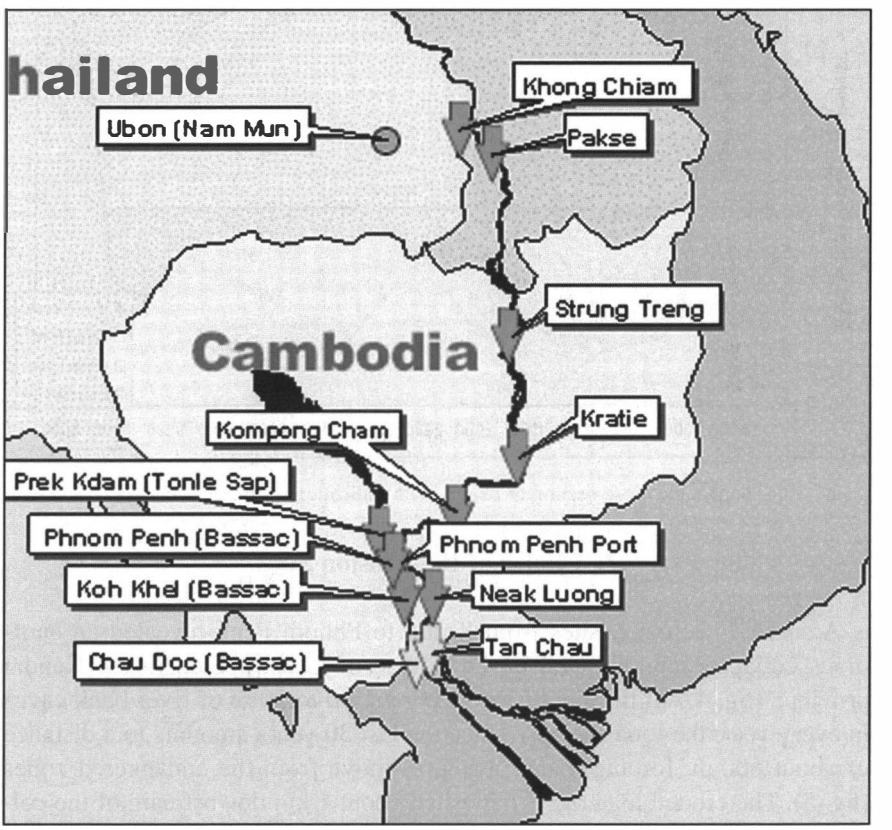


Fig. 2. — The Mekong River in Cambodia.

Nearly 25 % of the Mekong water in Cambodia originates from the Tibetan Plateau and from China, 50 % from the north-east of Thailand and Laos, 20 % from the north-east of Cambodia and the regions near Laos and Vietnam; the rest, about 5 %, comes from nine small rivers flowing into the Tonle Sap basin. The highest recorded flood level occurred in 1939 in the Kratie province of Cambodia: 23 m a.s.l. with a discharge of about 66,700 m^3/sec; the critical level was 22 m (fig. 3). A survey showed that the erosion of many natural banks along the Mekong starts upstream and proceeds downstream. This bank erosion is mainly due to human activities : beating waves created by boats, surface runoff during the rainy season on cultivated fields close to the river banks.

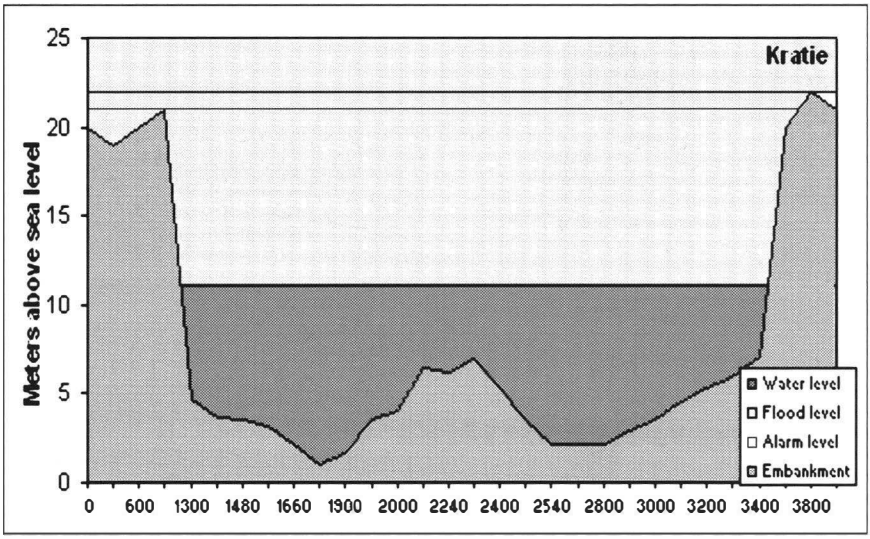


Fig. 3. — Schematic cross-section at Kratie, with indication of the different water levels.

3. Choice of the Erosion Sites

A survey of erosion sites from Kratie to Phnom Penh revealed an enormous collapse zone situated in the village of Chrouy Taek in the Kandal province (fig. 4). At the site of Koh Choram, 20 to 30 m of river bank caves in every year; the total collapse since the last 30 years amounts to a distance of about 600 m, forcing many people to move from the endangered zones (fig. 5). The eroded material is deposited about 1 km downstream of the collapse zones. As a consequence a large sand island is formed hindering water circulation during the dry season (fig. 6).

(a)

(b)

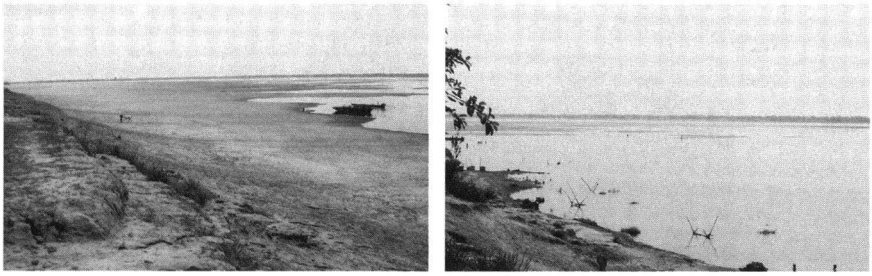
(c)

Fig. 4. — Collapse zones at the site of Koh Choram in the village of Chrouy Taek.

(a)

(b)

Fig. 5. — Houses moved from endangered sites in the village of Chrouy Taek.



(a) (b)

Fig. 6. — Large sand island formed downstream by sedimentation of the eroded material.

4. Soil Sampling and Water Measuring

4.1. Soil Sampling

In order to test the texture and shearing of the material, soil samples were taken at different depths. At Coh Choram, the caved-in banks are vertical and deep; for that reason the application of big mechanical drilling equipment is difficult, if not impossible. As an alternative, the soil sampling was done by hand by driving PVC tubes of 10 cm diameter and 20 cm length in the bank wall (fig. 7). The soil samples were taken at 4 depths (2 m, 6 m, 8 m, 10 m) in 3 rows with a distance in between of 20 m.

The results of the laboratory tests for hole I-1 are presented in tables 2 and 3 and figure 8.

4.2. Observing the Flow Direction of the Groundwater

The direction of the groundwater flow at the collapse sites is measured in 5 boreholes drilled on a line perpendicular to the river; the distance in between the boreholes is 100 m (fig. 9-a). Piezometers were installed and the water level was measured three times a day: at 06:00, 12:00 and 18:00 (fig. 9-b). Samples of the borehole sediments were tested in the laboratory to determine the texture at different depths (6 m, 18 m, 21 m, 27 m and 35 m); the results of one of the boreholes is presented in figures 10 and 11.

Fig. 7. — Soil sampling in the bank wall of the erosion sites.

Table 2
Texture analysis by sieving of sample I-1

Total weight of sample before drying and sieving		365.45 g	
Total weight of dry sample		117.43 g	
d (mm)	**Weight of soil retained on each sieve** (g)	**Percent of soil retained** (%)	**Percent passing** (%)
5	2.43	0.66	99.34
2.5	4.63	1.27	98.73
1.25	5.4	1.48	98.52
0.63	6.07	1.66	98.34
0.315	6.77	1.85	98.15
0.16	7.51	2.06	97.94
0.08	117.43	32.13	67.87

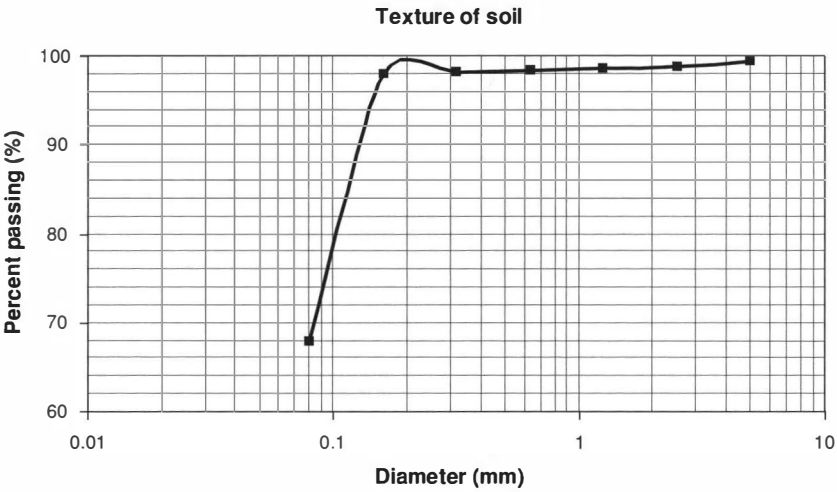
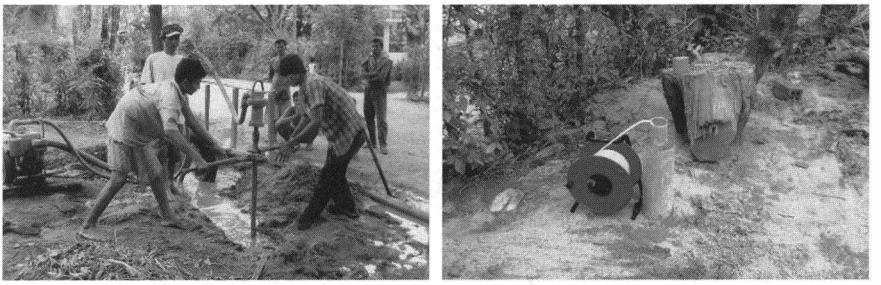


Fig. 8. — Texture graph of soil sample I-1.

Table 3
Shear test of soil sample I-1

No.		1	2	3
Volume of cutting shoe	V (cm^3)	132.72	132.72	132.72
Weight of cutting shoe	M_t (g)	168.58	168.58	168.58
Weight of cutting shoe and humid soil	M_t+M_s (g)	343.9	340.71	353.07
Bulk specific density	□ g/cm^3	1.32097	1.29694	1.39006
Average of bulk specific density	□ g/cm^3	1.34		
Weight of container	M_o (g)	28.12	27.67	27.99
Weight of container and humid soil	M_1 (g)	68.98	80.91	58.42
Weight of container and dry soil	M_2 (g)	65.47	78.85	55.02
Moisture content	W (%)	9.39759	4.02500	12.5786
Average of moisture content	W (%)	8.67		
Vertical stress (kPa)	□	48	96	144
Tangential stress (kPa)	□	43	86	126
Cohesion (kPa)	C	2.00		
Angle of internal friction	□	40.85		



(a) (b)

Fig. 9. — Drilling of the boreholes and installation of the piezometers.

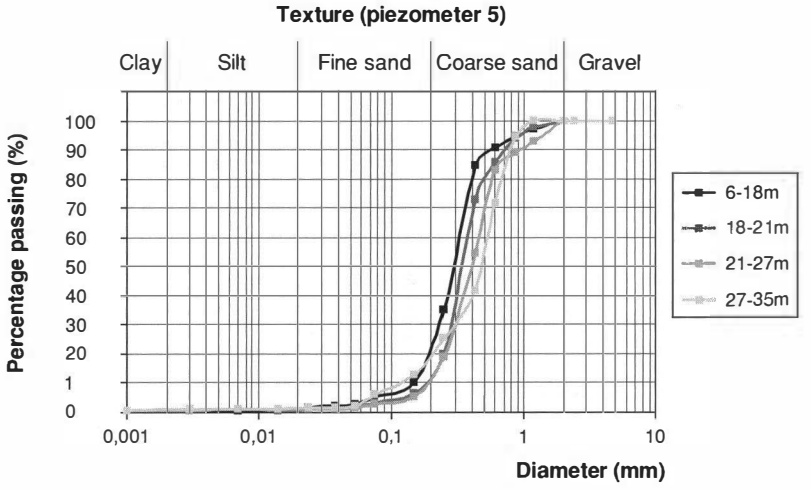


Fig. 10. — Texture graph of soil samples in borehole 5.

4.3. Measuring of the Mekong Water Levels

The water level in the Mekong River was measured three times a day at the same moment of the measurements in the piezometers, by means of a graduated wooden post (fig. 12). A comparison of the water level in the piezometers and in the Mekong river is presented in the histogram on figure 13.

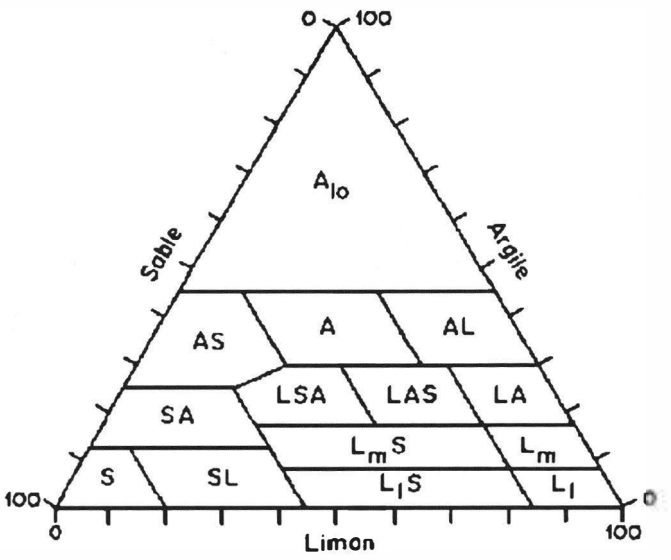


Fig. 11. — Diagram of textures after Jamagne: A: Clay, L: Silt, S: Sand, l: slight, m: average, lo: heavy.

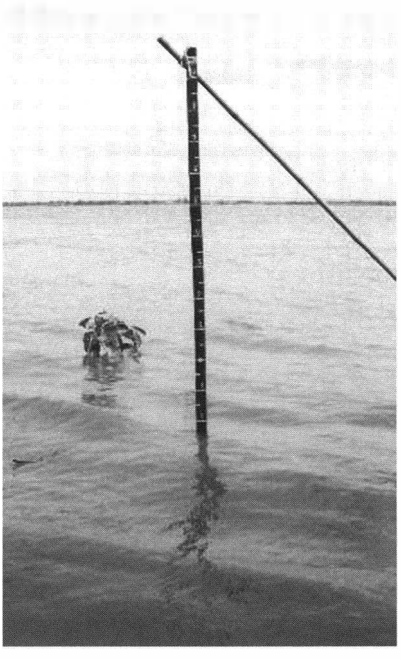


Fig. 12. — Graduated wooden post to measure the Mekong water level.

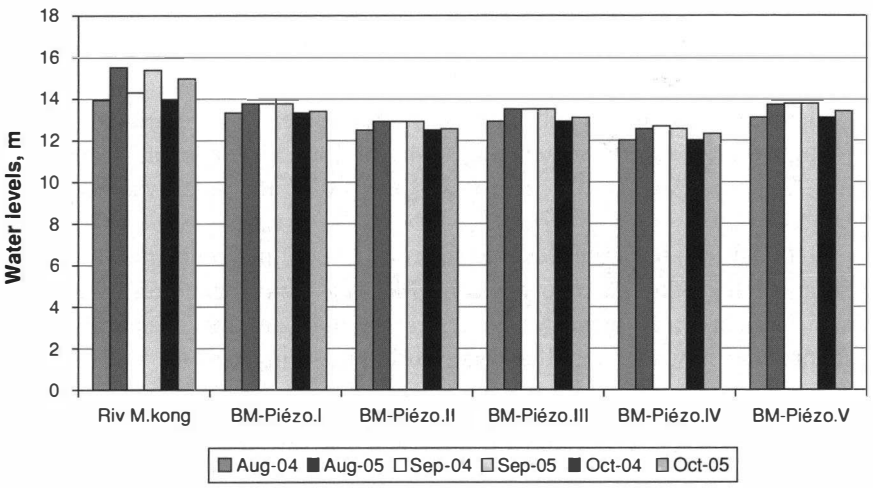


Fig. 13. — Relation between the water levels in the Mekong and the piezometers.

4.4. Interpretation of the Water Level Results

The histogram on figure 12 shows the maxima of the water levels in the Mekong River and the piezometers for three months, from August to October, in 2004 and 2005. In general, the maximum water levels in the Mekong River are higher than those in the piezometers.

According to the histogram, the maximum water levels of the Mekong River were higher in 2005 than in 2004 (15.4 m in August 2005 and 13.9 m in August 2004; 15.3 m in September 2005 and 14.3 m in September 2004; 14.9 m in October 2005 and 13.4 meters in October 2004).

The maximum groundwater level in piezometer I was about 13.7 m in August 2005, higher than in August 2004. Surprisingly, the maximum water levels in September 2004 and September 2005 reached the same value (13.8 m) as the one in August 2005; also the water levels in October 2004 and October 2005 were the same (13.5 m).

The maximum water levels in piezometer II were lower than the ones in piezometer I. The maximum water levels reached about 12.9 m in August 2005, which was equal to the water levels in September 2004 and 2005. The water levels were only 13 m in October 2004 and 13.3 m in October 2005.

Concerning piezometer III, the maximum water levels were 13.4 m for three months: August and September 2005 and September 2004. In August and in October 2004 the levels were about 12.9 m and approximately 13.0 m in October 2005.

In piezometer IV, the levels reached almost the same value (12.5 m) for all the months, except for August and October 2004 when the water levels were only 12 m.

Finally, the maximum water levels in piezometer V were around 13.6 m in August 2005 and in September 2004 and 2005. Their levels dropped to only 13.0 m in August 2004 and in October 2004; the level was 13.4 m in October 2005.

In conclusion: the water level as measured in the piezometers follows the rise and fall of the water level in the Mekong River but in an extenuated way. The curve, as presented in figure 13, indicates the direction of the groundwater flow that supplies water during the rainy season.

5. Cross Section and Flow Velocity of the Mekong River

A cross section of the Mekong River was measured and a flow velocity profile was recorded by ADCP (Acoustic Doppler Current Profiler) at Koh Choram in 2004 and 2005.

According to the graphs presented in figure 14 , the width of Mekong River was larger in 2005 as compared to 2004. Whereas, the water depths on the left side varied from 2 to 4 m in 2004, they were deepened from 2 to 6 m in 2005. However, on the right side the water depth in 2005 was shallower than in

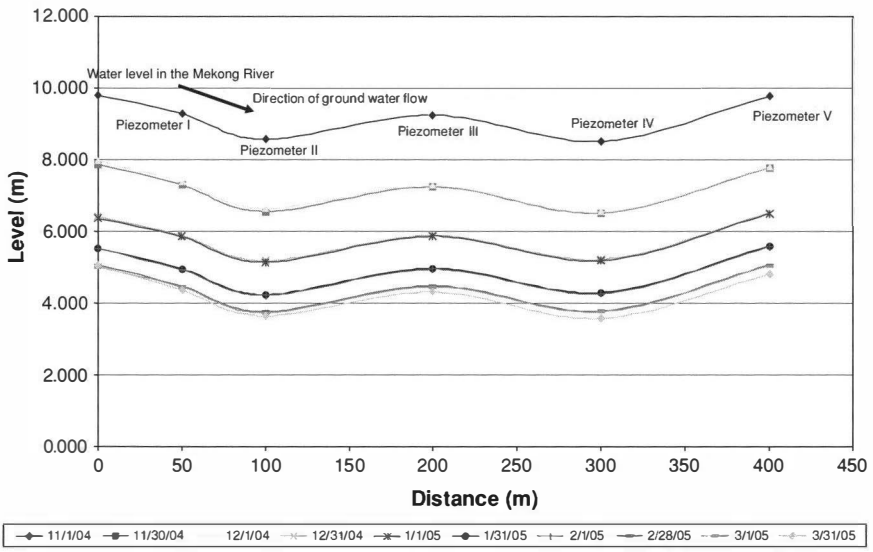
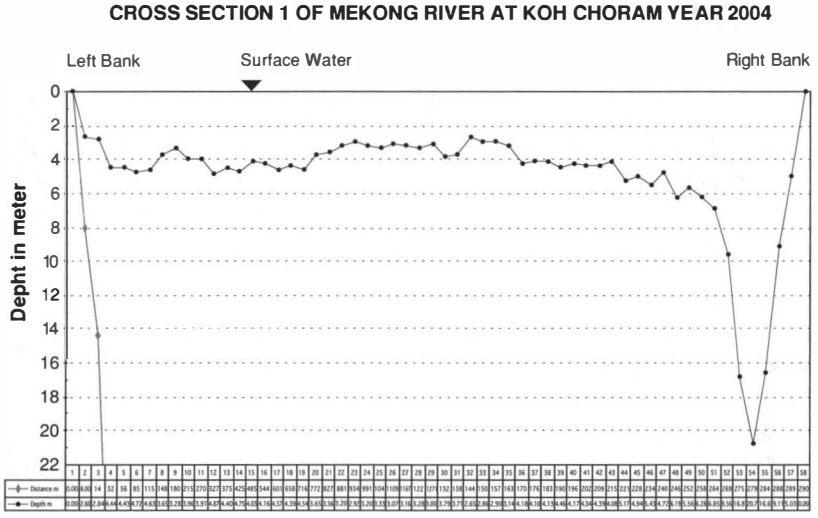
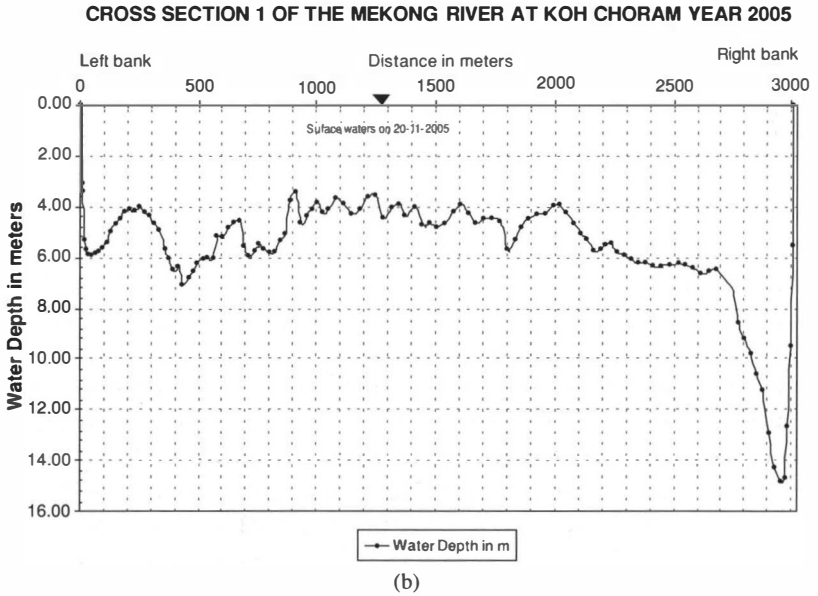


Fig. 14. — Direction of the groundwater flow.

2004. Meanwhile, the discharge was variable in function of the depth: the maximum discharge measured in 2005 was higher than 2004; moreover, the maximum velocity of flow in 2005 was much faster than in 2004 (fig. 15).



(a)



(b)

Fig. 15. — Cross section of the Mekong River at Koh Choram for 2004 and 2005.

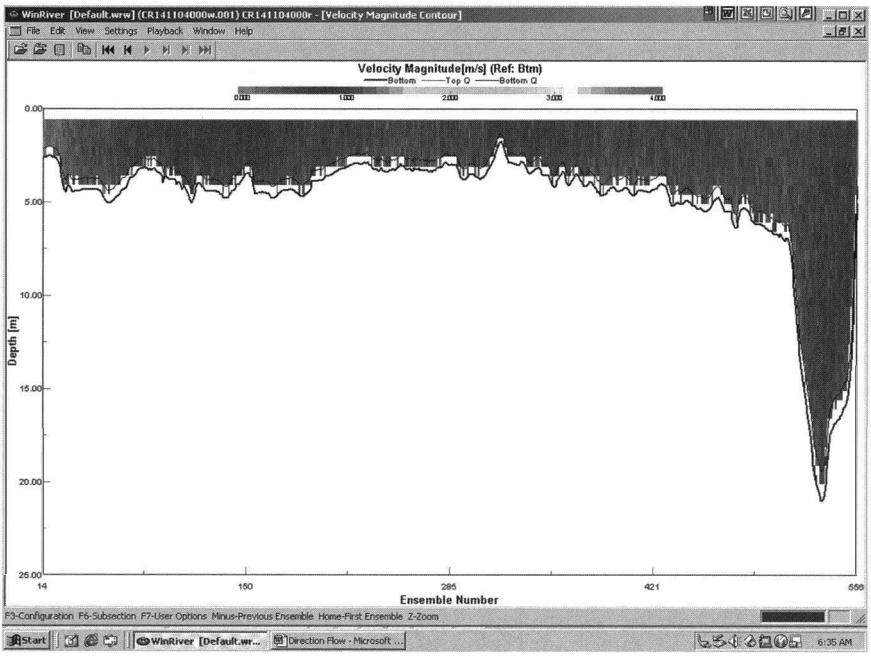


Fig. 16. — Flow velocity magnitude of the Mekong River water (m/s) at Koh Choram.

6. Conclusion

A geotechnical study of the Mekong River bank material at Coh Choram showed following characteristics: from the surface up to the depth of 8 m, a non plastic sandy silt (soil characteristics $\gamma = 16.6$ kN/m^3, $\varphi = 37°$ and C = 6.5 kN/m^2); from 8 m to 20 m, a sandy plastic clay (soil characteristics $\gamma =$ 15.5 kN/m^3, $\varphi = 26°$ and C = 19 kN/m^2). Applying Geo-slope software, following safety factor (FS) values are obtained: 0.699 for the Ordinary Method, 0.678 for the Bishop Method, and 0.712 for the Janbu Method. Anyhow, the safety factor of the bank slope is lower than the limit value of 1.5; therefore this slope is unstable even without taking into account the interstitial pressure. To avoid collapse, the bank slope must be protected by applying geotextile or constructing retaining walls.

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Trace Metals Accumulation by Green Mussel (*Perna viridis*, L) Cultured in a Highly Polluted Area of Jakarta Bay, Indonesia

by

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1. Introduction

Jakarta Bay is a semi-enclosed bay, and is connected to the Java sea. The bay is bordered by two capes, Tanjung Pasir in the west and Tanjung Karawang in the east, and administratively within three provinces *i.e.*, Banten Province, the capital city Special region of Jakarta, and West Java Province. The waters of the bay have been profoundly affected by discharge from 13 rivers that flow through the three provinces. The bay provides ecological services ranging from port industry, shipping, and tourist to fishery sectors. A fishery has long been a major income for local coastal communities. Cultures of green mussel were started in early 1980s, and in the last 20 years the green mussel's culture area has expanded both in the eastern and western part of the bay.

Green mussel (*Perna viridis* Lin.) is an important source for daily consumption and economic income. Traditional farming extends from two to six miles offshore and involves a number of 18,152 fisher families. Traditionally the mussels have been farmed in bagan, a bamboo floating structure with 3-meters deep ropes system. It is estimated there are more than 3,410 bagans that streach from east to west coast of Jakarta Bay (DP2K-DKI 2003). Daily mussel's harvest is estimated 120-175 ton per day and marketed around

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Greater Jakarta Area, Banten and West Java provinces. However in the last decades, domestic and industrial pollution strongly influence Jakarta Bay water quality.

Based on data of primary production (1976-1977), Jakarta Bay is classified under mesotrophic (SUSANNA & YANAGI 2002). Recent studies (DAMAR 2003, ARIFIN *et al*. 2003) showed that areas at distance less than 3 miles are categorized as hyper-eutrophic. Nutrient load and recycling dissolved inorganic nitrogen (DIN) play an important role in the increasing chlorophyll-a concentration in Jakarta Bay. Loads of phosphate, DIN and silicate from incoming rivers to the bay are 6,741 t/y, 21,260 t/y and 52,417 t/y, respectively (DAMAR 2003). Chl-a and DIN are higher in wet season (west monsoon) than in dry season (east monsoon). Moreover, besides high primary productivity, the coastal areas of the Bay are also highly polluted by both inorganic (trace metals) and organic (pesticides) contaminants from land based activity.

Mussels have been successfully used as a bio-indicator of water quality in northern countries. This may also be a potential indicator of health for human being. Hence the objective of the present study was twofold, 1) to determine the influence of season and culture sites on the accumulation of trace metals (Hg, Cd and Pb) on the green mussels that were cultured in highly polluted area, and 2) to estimate allowable intake of green mussels for local communities.

2. Materials and Methods

2.1. STUDY SITE AND SAMPLING

The study was conducted for six months, in July, August and September 2002 to represent east monsoon, and in December 2002, January and February 2003 to represent west monsoon (fig. 1). The Jakarta Bay is a shallow bay (an average depth of 8.5 m) with a shoreline about 149 km and covers an area of approximately 595 km^2. An average precipitation was lowest during east monsoon, and highest during west monsoon, 600 mm (fig. 2). The water temperature varied from 27.0 °C in west monsoon to 30 °C in east monsoon. Water clarity varied between 41 and 93 cm in the area within 3 miles from the shore line.

Water samples were collected from the area of mariculture, *i.e*., Kamal Muara and Cilincing in Jakarta Bay. One liter of seawater was sampled for trace metals (Hg, Cd, Pb) analysis using polypropylene bottle that has been

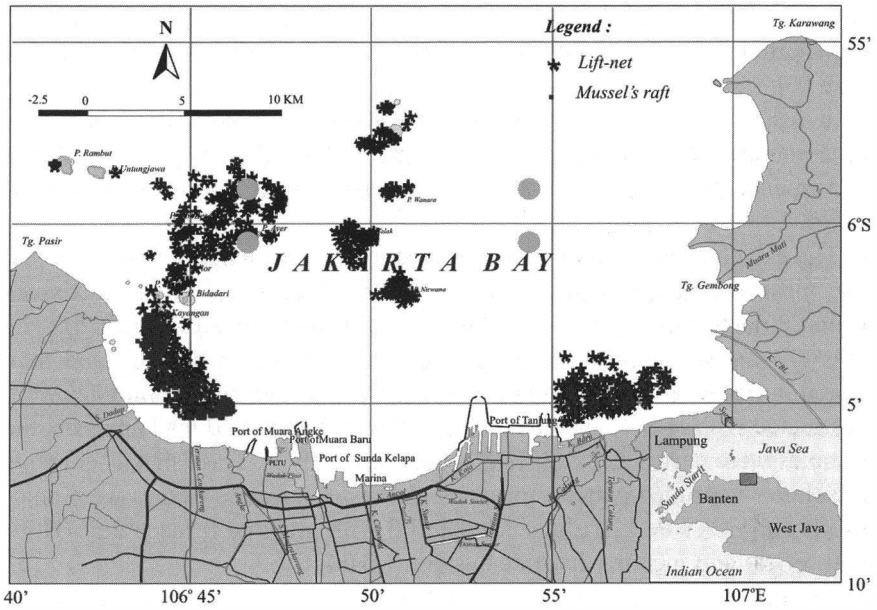

Fig. 1. — Mussel's culture areas and study sites (dots) in Jakarta Bay, Indonesia (data: number of rafts from Department of Marine Affairs and Fisheries, Jakarta, 2003).

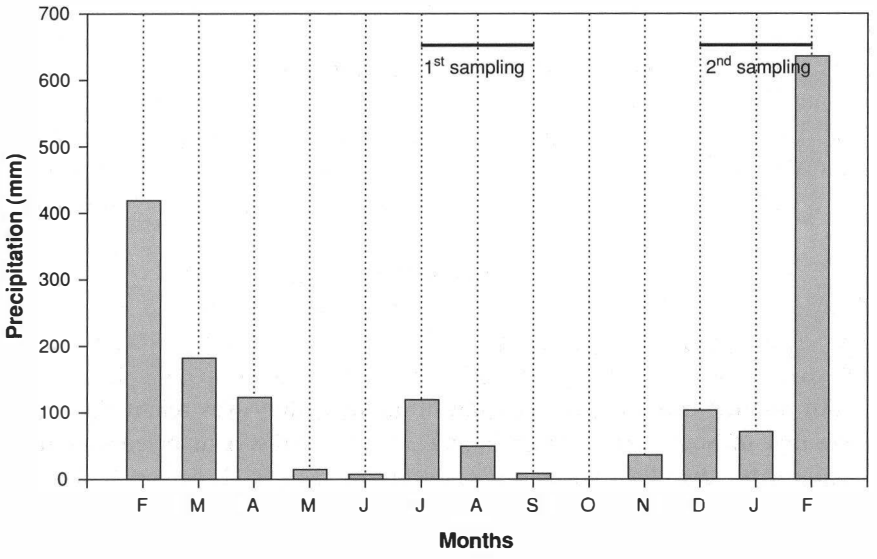

Fig. 2. — Average rainfall (precipitation, mm) from two locations near sampling sites (Feb. 2002 — Feb. 2003).

washed with 7 N HNO_3. The bottles were then placed in an icebox and transported to a laboratory. Once arrived in the lab, the water was filtered with 0.45 μm cellulose nitrate membrane filter. Filtrate water was then acidified using 6 N nitrate acid for analysis. Suspended solid from filtration process was let to dry at room temperature and weighed to get final weight of suspended solid. Metals associated with suspended solid were then analyzed.

Three replicates of 30 green mussels (5-6 cm shell length) were collected and cleaned from bio-fouling organisms. Trace metals in mussels tissues were carried out according to a procedure described by APHA (1985). The mussel's tissue was ground using a stainless steel-food blender, and then stored in freezer for further analysis. For mercury analysis, the samples were destructed with H_2SO_4 and HNO_3, while for cadmium and lead analysis, the samples were destructed with HNO_3 and $HCl + H_2O_2$. Trace metals contents in solute, suspended particle forms as well as in mussel's tissues were analyzed using AAS Perkin Elmer Model 300 with graphite furnace unit (HGA 800 series) and mercury hydride system (MHS-10).

2.2. Statistical Analysis

Analysis of variance (ANOVA) on trace metal contents in mussel's tissues was used to see any significant differences between culture sites, seasons and distance of mussel's culture from seashore (SYSTAT Program version 10). Before subjected to statistical analysis, Cohran's test was used for testing data normality. Hg content in mussel's tissues was analyzed using raw data, while Pb and Cd data were transformed to ln (x) to meet the ANOVA requirement. Graphs were produced using SigmaPlot Program.

3. Results

3.1. Trace Metals in the Seawaters

An average of dissolved Hg concentrations in July was relatively higher than that in Sept., Dec., and Jan. (fig. 3); in contrast a reversed condition occurred for dissolved Cd and Pb concentrations (fig. 4, 5), *i.e.* both trace metals elevated in Dec., Jan. and Feb. The trend of dissolved Pb concentrations during west monsoon (Dec., Jan., Feb.) was consistently elevated compared to those during east monsoon.

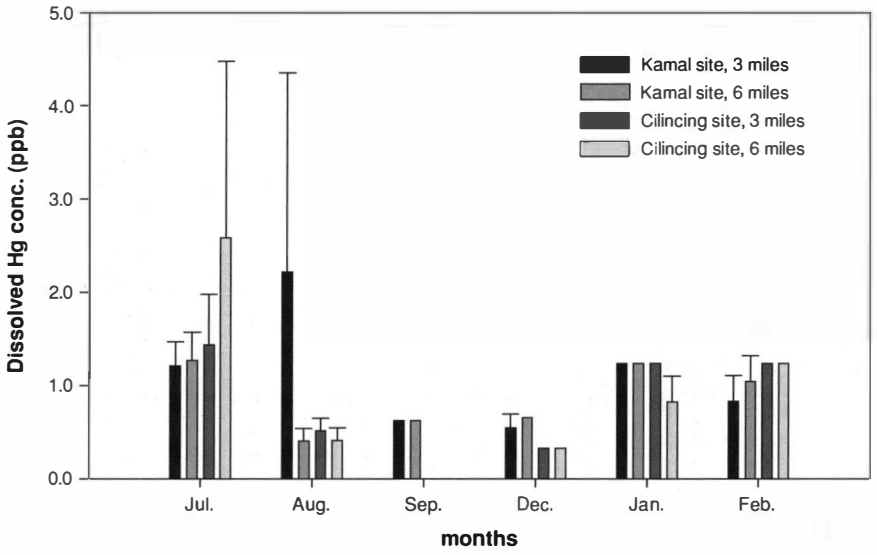

Fig. 3. — Dissolved Hg concentrations (ppb, mean ± sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

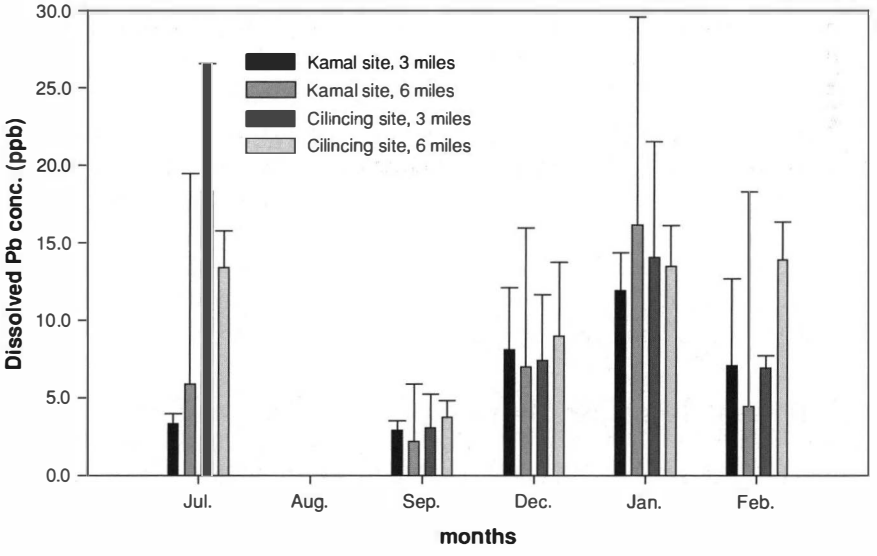

Fig. 4. — Dissolved Pb concentrations (ppb, mean ± sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

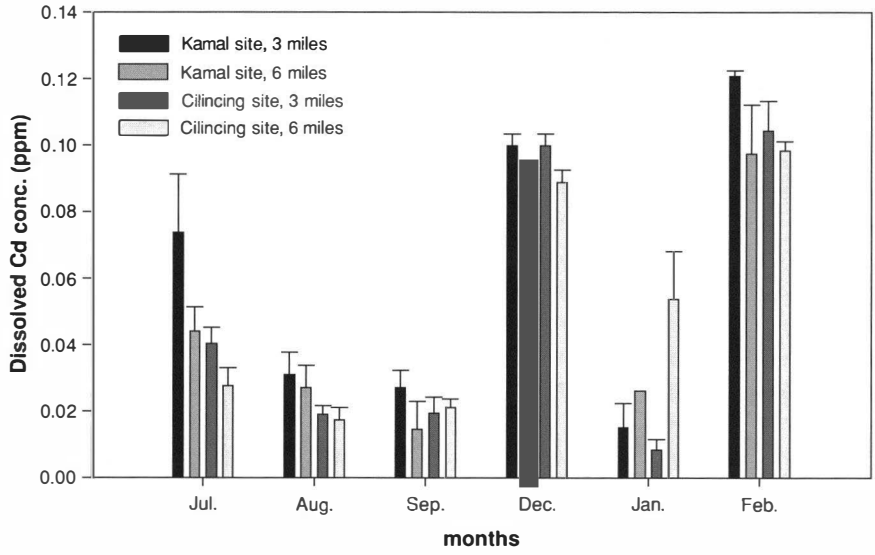

Fig. 5. — Dissolved Cd concentrations (ppm, mean ± sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

Total mercury concentrations in seawater varied between 0.74 and 1.23 ppb during east monsoon (mean ± sd, 0.94 ± 0.24 ppb), and between 0.83 and 1.05 ppb during west monsoon (0.96 ± 0.09 ppb) (tab. 1). Mercury concentrations in water column were generally below the maximum standard concentration for fishery purposes (Hg ≤ 3 ppb), while lead concentrations mostly approached the maximum standard concentration (Pb ≤ 10 ppb) during west monsoon (10.10 ± 1.44 ppb). Total Pb in seawater varied between 9.19 and 12.24 ppb during west monsoon, and 3.00 — 6.95 ppb during east monsoon. In contrast, total cadmium concentrations mostly exceeded a maximum standard concentration (Cd ≤ 10 pp) both during east and west monsoons, *i.e.*, 28.97 ± 10.59 ppb and 73.17 ± 7.87 ppb, respectively.

3.2. Trace Metals in the Mussel's Tissues

Mercury was accumulated at high rate by green mussels (FC_{Hg} = 12.4), followed by cadmium (FC_{Cd} = 6.3) and lead (FC_{Pb} = 5.0). Concentration factor of Hg was relatively constant during east and west monsoons, while concentration factors of Cd and Pb were 3.5 times and four times higher during east monsoon than that during west monsoon (tab. 1).

Table 1
Average value of total suspended solid (TSS), Hg, Pb and Cd in seawater, mussel's tissues and factor concentrations

Seasons	Sites	Distance (miles)	TSS (mg/l)	Metals in sea water (solute+particulate, ppb)			Metals in mussel's tissue (µg/kg wet weight)			Factor conc.		
				Hg	Pb	Cd	Hg	Pb	Cd	Hg	Pb	Cd
East monsoon	Kamal	3	54.30	1.23	3.00	43.89	20.99	14.91	185.00	17	5	4
		6	139.08	0.75	3.20	26.89	11.38	27.25	158.30	15	9	6
	Cilincing	3	88.82	0.74	6.95	26.22	9.68	70.67	343.00	13	10	13
		6	108.93	1.03	5.92	18.88	6.63	47.46	301.30	6	8	16
West monsoon	Kamal	3	52.25	0.95	9.31	78.49	10.51	10.32	160.50	11	1	2
		6	100.41	1.05	9.19	63.10	12.82	15.74	466.00	12	2	7
	Cilincing	3	81.18	0.99	9.64	70.82	11.92	21.48	71.33	12	2	1
		6	154.39	0.83	12.24	80.28	10.85	39.53	95.66	13	3	1
									Average	12.4	5.0	6.3

Mercury concentrations in cultured mussels ranged 3.97 — 36.61 µg/kg wet weight (ww) in Kamal coastal area and 2.39 — 20.97 µg/kg in Cilincing area (fig. 6). Maximum Hg in mussels was recorded in July both in Kamal and Cilincing sites. There is no significant influence of cultured site nor culture distance on mercury concentrations in mussel's tissues, but they were significantly different between seasons ($p = 0.044$). In contrast, Pb tissues concentrations were significantly affected by culture sites ($p = 0.001$). Pb tissue's concentration from Cilincing site was higher than that of Kamal site; the concentrations varied from 4.21 to 100.42 µg/kg and from 2.14 to 71.66 µg/kg, respectively (fig. 7). Cd concentrations in mussel's flesh ranged 84.30 — 1,233.80 µg/kg and 83.10 — 653.00 µg/kg in Kamal and Cilincing sites, respectively (fig. 8). Cd tissues concentrations were significantly influenced by interaction between site and season ($p = 0.004$).

3.3. Acceptable Daily Intake of Green Mussels

Acceptable daily intakes (ADI) for total mercury (Hg) and lead (Pb) were 0.43 and 3.57 µg/kg body weight/day, respectively (Anonymous 1995), whereas ADI of Cd is 45 µg/kg BW/day which is equal to 15-20 % Cd concentration that causes toxicity. We know that maximum concentrations of

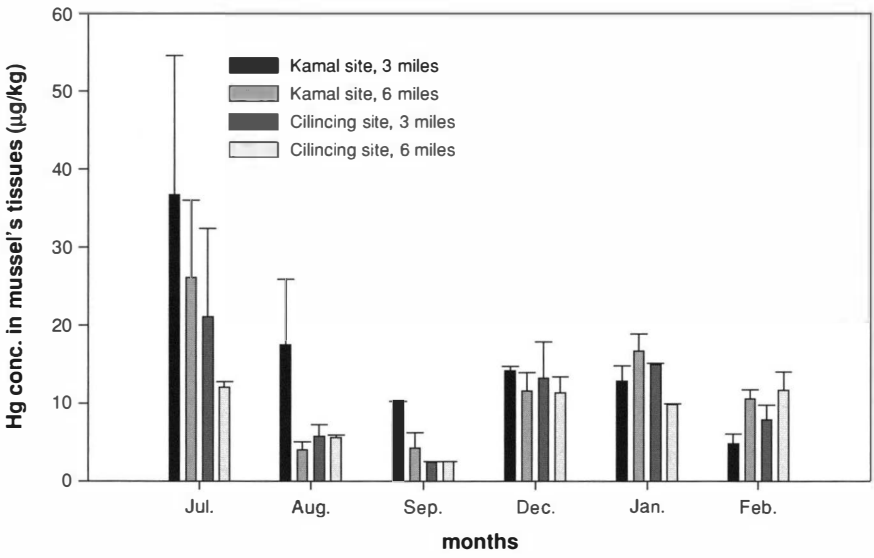

Fig. 6. — Hg concentrations in mussel's tissues (µg/kg, mean ± sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

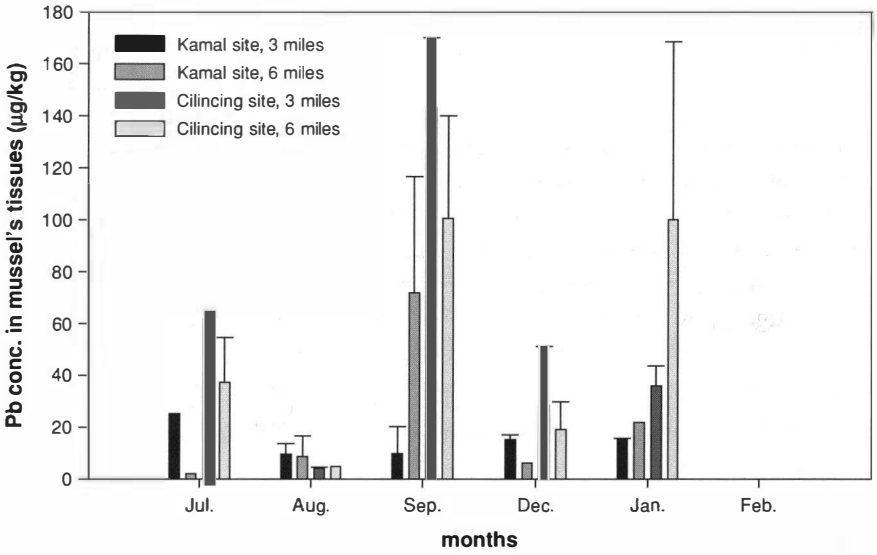

Fig. 7. — Pb concentrations in mussel's tissues (μg/kg, mean±sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

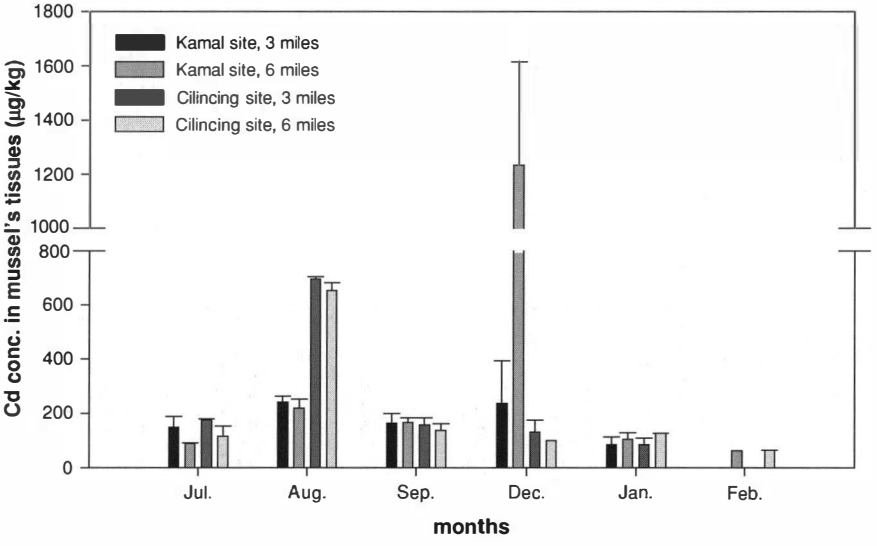

Fig. 8. — Cd concentrations in mussel's tissues (mg/kg, mean±sd) in Kamal and Cilincing sites at a distance of 3 and 6 miles from coastline.

total Hg, Pb and Cd in mussel's tissues of Jakarta Bay are 21, 71, and 466 µg/kg, respectively. Assuming that 1) food ingestion is the major exposure route for the metal contaminant to coastal communities (95 % of total exposure to metal contaminant) and 2) average of mussels is 6 gram (0.006 kg), then the acceptable daily intake of green mussels for a person with 50 kg body weight (BW) without Hg toxication can be calculated as follows,

$$\begin{aligned} ADImussels_{Hg} &= \{(0.43\ \mu g/kg\ BW/day): (21\mu g/kg \times 0.006\ kg/mussel)\} \times 50\ kg\ BW \\ &= \{3.4\ mussels/kg\ BW/day\} \times 50\ kg\ BW \\ &= 170\ mussels/day \text{ or } 1.0\ kg\ mussels/day \end{aligned}$$

Using similar calculation, acceptable daily intake of green mussels harvested from Jakarta Bay area without toxication of Pb and Cd were 2.5 kg/day and 96 g/day, respectively.

4. Discussion and conclusion

Toxic metals accumulation in biota may occur through exposure to contaminated water, food and sediments. Dissolved Hg, Cd and Pb showed different patterns of distribution. Dissolved Hg and Cd generally distributed in areas close to the coastal area (3 miles from the seashore), while dissolved Pb distributed toward the offshore. Among three trace metals, dissolved Cd was shown to be a 100 times higher than dissolved Hg and Pb. Dissolved Cd is a more dominant form compared to particulate Cd (tab. 1). Other related studies on trace metals concentrations have been done in coastal waters of the Jakarta Bay (tab. 2).

Table 2
Metal concentrations in coastal waters of Jakarta Bay

Site/sampling	**Hg** (ppb)	**Cd** (ppb)	**Pb** (ppb)	Source
Kamal/1993	1.10 — 4.70	48.30 — 95.40	5.10 — 7.90	WAHYONO (1994)
Kamal/Aug. 1993	- 2.16	84.00 — 110.00	1,320 — 1,750	DINIAH (1995)
Kamal/July, Sept., Nov. 2000	0.02 — 420.0	3.00 — 20.00	40.00 — 150.00	VITNER *et al.* 2001
Kamal/2001	0.08 — 0.13	6.00 — 46.00	6.00 — 34,00	MULYAWAN (2005)
Kamal/2002	0.75 — 1.23	26.89 — 78.49	3.00 — 9.31	Present study
Cilincing/2002	0.74 — 1.03	18.88 — 80.28	5.92 — 12.24	Present study

In early 1980s, samples of fish, shrimp and mollusk were found to contain Cd, Cu, Cr, Hg and Pb, but the concentrations were still below maximum limit (HUTAGALUNG & RAZAK 1982). However, studies during 1990s and early 2000s showed that metal concentration in many commercial fish and shellfish tend to increase, for example in fish (DINIAH 1995), in cockle (*Anadara indica*) (WAHYONO 1994), and in green mussels (*Perna viridis*) (MULYONO 2005). Furthermore, concentrations of the metals in sediment ranged from 10 to 100 times higher compared to those in waters (HUTAGALUNG 1994). A recent study showed highest metal concentrations (Cd, Cu, and Pb) in sediments generally distributed in river estuaries within 5 km from the shoreline (ARIFIN 2004). Similarly, concentrations of pesticides (pp-DDT, pp-DDD, aldrine, heptachlor) were detected in several estuaries in the bay (MUNAWIR 2004). Despite increasing contaminants, the mussels grow reasonably well in the bay. This phenomenon is likely because of, at the same time, increasing concentrations of nutrients run off especially of nitrogen and phosphate from urban areas. Culture site and culture distance did not influence Hg concentration in mussel's tissues, this indicated that Hg contamination in waters of Jakarta Bay has been distributed in all area of Jakarta Bay within 6 miles from the coastline. In contrast, Pb concentration in mussel's tissues that were cultured in Cilincing site was significantly higher than that in Kamal site.

Based on acceptable daily intake of Cd, Hg and Pb (Anonymous 1985), green mussels cultured in both Kamal and Cilincing coastal sites with an average wet weight of 6.0 gram/mussel is relatively safe when they are consumed at 96 gram or 16 mussels/day for Cd, 1.02 kg or 170 mussels/day for Hg and 2.5 kg or 420 mussels/day for Pb. In order to protect public health especially of low-income families, we suggested that acceptable daily intake of green mussels is 96 gram or 16 mussels per day. We also suggested that the government should take proactive actions to reduce land-based pollution and strict regulations on industries that are categorized as black rating industries. Moreover, a regular monitoring of shellfish resources around Jakarta Bay would be a good exercise for all provincial governments in protecting the health of the public especially of low-income communities who on daily basis rely on cheap protein sources.

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Potential Risk of Contamination of Heavy Metals in Paddy Land and Rice from Different Waste Sources in Red River Delta, Vietnam

by

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1. Introduction

Vietnam covers an area of 32,924.1 km^2 in Southeast Asia. It shows a great economical development in which agriculture has an important contribution. In the last 17 years of renovation (1996-2002), the Vietnamese Party and Government have issued many policies to encourage development of agriculture and rural economy in the direction of linking goods production to market. One of these policies is the Law on Land. The Government allocated land to households and industries for long use with 5 rights: conserving, transferring, renting, inheriting and mortgaging. The Law on agricultural land use, with lower tax rates than the normal agricultural tax, was intended to increase the contribution of farmers and to encourage households to utilise effectively agricultural land. In December 1996, an important policy related to industrialisation and modernisation of agriculture and rural area was issued. The aim of this policy is to promote agricultural development. In addition, investment for agriculture increased by 50 % in the budget for 1999.

Thanks to the new economic development trend, the national economy has changed during the last years. In 2001 the National GDP was 484.493 billion dong, of which, agriculture contributed for 91,687 billions dong (18.92 %). The Red River Delta includes 11 provinces and cities, covering an area of 1,479,416 ha, estimated as 4.46 % of Vietnam. Its population is

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17,648,700 people (21.8 % of the country in 2003). Agricultural production plays an important role in the economic development of the region. Food plants are cultivated on 1.2 ha 10^6 (14 % of food cultivated land in the whole country), with a harvest of 6.1 10^6 tones (18 % of the food production in the country in 1999). Rice is the most important component of the food production. It is planted in the whole country, but the Red River Delta is the second principal area. Rice production is facing many problems. Different contamination sources from industrial and urban origin are causing high risks for environmental contamination and human health, especially for children.

2. Rice Production in the Red River Delta

Rice is an essential crop in Vietnamese agriculture. It plays an important role in both food security and cash generation. Rice areas are distributed thtoughout the whole country (fig. 1). In the Red River Delta it is dominantly planted on alluvial soils (Fluvisols) (fig. 2). Following cropping systems are applied: rice-rice, rice-corn, rice-rice-potato/sweet potato, rice-rice corn/bean, rice-rice-vegetables (tomato, cabbage, ...).

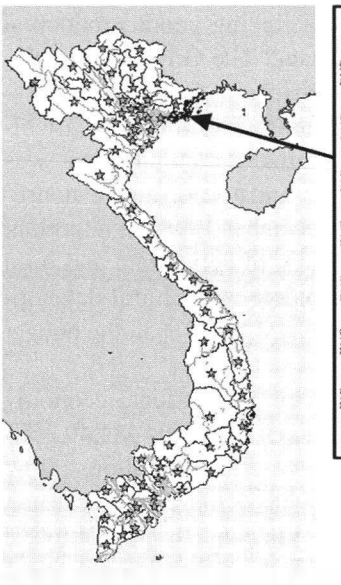

Fig. 1. — Rice distribution in Vietnam.

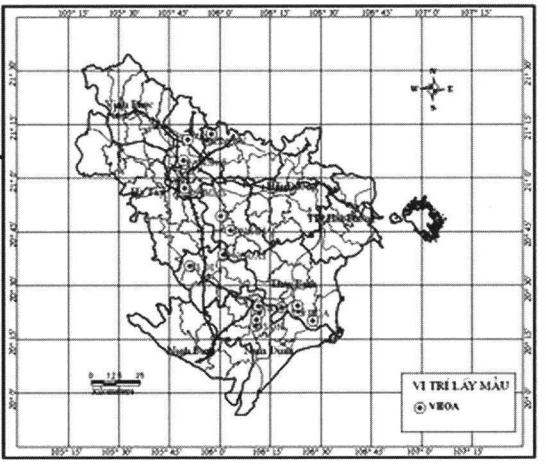

Fig. 2. — Study Sites in Red River Delta.

Due to the application of new technologies, such as new varieties, soil management and important policies to develop agriculture (allocation of land use to farmer/household and reduction of the land tax for farmer), rice production in Vietnam has been increased yearly both in area and productivity. In the Red River Delta, rice production made big progress, both in extension and production throughout the whole region (tab. 1).

Table 1
Rice production in the Red River Delta, 2000-2003

Location	2000			2003		
	Area (1,000 ha)	**Yield** (t/ha)	**Production** (1,000 t)	**Area** (1,000 ha)	**Yield** (t/ha)	**Production** (1,000 t)
Whole country	7,666.3	42.4	325,051	7,449.3	46.3	344,903
Red river delta	1,212.6	55.2	66,935.5	1,183.6	54.8	64,861
Hanoi	54.2	41.4	2,243.88	50.8	40.2	2,042.2
Hai Phong	95.9	51.1	4,900.49	92.1	54.7	5,037.9
Vinh Phuc	74.8	43.7	3,268.76	74.2	48.2	3,576.4
Ha Tay	168,8	54.6	9,216.48	166.5	56.6	9,423.9
Bac Ninh	84.0	52.5	4,410	82.5	53.5	4,413.8
Hai Duong	147.5	55.8	8,230.5	139.9	58.4	8,170.2
Hung Yen	89.7	59.1	5,301.27	87.3	60.7	5,299.1
Ha Nam	75.4	51.1	3,852.94	74.7	52.0	3,884.4
Nam Dinh	166.2	58.1	9,656.22	163.0	58.0	9,454
Thai Binh	173.1	60.7	10,507.2	170.6	54.6	9,314.8
Ninh Binh	83.0	51.4	4,266.2	82.0	52.2	4,280.4

Source: General statistic department 2004.

In 4 years (from 2000 to 2004), rice was cultivated on an area of 6,756.6 thousands ha increasing up to 73,262.7 thousands ha (1999) and 7,463.2 thousands ha (2002). Rice crop increased from 24,963.7 thousands tons in 1999 to 33,622.4 thousands tons in 2002. Vietnam officially entered the world rice market in 1999; it exported 4.6 10^6 tons in 1999, 4 10^6 tons in 2000 and 3.56 10^6 tons in 2001 (NGUYEN SINH CUC 2003). Socio-economic condition improved even as the living standard with this higher production. In spite of the limited volume of exported rice, the low price and the unsuitable quality for the world market, this result marks a positive change for Vietnam (tab. 2), from a self-subsidy production to a production of goods for market and export.

Table 2
Rice production in the Red River Delta

Rice season	2000	2002	2004	2010*
	Cultivated land (1,000 ha)			
Total	7,492.7	7,463.2	7,400	7,500
Spring rice	3,056.9	3,033.1	2,870	2,900
Summer rice	2,210.8	2,253.0	2,170	2,200
Winter rice	2,225.0	2,177.3	2,440	2,400
	Rice production (1,000 tons)			
	2000	**2002**	**2004**	
Total	32,108.4	33,622.0		
Spring rice	15,474.4	16,714.6		
Summer rice	8,328.4	8,596.1		
Winter rice	8,305.6	8,311.7		

Source: NGUYEN SINH CUC 2003.
(*) Estimated by NISF 2003.

Rice land tends however to decline gradually due to urbanisation, industrialisation and conversion of land to land tenure. Moreover, rice production in the Red River Delta suffered from deteriorating land and water environmental conditions. Potential contamination due to over-fertilisation, industrial and domestic contamination or wastes from traditional trade villages form important risks, so that agriculture based on rice farming becomes a serious problem if no appropriate solutions are proposed.

3. Potential Risk for Contamination of Agricultural Land in Red River Delta

3.1. Soil and Plant Sampling

Soil survey and sampling was done at harvesting time in the period of summer rice 2003-2004. Soil survey was done in transect walk throughout different fields which were influenced by various potential contamination sources in provinces (tab. 3). Soils representative for each type of contamination source (heavy metal recycling, industrial zone, domestic contamination from pre-urban surrounding of Hanoi city, Ha Tay, Nam Dinh, Bac Ninh provinces,...) were collected at the depth of 0-15 cm. At the same time, rice grain samples were taken for analyses. For comparision, non contaminated soils were sampled in each site at the same time as the contaminated soils.

Table 3
Localisation and number of samples

Location	Non waste	Trade waste	Industrial waste	Domestic waste	Total
Total samples	28	17	11	9	67
Super Hanoi	7	–	11	–	18
Ha Tay	7	–	–	–	7
Hung Yen	7	9	–	–	16
Thai Binh	4	–	–	–	4
Nam Dinh	4	4	–	9	17
Bac Ninh	–	4	–	–	4

3.2. Result and Discussion

3.2.1. Heavy Metals in Contaminated Soils

The content of heavy metals in the soils is presented in table 4 and figures 3 and 4. Heavy metal accumulation in the soils varies according to the contaminating conditions.

Table 4
Total content of heavy metals in soil (mg/kg dry soil)

Samples	Range	Cd	Zn	Cu	Pb
Non waste	Min	0.19	44.00	21.75	27.22
	Max	1.12	109.09	49.34	56.20
	Average	0.72	90.60	37.39	42.12
Heavy metal recycling waste (trade)	Min	0.56	55.89	27.90	29.21
	Max	2.11	200.12	187.97	289.91
	Average	1.44	127.93	94.82	130.37
Industrial waste	Min	0.29	89.21	39.34	35.90
	Max	1.55	272.12	55.91	46.78
	Average	0.98	157.75	46.02	41.41
Domestic waste	Min	0.91	33.28	32.01	39.19
	Max	1.82	48.99	41.91	51.53
	Average	1.48	42.02	37.74	45.47
UN standard		2	200	50	70

In the control soils, total content of Cd ranges from 0.19 to 1.12 mg Cd/kg dry soil (averaged 0.72 mg/kg) , while the total concentration of Cd is in

the range of 0.56-2.11 mg/kg (averaged 1.44 mg/kg) in soils contaminated by water and dust waste from heavy metal recycling villages, 0.29-1.15 mg kg (averaged 0.98 mg/kg) in soils affected by industrial waste and 0.98-1.82 mg/kg (averaged 1.48) in soils contaminated by domestic waste.

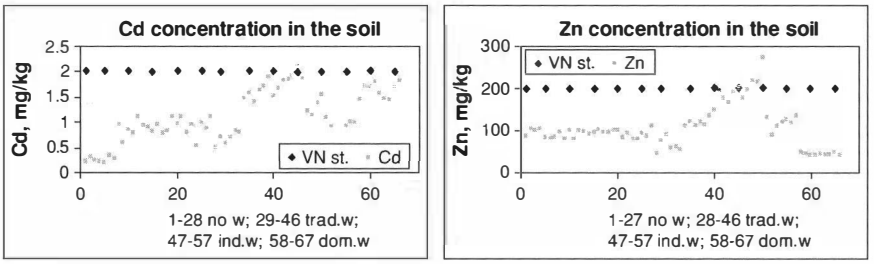

Fig. 3. — Ca and Zn accumulation in soils affected by waste sources.

In the control soils, total content of Zn ranges from 44.0 to 109.1 mg Zn/ kg dry soil (averaged 90.6 mg/kg),) while the total concentration of Zn is in range of 55.89-200.1 mg/kg (averaged 127.3 mg/kg) in the soils contaminated by water and dust waste from heavy metal recycling villages, 89.2-272.1 mg/kg (averaged 157.8 mg/kg) in soils affected by industrial waste, and 33.3-49.0 mg/kg (averaged 45.5 mg Zn/kg) in soils contaminated by domestic waste.

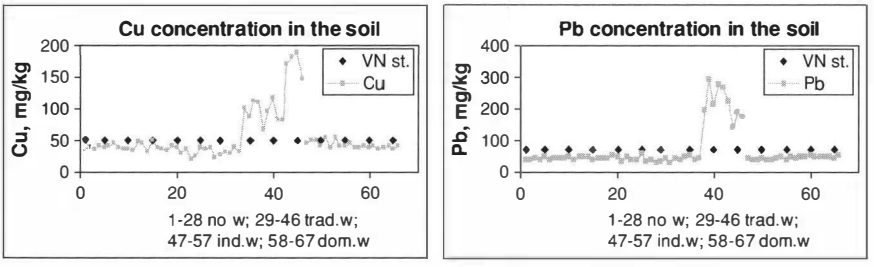

Fig. 4. — Cu and Pb accumulation in soils affected by waste sources.

In the control soils, total content of Cu ranges from 21.75 to 49.34 mg Cu/kg dry soil (averaged 37.39 mg/kg) while the total concentration of Cu is in the range of 27.9-187.97 mg/kg (averaged 94.8 mg/kg) in the soils contaminated by water and dust waste from heavy metal recycling villages, in range of 39.34-55.9 mg/kg (averaged 46.02 mg Zn/kg) in soils affected by

industrial waste and 32.01-41.91 Cu mg/kg (averaged 37.74 mg Cu/kg) in soils contaminated by domestic waste.

In the control soils, the total content of Pb ranges from 27.2 to 56.2 mg Pb/kg dry soil (averaged 42.12 mg/kg), while the total concentration of Pb is in range of 29.1-289.9 mg/kg (averaged 130.4 mg/kg) in the soils contaminated by water and dust waste from heavy metal recycling villages, 35.9-46.78 mg/kg (averaged 41.4.8 mg/kg) in soils affected by industrial waste and 39.2-51.53 mg/kg (averaged 45.47 mg Pb/kg) in soils contaminated by domestic waste.

The average value of Cd in soils affected by heavy metal recycling equals that of domestic waste and is two times larger than in non affected soils and 1.6 times larger than in soils affected by industrial waste.

The content of Zn in the soils contaminated with industrial wastes is highest, 1.7 times higher than in non contaminated soil and 3.6 times higher in soils affected by domestic waste. The content of Zn in soil contaminated with heavy metal recycling is 127.9 mg/kg soil, this is 3 times higher than in domestic affected soil and 1.4 times higher than in the control soils.

The content of Cu in the soils changes as follows: trade waste > industrial waste > domestic waste = non waste. The Cu value in soil contaminated by heavy metal recycling is 2.5 times that of soils contaminated with domestic waste and 2 times in soils contaminated with industrial waste.

Pb accumulation in the soils shows following sequence: heavy metal recycling > domestic waste > industrial waste = non waste. Value of Pb in the soil contaminated with trade waste is 3 times higher than in industrial waste and non waste, and 2.8 times higher than in domestic waste.

In comparison with Vietnamese standard, the content of Cu and Pb in soils contaminated with trade waste is approximately 2 times higher than accepted values. The soil affected by industrial waste shows high potential contamination of Cu and Pb. The content of Zn in soil affected by trade waste and industrial waste is a high risk to the soil environment.

3.2.2. Heavy Metals in the Rice Grain grown on Contaminated Soils

Heavy metal accumulation in rice is shown in table 5. The cadmium values in rice grain are changed from 0 to 0.12 mg/kg in non waste soils, from 0.03 to 0.2 mg/kg in soil affected by trading waste and industrial waste, and from 0.03 to 0.98 mg/kg in soil affected by domestic waste.

The zinc values in rice grain vary from 10.51 to 23.4 mg/kg in non waste soil, from 8.83 to 41.99 mg/kg in soil affected by trading waste, from 11.13-21 mg/kg in industrial waste and from 9.15 to 18.83 mg/kg in soil affected by domestic waste.

Table 5
Total content of heavy metals in rice grain (mg/kg dry weight)

Samples	Range	Cd	Zn	Cu	Pb
Non waste	Min	0.00	10.51	1.79	0.20
	Max	0.12	23.94	8.36	1.44
	Average	0.04	17.20	4.23	0.86
Trading waste	Min	0.03	8.83	2.80	0.26
	Max	0.20	41.99	42.32	6.65
	Average	0.11	19.72	13.83	2.55
Industrial waste	Min	0.03	11.13	3.76	0.38
	Max	0.20	33.05	6.38	0.92
	Average	0.13	21.00	5.40	0.67
Domestic waste	Min	0.03	9.15	2.39	0.71
	Max	0.98	18.83	6.68	1.81
	Average	0.12	12.68	4.20	1.15

The copper values in rice grain varies from 1.79 to 8.36 mg/kg in non waste soil, from 2.8 to 42.32 mg/kg in soil affected by trading waste, from 3.76 to 6.38 in soils affected by industrial waste, and from 2.39 to 6.68 mg/kg in soils affected by domestic waste.

The lead values in rice grains vary from 0.2 to 1.44 mg Pb/kg dry soil in non waste soil, from 0.26 to 6.68 mg/kg in soil affected by trading waste, from 0.38 to 0.92 mg/kg in industrial waste, and from 0.71 to 1.81 mg/kg in soil affected by domestic waste.

Cd values in the soil are ranked as follows: industrial waste ≥ domestic waste ≥ trading waste » non wastes. Zn concentrations in rice grain are ranked as follows: industrial waste > trading waste > domestic waste > non waste. Contents of Cu in the soils rank as follows: trading waste » industrial waste > domestic waste = non waste. Content of Pb in the soils is ranked as follows: trading waste » domestic waste > non waste = industrial waste.

4. Summary and Recommendation

4.1. Summary

Surveying concentrations of heavy metals in paddy lands near areas contaminated by different sources such as re-cycling of heavy metals, industry and domestic wastes demonstrates that those wastes lead to soil contamination with heavy metal, particularly Cu and Zn. The heavy metal

content in the soil is a potential risk for public health and soil and water environment.

In the soil contaminated with recycling waste, the content of Cu in 52.9 % of the samples is higher than accepted by the Vietnamese standard (TCVN7209-2002). Cu content can reach up to 1.9 times and Pb content up to 1.86 time the accepted value. In the soils contaminated by industrial waste, 4 samples (40 %), have a Cu content higher than that in non contaminated soils and 3 samples (30 %) a higher Zn concentration. The content of Cd, Pb in the soils remains below the accepted Vietnamese standard (TCVN7209-2002). Contaminating wastes remarkably increased the content of heavy metal in paddy lands. Heavy metals in contaminated soils increased by 5-154% for Cu, by 8-209% for Pb, by 41-74% for Zn and 36-105.3% for Cd, compared to the non contaminated ones.

The heavy metals in rice grains grown on soil influenced by contaminating waste were higher than that those grown on control soils. Heavy metals in rice grain contaminated were increased by 27.7-226.9% for Cu, by 34.1-196% for Pb, by 14.6-22.1 % for Zn and 162-228.6% for Cd, compared to rice from non contaminated land.

4.2. Recommendation

Sources of heavy metal/metalloid contamination to agricultural systems in the Red River Delta include uncontrolled runoff and leaching from the extraction and processing of non-ferrous ores, solid waste, water polluted by industrial and domestic wastes and re-use of waste water for irrigation. These factors should be documented in order to support environmental protection policies.

To be safe for public health and environment, waste water should be treated before re-use for agricultural irrigation.

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Achievement on Vector-borne Disease at National Centre for Parasitology, Entomology and Malaria Control Cambodia

by

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Vector-borne disease is still a major public health problem in Cambodia. During the last years, the National Centre for Parasitology, Entomology and Malaria Control (CNM), has made some great achievements in investigating, monitoring and controlling of major vector-borne diseases in the country. Malaria remains the leading cause of hospital admission and mortality even if major part of the country is malaria free... The malarious endemic areas are closely related to forest environment where *Anopheles dirus* and *minimus* act as the principal vector mosquitoes. There are four main categories of peoples at risk: ethnic minority groups, forest fringe inhabitants, temporary migrants and new forest settlers. Settlements of non-immune adult populations in high malaria transmission areas and areas where health system is not available or inadequately covered are prone to outbreaks.

The actual implementation of malaria control programme activities are integrated into the general health services at the provincial, district and commune level. The programme is receiving support from the International Organizations and number of NGO's. Close collaboration between the National Center and NGOs is well maintained to achieve an effective planning, implementation, monitoring and evaluation of the programme. Malaria situation has greatly improved within the last few years and the programme has been able to achieve a number of breakthroughs. Since 1999, no further malaria epidemics have been recorded in former Khmer Rouge areas and number of malaria cases have been reduced by almost two-thirds in several

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areas due to effective control measures such as improving access to treatment and massive deployment of impregnated bed nets in areas of transmission. Overall the malaria incidence rate declined from 12.2 per 1,000 in 1999 to 5.5 in 2005. Similarly, mortality rate declined from 7.8 to 2.19 per 100,000.

The program has been able to introduce and scale up a number of innovative strategies such as:

— Free distribution of pre-packaged Artemisine Combination Treatments (ACTs) in the public health sector,
— The use of simple diagnostic dipsticks and pre-packaged ACTs and rectal suppositories of artesunate by a group of trained and closely supervised Village Malaria Workers (VMWs) in hyper endemic areas,
— Social marketing of Malacheck and Malarine (a pre-packaged ACT) through the private sector,
— Recording of malaria information by private providers in 4 selected provinces,
— Free distribution and retreatment of insecticide-treated bed nets (ITNs) in malaria endemic villages, especially through "combined outreach activities" such as: delivering vaccinations under EPI programme, malaria treatment, deworming, Vitamin A and iodine capsules for specific target groups,
— Social marketing of insecticide treated hammock nets for temporary forest-visitors,
— Health education and participation in bed net distribution by village health volunteers.

Despite remarkable achievements made in a very short period of time, the NMCP still faces a wide range of constraints affecting the organizational efficiency and programme effectiveness. NMCP faces major obstacles such as:

— Low motivation attributed to low civil servant salaries common for the general public service in Cambodia,
— Limitation of resources both human and material,
— Inaccessibility of at-risk populations, especially during rainy season coupled with inadequate and/or inaccessible health care facilities, and poor communication systems (poor road conditions, lack of suitable vehicles, lack of telephone facilities), etc. resulting in treatment delays.

Dengue fever (DF) and Dengue haemorrhagic fever (DHF) have become one of the worst and most complex public health problems in the Kingdom of Cambodia. The epidemic potential of the disease, its particular high mor-

tality for children, its high prevalence among the poorest urban populations and the increasing spread of the disease to rural areas, make it a permanent threat for all Cambodian children. The disease itself and the efforts to control it bring a significant economic and social burden. Following the first reported epidemic in 1981, there have been increasingly larger epidemics every two to three years. The lack of adequate water supply and sanitary services explains the high incidence of DHF when compared to other neighboring ASEAN countries. From 1980-1998 epidemics of the diseases have recurred every 3-5 years with the latest epidemic occurring in 1998. The disease is hyper- endemic in both urban and rural areas and children are more vulnerable than adults, with obvious clinical illness, and case fatality rate (CFR) as high as 3 % - 20 % depending on the remoteness and quality of available health care.

Since 2001 following the WHO's recommendations on strengthening the implementation of the Global Strategy For Dengue Fever/Dengue Haemorrhagic Fever Prevention and Control (WHO/CDS/(DEN)/IC/2000.1), the National DHF Prevention and Control Programme has intensified disease surveillance by establishing sentinel hospital based surveillance to complement the health information system. Hence, epidemiological data in the country is being collected in a timely and comprehensive manner. Our recent activities have put higher priority to control dengue. Mass larviciding with temephos in key vector breeding sites has been the mainstay for epidemic containment. The dengue incidence rate per 100,000 had decreased from 94.6 in 2003 to 78.2 in 2004. In 2005 the rate was 70.8, a reduction of 9.5 % over the previous year (2004). The case fatality rate (CFR) among hospitalized cases, at 3 % in 2000, has declined to 1-2 % for the past 3 years. However, this death rate is high compared with a CFR of <1 % reported from neighbouring countries.

A number of parasitic diseases such as schistosomiasis and lymphatic filariasis are also endemic in Cambodia. Schistosomiasis has dramatically decreased in two endemic provinces of Cambodia after huge effort of mass drug administration. The morbidity and mortality indicators have shown excellent results. The prevalence rate of the disease in the villages where schistosomiasis is endemic has declined. In March 2005, with the evidence of low prevalence of schistosomiasis in 2 provinces, the program would like to move towards elimination by 2015 and eradication of *Schistosomiasis mekongi* in Cambodia in future.

In 2004, Cambodia became the first (and still the only) country to reach the target of covering 75 % of 2.8 million primary schoolchildren with regular deworming *(WHO Bulletin: experiences collected from 102 countries repre-*

senting all WHO region and available from: http://www.who.int/medicines/library/trm/Consumer.pdf.) This achievement is the result of an intense collaboration among the National Center for Parasitology, Entomology and Malaria Control of the MoH, the School Health Department of the Ministry of Education, and the national subcommittee of Iodine Deficiency Disorders, and international institutions such as the Government of Japan, JICA, GTZ, UNICEF, WFP, WHO and the Sasakawa Memorial Health Foundation (SMHF).

The pilot study in Meanchey district, urban area of Phnom Penh city, showed the prevalence of round worms and hookworms were 45.9% and 18.4% in 1998, respectively. However, after mass drug administration of Mebendazole and health education to school children twice a year, the prevalence has been decreased to 5.2% for round worms and 2.6% for hookworm in 2004. The method of mass drug administration with effective health education does reduce the morbidity of helminthiases. There is evidence that regular distribution of anthelminthic drugs can effectively reduce morbidity of ascariasis, hookworms and other intestinal parasite infection in Phnom Penh areas.

The National Malaria Center has jointed the WHO global elimination programme on lymphatic filariasis (LF) in 2003 with the aim to eliminate LF by the year 2015. The LF programme in Cambodia started with surveys in 1999 to find out the distribution of the disease. The first mapping of LF at provincial level was done in 2003 and the additional mapping at district level in Siem Reap and Preah Vihear in 2004-2005. Following the global elimination strategy, the implementation units for LF elimination was installed in the following sites:

— Ratanakiri province;
— Stung Treng province;
— Rovieng district in Preah Vihear;
— Angkor Chum district, Siem Reap district, and Varin district in Siem Reap.

The LF programme has completed its first year mass treatment with DEC and Albendazol in all implementation Units in 2005. Health education to the community on prevention morbidity and disability was provided through provincial health staffs, school-teachers and local authorities.

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Malaria Vectors in the Mekong Countries: a Complex Interaction between Vectors, Environment and Human Behaviour

by

Marc COOSEMANS* & Wim VAN BORTEL**

1. Introduction

After many decades of control efforts, the malaria situation in the Mekong region deteriorated dramatically in the late eighties of last century. In these years, political isolation of Vietnam, Cambodia and Laos was responsible for reduced access to efficient drugs and insecticides. In Vietnam, the peak of resurgence of malaria with devastating epidemics was reached in 1991 when over one million cases and about 5,000 deaths were reported. Today, the malaria burden has decreased drastically due to the intensive control programme deployed over the past fifteen years (SCHUFTAN 2000, NIMPE 2005). However, the burden of malaria is largely underestimated in the region as the registration system relies essentially on passive case detection by weak health facilities (SNOW *et al.* 2005, ERHART *et al.* 2006). Malaria is at its lowest level ever recorded and control activities could be progressively phased out. However, active transmission is still occurring in remote forested foci and human migration from these endemic foci to non-transmission areas can reintroduce the disease in areas now free of malaria (VERLE *et al.* 1998). The control of these foci will be essential to obtain a sustained reduction of malaria in the region.

A crucial determinant of malaria transmission is the survival of the vector. Mosquitoes will be able to transmit malaria only if they survive, after an

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allows a quality control on the morphological identification of species usually performed under difficult field conditions. This proved to be useful in Vietnam and Cambodia where the vector *An. minimus* was confused with the none vector species *An. varuna* and *An. culicifacies* B (VAN BORTEL *et al.* 2001, 2002).

Table 2
List of *Anopheles* species observed from 2001 to 2005
in domestic environments in Cambodia, Laos and Vietnam
(classification following HARBACH 2004, LINTON *et al.* 2005, GARROS *et al.* 2006)

Genus (subgenus)	**Section/series**	**Group**	**subgroup**	***species***
Anopheles	Myzorhynchus	Barbirostris		*barbirostris*
				campestris
			Vanus	*barbumrosus*
		Hyrcanus		*argyropus*
				hyrcanus
				nimpe
				sinensis
		Hyrcanus	Lesteri	*paraliae*
				crowfordi
				peditaeniatus
		Umbrosus	Umbrosus	*umbrosus*
Cellia	Myzomyia	Funestus	Minimus	*minimus A*
				minimus C
			Culicifacies	*culicifacies* B
			Aconitus	*varuna*
				pampanai
				aconitus
				jeyporiensis
	Neocellia	Annularis		*annularis*
				philippinesis
				nivipes
				pallidus
		Jamesii		*jamesii*
				splendidus
		Maculatus		*pseudowillmori*
				willmori
			Maculatus	*maculatus*
			Sawadwongporni	*notanandai*

Genus (subgenus)	Section/series	Group	subgroup	*species*
				sawadwongporni
				karwari
	Neomyzomyia	Kochi		*kochi*
		Leucosphyrus	Leucosphyrus	*dirus sensu stricto*
		Tessalatus		*tessalatus*
	Pyretophorus		Sundaicus	*epiroticus*
				subpictus
				indefinitus
				vagus

3. Major Vectors: Species and Association with Landscape

In Vietnam, Cambodia and Laos, three major malaria vectors are recognised. They belong to the species complexes of Dirus, Minimus and Sundaicus. These vectors have a wide geographical distribution where their role in malaria transmission is obvious, at least before the enormous control efforts of the last fifteen years.

The classic breeding places for *An.minimus sensu lato* are margins partially shaded with grass of moderated sized clear-water streams. Larvae can also be found in rock or ground pools and irrigation drains. These habitats are commonly found in foothills. Three species are recognised within the *An.minimus* complex (HARBACH 2004) of which two are found in the region: *An.minimus* A and C. Both species occur in sympatry in a large area that includes northern Vietnam, southern China and northern Laos (GARROS *et al.* 2006). So far only *An.minimus* A was detected in Cambodia (VAN BORTEL *et al.* 2004, TRUNG *et al.* 2004). In the province of Hoa Binh (northern Vietnam), the relative proportion of both species varies from one village to the other (from 2 to 65 % of species C) suggesting different environmental requirements (VAN BORTEL *et al.* 1999). In central Vietnam (Khanh Hoa Province) high densities of *An.minimus* A were observed in a village until April 1998 after which this species disappeared from the collections (TRUNG *et al.* 2004, VAN BORTEL *et al.* 2004) probably due to the wide use of ITNs (GARROS *et al.* 2005). *An.minimus s.l.* reappeared abundantly in 2002, but species C became predominant (98 %) suggesting an unknown mechanism of interspecific competition between both species (GARROS *et al.* 2005). More recently Garros *et al.* 2006 suggested that species C is associated with new agro-ecosystems in deforested areas (*e.g.* maize) whereas species A

occurs in less disturbed forested areas with traditional rice agrosystems. However, it was species A that was found in the suburbs of Hanoi where it breeds in water tanks near houses (VAN BORTEL *et al.* 2003) but was not found in other parts of the Red River Delta (Trung, pers. comm.). Although density of *An.minimus s.l.* was negatively related to landscape fragmentation due to human exploitation (OVERGAARD *et al.* 2003) it seems that the members of the species complex are able to adapt to new man-made environments.

The Dirus complex includes seven species (SALLUM *et al.* 2005) but so far only *An.dirus s.s.* (formarly *An.dirus* A) was found in Laos, Cambodia and Vietnam and is among the most efficient vectors in Southeast Asia. *An.dirus s.l.* is not reported in northern Vietnam, although it is present in southern China, northern Thailand and Laos. Several members of the complex occur sympatric in Thailand, and Myanmar (WALTON *et al.* 1999). In the western part, from Bangladesh to Myanmar, *An.baimaii* (formerly *An.dirus* D) is the most efficient vector. *An.dirus s.l.* is confined to forested areas where it breeds in small temporary shaded pools widely spread in forest, in forest fringe areas around the villages, and in the exploited forest areas, such as rubber plantations or even orchards. The abundance is often the highest in the late rainy season as a consequence of available breeding sites. Different observations in the western distribution of *An.dirus s.l.* revealed an expansion of the mosquito population during the rainy season from mother foci in deep forests to secondary breeding sites at the periphery (KONDRACHIN *et al.* 1991). This may explain the low densities of this forest-dwelling species observed in villages near the forest. Moreover, forest fragmentation has probably direct consequences on the maintenance of the *An.dirus s.l.* populations.

Species of the *An.sundaicus* complex are brackish water breeders on islands and along coastal areas of Southeast Asia. Breeding places are sunlit bodies of stagnant saline water with floating algae (DUFOUR *et al.* 2004a). Recent studies showed that only one species of the complex is present on the mainland and was formally named *An.epiroticus* whereas *An. sundaicus s.s.* occurs only in Borneo (LINTON *et al.* 2005). In Vietnam, *An.epiroticus'* distribution is confined to the Mekong Delta. In one study site of the Mekong Delta, the density increased drastically in two years (from 3,1 bites per man per night in 1998 to 190 bites/man night in 2000). The recent changes in land use from rice cultivation to shrimp farming probably explain this sudden nuisance of mosquitoes (TRUNG *et al.* 2004). Low densities are reported on the Cambodian and Thai Coast (Tho Sochanta, V. Baimai, pers. comm.).

4. Inter- and Intra-specific Behaviour of Vectors

Behavioural traits often exhibit geographical patterns and the variation is often indicative of underlying genetic differentiation or even cryptic species. However, environment factors may also influence the behavioural patterns at the intraspecific level, which are relevant for disease transmission and control (VAN BORTEL *et al.* 2004). By analysing the ratios of outdoor human-to-cattle landing rates and indoor-to-outdoor human landing the trends for respectively antropophilic and endophagic behaviour was estimated. While *An.dirus* s.s. and to a less extent *An. epiroticus* bite almost exclusively on man, different trends where observed according to the locality for *An.minimus* A, *An.sinensis*, *An.philippinensis* (fig. 1) and other species in relation to the availability of cattle in the villages (TRUNG *et al.* 2005). The biting activity inside the houses was relatively low for most species except in one site of central Vietnam (fig. 2). This site is a forest village of a minority group living in houses with incomplete walls of split bamboo and very large eaves allowing easy entry of the mosquitoes (fig. 3). Outdoor biting mosquitoes are more difficult to control and this behaviour may explain the persistence of malaria transmission after vector control (MEEK 1995).

Insecticide treated nets are mainly effective on late biting vectors. In figure 4 we can see that most anopheline species in the area are early biters by which they will avoid the contact with ITN. However, the main vectors bite later in the night and can be well controlled by ITNs, except in villages of central Vietnam with open construction. In these villages ITN used after 22 p.m. will prevent only 50 % of the bites of *An.dirus s.s.* (TRUNG *et al.* 2005).

After blood feeding, mosquitoes spent most of their time to rest. If they rest inside the houses (endophilic) conventional interventions based on residual indoor spraying of insecticide can be very effective to control malaria. However the major vector *An.dirus s.s.* rarely rests inside the houses making this kind of intervention not appropriate. *An. minimus s.l.* and *An. epiroticus* have been characterised to be endophilic species, however TRUNG *et al.* (2005) found both species and all other anopheline species to be highly exophilic. Only in northern Vietnam, *An. minimus* A exhibited a moderate degree of preference to rest indoors but not *An. minimus* C (VAN BORTEL *et al.* 1999, VAN BORTEL *et al.* 2004, TRUNG *et al.* 2005). However, differences in behaviour between species A and C was only studied in one site and more studies over the sympatric range of distribution are needed to understand the range of interspecific divergences in behaviour.

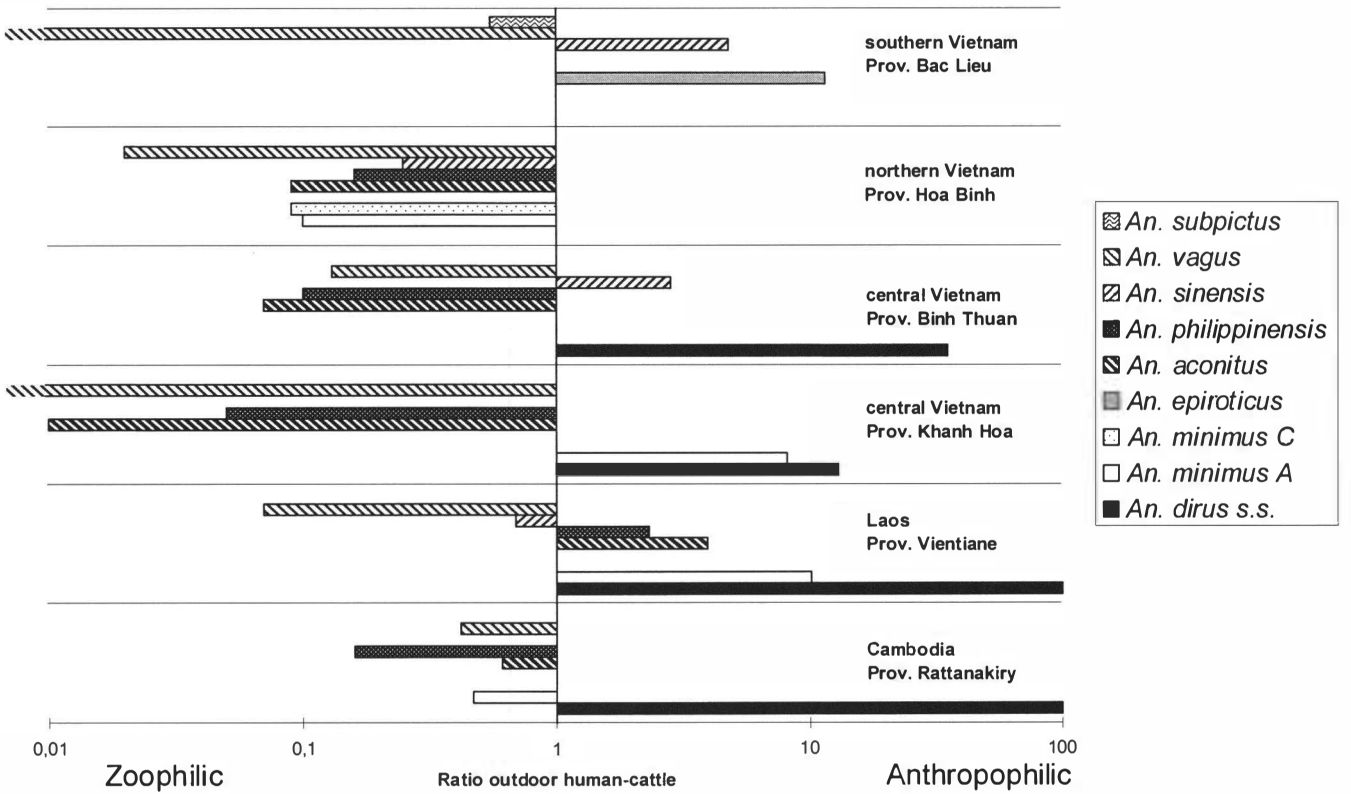

Fig. 1. — Trends of *Anopheles* species in preferring human host to cattle based on the ratios of outdoor human to cattle landing rates (after TRUNG *et al.* 2005). The degree of anthropophily increases from the left to the right.

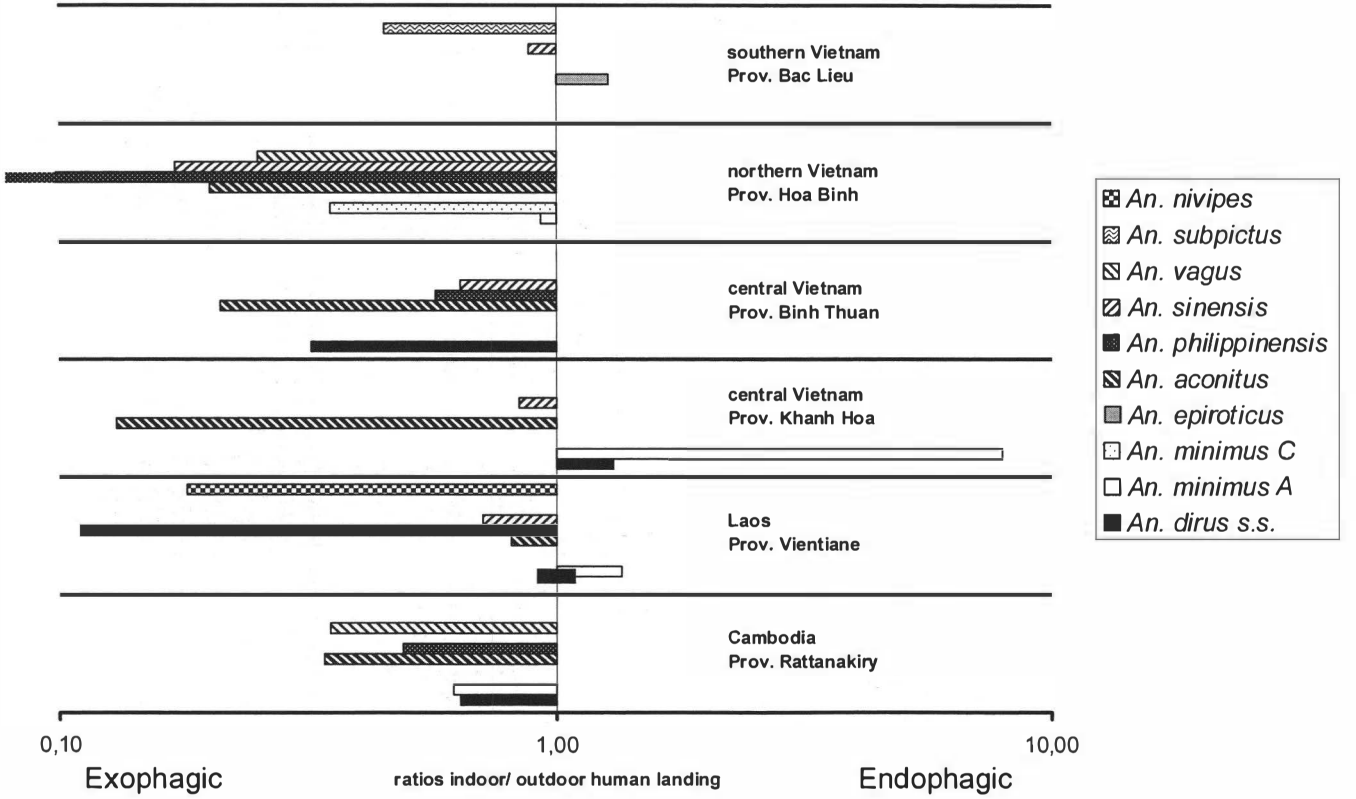

Fig. 2. — Trends of *Anopheles* species in preferring to bite indoor to outdoor based on ratios of indoor to outdoor human landing (after TRUNG *et al.* 2005). The degree of endophagy increases from the left to the right.

Fig. 3. — Open house construction of the ethnic group of Rac Ray in the Province Khan Hoa.

5. Malaria Transmission in Relation to Vector Distribution

In the region, malaria risk is not evenly distributed and depends on the occurrence of vectors, human behaviour and the performances of the control programmes.

In northern Vietnam, the major malaria vector, *An.minimus s.l.*, is confined to the hilly areas. Consequently lowlands, mountain and coastal areas have been almost preserved of malaria in the past. Malaria pressure on human populations occurred during centuries on the foothills and traces of this are still present in some ethnic minority groups. Indeed, the G6PD deficiency trait, conferring resistance to *Plasmodium falciparum*, is high (up to 34 %) in ethnic groups (*e.g.* Muong, Thai, Tho, Dao) that traditionally lived in the malaria endemic foothills, whereas it is almost absent among groups (ea, Mong, Kinh) that lived in the past in mountainous or lowland areas (VERLE *et al.* 2000). The intensive control programme, based on improved case-management and vector control, has been very successful in this region. In 1992 in the province of Hoa Binh, the health services reported 32,673 cases. Five years later the number of reported cases had dropped by 88 %. Only 59 cases could be confirmed by the laboratory and half of them had been infected in

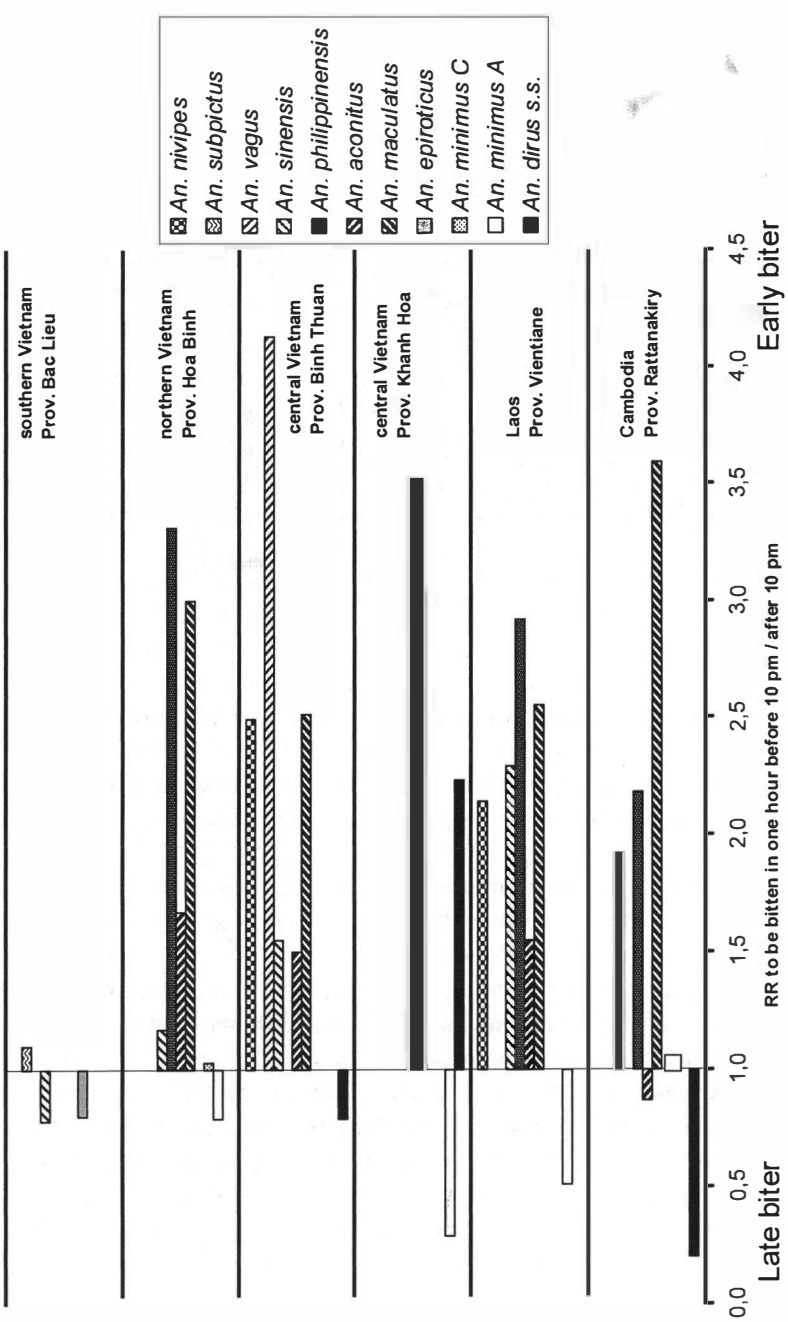

Fig. 4. — Trends for early biting activity based on the relative risk of being bitten in one hour before 10 p.m. compared with one hour after 10 p.m. (after TRUNG *et al.* 2005). The degree of early biting increases from the left to the right.

the southern provinces (VERLE *et al.* 1998). The northern part of the country is now almost free of malaria. However, *An.minimus A* and C are still present. Their high longevity suggests that transmission can occur at almost any time if parasite reservoirs are reintroduced (TRUNG *et al.* 2004). This could explain the reactivation of transmission in some small foci at the border of Laos and China facing uncontrolled migration (NIMPE 2006).

The situation is more complex in the tropical forested hilly areas of central Vietnam, Laos and Cambodia where two major malaria vectors can be found (*An.minimus* A and *An.dirus s.s.). An.minimus s.l.* is mainly present during the dry season (January-July), as during the rainy season larvae of this species are flushed away from their river breeding places by the heavy showers. If *An.minimus* A is clearly involved in malaria transmission (TRUNG *et al.* 2004), the vectorial status of species C needs still to be clarified (GARROS *et al.* 2006). *An. dirus s.s.* is mainly present during the second part of the rainy season once its breeding sites, small rain fed pools, are omnipresent. When both species are present, the successive occurrence of both vectors leads to perennial transmission. *An.dirus s.s.* is certainly the most effective vector in the region: it is highly susceptible to human *Plasmodium*, long living, and almost exclusively anthropohilic, even if they feed primarily on monkeys in the tree-tops (SALLUM *et al.* 2005). It is than not surprising that high levels of transmission can be maintained at low vector densities (TRUNG *et al.* 2004). However, the control of these species is a real challenge for the control programmes regarding the exophagic and exophilic behaviour of this vector. Moreover, a large proportion of forest villagers contract the disease by the bites of this vector during their night activity in the forest (ERHART *et al.* 2004b, 2005).

In the Mekong Delta and along the coast of Cambodia the main vector is *An. epiroticus*, a brackish water-breeding mosquito. This vector was described as being an efficient vector in Vietnam (with sporozoite rates from 0.18 to 4.4%) and in Cambodia (sporozoite rate 0.4%) (DUFOUR *et al.* 2004a). In a village of the Province of Bac Lieu, none of the 11,000 mosquitoes that were examined for the presence of sporozoites, were found positive (TRUNG *et al.* 2004). For explaining the present low incidence of malaria in this site (2.6 case/100 person /year) (ERHART *et al.* 2004a) we should have analysed more than 300,000 specimens! This shows the difficulty of incriminating vectors when the incidence decreased due to interventions. The vector status of the species belonging to the *An. sundaicus* complex may vary in time and from place to place (in DUFOUR *et al.* 2004) which can be responsible for potential risk of malaria outbreak as consequence of environmental changes or natural catastrophes, *e.g.* tsunami (KRISHNAMOORTHY *et al.* 2005).

Beside the major vectors many anopheline species have been suspected or incriminated as malaria vectors in the area. Species such as *An.maculatus s.l.*, *An.aconitus*, *An.subpictus*, *An.philippinensis*, *An.vagus*, *An. sinensis*, *An.campestris* are listed as vectors in the Oriental Region (MOUCHET *et al.* 2004) and occur in the Mekong countries. In Vietnam, more than ten species were incriminated as secondary vectors (PHAN 1998) but their current importance in malaria transmission is unknown. In Laos, *An. nivipes*, breeding in flooded pools of rice fields settings, is suspected to be responsible for the malaria transmission in settlements other than in foothills or forest (KOBYASHI *et al.* 2000). This species was found positive for sporozoites in the central plain of Thailand (HARBACH *et al.* 1987). In Sekong province of Laos, VYTHILINGAM *et al.* (2003) found *An.maculatus s.l.* and *An.jeyporiensis* positive with the ELISA test alongside *An. dirus s.s.* This test is however not the most appropriate test to incriminate vectors and additional confirmation may be required. The study of impact of land use, environmental changes and human behaviour on the distribution and abundance of the secondary vectors is important for understanding the complexity of malaria transmission in Southeast Asia and will allow the risk of malaria transmission to be tracked in a fast changing environment.

6. Human Behaviour Patterns as Risk Factors for Malaria

Variability in malaria endemicity is not only linked to a complex interaction between environment, parasites, and vectors but also to human behaviour, a determinant factor in the occurrence of the disease. Some ethnic minorities are high-risk groups because of agricultural practices near or in the forest, and poverty.

Housing conditions will influence the behaviour of mosquitoes. Open construction such as found in minority groups allows anthrophilic mosquitoes to easily detect attractant stimuli from human hosts (TRUNG *et al.* 2004). The proximity of the houses to the forest edge is a considerable risk factor for malaria. The presence of cattle around or under the houses deviate part of the vectors so that the contact man-vector is lower compared to other places where cattle is almost absent (VAN BORTEL *et al.* 2004, TRUNG *et al.* 2005).

Human sleeping behaviour is important in determining man-vector contact considering that anopheline mosquitoes bite only during the night. The introduction of electricity in the villages, sometimes using ingenious ways like small dynamos on rivers, determined an increase in outdoor activities

during the evening and a delay in bedtime. In these conditions the period of protection for insecticide-treated bed nets is decreased, particular when early biters and exphagic anopheline species are involved in malaria transmission.

Malaria is an occupational disease affecting people during their temporary stay in the forest like forest workers, gem miners, plantation workers. Farmers may stay away from their village to cultivate their cut-and-burn plot in the forest. They live in temporary houses often without walls. During their temporary stay in the forest, people sleep in hammocks and bed nets are useless. Regular forest activity increases by 4-fold and 10-fold the odds of disease and infection, respectively (ERHART *et al.* 2004). Adapted control tools such as long lasting impregnated hammocks could be appropriate in such environment.

7. Insecticide Resistance

Knowledge of vector resistance and changing trends of resistance in target species are basic requirements to guide insecticide use in malaria control programmes. Only long lasting pyrethroids can be used for impregnation of bed nets, which is nowadays the most effective tool to be protected against malaria. A network (MALVECASIA [1]*) was set up for the monitoring of insecticide resistance in Cambodia, Vietnam, Laos and Thailand. After three years of intense insecticide resistance monitoring in more than hundred twenty sites, a clear picture of the status of insecticide resistance of malaria vectors was achieved. In Laos and Thailand, resistance is almost absent. In Cambodia, only *An. vagus*, a non-vector species, was found resistant to DDT and different pyrethroid insecticides. In southern Vietnam, high levels of resistance in *An. epiroticus* were detected for all pyrethroids that were tested (MALVECASIA 2005). In northern Vietnam, at the border with China, *An. minimus* species A and C were found resistant to pyrethroids. But, insecticide resistance in Vietnam was only observed in low or transmission free areas so that there is no need to change the malaria control strategy that is currently implemented in Vietnam.

However, due to the high levels of insecticide resistance observed in southern Vietnam and potential risk for epidemics, there is an urgent need to assess the operational consequences of the observed insecticide resistance.

* The number in brackets [ ] refers to the note p. 566.

For this purpose, experimental houses will be constructed to evaluate the efficacy of existing vector control tools (*e.g.* insecticide impregnated bed nets) on wild resistant populations of vector species.

8. Conclusions

The goal of malaria control is not to eradicate malaria mosquitoes but anophelism without malaria has been achieved in temperate countries and in large areas of northern Vietnam. Relatively high incidence is still observed in the remaining forested areas, the biotope of *An.dirus s.l.* Transmission still occurs inside the villages located close to the forest edge, but the burden of the disease is mainly associated with forest activity (*e.g.* logging, farming, and mining). Moreover anopheline species other than main vector species could be involved in malaria transmission, hence, intensified research efforts on these so called 'secondary vectors' in different ecological settings is needed. Impact of land use, environmental and human behavioural changes on the distribution and abundance of vectors should be further explored to understand the complexity of malaria transmission in the Mekong Countries. This will allow to progressively assessing the risk of malaria transmission in a fast changing environment. For this purpose a Geographical Information System (GIS) is now under development to analyze the distribution of *Anopheles* species to environmental parameters. All the information has been integrated into a simple visualization tool, SEAGIS.

The most efficient vector, *An. dirus s.s.*, is exophilic, exophagic and bites early (before 22:00) so that ITNs and IRS have little impact on transmission. Thus, innovative interventions targeted to forest workers and taking into account the vector bionomics are urgently needed (ERHART *et al.* 2006). Insecticide resistance observed in the Mekong Delta and to a less extent in northern Vietnam is not yet a major issue as it occurs in very low or non-endemic areas. However further monitoring of insecticide resistance is recommended and operational implication of existing resistance should be assessed.

The most difficult factor to control is certainly human migration. Seasonal workers from non endemic areas with low immunity against malaria work in the endemic foci of forested provinces. When they go back to the malaria free areas, these potential malaria reservoirs can again contaminate the local malaria vectors and annihilate years of control efforts. Therefore, the maintenance of a good surveillance system including the most remote areas, in particular forested borders, is crucial for the future (VERLE *et al.* 1998, ERHART *et al.* 2006).

NOTE

[1] MALVECASIA is a research network studying the distribution and insecticide resistance of malaria vectors in Southeast Asia (Vietnam, Cambodia, Laos and Thailand). Partners are the Institute of Malariology, Parasitology and Entomology (Vietnam), the Centre of Malariology, Parasitology and Entomology (Laos), the National Center for Malaria Control, Parasitology and Entomology (Cambodia), the Mahidol University (Thailand), the Liverpool School of Tropical Medicine (UK), the Institut de Recherche au Développement (France), The Natural History Museum (UK) and the network is coordinated by the Institute of Tropical Medicine (Belgium). The project is supported by the INCO-DC programme of the European Commission (IC4-CT-2002-10041) and by the Belgian Cooperation.

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The Patterns of Commercial Sex in Cambodia

by

HOR BUNLENG*, SENG SUTWANTHA* & CHHEA CHHORVANN*

1. Background

HIV/AIDS still remains one of the major health issues in Cambodia despite the fact that the trend of the outbreak is going down. The disease has been spreading very quickly since its start in 1991, making Cambodia the most HIV/AIDS affected country in South East Asia. In order to respond to this infamous epidemic, the National Center for HIV/AIDS, Dermatology and STD (NCHADS) was established. NCHADS has delivered numbers of intervention programs with the aim of taming the HIV/AIDS epidemic, for instance by providing STD services, promoting consistent condom use, and educating people about HIV/AIDS and STD, its modes of transmission and the prevention methods.

It has been found that in Cambodia HIV is commonly infected through heterosexual. There is no evidence of homosexual and injecting drug use, responsible for the spread of the disease, while in neighboring countries, such as Thailand and Vietnam, homosexual and injecting drug use are important risk factors for HIV transmission. It appears that commercial sex work in Cambodia is what we should pay additional attention to because, according to behavior surveillance in previous years, Cambodian men heavily used commercial sex services (16.3% versus 23.2% for married and single men, respectively), no matter what their marital status is.

NCHADS strategically classifies female sex worker as one of the female high-risk groups that need special attention in terms of HIV/AIDS prevention. In addition, since the chance of transmitting HIV and STD presumptively

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occurred at these settings, it is worth exploring the characteristics and related information of commercial sex work at brothel level, where Cambodian and Vietnamese female sex workers predominate.

NCHADS should understand well about the situation of female sex worker in Cambodia, before designing HIV/AIDS any intervention programs for them. In fact, commercial sex is illegal in Cambodia; however it has been found that there are numerous entertainment establishments, which provide sexual services such as brothels, karaoke, or massage parlous-remaining in highly populated areas such as provincial towns and capitals. In brothel settings, there are two types of female sex workers — Khmer and Vietnamese sex workers. Apparently, the patterns of sex work in both groups are not similar although they all provide sexual services in Cambodia. The sexual patterns of these groups may have some effects on the attitudes and behaviors of female sex workers towards HIV/AIDS prevention. Therefore, the sexual patterns of Khmer and Vietnamese girls must be explored.

2. Objectives

The primary objective of the study is to comprehensively explore the pattern of being Cambodian and Vietnamese commercial sex worker and to compare such patterns of the two predominant groups. Specific objectives:

— To identify a pattern of being a sex worker;
— To identify the frequency of their mobility;
— To identify their demographic characteristics in general;
— To identify the pattern of their health seeking behavior;
— To clarify the meaning of regular partners, sweethearts, clients, etc.;
— To identify their daily life, and socio-economic status;
— To identify their future expectations;
— To identify the difference between Cambodian and Vietnamese sex workers.

3. Methodology

3.1. Study Design

A qualitative study will be designed by using both in-depth interview and Focus Group Discussion (FGD).

3.2. Study Sites

Five sites will be selected for the study, namely Sihanouk ville, Odor Mean Chey, Kampong Cham, Battambang, and Rattanakiri. These five provinces are located in different regions in the country. For instance, Sihanouk ville is a coastal area while Rattanakiri is in mountainous region. Again, Odor Mean Chey is situated along the Thai border and Kampong Cham is in the central region.

3.3. Study Population

Female commercial sex workers (FCSW), both Cambodian and Vietnamese, working in brothels in all the selected five sites were selected as study population. Among this population some will be sampled to include in in-depth interview and FGD.

3.4. Sampling Strategy and Sample Size

Purposive sampling was implemented. The aims of the selection of Cambodian and Vietnamese FCSW into the study is to identify the case that will be able to provide a full and sophisticated understanding of all patterns of commercial sex. However, in case of Vietnamese FCSW, only those who can speak Khmer fairly good or good will be selected.

Data collection started with a convenient sampling in order to recruit FCSW for in-depth interview. Then, purposive sampling was used to include subjects who can provide rich information relating to the questions asked in the study.

3.4.1. Khmer Sex Worker

Eighty-seven female Khmer sex workers (KFSW) and eight Khmer brothel owners participated in the study. Five FGD, each group made of 6 to 9 people, were organized while forty-six KFSW were in-depth interviewed and there was also an additional group interview.

3.4.2. Vietnamese Sex Worker

Forty-five Vietnamese girls working as female sex workers were included in the study. Among them, 31 Vietnamese female sex workers (VFSW) were in-depth interviewed, while the rest participated in FGD. Besides, three

brothel owners, whose brothel has only VFSW, were also in-depth interviewed in order to enrich the information derived from VFSW. It has been found that among VFSW attending this study, some were born in Cambodia.

4. Findings

4.1. Demographic Characteristics in General

4.1.1. Family Background

Some common patterns were found although female commercial sex workers (FCSW) included in the study had different demographic characteristics. Some were single, divorced or single mothers. However, there were no married women who, currently living with husbands, worked as FCSW. For those, who used to get married, their husbands were paired by their parents. Some sex workers reported that they got children living with their parents in their hometowns.

4.1.2. Educational Level

Educational level for both Khmer and Vietnamese girls is very low since only few have finished primary school. It has been found that VFSW who were born in Cambodia had received very low education in both Khmer and Vietnamese languages. Similarly, for those whose origins were in Vietnam, their educational attainment is also very low.

4.1.3. Smoking

Some of the study participants smoke. A Khmer sex worker said that she smokes because smoking makes her look like a professional sex worker and groovy. Vietnamese sex workers said that they smoke because of boredom, while some girls said that, as they often lighted a cigarette for their friends, they get addicted to smoking. It is usual that female sex workers drink alcohol sometimes with their clients. Most of female sex workers stated that they drink because their clients force them and if they refuse to drink alcohol, their clients will get upset and may stop having sex with them.

4.1.4. Drug Use

Drug use was not often found among study subjects. However, some of them reported that some girls in other brothels might have used drug although they could not give significant information about that issue. Only one case of drug use was found. A KFSW revealed that she has been using drug "Ya ma". She got the drug from her boyfriend. She can purchase the drug if she needs, by asking an agent (bullies) to buy for her. She said that the agent accepts the order only if she orders more than 5 tablets — each tablet cost 7,000 Riel. She also said that she could buy the same drug for other female sex workers who work in other houses. The girl smokes drug secretly in her room so that the brothel owner does not know. It takes from 5 to 10 minutes to finish one tablet. One Khmer sex worker had met a male client who uses drug. The client intimidated her to smoke drug before having sex by pointing his gun at her head. After she strongly refused to consume that drug, the client asked the brothel owner to change girl for him. Another Khmer sex worker reported that she has a boyfriend who is a drug user. Yet another one, a Khmer sex worker, has experienced with a men who applied a "black substance" on his penis 15 minutes prior to having sex with her. In a nutshell, it has been observed that drug issues are more likely found in the group of Khmer sex workers.

4.2. Socio-Economic Status

The common pattern found was that all commercial sex workers accommodate in the brothels with their pimps. Brothel owner and their girls live together like a family. Girls usually call "Mum" or "Dad" female and male brothel owner, respectively.

4.2.1. Income

It has been found that female sex workers get paid in different ways in different brothels. Apparently, in Khmer brothels, there are two main methods used. The first method is called "50 % share" meaning that money girls earn from having sex with a client, excluding incentive, will be paid 50 % to the brothel owner. Again, in this method, girls may get paid every day or on monthly basis depending on their agreement with their pimps. In general, there is no clear payment rule since in some brothels, the owners charge female sex workers the expenses for water, electricity, and the fee for the local authority. In this method, brothel owners note the number

of partners each girl sleeps with each day. At the end of each day or each month, the brothel owners use that notebook to calculate the income for each girl in the house. Most of KFSW said that they do not know the number of sexual partners they had and they rely totally on the records of the owner at the time they get paid. The second method of payment is "monthly salary". In this method, female sex workers have to negotiate with their pimps before deciding to work in a particular brothel. Moreover, in "monthly salary" method, girls can keep all their incentive, and they do not need to pay for water, electricity and food.

In Vietnamese brothels, the common method of payment used is "50 % shared". VFSW get paid every month or every two months depending on their agreement with the owner. Some VFSW have their own notebooks to record numbers of sexual clients they had to check with the one of the owner. Thus girls know exactly how much they get each month.

The difference between KFSW and VFSW was found in terms of income. Vietnamese sex workers are more likely to make a higher salary than their Khmer counterparts. For instance, Vietnamese girls can receive from 150 US$ to 250 US$ per month while Khmer sex workers may get paid 50 US$ to 70 US$ per month. The reason behind this difference was not completely discovered. So far, the assumptions made are: VFSW are more beautiful or have more skill in pleasing clients than KFSW. Likewise, VFSW are more hygienic than Khmer counterparts. In addition, it has been observed that all VFSW were told by their owners to provide massage services to their clients before having sex. These assumptions were quite accurate because it has been found that most VFSW get paid 8,000 to 10,000 Riel/per sex while most of KFSW receive only 3,000 to 5,000 Riel/per sex. In order to increase their incomes, some Vietnamese girls used to have cosmetic surgery to make them look relatively prettier; consequently they may attract more clients.

Furthermore, it has been found that the cost per sex may change depending on the types of clients. For instance, if the client is a foreigner, a sex act costs 5 US$ or 20 US$ per night. Apart from their salary, female sex workers may receive incentive from clients. Female sex workers do not share their incentive with brothel owners. Actually, all Khmer and Vietnamese girls do not choose their sexual partners as long as they get paid. Interestingly, a Vietnamese girl mentioned that she did not select partners, but if she meets a client she does not want to have sex with she may double the actual fee, so the client may refuse her instead.

4.2.2. Setting the Fee for Sex

Brothel owners are responsible for setting the cost "per sex" of their girls. The higher cost will be set for a girl who is relatively beautiful, more playful, friendly and able to please more clients. Likewise, a young female sex worker may cost more than an old one. In some cases, female sex workers set the cost for their sex but not less than the cost set by the owner. According to a brothel owner, the selection of girls is based on their complexion, body shape, and face appearance. For example, too short or very black or too old girls will not be accepted to work in their brothels. Consequently, these girls may work as sex worker in the streets.

4.2.3. Issues in Brothels

It is interesting that KFSW and VFSW are unlikely to work together. There may be a lot of conflict between Khmer and Vietnamese sex workers — a concern raised by a brothel owner. In contrast, the brothel owner, where both KFSW and VFSW work together does not very much believe so. It is true that language may be one of the factors separating both female sex worker groups. Similarly, pimps who know Vietnamese language are more likely to recruit VFSW in their brothels. A brothel owner who has only VFSW in his/her house stated that VFSW are easy to control, they are respectful, not tricky, disciplined, tidy, and easy to get advised. Most importantly, VFSW like working to earn money and most of them are very good at saving money. Likewise, these girls do not have much network outside the brothels, so they are free from drug use, bully or boyfriends, thus they concentrate only on their work. In contrast, KFSW create a lot of problems in brothels. They do not listen to the owners. They may cheat the owner by borrowing money and then escape from brothels or even filling a case of trafficking women into the sex industry against the owner. This is because KFSW know a lot of people outside brothels, especially gangs and their boyfriends. According to a Khmer brothel owner, KCSW are not disciplined and they do not like working to earn money, but to enjoy their life. It has been often found that KFSW waste a lot of money for going out with their friends or sweethearts or buying unnecessary stuff.

4.2.4. Their Expenses

Despite the fact that only some female sex workers reported that they were breadwinners, the majority regularly sent their salary to their families.

It has also been observed that few FCSW work as sex workers to earn their own living. Apart from sending money home they save some money for their daily expenses. It is interesting that one girl revealed that she used her money to play card (gambling) with their peers.

4.2.5. Debt

According to brothel owners, some female sex workers borrow money from their pimps. Pimps generally allow their girls to borrow less than 200US$ with no interest. Some female sex workers borrow money from their pimps to send home in case of urgent need. In addition, brothel owners will not lend to those who have no reasonable reasons for borrowing money since they are afraid of being deceived by sex workers: "I lent my girl 200 US$, and then she escaped from the brothel". Most of the time, both Khmer and Vietnamese female sex workers start their work after they become in debt. For instance, when a Vietnamese girl arrives at the brothel she has to borrow money to pay the agent who brought her from Vietnam. Similarly, Khmer girls are likely to borrow money for their families at the start of their work.

4.3. Their Sexual Life and Sexual Practices

4.3.1. Age of First Sex

Age at first sexual intercourse among Khmer and Vietnamese female commercial sex workers varied from 15 to 19 years old. Their first sexual intercourse was with boyfriend or husband or client. Few of Khmer girls were raped by their neighbors or relatives before heading to work in prostitution.

4.3.2. Selling Virginity

For those who sold their virginity, they got paid about 300 to 700 US$, while about 1,000 US$ in Vietnam. Most Khmer and Vietnamese girls uncovered that they sold their virginity because of poverty. Interestingly, most of Vietnamese girls participating in the study exchanged their first sex with money although their sexual partners were their boyfriends. Some decided to sell their virginity before agreeing to have sex with their sweethearts. Most Khmer girls, on the other hand, do not exchange their first sex for money if their sexual partners were their boyfriends. Desperate need for money — to clear debt, to send their parents to hospitals — is the main factor that makes

Khmer girls sell their virginity. For example, a girl from a very poor family decided to sell her virginity at a cost of 500 US$ because her mother was suffering from tumor in her brain and what is worse, at home, her stepfather had been attempting many times to rape her.

4.3.3. Network for Selling and Buying Virginity

It has been found that most of women sold their virginity to middle-aged businessmen — Khmer, Chinese, and Japanese — or high-rank government officials. Surprisingly, a belief involving in buying a virgin girl has been detected. That is: men will have good luck if they have sex with virgin girls. This belief may reflect the numerous cases of selling virginity reported occurring in Sihanouk ville, where a lot of casinos are located. Generally, it has also been observed that selling and buying virginity occurs frequently in Cambodia since even most Vietnamese girls who migrated from Vietnam, reported that they sold their virginity in Cambodia.

According to girls who used to sell their virginity, there is an agent — mostly female — who actively searches for girls who want to sell their virginity or clients who need it. The girl told the agent she wanted to sell her virginity at the cost of 400 US$, then the agent would spend some time to find a client. After selling her virginity, the girl gave 50 US$ to the agent despite she did not know whether the agent received money from the client or not. Actually, the agent is hardly found by people outside the network. A brothel owner said that one time an agent went to her house and asked whether she knew clients who wanted to buy a virgin girl. In other cases, the virgin girl is sold in brothels. After the agreement between brothel owner and girl or people in charge of her, the virgin girl stays at the house and works as a house helper (cleaning, cooking,...) till there is a client. Paradoxically, there is no brothel owner participating in the study who said to be involved in this traffick activity. From in-depth interview, all of them refused that they receive virgin girls to work in their brothels since they are clearly informed that trafficking women and children into the sex industry is a criminal act in the country; however, in the real world, some female sex workers revealed that they sold their virginity in their current brothels.

4.3.4. Reasons for Selling Virginity

So far, there has been no clear explanation on why girls sell their virginity. And that is still doubtful although all girls said that no one forced them to sell their virginity or to work in sexual establishments. One case was

found since a girl confessed that she was sold by her elder sister, despite her agreement. Interestingly, some girls mentioned that they came to brothel with their mothers and they send all their salary home or their mothers come to the brothel each month to collect their salary, so mothers appear to have some subtle influence on their decision to work as sex workers. "A girl has a mother who was a pimp, and later on, her mother decided to sell her virginity to a client in Phnom Penh at the cost of 300 US$...": this is one of the examples showing a mother selling her daughter's virginity.

Besides, family problems are other factors driving girls into the sex industry. For instance, some girls decided to leave their family just because they knew that their husband had another wife. Other girls had experienced broken heart with their boyfriend, with whom they had their first sexual intercourse. One girl narrated that she decided to work as a sex worker because she was raped by her boyfriend who used date-raping drug to make her lose her consciousness before bringing her to a guesthouse after a friend's birthday celebration.

In short, these are reasons derived from all Khmer female sex workers for deciding to sell virginity. Poverty of families, need for more money to enjoy their own life, enjoy sexual life, and falling into the traps of false friends who promise to find a better paid job.

4.3.5. Previous and Current Work Situations

Before coming to work in brothels, both Khmer and Vietnamese sex workers did not have any good jobs. Since they do not have high education, most of them were found working in garment factory, in the markets as fruit sellers, farmers, small traders, or even jobless. Consequently, it is quite accurate to assume that since girls do not have stable and profitable jobs, they are more likely to leave their home to work in commercial sex industry.

Interestingly, most of the girls choose to work in the areas which are situated quite far from their hometown or their family house. This assumption is quite consistent because most female sex workers interviewed in Battambang derived from other places, such as Phnom Penh, Kampong Cham, Kampong Chhang,... A girl said that she used to live and work in a karaoke in Phnom Penh, but when she wanted to work as a sex worker, she decided to move to Battambang. Despite the fact she heard that Battambang was a good place to live, the fact underneath her move might be to be far away from people she knows. This pattern was also found in Sihanouk ville among the group of KFSW. They all have families living in Phnom Penh, but no one used to work as a female sex worker in Phnom Penh.

Likewise, Vietnamese girls, excluding those who migrated from Vietnam, are likely to work as female sex workers in the brothels located far from their family homes. Most of Vietnamese girls who work in Sihanouk ville have families living in Kampot or Phnom Penh.

4.3.6. Work Requirements

All girls did not receive any training on how to provide commercial sex services at the beginning of their work. When asking about whether they got any training or not, all of them looked surprised. They believed that they all know how to have sex and training on how to provide sex services seems to be silly and funny to them. Similarly, brothel owners seemed astonished when asking whether they provided that kind of training to their girls or not. Brothel owners stated that they did not need to provide any training to their girls since they accepted only "bad girls" — girls who used to have sex before being married or enjoy having sex and those who used to work in commercial sex before; consequently they all know how to provide sex services. Furthermore, some brothel owners may provide advice on how to greet clients, how to use condom and how to save more money, etc. A group of Vietnamese newcomer girls said that they learnt all services, such as how to provide sex and massage services, from their senior mates in the brothel. Vietnamese brothel owners mentioned that they used to teach their girls how to keep their body and sexual organs hygienic and how to take care of their health as being a sex worker, however this concept was not mentioned by Khmer brothel owners.

4.3.7. Commercial Sex Clients

Clients of brothels are all types of males — from young to very old clients and from businessmen to government officials. This means that males use commercial sex services heavily. Each female sex worker (both Khmer and Vietnamese) has sex with 2 to 10 clients per day — that is a lot. Some girls said that they feel happy when having sex with young men because they have sexual feelings with their clients and the intercourse is relatively shorter than that of middle-aged men. Some girls uncovered that they feel they hate men when they have sex with many clients in a day, while some stated that they feel nothing since having sex with men is their job or they do not care as long as they can earn money. According to FCSW, clients are more likely to visit brothels in the evening and girls have more clients during the holiday period or festival days, such as New Year.

4.3.8. Types of Sexual Acts

Vaginal sexual intercourse is the most common practice in brothel in Cambodia. There is no evidence of anal sex. Oral sex has been generally called "special" or "eat ice cream". According to FCSW, "special" is more expensive than vaginal sex; however, very few female sex workers know how to do it or want to do it. It has been observed that many VFSW can perform oral sex; in contrast only a handful of KFSW can do so. Besides the fact that some female sex workers do not know how to perform oral sex, some said, "It is disgusting...mouth is used for eating". Although many clients ask sex workers to provide them "special" or "eating ice cream" sex, girls can deny it and neither clients nor brothel owners do force them to do it. Girls consistently said that they like to perform vaginal sex since it is natural. In the study, it has been found that white men are likely to ask for oral sex, while Khmer men prefer vaginal sex.

4.3.9. Violation in Brothels

Since they started working as brothel-based sex workers, they have not been experiencing any violation from clients. Generally, drunk clients are more likely to force girls to have sex with them without using condom or force them to perform oral sex. In addition, all girls seem to be very satisfied with their current brothel owner because they are rarely blamed or punished from their boss. The most common reasons why they get blamed or punished are for going out too often and too long, having conflict with other sex workers in the same house or other brothels.

4.3.10. Brothel Regulations

According to brothel owners, there is no clear regulation in brothels in order to manage sex workers. Regulations vary from one house to another but it has been found that Vietnamese brothels appear to focus more on hygiene of their places and girls. In Khmer brothels the owners do not allow their girls to visit other brothels in order to prevent trouble caused by the conflict between girls. Some owners emphasize their girls' behavior, for example, they have to behave well in their community by avoiding using "bad word" or have to wear proper dress like ordinary girls in daytime. However, they can wear sexy dress in the evening. Some owners do not want their girls to have boyfriend since they often find that girls may waste a lot of money for their boyfriends; consequently, they stop sending money

to their poor families. What is worse, some girls may borrow money to send home, and then they will get into debt. More importantly, all girls must have sex with condom — this regulation exists in all brothels in Battambang and Sihanouk ville since 100% condom use program has been covered. Similarly, condom use is compulsory in Vietnamese brothels. "It is not 100% condom use but 200%, since they use 2 condoms for each sex act", a Vietnamese brothel owner claimed. Again, the Vietnamese brothel owner lays emphasis on the hygiene of his/her girls as it is compulsory that all girls have bath in every early morning and have their sexual organs washed with warm solution (warm water, salt, and lemon) after having sex, or before going to bed at 2 am. In addition, the owners also advise their girls to sleep and eat properly to maintain their health and beauty. It is interesting to find that Khmer brothel owners also explain and give advice on health and hygiene to Khmer female sex workers. However, as it is not compulsory, Khmer girls seem to be stubborn.

4.3.11. Sickness and Pregnancy

Regarding FCSW health, brothel owners will cover the fee of their girls' medical visit as well as fee for treatment of minor illnesses. However, the girl has to pay by herself if she has a serious disease, which requires a lot of money. Some brothel owners insist that girls report as soon as possible about their health status, so that they can find the appropriate solutions in time. Interestingly, a Khmer brothel owner said that she fired a girl who was pregnant while working in her house, since she believes that "it brings bad luck for their business if there is a pregnant girl working in the brothel". Generally, in brothel settings, pregnancy case is called "four eyes". If a girl is pregnant, it means that the girl did not use condom, so the owner may punish the girl by dismissing her from the brothel. Therefore, girls have to use condom to prevent from having pregnancies.

4.3.12. Commercial Sex Networks

In order to enter into prostitution, girls often use existing networks such as former female sex worker or friends or agents. It is seldom that girls come to any particular brothel they do not know alone because at least they need some basic information about that brothel, such as information relating to the brothel owner in advance. From in-depth interviews, many girls said that they have heard about the brothel from their friend, who was a former sex worker in that particular brothel. Some have never heard about the

brothel before, but they had accompanied their mother or older sister when they first came to seek for a job.

4.3.13. How to Recruit Female Sex Workers

Data derived from the study illustrated that coming alone to brothels is not considered good for girls, since this act is called "parachutist girl". That is a girl who comes to ask for a sex work in a brothel, and after she is accepted, she borrows money from the owner, and then she will escape or call the police authority to free her from the brothel. This makes police misunderstand that the girl has been forced to work in that particular brothel. Thus, it is often found that girls usually come with friends or relatives or agent to ask for a job in brothels although most of Khmer girls can go there alone. Similarly, Vietnamese girls, especially those who have just migrated from Vietnam, definitely need agents or friends to bring them to brothels. Again, the person who accompanies the girls to brothels has to be known or accountable by the brothel owner. It is worth exploring more about how girls can find the network or agents since in this study all girls were unwilling to or could not give significant illustrations on that issue.

Brothel owners, on the other hand, play a very passive role in recruiting girls to work in their houses. Prior to accepting any girls, they generally ask information about the girl's background. By asking "have you ever worked as sex worker before?" or "have you ever had sex before?" and "how old are you now?" the owners are able to decide whether they accept the girl or not. Furthermore, the owner and the girl have to reach agreement on how she will get paid. Brothel owners stated that they would accept only girls aged over 19 years old and those who had sex before. Generally speaking, brothel owners want "bad girls" — this means girls who used to have sex before being married or those who enjoy having sex. They believe that girls who never had sex before do not know how to work as sex worker. This information is very consistent with what derived from both Khmer and Vietnamese sex workers included in the study. Furthermore, some brothel owners may go to visit other brothels to negotiate about transferring female sex workers to their establishment. If an agreement has been reached, the pimps who need girls have to pay for the girl debt, and sometimes including transferring fee. Thus girls are allowed to work in the new house and they still have to clear their debt with their new owner.

Soon after the acceptance of girls, the owners will inform the presence of newcomers to the local authority so that they cannot be accused of trafficking children and women into the sex industry. In this process, brothel owners

have to pay local authorities for documenting or issuing a card for a girl, but this fee will be taken from the girl's income. Likewise, some brothel owners require the girl to sign documents stating that she voluntarily comes to work as a sex worker.

4.3.14. Reasons for Working as Commercial Sex Worker

It is not uncommon that these girls (Khmer and Vietnamese sex workers) derive from very poor families and they do not have a job. Consequently they decided to work as sex workers, which helps them to earn enough money to feed their whole families. What is worse, some girls' families are chronically in debt. They desperately need money to clear their debt, or they will lose their farmland or even house. It is sad that there is no breadwinner in her family, so she (female sex worker) has to play this stressful role. However, this is not always the case, some KFSW and a VFSW said that they decided to enter into prostitution because they like sex. Some stated that they chose this job because they do not want to work hard, while some said that they have no hope for their future. Others come to work as commercial sex worker as a result of karaoke crackdown, which took action nationwide in early July 2002.

4.4. The Meaning of Regular Clients and Sweetheart

"Client or guest", "regular client" and "boyfriend" are commonly said in brothel settings. Based on the discussion with KFSW as well as VFSW, we can clearly distinguish these three words. "Client or guest" is the word describing men who come to visit brothels irregularly. Those men may have sex with any girl who is available in that particular brothel. It does not matter how often those men visit the brothel, as long as they do not have sex with any particular female sex worker. Another one, as far as "regular client" is concerned, is the client who comes to have sex with only one specific girl. He may wait for the girl he came for if the girl is engaged or he may go back if the girl is not available during his visit. Yet another one, "boyfriend", is used only when there is a love agreement between the boy and the girl. It means that both girl and boy are falling in love with each other. The boyfriend is not always a regular client of the beloved girl. Some girls added that the boyfriend comes to brothel not always for having sex, but just to meet his lover. When the boyfriend comes to have sex with his girlfriend in brothel, he still has to pay for his sex to the brothel owner. In contrast, if they have sex somewhere outside

brothel, the boyfriend does not need to pay. It is interesting that although a girl claims she has a boyfriend she is not sure her boy may want to marry her or not. One Khmer female sex worker acknowledged that having boyfriend is very good for her, since her boyfriend can provide her love, comfort and companion. In contrast, some VFSW acknowledged that they do not want to have boyfriend since they all used to have bitter experience with their boyfriends in the past.

It has been observed that Khmer and Vietnamese sex workers react differently to the question of having boyfriends. Most Khmer girls are interested in having boyfriends when they work as sex workers. Some of them are happy to give money or gift to their sweethearts. In contrast, none of Vietnamese girls participating in the study currently have boyfriends. "I come here to generate money, not to look for a boyfriend", a Vietnamese sex worker voiced. Others supported that they do not want to have boyfriends because they clearly know that men will not be faithful to them or have true love for them, because they work as sex workers.

4.5. Condom Use

Regarding condom use, there is no difference between Vietnamese sex workers and Khmer counterparts in terms of consistence at their first sexual intercourse. Girls did not use condom when they had their first sex whatever their sexual partners. Few started using condom when they started working as sex workers and some started consistently using condom after they have worked as sex worker for a while. In the meantime, girls assured that they consistently used condom when they have sex with their clients or regular clients. However, it is believed that the rate of condom use remains low when girls have sex with their sweetheart. Owing to the launching of 100 % condom use, having sex with condom is compulsory in Battambang, Kompong Cham, and Sihanoukville.

The knowledge about the benefits of using condom among both Khmer and Vietnamese female sex workers is very good. They all know that using condom can prevent from transmitting HIV/AIDS, STD as well as from unwanted pregnancy. Besides, only very few girls reported experiencing slippery or broken condom during intercourse. Before having sex, girls prefer to put condom for their clients, since they are afraid that their clients do not know how to wear condom properly or men may secretly cut the tip of the condom with their fingernails. Most of the time, 2 condoms are used for each sexual intercourse. The reason is that girls need extra protection measure since they have been experiencing condom breakage accidentally or

deliberately cut by fingernails of clients. Some girls believe that if a client does not want to use condom with them, it is possible that he suffers from STD or HIV/AIDS. This makes them become very cautious when dealing with the group of clients.

On the other hand, the majority of clients visiting brothels understand the advantages of using condom, still some keep insisting on having unprotected sex with girls. They often complain that condom reduces their sexual pleasure when having intercourse or when wearing condom they feel their penis is tightly wrapped.

4.6. Sexually Transmitted Diseases

It appears that the prevalence of STD is very low among female sex workers. Some of them experienced vaginal discharge in the past. Thanks to regular medical check supported by brothel owners, STD has no longer major issues for them. When female sex workers suffer from STD they will inform their owner, then they will be sent to a private clinic that the owner has selected for them.

It has been found that both Khmer and Vietnamese girls often suffer from vaginal erosion caused by multiple sex acts per day or lack of lubricant during sexual intercourse. Public STD clinic is a health facility that is commonly used by the group of female sex workers, especially in Sihanouk ville. Some girls said that they like to go to public STD clinics because they do not need to pay for their sickness consultation and treatment.

4.7. Identifying the Pattern of their Health Seeking Behaviors

Private clinics and pharmacies are the most common places where female sex workers often go to seek treatment. This group has very little knowledge about health services available for them at public clinics. Apart from STD and HIV/AIDS infection, female sex workers do not voice any concern about other diseases that might destroy their health as a result of working as female sex workers.

Girls are usually allowed to restrain from having sex for 4 to 7 days during their menstruation period. No one reported that the owner forces them to work during their menstruation. They believe that if they keep having sex during that period their body will become weaker. Interestingly, they mentioned nothing about the vulnerability of getting infected with STD or HIV if they continue having sex during their menstruation period.

4.8. The Frequency of Mobility

The majority of girls included in this study have been working as sex workers for at least 2 months. Not many of them used to work in other brothels before. It is common for both VFSW and KFSW that they decided to select their brothels while they came to seek for a job and they do not want to change their working place after that.

Having conflict with other female sex workers or having conflict of interest with brothel owners are the main causes that make girls move to other brothels. Moreover, some girls may move to other places because they were told they would earn more or the pimp in the new place was a relatively better person (friendly, open-minded, honest with their girls in terms of sharing money). Interestingly, only one girl stated that she moves from one brothel to another because she gets bored when staying in the same place for a long time. It is also possible to argue that girls may not want to change their working place because they are afraid of not finding the place that has good owner as their previous one. This statement is quite consistent since some owners said that they often accept their former girls after they stopped working or going to work in other places for a while.

For VFSW participating in the study, some of them were born or grown up in Cambodia, so they do not have any experience in crossing border to work in Cambodia. Again, in order to work as sex worker, most of them came straight from their hometowns. For those who were born in Vietnam migrated to Cambodia a few years ago through Svay Rieng province and other crossing points they don't know. To migrate to Cambodia, Vietnamese girls have to find an agent at the Cambodia-Vietnam border. Most of the agents are moto-taxi drivers. Girls have to pay the agent from 40 US$ to 50 US$ for the trip by moto-taxi from the border to Phnom Penh. All Vietnamese girls did not know which way they travelled to Phnom Penh, but they knew they were sent to a house in Phnom Penh. The owner of the house will bring them to brothels or café houses. Again, girls have to pay the house owner again for finding jobs for them. It has been found that girls are able to borrow money from their future boss to pay the people who accompanied them to their working place. Then, Vietnamese girls have to start working to clear their first debt before allowing to move to other places.

KFSW and VFSW rarely visit their families although they send money home regularly. This may reflect that girls may try avoiding meeting people they know.

4.9. Knowledge about HIV/AIDS

Surprisingly, the knowledge about HIV/AIDS among female sex workers, both Khmer and Vietnamese, is reasonably good, although very few still hold the misconceptions that HIV can be transmitted through sharing house, food or dress with HIV carriers or AIDS patients.

Thanks again to the 100% condom use program, all female sex workers understand clearly the benefits of condom use. They all know that condom can be used to prevent HIV/AIDS transmission. They all use condom when having sex in brothel base since 100% condom use is strictly imposed in brothel settings. However, it is still not clear how these girls use condom if they have sex outside this setting.

4.10. Daily Life

Apart from their routine work, female sex workers do not have any extra work. Sex service is available for 24 hours/day although their main working hours start from 4 pm till 2 am.

Betting on playing cards with other girls in the brothel is commonly found when they have spare time. Some of them may go out or shopping. For those who have boyfriend they may use their free time to go out with him. It has been observed that Khmer female sex workers are more likely to go out than Vietnamese.

It has been found that most girls spend their money to buy clothes, cosmetic products. Some Khmer girls may spend all their money with their boyfriend when they go out. Vietnamese girls use only the incentive they got from clients to spend for their daily life, while they save all their salary to send home.

It has been observed that both Khmer and Vietnamese female sex workers do not have many friends outside their brothel settings. This reflects that the social network of this marginalized group is very poor, resulting in the isolation of these girls. It is very sad to hear that all of them do not know who they should discuss with when facing any problems.

4.11. Future Expectations

Asking about their future, Khmer girls seem to be less certain. Most of them said that they would stop working as sex workers as soon as they can accumulate enough money for their families as well as for them to start a new life. They plan to run a small business in order to generate the income and they will not come back to work as sex worker again. However, we

really have no idea whether this idea works or not in the real world. Some girls said that they do not care about what job they do as long as it is not a hard work and that they can earn money. So, these girls may come back again to work in brothel after they have found that all alternative jobs are relatively harder or less paid than their current job.

Some girls want to marry or remarry after stopping working, while others feel that no man will ask them to marry since they used to work as sex workers. They recognized that other people consider prostitution as very bad and as a shame for society. They also stated that their families will lose their fame if people know that one of the family members is working or used to work as a sex worker.

For some Vietnamese girls who migrated from Vietnam would go back to their country if they had accumulated enough money for running a small trade in their hometown.

5. Discussion

The reasons for entering the sex industry of Cambodian and Vietnamese female sex workers are not different. Poverty is the main factor dragging girls into commercial sex work. In addition, the reason for Vietnamese girls to migrate and work as sex workers in Cambodia is that sex work is prohibited in Vietnam.

The study shows that Vietnamese girls have more precise plans for their work. It is commonly heard that Vietnamese girls intend to start a non-sexual business, either in Cambodia or Vietnam, when they have saved enough money. In contrast, Khmer sex workers are unlikely to plan or are not well prepared to leave the sex industry for their better future while working as sex worker. This may have an influence on the attitudes of these girls towards HIV/AIDS and STD prevention since Vietnamese girls are more concerned about their health than their Cambodian counterparts. Therefore, it is essential that the health services providers — NCHADS — should challenge to encourage girls to raise their self-esteem and value their life. Consequently, they may practise safe sex during their commercial sex work.

From the study, it has been observed that Vietnamese girls comply relatively well with the health education information compared to Cambodian girls working in brothel settings. This may generate the hypothesis that because Vietnamese girls have high self-esteem and tangible future plans, they are more likely to take advantages of health education, especially about HIV/AIDS prevention and STD to remain healthy and away form this deadly disease.

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Road Safety Issues in Southeast Asia

by

Jean VAN WETTER*

1. Introduction

Road traffic accidents are a crucial public health and development issue, killing *every day* more than 3,000 people (the equivalent of 7 fully loaded Boeing 747 crashes every day killing all passengers), and disabling for life more than 15,000 around the world (WHO 2004). They are the second leading cause of death globally among young people aged 5 to 29, after AIDS (WHO 2004).

Ninety percent of fatalities related to road traffic accidents occur in low and middle-income countries (WHO 2004). The problem is particularly important in the Asia-Pacific region which already contributes up to 44 % of global road deaths, although it currently only has around 16 % of the world's motorized vehicle fleet (Transport Research Laboratory 2000).

Whereas in recent decades, high-income countries have steadily and systematically reduced the number and severity of road traffic accidents by implementing coordinated multi-sector prevention programs, the problem is growing in developing countries where road traffic fatalities are estimated to increase by 80 % by 2020, outstripping AIDS related fatalities. According to the World Health Organization, road traffic injuries are also likely to be the third leading cause of disability-adjusted life years lost (DALY) in 2020 (tab. 1).

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Table 1
Change in rank order of DALYs for the 10 leading causes of the global burden of disease

1990		2020	
Rank	Disease or injury	Rank	Disease or injury
1	Lower respiratory infections	1	Ischaemic heart disease
2	Diarrhoeal diseases	2	Unipolar major depression
3	Perinatal conditions	3	Road traffic injuries
4	Unipolar major depression	4	Cerebrovascular disease
5	Ischaemic heart disease	5	Chronic obstructive pulmonary disease
6	Cerebrovascular disease	6	Lower respiratory infections
7	Tuberculosis	7	Tuberculosis
8	Measles	8	War
9	Road traffic injuries	9	Diarrhoeal diseases
10	Congenital abnormalities	10	HIV

DALY: Disability-adjusted life year. A health-gap measure that combines information on the number of years lost from premature death with the loss of health from disability.

Source: PEDEN *et al.* 2004.

Despite those alarming figures, people continue to accept road traffic fatalities as part of the price of living in modern societies and national political decision makers and the international community have so far paid little attention on the issue. There exist however proofed, cost-effective and publicly acceptable solutions to address and prevent the problem.

The objective of this paper is to briefly summarize the road safety issues in developing countries with a particular focus on Southeast Asia and to try to explain why and how the international community should pay closer attention to the issue.

This paper is not based on specific research and aims only at providing a general opinion on the global road safety crisis. This opinion is based on two years of experience coordinating road traffic accidents prevention programs in Southeast Asia.

2. Road Safety Issues in Southeast Asia

The Asian Development Bank estimates that over 75 thousand people die and almost 5 million are injured annually in road accidents across the ASEAN (Association of Southeast Asian Nations) region and that this costs the region's economy about 15 billion US$ every year.

ASEAN however covers a region of immense contrasts, with motorization ranging from some of the least motorized countries in the world (at 9.5 vehicles per 1,000 people) to highly motorized countries (with 683 vehicles per 1,000 people), populations ranging from the smallest in the world to one of the world largest, urbanization ranging from as low as 20 % to as high as 100 % of the population and GDP per capita ranging from 128 $ per year to 23,000 $ per year (Asian Development Bank 2005). The road traffic accident rates in the region therefore vary considerably depending on each country, with poorer countries such as Cambodia, Laos and Vietnam indicating the highest rates (compared to the number of motorized vehicles in use) (fig. 1).

The very high share of 2-wheeled vehicles in the vehicle fleet of those countries (*e.g.* Vietnam - 95 %, Laos PDR - 79 %, Cambodia - 75 %), the newly developed road infrastructure allowing speed increases, the heterogeneous traffic mix (*e.g.* ox carts and bicycles sharing the road with high-

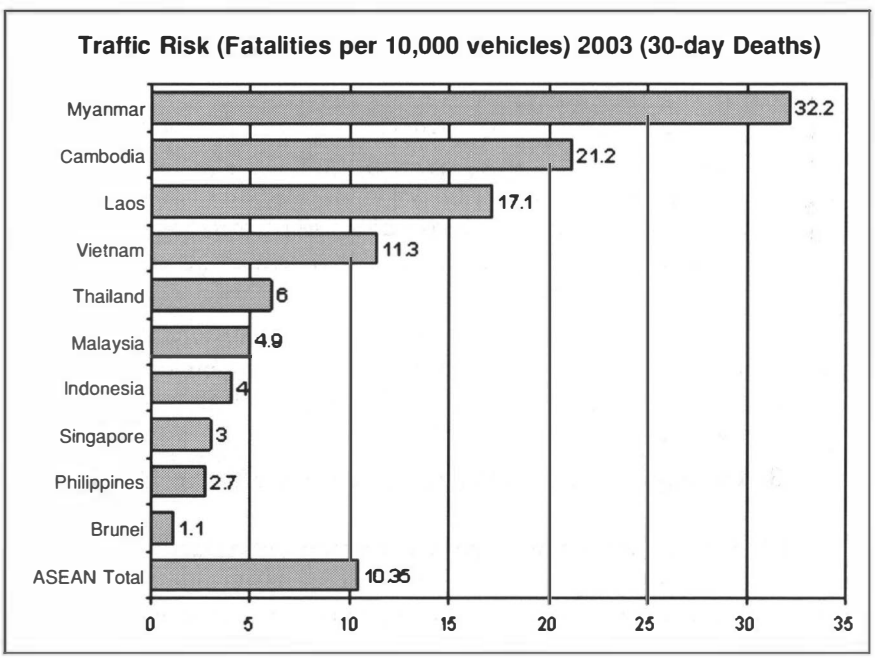

Fig. 1. — Road traffic fatality rates (number of fatalities/10,000 vehicles) in ASEAN — 2004 (*source*: Ross 2004).

speed 4-wheelers), the very fast growing vehicle-ownership rate, the weaknesses of the responsible institutions leading to poor traffic regulations and insufficient enforcement, the lack of road safety education, the inadequacy of public health infrastructure in providing treatment for traffic injuries and the poor access to health services are all contributing to the growing problem in those countries.

The example of Cambodia is revealing. Given its recent relative stability and growth, the country has seen a rapid increase in the volume of road traffic over the last three years (+ 35 %). In the meantime the number of accidents increased by 40 % and the number of fatalities doubled, representing the highest increase in the region (fig. 2). Today, more than 3 persons die and 100 other are injured *every day* on the roads of Cambodia (Cambodia Demographic and Health Survey 2001).

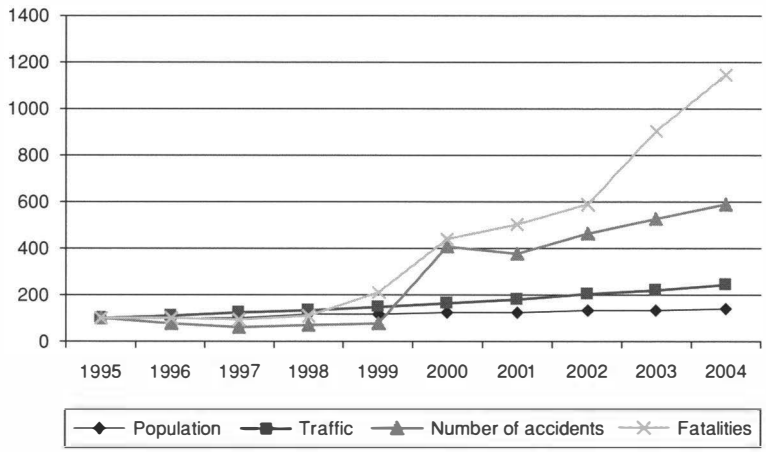

Fig. 2. — Evolution of road accidents and fatalities in Cambodia compared to traffic and population (base 100 = 1995) (*source*: Handicap International Belgium analysis, based on Ministry of Public Works and Transport reports; National Institute of Statistics 2000).

3. Development Issues Related to Road Traffic Accidents

Road traffic accidents hinder development by killing and disabling the economically active population. Over 50 % of all deaths due to road traffic injuries in the world occur among young adults aged between 15-44 years, the most active part of the population. In Cambodia, this percentage reaches 75 % (fig. 3), of which 20 % are students, 20 % are workers and 17 % are farmers (fig. 4).

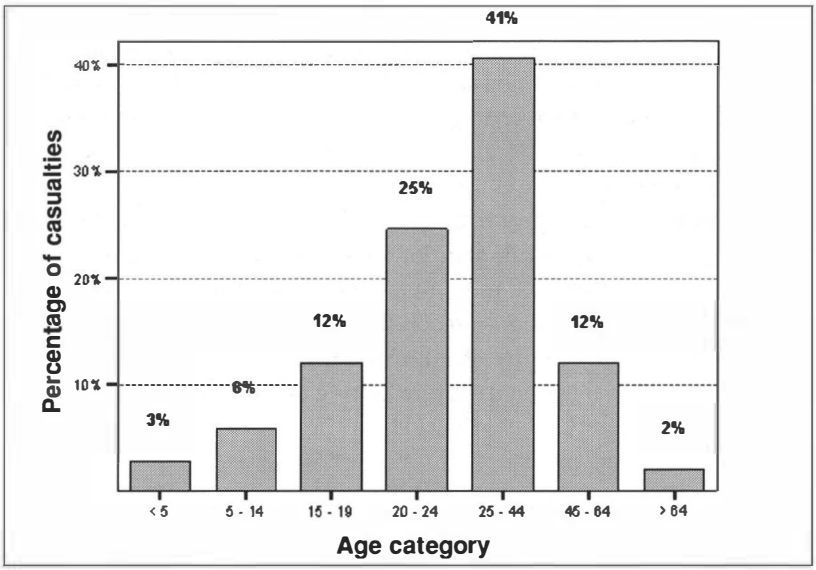

Fig. 3. — Age pyramid of road traffic casualties in Cambodia January to September 2005 (*source*: VAN WETTER 2004).

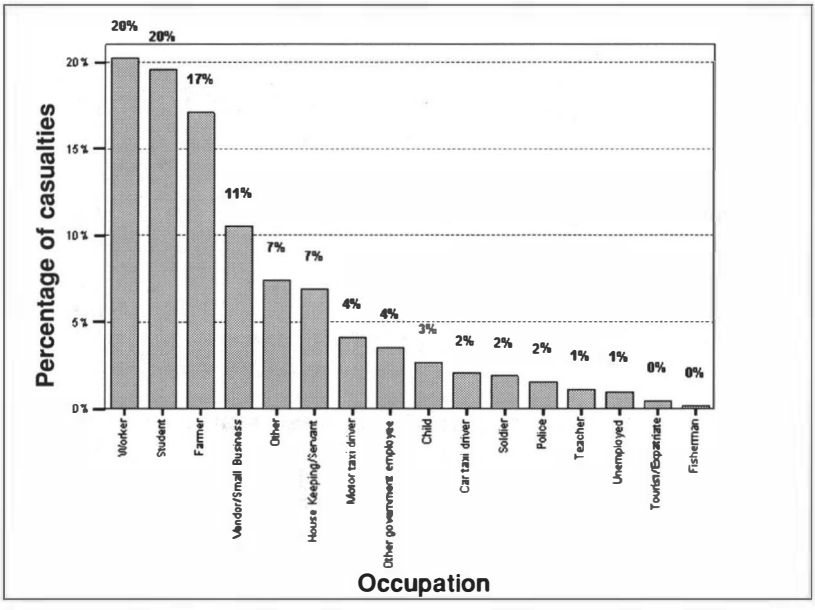

Fig. 4. — Occupation of road traffic casualties in Cambodia January to September 2005 (*source:* VAN WETTER 2004).

The cost of prolonged medical care and long term rehabilitation, coupled with the loss of income due to disability or loss of a family "bread winner" can easily lead an affected household into poverty. According to the Asian Development Bank (2004), road traffic accidents in Southeast Asian countries already cost between 2 % and 3 % of those countries' GDPs, much more than the total development aid that those countries receive each year.

The consequences of injury related to an accident in developing countries are also increased by the poor state of the healthcare services and the slow access to them. In Cambodia, more than 30 % of the severely injured casualties take more than two hours to reach the first hospital and then often need to be referred to more than two health structures (*e.g.* health center, district hospital and provincial hospital) before getting appropriate treatment (fig. 5). In many cases, severely injured casualties die or become disabled for life before to reach the hospitals.

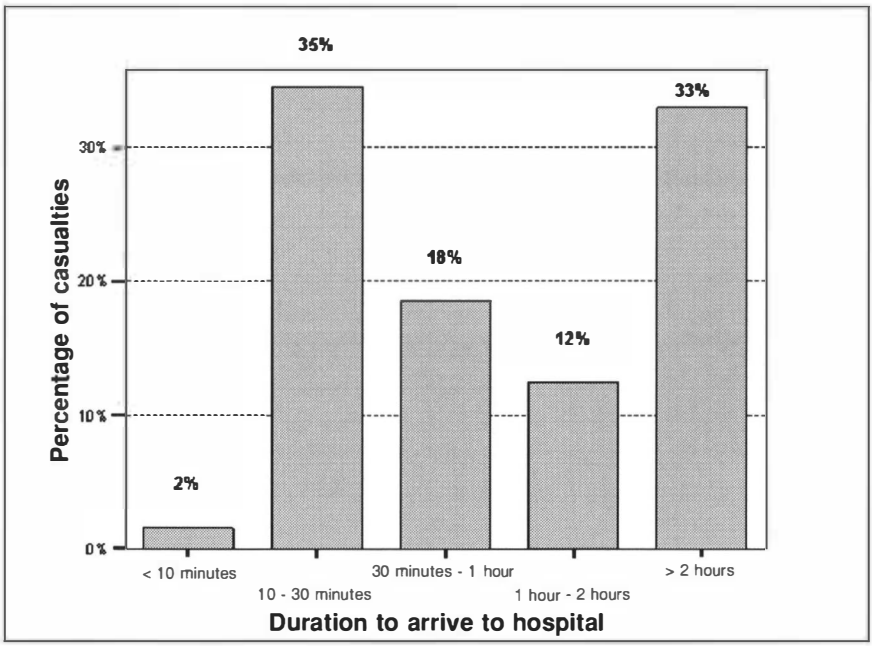

Fig. 5. — Duration from accident to arrival to hospital for severely injured casualties in Cambodia January to September 2005 (*source:* VAN WETTER 2004).

Road traffic accidents also affect more the poorest and the most vulnerable part of the population. In Cambodia, the means of transport frequently used by the poorer people — motorbike, walking and cycling — are responsible for more than 85 % of the casualties (fig. 6). Car drivers and passengers, although cars represent 14 % of the number of vehicles in use in the country, represent only 8 % of the casualties.

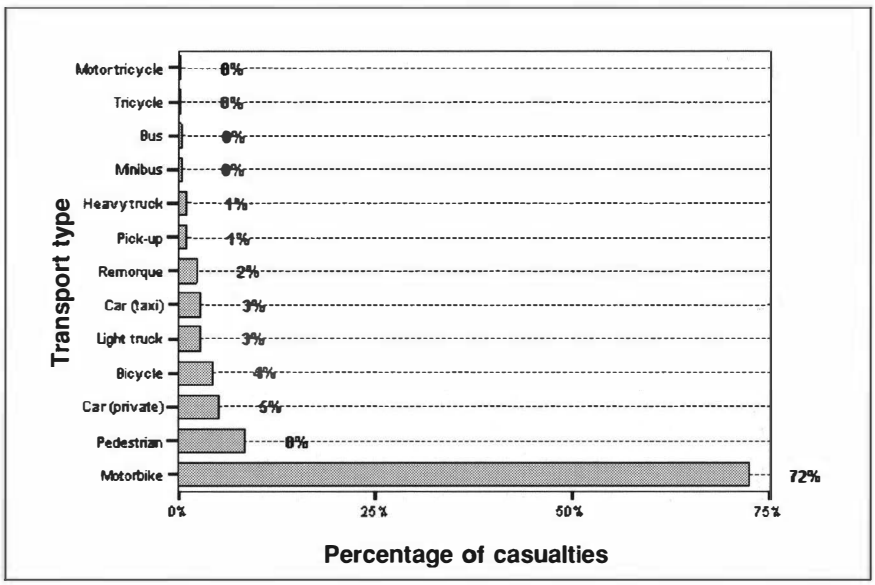

Fig. 6. — Types of transport of road traffic casualties in Cambodia January to September 2005 (*source*: VAN WETTER 2004; comparisons with other development issues).

Despite those dramatic social, health and economic impacts, few governments and international stakeholders have so far invested in road safety initiatives in developing countries. This is especially true if we compare with other health and development issues such as malaria, mines/UXO (Unexploded Ordnance) and HIV/AIDS (fig. 7). For instance, worldwide, road traffic accidents kill 60 times more than landmines/UXO but development aid for road safety is 14 times lower.

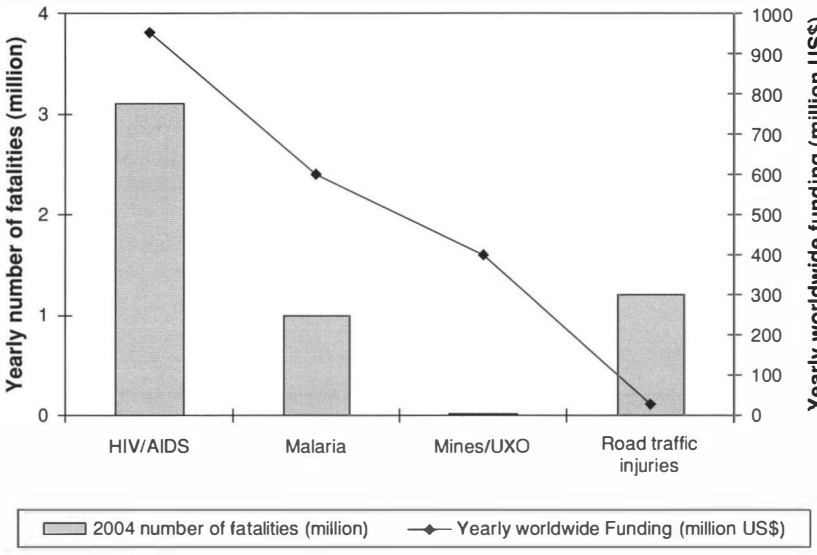

Fig. 7. — Estimated global research and development funding for selected issues compared to number of fatalities — 2004 (*source*: PEDEN *et al.* 2004, Handicap International Belgium analysis).

The international community still does not recognize seriously road safety as a development issue. For many people in high-income countries, road safety is still considered as a "developed country" issue, which they already have to deal with within their own country. Considering the numerous other "recognized" public health calamities in the Southern Hemisphere (malaria, HIV/AIDS), road traffic accidents are not considered as a priority. In fact, only few people are aware of the magnitude of the road safety problem in poor countries.

On this aspect, the example of Cambodia is again revealing. In the mind of many people, and even in the mind of those working in the development sector, landmines/UXO are still considered as one of the major development issues. On the other hand, only a few people understand the link between road traffic accidents and development. As a result, substantial humanitarian efforts are still focussed on preventing mine threat although road traffic accidents kill 10 times more and injure 5 times more than mines and UXO (tab. 2). In 2004, the total budget dedicated by the international community and the Cambodian Government to prevent landmines/UXO accidents and clear mines/UXO was 30 million US$. The same year, the budget for road traffic accidents prevention was 200,000 US$.

Table 2
Comparisons of HIV/AIDS,
mines/UXO and road traffic accident fatalities and funding in Cambodia — 2004

	AIDS	Mines/UXO	Road Traffic Accidents
Funding (million US$)	50 million US$	30 million US$	0.2 million US$
Number of fatalities	15,000	160	1,200

Source: Handicap International Belgium analysis, based on Cambodia National AIDS Authority and Cambodian Mine Action Authority reports.

One might argue that comparing road traffic accidents to mines/UXO accidents and to HIV/AIDS is not scientifically acceptable, given the different natures (injury versus disease), origins (conflict versus economic growth), consequences (transmission versus no transmission) and solutions (humanitarian approach versus development) of those issues.

Regarding the origin, landmines/UXO issues have indeed been (and are still being) produced and used by countries whose governments might feel responsible for the damages they continue to cause to civilians, even years after they were placed. Obviously, no country feels responsible for the road traffic injuries of another country as road accidents are viewed as the result of the intrinsic development of a country. Leaders of affected countries themselves do not feel responsible for the road traffic accidents and certainly do not consider them as a development issue. Even the contrary, road crashes are sometimes considered as a positive indicator that the economy is growing and that more people can afford to buy motorized vehicles!

Regarding the consequences, HIV/AIDS is transmissible and constitutes a real threat of a worldwide growing and uncontrollable pandemic whereas road traffic accidents, while certainly due to increase dramatically in the coming years, will never constitute such an uncontrollable pandemic.

Also, landmines/UXO do not only injure and kill innocent individuals but their presence hinders the accessibility and use of land. This leads to other negative economic and social consequences (isolation of villages, lack of access to water and natural resources,...) whereas the direct consequence of a road traffic accident is more limited.

However, despite those important differences in origins and consequences, those three development issues have also a lot of common characteristics (tab. 3). All three result in a high number of fatalities and casualties/diseased and therefore strongly impact the health system. In some hospitals in Cambodia for example, road traffic casualties make up for more than 50 % of hospital beds and represent more than 80 % of emergency interventions. All

Table 3
Comparisons of mines/UXO, road traffic accidents and AIDS issues

	Road traffic accidents	Mine/UXO accidents	HIV/AIDS
Impact			
High number of fatalities and casualties/diseased	Yes	Yes	Yes
High impact on the health costs of the country	Yes	Yes	Yes
Continuous medical treatment needed	In some cases	In some cases	**In all cases**
Unability to work	In some cases	In some cases	In some cases
Transmissibility	No	No	**Yes**
Accessibility/use of land issues	No	**Yes**	No
Moral/ethics issues	**No**	Yes	Yes
Cause			
Conflict	No		No
Personal behavior	Yes	Yes	Yes
Other's behavior	Yes	Yes	Yes
Prevention			
Preventable via awareness/education	Yes	Yes	Yes
Preventable via enforcement	Yes	Yes	**No**
Dedicated international agencies	Yes	Yes	Yes
International advocacy campaigns	**No**	Yes	Yes

three also may result in disability issues that make it more difficult from working and having a normal social life. Finally, they all three are caused by a human behavior that could in many cases be prevented or anticipated.

The statement that accidents are preventable is often neglected in the case of road traffic accidents. The public opinion is convinced that it is possible to prevent landmines/UXO accidents by banning the production and the use of landmines, by clearing the ones that have already been dropped and by educating populations leaving in affected areas. The public opinion is convinced that it is possible to considerably reduce the progression of HIV/AIDS by investing in research and by educating populations on the risk of unprotected sex and drug abuse. But the public opinion seems not yet convinced that it is possible to dramatically reduce the number of road traffic accidents. There are however effective prevention strategies which have

already been tested and used in many developed countries. Those strategies are a combination of political will, strict law enforcement (alcohol-tests, usage of seat-belts and crash helmets, fixation of speed limits,...), engineering (road marking, lighting, traffic signs,...), education and awareness, combined with an improvement of emergency services and assistance. Although all these levers should be activated simultaneously, the most important of them is the political will. And on this aspect, the international community can have a strong lobby and advocacy role. In the case of humanitarian mine action for example, the role of the international community to ban production and use of landmines has been decisive.

Therefore, if road traffic accidents have an enormous public health impact (higher than mines/UXO and rapidly catching up with HIV/AIDS) and are preventable, why has the international community not yet considered them as a top development issue? One explanation might be that the international community is sometimes not rational in the allocation of development aid and tends to follow trends and influences rather than always analyzing the real needs. The fights against landmines/UXO and HIV/AIDS have mobilized world famous ambassadors, have been supported by very visible global campaigns and have been organized by dedicated international agencies. This has surely influenced the funding choices of the international community. On the other hand, road traffic casualties have so far not yet had a chance to be "defended" by global ambassadors and advocacy campaigns, but the trend might be hopefully changed in the coming years, notably thanks to efforts of the World Health Organization that has dedicated World Health Day 2004 to road safety and has co-published the world report on road traffic injuries, which was the basis for development action in the field of road safety. Also, the United Nations have recently adopted a new resolution on road safety and we may expect further commitment to promote road safety in developing countries.

Those recent developments might help to make the international community more aware of the true magnitude of the world's road safety crisis and to stop having road crashes being considered as the price to pay for development and access to infrastructure.

4. Response of Handicap International Belgium

Handicap International Belgium (HIB) is a non governmental organization. Its mission is to contribute to the prevention of disabilities and to support the improvement of the life of disabled people in all related areas

(medical, social and economic). The organization was born in and has been present in Cambodia since 1982. In Cambodia, the organization firstly focused its activities on mines/UXO issues (physical rehabilitation, mine clearance, mine awareness and mine risk reduction) but has progressively diversified its intervention to provide a direct answer to the actual needs in terms of disability.

To avoid non rational investment of humanitarian aid, HIB has often been considered as innovative in the search for new approaches, driven by analysis rather than trends. This approach has led HIB to recently refocus its efforts in the field of mine action more on research than on pure mine clearance. This approach has also led HIB to initiate a road traffic accidents prevention program in Cambodia in 2000. Based on statistics on the people with disabilities being treated in the country rehabilitation centres and on additional surveys, HIB realized that the number of road traffic casualties was rapidly increasing and that it would become one of the major public health issues in the country in the coming years.

The first initiative consisted in a survey at the main hospital of Phnom Penh (Calmette hospital) in order to understand major causes of accident and injury. This first survey allowed HIB to already lobby the Cambodian Government and the international community and raise awareness on the growing issues of road injuries in the country.

In 2003, the road safety program received its first major funding and has progressively developed to cover the following projects, all of them being integrated in the National Road Safety Action Plan of Cambodia:

— Development and implementation of a national Road Traffic Accident and Victim Information System (RTAVIS);
— Development and implementation of a national road safety curriculum for primary and secondary schools;
— Road Safety publicity and campaigns;
— Community Based Road Safety Education;
— Development and management of Road Safety Network;
— Lobby and advocacy.

The development and implementation of a national Road Traffic Accident and Victim Information System (RTAVIS) constitutes one of the main challenges of the program. The system has been developed in collaboration with the ministries of Interior, Health and Public Works and Transport and aims to provide government and development stakeholders in Cambodia with accurate, continuous and comprehensive information on road traffic accidents and victims. The originality of the system is that it integrates and disseminates

information provided by three different sources: public hospitals, private clinics and traffic police. This integration of data from those three different sources is unique in the region.

Being aware of the added value of such a data collection system for lobbying and for understanding the needs of the people, HIB is now working on the development of a larger injury surveillance system that would later integrate all existing injury data collection systems (mines/UXO, road injuries, domestic violence, small arms, drowning,...).

With those actions, HIB hopes to influence development aid prioritization so as to bring more attention to issues that:

— Cause most fatalities and disabilities,
— Are likely to grow in the coming years,
— Hamper developing countries pace of economic and social development.

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Closing Session

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Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives
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Synthesis

Of necessity issues arising from the management of waterways, riverbank areas, deltas, maritime and river ports must be conducted within a regional frame of reference. It is therefore from the perspective of integrated regional development, as put on the agenda of the regional institutions, that solving the risks and challenges which affect the totality of this geographic area must be found.

The process of integrated regional development covers a whole range of domains, each of which must not only be examined as such, but equally in terms of their interdependence. The diagram attached to this synthesis reflects the multidisciplinary and intercultural approach taken in the present conference.

An illustration of this process is the case of the integrated management of water resources. Transport, for example, requires finding solutions within a "multi-modal" and "inter-modal" framework if the different bottlenecks, be they geographic, chronological, economic, or technical, are to be avoided. Solutions therefore must analyse what the situation is upstream and downriver, tidal effects and the study of alternative solutions, before applying a global system identified as the most appropriate one. As for the environment, challenges in terms of pollution, deforestation or soil degradation equally require coordinated solutions and should benefit greatly from the lessons provided by varied experience both within the region and elsewhere, something which is not yet happening, or only inadequately at present. As for inter-sectorial relationships, these should be envisaged in a more balanced fashion, especially, on the one hand in the economic field and on the other the social aspects, given that till now mainly economic aspects have been taken into account. But in future one will have to make development more 'population friendly' and to address as a top priority the reduction of poverty as one of the major objectives, and not merely through speeches and posturing propositions. Far too often the secondary effects of projects undertaken (which are problematic in the short and medium term in different ways and to a greater or lesser extent) are not adequately taken into account at the time of their inception, with at times extremely damaging consequences.

This is notably the case with the excessive expansion of shrimp farms, the problem of disposing of used water and domestic and industrial garbage, where urgent needs are tied in to population expansion, irrigation projects to increase agricultural production which increases the proliferation of mosquitoes, leading to an upsurge in malaria, or deforestation due to the extensive practice of aquaculture, resulting in a further pollution of water. In general the different types of contamination caused by a large number of activities and projects often have negative consequences for the local communities: lack of drinking water, decline of fish stocks, of fishing possibilities and consequently of fisheries, and eventually the disappearance of the shrimp farms.

On the scientific level multidisciplinarity is an absolute necessity and from a methodological perspective it is important to work in networks and to standardise data gathering and data presentation, so as to make it easier to confront field experience and to enable the extraction of useful lessons. In this area it is also essential to build bridges which will transfer the results of the investigations undertaken to local populations. Finally, one of the keys to successful cooperation is improving language study and language skills. By adopting teaching to incorporate content and language integrated learning, or some even modest form of bilingual education, cooperation and multidisciplinarity should be enhanced.

Port development is one area where, in the quest for efficiency, for preservation of the environment, for a balance between economic and social sectors, progress depends on a process of regional integration, which can be advanced on condition that it has been looked at from this perspective. Port activities contribute to the development of the economy and hence are capable of favouring regional integration. The development and modernisation of port installations are a current necessity, given the problems of congestion which affect many ports, the appearance of new needs due (amongst others) to the increase in the size of ships and the economic constraint of lowering transport costs. Moreover, the prosperity and success of a particular port area often brings in its wake the development of contiguous regions, as can be seen from the case of Hong Kong as a good illustration of this process.

But port development cannot be undertaken without confronting a certain number of problems and challenges. Relationships between ports are today of a competitive nature. Singapore still maintains a dominant position, even though other sites appear to be developing as rivals which are ever more eroding this supremacy. Rather than allowing this competition to produce negative effects development should be oriented towards greater complementarities. Port development can also compete with other sectors of economic

activity. Tourism is a case in point, as for example when port development brings in its wake the destruction of coral reefs, which in themselves are tourist attractions. The expansion of port areas may lead to deforestation of the surrounding zones or the use of land formerly devoted to agriculture, leading of necessity to the limiting of such activity, but also to the impoverishment of peasant populations by the expropriation of their land. By the same token, ports, given the nature of the activities they engender, are poles of attraction for the working population of the interior regions on their periphery. Again rural activities suffer from such migratory movements, even though agricultural products are vital for the needs of local populations. It is therefore necessary to avoid the collateral damage that may follow upon over-investment and to take into account the availability of human resources.

Generally deltas are fragile eco-systems which can rapidly deteriorate and undergo speedy and significant changes. As has been shown, the inhabitants of such regions have often seen their conditions of life degraded by the perverse effects of the activities which have been developed. The use of modern technology, like satellite imaging, enables us to see better and to analyse the realities of the terrain and consequently to look for methods and means of intervention which are adapted to local conditions, enabling sustainable development which should be, as referred to earlier, population friendly. For it must be underlined that modern technology, with its high degree of sophistication, is an instrument of undoubted usefulness, but nevertheless an instrument which must be at the service of local circumstances as identified by high quality studies carried out in the localities concerned.

To sum up. It appears that development perspectives must be envisaged on several levels beyond those of regional integration and inter-sectorial planning.

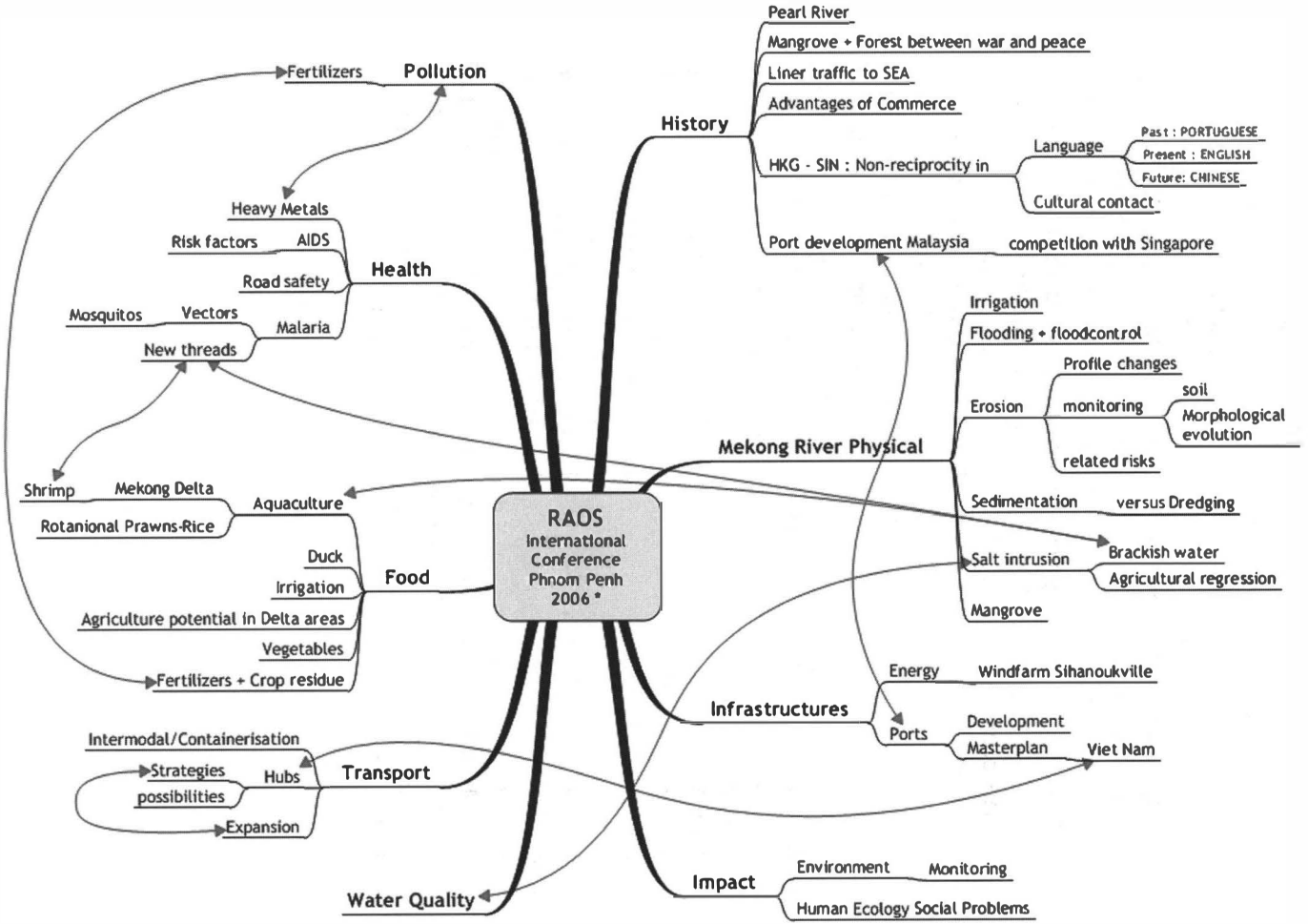
At the political level first. Several problems mentioned during the conference can only be addressed via measures which are under the responsibility of public bodies: measures aimed at combating soil erosion, water control, the development of alternative energy sources, *e.g.* wind generators, public health campaigns, the fight against prostitution, improving public hygiene, education strategies adapted to the development of human resources,...

A second area is that of management. It is necessary to have sufficient qualified people whatever the sector of activity or the level of responsibility. This covers not only technology, logistics, administration, but also monitoring relative to data gathering, prevention campaigns in public health and social issues, awareness raising on environment protection, the establishing of dialogue between planners and peasants, and reflection on ways and

means to campaign and address social deviation. This leads to thoughts on the responsibility of public bodies in providing educational structures adapted to the urgent need for capacity building in all its guises.

A third axis of concern is research. Throughout this conference multidisciplinarity came across as an absolute necessity. And yet, as illustrated by the papers presented, carrying out multi-disciplinarity is a difficult exercise. As was seen, depending on the topic being presented, the type of knowledge engaged differs considerably and the methodologies applied are topic specific. That is why it is necessary to multiply exchanges, contacts, and encounters between researchers from different disciplines so as to create the necessary connections. In fact today there is still a lack of communication between researchers, in spite of current technological possibilities. In addition there is also a lack of communication between those who are or should be the beneficiaries of the projects being implemented and those who are the decision takers of their goals and orientations. Far too often exchanges are mainly a top-down process and not enough a bottom-up process, so that the genuine concerns of the populations and their own knowledge are too often ignored or inadequately taken into account.

Finally, the environments, both physical and human, which have been investigated are characterised by rapidly evolving changes, the range of areas covered very open-ended and with a high degree of urgency. Moreover these changes affect each other and have effects on other neighbouring areas, so that such dynamics have to be studied in a holistic fashion. This implies that in spite of the important results already registered in a whole series of domains, research still has to be innovative so as to match up to the consequences of such dynamics, including their perverse effects. This means that we have to produce tools that can anticipate such situations which, instead of representing an improvement for the well being of populations they are applied to, provoke the opposite and damage their living conditions.



* Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives - Organized by the Royal Academy of Overseas Sciences of Belgium

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Conclusions and Recommendations

Considering "the critical role of Asia and the Pacific in promoting global sustainable development", as stated by the "Phnom Penh Regional Platform on Sustainable Development for Asia and the Pacific", the Royal Academy of Overseas Sciences has drawn from the given presentations, from the ensuing discussions and from the comments made at the Round Table during the International Conference on "Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives" (Phnom Penh, 6-8 February 2006), the following conclusions and recommendations.

1. It is up to the authorities to accelerate and reinforce the regional integration process, which is a prerequisite for sustainable development; with regard to the implementation of local potentialities, this implies the adoption of protective measures concerning environment, health, security and of a training policy adapted to the needs of capacity building. As for the private sector, its activities should be part of these protective measures in order to avoid the pernicious effects (already noticed in various fields) of certain practices or ventures, which results in increasing poverty instead of contributing to its eradication or at least its reduction.
2. As mentioned by the Phnom Penh Regional Platform according to which "... the key issues and priorities for sustainable development in the region are multisectorial and cross-cutting, embracing the environmental, economic and social spheres", the development of port facilities, of waterways, of riverside areas and their hinterland should be considered not only at the economic level but also at the social level which is very often overlooked in the facts.
3. Generally speaking, as far as the implementation of strategies is concerned, the development of maritime economy and port areas should systematically take into account the links between the different sectors involved and the different intervention sequences as well as the action-retroaction dynamics on the basis of which it is important to conceive medium- or long-term prospective platforms.

4. In and between the different fields of intervention, the activities should necessarily be carried out on the network and the relations between the different actors, whatever their level in the research and/or operations channels, should be partnership relations; the quality of planning and management all depends on that.
5. Delta regions and riverside areas are fragile and complex ecosystems characterized by rapid changes which need accordingly a permanent updating of the research conducted in the field and a rapid availability of it by public and private actors.
6. The studies to undertake should be conducted according to a global approach considering the multisectorial interdependences characteristic of the region of Southeast Asia; therefore they should necessarily include the cultural dimension of local societies which is very often ignored or minimized in schemes and programmes. This implies that not only the daily real life and the value systems of directly or indirectly involved populations would be taken into account, but also the language through which they express themselves and communicate as well as the symbolic representations they make real.
7. As far as field research is concerned, the optimization of the expected effects regarding development requires a standardization of the methodologies adopted (data gathering and results' formulation) so as to make the reading and interpretation of their results easier.
8. Teaching structures and training channels should be adjusted according to the needs of the labour market, particularly in port, water resources, environment management, etc. owing to the lack of qualified human resources which remain in those fields both at quantitative and qualitative level.
9. Systems of information exchange on the results of research and field experiments (success stories but also failures) should be implemented both horizontally, *i.e.* between the various bodies and actors concerned in order to draw the useful lessons, and vertically, *i.e.* between researchers and field agents on the one hand and local populations on the other hand, so as to set up not only top-down but also bottom-up relations between them which would be very instructive as well.
10. In the particular case of transport policy, sea and river transport should be encouraged as a priority (the cost of 1 km road transport being twelve times higher than that of 1 km water transport) and strategies of operational collaboration and cooperation should be implemented in this field so as to avoid abusive and debilitating competition which hinders development instead of accelerating and boosting it.

11. As far as health is concerned, besides collective as well as individual preventive measures which are essential in a whole series of diseases, food safety requires the adoption of protective measures both before and after putting the products on the market and that the standards to be enacted or improved on the subject would now be based on health criteria.
12. Finally, as the energy needs are likely to increase as fast as development progress, the strategies to encourage should aim at varying the sources of energy and favouring the sources of renewable energy of which, for example, wind energy.

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Statement

by

Sven CALLEBAUT*

The International Conference "Hubs, Harbours and Deltas in Southeast Asia: Multidisciplinary and Intercultural Perspectives" (Phnom Penh, 6-8 February, 2006) allowed me to witness the vast amount of energy and effort being deployed for increasing not only the flow of goods along the Mekong River, but also the flow of ideas and communication among leading experts, particularly in the port and shipping field.

As we have heard from leading speakers from the region and overseas, the role of ports is crucial in the economy of the Mekong countries, and in particular for those not having a link to the sea. Ports traffic is a good indicator of the vitality and energy of the economy of a country. But ports operate in a highly competitive market, therefore cooperation among regional ports becomes a natural path to face the challenges of more and more globalization. I have noted with interest that numerous initiatives in the field of renewable energies, environment protection and port infrastructures are undertaken at the regional levels for the least well off countries of the ASEAN regions.

Notwithstanding, we should not forget that behind these port infra and superstructures, these huge investment and generous loans from donors, are people. As a famous French philosopher said in the 16th century, man(kind) is the only true source of wealth. This was true then, this is still true nowadays. Therefore, the "Multidisciplinary and Intercultural Perspectives" of this workshop was of great importance and value and I am delighted to have seen so much exchange happening here.

This is also true for us, the United Nations Conference on Trade and Development, as most of our assistance to Cambodia and Laos is in the field

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of capacity building and human resources development. Our Port Training Programme for the ports of Phnom Penh and Sihanoukville have met highly committed port managers, whose efforts were a key to the success of this programme in Cambodia.

Last but not least, I am appreciative of the invitation extended to UNCTAD to join the closing roundtable of this workshop, as it was also an occasion for me to meet with officials and academics who share the same desire to see this country going on the development path it has chosen. I am grateful to the Royal Academy of Overseas Science, the Mekong River Commission and the Belgian Technical Cooperation for having organized this seminar here in Phnom Penh. I hope this is the beginning of a fruitful cooperation in the field of human resources and sustainable development.

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Statement

by

Khim LAY*

Ladies and Gentlemen,

It is my great honour to be invited to join a round-table discussion and to be asked to share some important points resulting from the outcome of the Phnom Penh Regional Platform on Sustainable Development for Asia and Pacific that are relevant to the themes of this conference.

As you are aware, the World Summit on Sustainable Development was held in Johannesburg, South Africa, in September 2002. For regional preparation for the World Summit, Cambodia hosted the Asia-Pacific Rountable on Sustainable Development and the high-level Asia Pacific Regional Meeting for the World Summit on Sustainable Development: 27-29 November 2001.

The regional round-table meeting was attended by over 190 representatives from 46 countries in the Asia Pacific and over 220 representatives from UN agencies, multilateral financing institutions, NGOs, and other stakeholders. One of the key outcomes of the Regional Conference is the Phnom Penh Platform on Sustainable Development for Asia and the Pacific Region. I would like to highlight some key relevant important points:

1. The region has an important role to play in promoting global sustainable development. It is the largest and fastest-growing region in the world, with over half of the world's population and the largest population of the world's poor, the world's largest EEZ's and migratory fish stocks and has the most diverse ecology.

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2. Since the United Nations Conference on Environment and Development (UNCED) in 1992, the region has made significant gains in many areas of sustainable development, including the provision of the basic physical and social infrastructures for promoting economic activity and alleviating poverty, the development of environmental policies, institutions and legislation and the conservation and management of natural resources and ecosystems, but the region's environment continues to deteriorate and the number of poor people continues to increase, outpacing the best efforts of many countries in the region.
3. The widespread poverty prevailing in the region and inadequate financial resources have been among the most serious constraints to effective implementation in sustainable development.
4. The platform outlines the key issues and priorities for sustainable development in the region including multisectorial and cross-cutting, embracing the environmental, economic and social spheres.
5. The platform lays out follow up actions:

   — Capacity-building for sustainable development,
   — Poverty reduction for sustainable development,
   — Cleaner production and sustainable energy,
   — Land management and biodiversity conservation,
   — Protection and management of and access to freshwater resources,
   — Oceans, coastal and marine resources and sustainable development;
   — Action on Atmosphere and Climate Change,
   — I hope the conference has discussed some of the issues mentioned above in the platform and will contribute to the implementation of the regional platform.
   — I hope that the regional platform will provide some principle guidance that can combine with the finding of the conference in order to respond specifically to the expected outcome of this conference.