SOUTHERN INSTITUTE OF WATER RESOURCES PLANNING
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
THE GOVERNMENT OF SOCIALIST REPUBLIC OF VIETNAM

# THE PROJECT FOR CLIMATE CHANGE ADAPTATION FOR SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT IN THE COASTAL MEKONG DELTA IN VIETNAM

## FINAL REPORT
## ( MASTER PLAN )

APRIL 2013

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

SANYU CONSULTANTS INC., JAPAN
NEWJEC Inc., JAPAN


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# PREFACE

In response to a request from the Government of Socialist Republic of Vietnam, the Government of Japan decided to conduct a project, “Project for Climate Change Adaptation for Sustainable Agriculture and Rural Development in the Coastal Mekong Delta in Vietnam”, and entrusted the implementation of the project to Japan International Cooperation Agency (JICA).

JICA selected and dispatched a project team headed by Mr. Kosei HASHIGUCHI of Sanyu Consultants Inc. and composed of members from the said consultancy company and a JV partner, NEWJEC Inc., between August 2011 and February 2013.

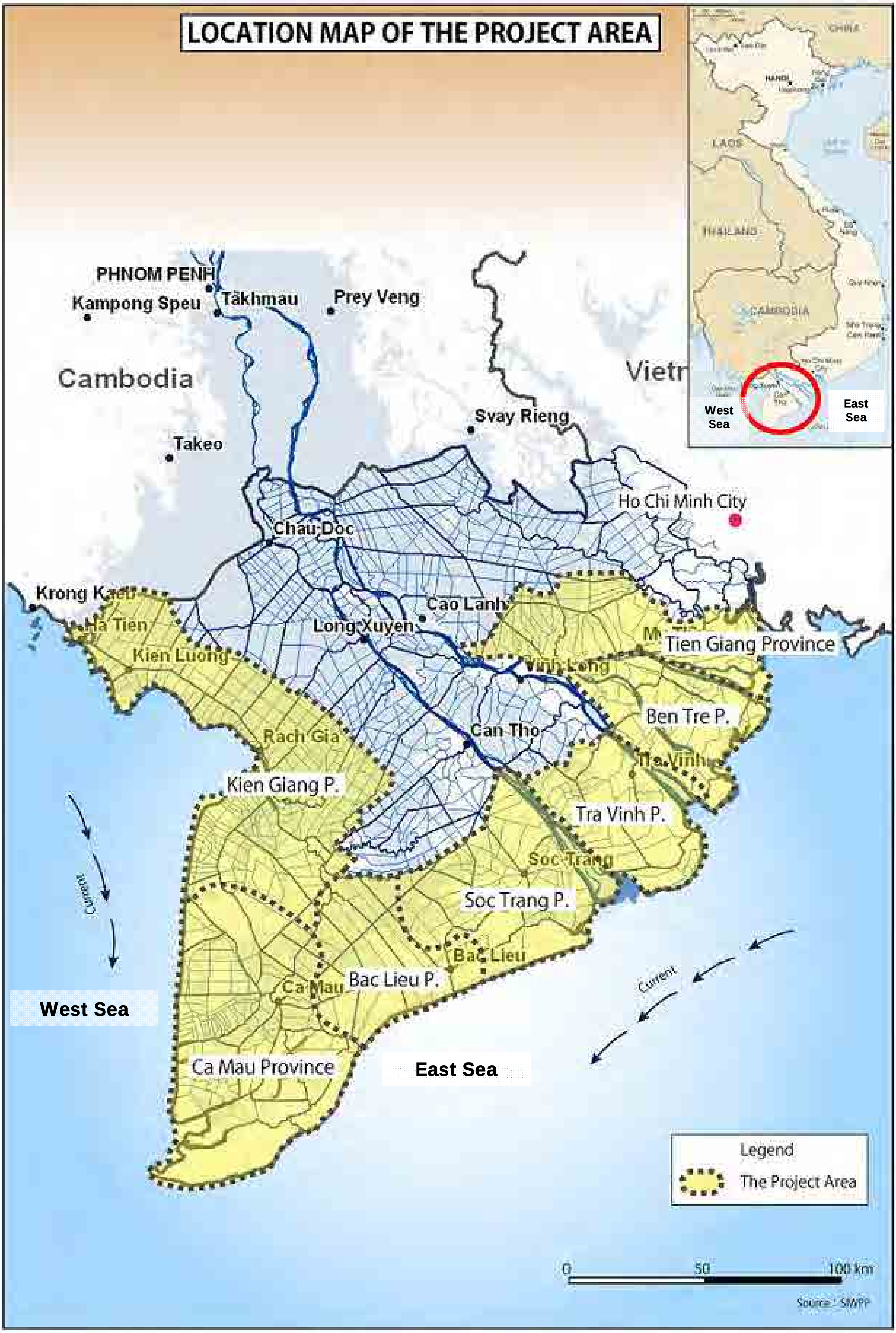
The team held discussions with the officials concerned of the Government of Socialist Republic of Vietnam and conducted a series of field surveys at the project area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the implementation of the climate change adaptation master plan formulated under the project and priority projects identified therein, and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Socialist Republic of Vietnam for their close cooperation extended to the project.

April 2013

Tsuneo KUROKAWA
Vice-President
Japan International Cooperation Agency


LOCATION MAP OF THE PROJECT AREA
PHNOM PENH
Kampong Speu
Tâkhmau
Prey Veng
Cambodia
Takeo
Svay Rieng
Vietn
Chau Doc
Ho Chi Minh City
Krong Kaeb
Ha Tien
Kien Luong
Cao Lanh
Long Xuyen
Tien Giang Province
Vinh Long
Ben Tre P.
Rach Gia
Can Tho
Tra Vinh
Kien Giang P.
Tra Vinh P.
Soc Trang
Soc Trang P.
Bac Lieu
Ca Mau
Bac Lieu P.
Current
West Sea
East Sea
Ca Mau Province
Legend
The Project Area
0
50
100 km
Source : SIWRP
CHINA
HANOI
LAOS
THAILAND
CAMBODIA
West Sea
East Sea

# EXECUTIVE SUMMARY

# PREFACE

Submitted herewith is the Final Report (FR) compiled according to the Scope of Works (SW) in regards to the “Project for Climate Change Adaptation for Sustainable Agriculture and Rural Development in the Coastal Mekong Delta in Vietnam”. This Project was authorised by the Southern Institute for Water Resources Planning (SIWRP), the Government of Socialist Republic of Vietnam, and the Japan International Cooperation Agency (JICA) on April 28, 2011. The Minutes of Meeting (MM) are attached.

This Report covers all the issues and activities that the JICA Project Team has undertaken inception to completion in respect of this Project. The issues incorporated in this Report are, amongst others: (a) the results of a situational analysis, (b) a future climate change prediction, (c) a vulnerability assessment in relation to climate change, (d) the formulation of the master plan framework inclusive of recommended projects/programs with priorities, (e) the identification of priority projects/programs, (f) a feasibility study (g) an examination of the short-listed priority projects, and (h) a conclusion and recommendations.

# 1. RATIONALE AND GOAL OF THE PROJECT

1.1 There is a global issue, i.e., climatic change, which in most cases entails global warming. Global warning raises sea water levels, as is well known. Therefore, the Mekong Delta where the surrounding land is just above sea level is likely to be greatly affected. Instead of waiting for the consequences of these changes in sea level to occur, the Government of Vietnam has embarked on a program to cope with the climate change. The program is called National Target Program to Respond to Climate Change (NTP-RCC). The Target Year of this program is 2020.

1.2 Climatic change adaptation is now a reality for many sectors of Vietnamese society, the agricultural and rural development sectors in particular. An Action Plan Framework has already been established by the Vietnamese government covering the agricultural and rural development sector (2008-2020). This Action Plan urges the concerned authorities of agriculture and rural development to formulate a tangible development plan that provides guidelines to the affected parties about how to cope with or adapt to climatic change. It is against this background that the Project for Climate Change Adaptation for Sustainable Agriculture and Rural Development in the Coastal Mekong Delta was started.

1.3 The objective of the Project is, as stated in the SW, to present ‘Climate Change Adaptation Solutions’ for sustainable agriculture and rural development in the coastal areas in the Mekong Delta. To this end, this Project has been carried out in partnership with the SIWRP, the Ministry of Agriculture and Rural Development (MARD), and incorporates the views of concerned stakeholders such as relevant departments under MARD, regional and field offices of MARD and local communities. The declared outcomes of the Project are as follows:

1) Climate change impact prediction (mid to long term, 2020-2050) and assessment is conducted,

2) Climate change adaptation Master Plan is formulated, based on which priority project plans are recommended,

3) Through the Project activities, SIWRP’s capacity for climate change adaptation planning and implementation for the sector of agricultural and rural development is strengthened.

1.4 To attain the objectives, this Project is carried out in a phasing manner divided into three: Phase 1 deals mainly with situation analysis of the project area and vulnerability assessment on climate change; Phase 2 continues the vulnerability assessment, and undertakes the implementation of in-depth study, draft master plan formulation and the identification of priority projects, and Phase 3 undertakes a feasibility level study for the priority projects and presents the final version of the Master Plan.

1.5 The responsible organization of this Project is the Ministry of Agriculture and Rural Development (MARD), while the implementing counterpart organization is the Southern Institute of Water Resources Planning (SIWRP). SIWRP has been engaged in carrying out surveys, simulation and analysis, environmental assessment, and formulating plans in the sector of water resources development in the Mekong Delta. This Project is therefore carried out in collaboration with the SIWRP as well as relevant provincial MARD, called DARD.

# 2. THE PROJECT AREA; SEVEN COASTAL PROVINCES

## 2.1 LAND, POPULATION AND ECONOMY

2.1 The Project area, which consists of seven coastal provinces, is located along the coast line of the Mekong Delta. The delta in southern Vietnam, bordering on Cambodia at its upstream point, or north-western, side. The Delta area lies immediately to the west of Ho Chi Minh City, roughly forming a triangle stretching from My Tho in the east to Chau Doc and Ha Tien in the northwest, and Ca Mau and the East Sea to the south. The area in question stretches from 08 degrees and 20 minutes to 11 degrees and 00 minutes north (latitude), and from 103 degree 50 minutes to 106 degree 45 minutes east (longitude).

2.2 Provincial populations in the Project area vary from a minimum of 867,800 in Bac Lieu, to a maximum of about 1.7 million in Kien Giang. The areas covered by this study vary from a minimum of about 2,295 people per $km^2$ to a maximum of about 6,346 people per $km^2$. The total population in the areas covered by the Project is approximately 9.02 million, which is about 52% of the total Mekong Delta population. The total area covered by the Project is about 24,631$km^2$, which is about 61% of the total Mekong Delta area. Population density is estimated at 366 persons per $km^2$. This population density is relatively high when compared to the national average of 263 persons per $km^2$.

2.3 The economy of the Mekong Delta is primarily agricultural. The Project area's overall economic structure is; 48% by primary sector, 23% by secondary sector, and 29% by tertiary sector. Primary sector agriculture in the Project area (48%) is higher than that of Mekong Delta as a whole (41%) and far higher than the national average (21%). The Project area and Mekong Delta as a whole have been achieving higher growth ratios – over 10% per annum in most provinces – compared to a national average of 5 – 8 % per annum.

2.4 GDP per capita in the Project area is, however, not as high as the national average. For example, the average GDP per capita in the Project area is US$ 987 - US$ 1,040 for Mekong Delta as a whole - while the national average is US$ 1,127. (These GDP estimates are based on 2009 figures reflecting an exchange rate of 17,100 VND/US$). The province showing the lowest GDP per capita is Tra Vinh, followed by Ben Tre. The province with the highest GDP - US$ 1,286 - is Kien Giang. There is little secondary and/or tertiary sector industry in the Project area despite huge production figures in the primary sector. As a result the GDP per capita in the Project area has been lowered.

2.5 Paddy and other products are grown in the Delta. The land covered by the Project comprises about 7% of Vietnamese farm land. (The Mekong Delta occupies 12% of Vietnamese farm land.) Gross output for agricultural sector is 16% and 33% for the Project area and Mekong Delta respectively. Gross output in these areas is larger than other areas in Vietnam. Paddy production in the Project area is 24% of the national total. The Mekong Delta as a whole produces 54% of the national total and is known as the Rice Bowl of Vietnam.

2.6 The percentage of the population raising livestock and/or involved in forestry are the same for the Mekong Delta as for the rest of the country. However, the percentage of people involved in the aquaculture sector in the Project area and the Mekong delta is very high – 71% compared to the national average of 67%. The percentage of people involved in shrimp farming in the Mekong Delta, and also in the Project area is over 70%. In other words, although the Project area and the Mekong Delta are renowned for agricultural production, these two areas are even more significant in terms of aquaculture.

## 2.2 METEOROLOGY

2.7 Air temperatures in the Mekong delta are relatively high compared to other parts of Vietnam, with an annual average temperature of about 27$^{o}$ Celsius. Generally speaking, mean annual air temperatures in the eastern area is a little lower - by about 0.4$^{o}$ Celsius - than those of the coastal and southwest areas (excepting Vung Tau). The highest mean annual air temperature is at Rach Gia (27.6$^{o}$ Celsius) and the lowest - 26.7$^{o}$ Celsius - at Ca Mau. The highest monthly average air temperature ranges between 28$^{o}$ Celsius and 34$^{o}$ Celsius. April, just prior to the onset of rainy season, is the hottest month of the year and December is the coldest month of the year.

2.8 Rainfall starts increasing from May and peaks in October. After October, it begins to decrease quickly, with minimum monthly rainfall occurring in February. About 90 % of the total annual rainfall falls during the rainy season. Mean annual rainfall varies from 1,300mm to 2,300 mm depending on location. Maximum annual rainfall occurs at Phu Quoc Island, which is located about 80 km to the west of the northern tip of King Giang province. About 3,067 mm falls on Phu Quoc compared to the mainland where less rain falls - 2,366 mm in Ca Mau, for example. The north-eastern and inland areas have less annual rainfall, around 1,350 mm - 1,349 mm at My Tho, 1,360 mm at Chau Doc, 1,356 mm at Cao Lanh and 1,544 mm at Can Tho).

## 2.3 HYDROLOGY

2.9 The Mekong River is a major water resource for the region and for Southeast Asia as a whole. The Mekong River meets the Tonle Sap River west of Phnom Penh, and then divides into the Tien River (to the north) and the Hau River (to the south). The discharge at Tan Chau station on the Tien River is 3-5 times larger than the discharge at Chau Doc station on the Hau River. The Vam Nao, which connects both rivers 20 km downstream of the Tan Chau and Chau Doc stations, conveys water from the Tien River to the Hau River, augmenting the flow of Hau River downstream from that point.

2.10 The flood season starts in July and ends in December, as does the rainfall. During this period large areas from the Tonle Sap River in Cambodia to the East Sea of Vietnam are flooded. Furthermore, a large part of the Delta, especially the upstream and midstream areas, are inundated by both the overflow from the Mekong River and because of rainfall. Upstream of the Delta the land is less affected by floods. During the tropical monsoon season, flood flows are about 25-30 times greater than those that occur during the dry season, March and April.

2.11 The daily discharge of Mekong River recorded at Kratie station in Cambodia goes over 30,000 cum/s, and in some years it reaches 40,000 cum/s and sometimes even over 50,000 cum/s. As for the average discharge during the flood season, it starts going over 30,000 cum/s from around mid August and stays there, being more than 30,000 cum/s, till late September. The average discharge peaks at around 35,000 cum/s in early September.

2.12 On the other hand, dry season's discharge remains very low. At the beginning of January, the daily discharge marks around 5,000 cum/s and continuously decreases towards the end of dry season. The average daily discharge goes down to less than 3,000 cum/s in February, and further down to less than 2,000 cum/s from late March to early April. After that, the reverse starts in as early as April, but the discharge in April still stays just over 2,000 cum/s. In May, the average daily discharge is now increasing quickly, starting from about 2,300 cum/s at the beginning of May and goes to 6,500 cum/s at the end of the month.

2.13 There are 2 gauging stations located on upper reaches of Mekong River near the border with Cambodia. These are Tan Chau on the Tien River and Chau Doc on the Hau River. At these two stations the water level remains very low in April and May. The average daily water level drops to less than 0.5 meter at Tan Chau station in April and to 0.4 meter at Chau Doc. In May the water level starts rising towards the peak of the flood season, which is October. In October, the average water level reaches as high as around 4.0 meter at Tan Chau station and about 3.5 meter at Chau Doc station.

2.14 The discharges from the 2 stations of Tan Chau and Chau Doc are very different. There is a much greater flow at Tan Chau than Chau Doc. While the flood season’s daily discharge at Tan Chau station can exceed 20,000 cum/s, the discharge at Chau Doc remains at around 7,000 cum/s. In total, taking both stations into account, the average peak discharge during the flood season reaches about 28,000 cum/s. This discharge is lower than that at Kratie (about 35,000 cum/s) due to the existence of the Great Lake in Cambodia. During the flood seasons, a great deal of river water flows back to the Great Lake via the Tonle Sap River.

2.15 The Great Lake discharges stored water back into the Mekong River during the dry season. This discharge augments the dry season flow running through the Tan Chau and Chau Doc stations. As figures obtained from hydrographs reveal, the total discharge of the 2 rivers at the beginning of January is about 10,000 cum/s with that measured at the Kratie station being about half this amount - 5,000 cum/s. During the driest season, April and May, the total discharge of the 2 rivers stays at around 3,000 cum/s, while that at the Kratie station drops to about 2,000 cum/s, or about two-thirds of the total. This means that the Great Lake works to mitigate the flood magnitude in the Mekong Delta during the flood seasons while augmenting freshwater flow during the dry seasons.

## 2.4 WATER WAY AND IRRIGATION CANALS

2.16 The Mekong Delta waterway network carries seagoing and inland traffic, including some cargo traffic from Vietnam to Cambodia. Domestic waterway traffic is very dense in the whole delta area. Hundreds of waterways of varying size - rivers, river tributaries, constructed canals, and natural creeks - interlace the area. It has been calculated that the total navigable length of the Delta is approximately 4,785 km and caters for a variety of vessels of varying size. This waterway network connects major cities and it plays a vital role in the economy and human life of the area.

2.17 The waterway network in the Mekong Delta was originally developed by the colonial French authorities for navigation and then drainage functions and irrigation functions were added. Nowadays, canals provide multifunctional services and are classified into four levels, namely Main, Level 1, Level 2, and Level 3. The Main and Level 1 canals were constructed by the central government, Level 2 by the provincial government, and Level 3 by local farmers. According to statistics provided to SIWRP, the total length of the canals in the Mekong Delta is estimated at over 90,000 km composed of 3,190 (Main); 10,961 (Level 1); 26,894 (Level 2); and 50,019 (Level 3) sections.

2.18 The average waterway density of the Mekong Delta is 2.39 $km/km^2$. Of the four hydrologically divided areas, Trans Bassac, (the area between Tien River and Hau River) has the highest waterway density at 3.48 $km/km^2$. In the mid part of the delta there is a confluence area involving both river flow and tidal water, and thus 2-way water flow in this area has created many natural channels. Conversely, the Long Xuyen Quadrangle in the northern part of An Giang and Kien Giang provinces has a water work density of only 1.69 km/km$^2$. In the hilly area at the northern end of An Giang province, the canal network remains underdeveloped.

## 2.5 ROADS AND RURAL WATER SUPPLY

2.19 The road network in the Mekong Delta totals about 22,870 km including community (village level) roads. Road density differs widely by province and/or area. The road density in Long An province is 1.11 km/km$^2$ while that of Ca Mau province is only 0.47 km/km$^2$, with an average density of 0.58 km/km$^2$ or 1.27 km/1,000 people. In total 15 national highway routes criss-cross the Mekong Delta having a total length of 2,471 km. At provincial road level, there are 127 road routes totaling 3,400 km, of which about 75% are paved by asphalt-concrete. The remaining stretches – a total length of 17,000 km - are communal roads that connect districts and communities, or provide inter-community networks.

2.20 The national roads in the Project area, total about 1,388 km, equivalent to 56% of the whole Mekong Delta. The length of the provincial roads covered by the Project is 2,263 km, or 66 % of the Mekong Delta. The total length of district roads is 2,820 km. Data for communal/community roads is not available by province. The density for the 3 levels of road in the Project area shows an average of 0.32 km/km$^2$ with the highest density being, 0.57 km/km$^2$, at Tien Giang province and the lowest density at Ben Tre province, 0.16 km/km$^2$. Note that the data for Kien Giang is not available.

2.21 There are four major methods for providing domestic water supply in the Mekong Delta - water supply stations, drilling wells, shallow wells, and rain water. About 19% of the population obtains domestic water from water supply stations. This is the most stable water supply system, 26 % by drilling wells, often more than 100 m deep and sometimes up to sometimes 150m deep and 22 % by shallow wells dug by the owners. The remaining population, - 33 % - depends on rainwater. In fact, rainwater is one of the safest water sources, but obtaining water in this way is difficult at the end of dry season when supplies run low. Normally, people who rely on rainwater resort to channel water when their water supply is depleted.

2.22 The history of groundwater development in the Mekong Delta started in the early 1940’s. There are four major aquifers composed of stratums of Pleistocene, Pliocene, and Miocene. There are now about 465 000 ground water supply wells that rely on these aquifers, which currently discharge about 1.3 million m$^3$/day (source: SIWRP). By coastal province, Kien Giang province has the greatest number of groundwater works as 96,950, followed by Tra Vinh and Bac Lieu. Tien Giang province has the least number of works as 1,165. The total capacity of this groundwater resource is estimated at about 86 million m$^3$/day, according to SIWRP, which far exceeds the amount of water currently being drawn.

## 2.6 AGRICULTURE

2.23 Cropping systems in the Project area and the Mekong Delta are quite diverse and highly sophisticated. There are several combinations of various crops including paddy, upland crops, and aquaculture. In the paddy crop calendar there are four major seasons: winter-spring, summer-autumn, autumn-winter and spring-summer (in an order of popularity in terms of planted areas). Among these four crop seasons, summer-autumn paddy (May-August) and winter-spring paddy (December-February) constitute the major part of paddy production in the Project area.

2.24 In rain-fed areas where irrigation water is barely available, paddy is planted only during the rainy season. If the area is heavily flooded toward mid to end of the rainy season, only one crop of summer-autumn paddy (early rainy season paddy) is cultivated. In areas not affected by floods, autumn-winter paddy is also cultivated. Where there are two paddy crops in a rainy season, however, farmers may face water shortages toward the end of rainy season. To avoid these water shortages, the farmers sometimes transplant 30 to 45 days nurseries to the main field for the second paddy crop, thus shortening the main field's growing season.

2.25 In respect of paddy production in the Project area in 2010, Kien Giang produces by far the most paddy (3,485,000 tons). This is the second largest volume in the Mekong Delta after An Giang (3,692,000 tons). The third biggest volume of paddy is produced in Dong Thap province. Kien Giang, An Giang and Dong Thap provinces are located in the upper reaches of the Mekong River. The coastal provinces, except for the Kien Giang, produce relatively small quantities of paddy. For example, Ben Tre province produces the least paddy - 368,000 tons - followed by Ca Mau (504,000 tons) and Bac Lieu (849,000 tons), which are all in line with the land use pattern.

2.26 As for paddy production per capita, the average comes to 1,066 kg and 1,249 kg for the Project area and the Mekong Delta respectively in 2010. The highest paddy producing province per capita is Kien Giang at 2,046 kg/capita or 164% of the Mekong Delta average. The province that produces the smallest quantity of paddy is Ben Tre with 293 kg/capita or 23% of the Mekong Delta's average. Ben Tre is followed by Ca Mau province (416 kg/capita, 33% of Mekong Delta's average). The low production in Ben Tre is explained by a fact that much of the farmland in the province has been devoted for fruit production. In Ca Mau province there is a great deal of saline intrusion which makes paddy cultivation difficult. Note that national average of the paddy production per capital is 460 kg.

2.27 Paddy production in the Project area is in an increasing trend, notwithstanding some stagnation in area planted. In particular, summer-autumn production and winter-spring production have been increasing in the past two decades, while the production of autumn-winter paddy is on a little decreasing trend. In fact, yield has been increasing for all the seasons' paddies including autumn-winter paddy. Of them, winter-spring paddy has kept the highest yield; 6.4 ton/ha in 2010 as an average of 7 coastal provinces, followed by 4.7 tons/ha for summer – autumn paddy and 4.12 tons/ha for autumn – winter paddy.

2.28 According to a survey conducted in 2011, net income from paddy cultivation per season for a typical farmer is estimated at 6,486,000 VND as a financial value and 9,736,000 VND at an economic value based on an average area of 0.74 ha (These figures were based on 139 valid responses). Note that the economic value includes what is consumed by family members in monetary terms, while the financial value excludes family consumption. If the economic income per average area of 0.74 ha is converted into the value for the unit 1.0 ha paddy area, the net income comes to an average of 13,122,000 VND ranging from about 11 million VND (autumn – winter paddy) to about 15 million VND (summer – autumn paddy).

2.29 A typical paddy farmer cultivates more than one paddy crop a year. According to the survey of paddy-only farmers, a typical average farmer cultivates a total area of 2.05 ha with an average of 2.76 harvests per year. The typical average paddy farmer therefore generates a total gross income of about 54 million VND and 63 million VND in financial and economic terms respectively. Subtracting the costs of producing 2.76 paddy harvests of about 36 million VND, net income per year per typical paddy farmer is about 17,901,000 VND in financial terms and 26,871,000 VND in economic terms.

## 2.7 AQUACULTURE

2.30 It is well known that aquaculture production in the Mekong Delta far surpasses aquaculture production in other regions. In fact, the overall aquaculture production in the Mekong Delta (1,940,181 tons) comprised 72% of the national total (2,706,752 tons) in 2010. With regards to the aquaculture production of fish, the most intensive production areas are located in the upper-mid parts of the Mekong Delta, though the Project area still produces a total 530,612 tons of fish through aquaculture. Per-capita production of fish through aquaculture in the Project area is estimated at 59 kg, which is far bigger than the national per-capita average of 24 kg.

2.31 Aquaculture shrimp production in the Project area by far exceeds production quantities of other regions including mid-upper parts of Mekong Delta. The total production of aquaculture shrimp in the Project area in 2010 came to 331,760 tons, compared to a national average of 450,364 tons. This means that the Project area produced as much as 76%, or approximately three-quarters of national production. Per-capita production of aquaculture shrimp is 36.8 kg per annum. Per-capita production in the other provinces and regions remains less than 5 kg per capita per annum.

2.32 Shrimp culture in Vietnam may be divided into four sectors: intensive, semi-intensive, improved extensive and extensive, although there are some variations to this categorization. In the coastal areas of the Mekong Delta, intensive and semi intensive shrimp culture occur in only 10% in terms of the cultivated area. The remaining areas all have extensive and improved extensive systems. An extensive system has less impact on the environment, although it results in quite low productivity. The annual yield of shrimp production under the extensive system is reported at being around 200-300 kg/ha while that of the semi-intensive system is 1.5-3.0 ton/ha. The intensive system produces 5.0-7.0 ton/ha and sometimes even more.

2.33 While the extensive system is used in 90% of the total cultivated area in the Mekong Delta, it produces only 43% of the shrimps harvested. By contrast, the semi-intensive system, which is used in only 8.2% of the area, produces 35.5% of total production. Similarly, while the intensive system is used in only 1.8% of the area, it produces as much as 21.1% of total production. “Intensive” is composed of semi-intensive and intensive, systems and produces nearly half of the total yield from only 10% of the land.

2.34 An extensive shrimp cultivation system is sometimes combined with paddy production. In this kind of system, shrimp is cultivated in the dry season when saline intrusion takes place. In this system, as the period available for shrimp culture is limited, post larvae are released only once, at the beginning of the dry season in most cases. After farmers have harvested the shrimp at the end of the dry season, they usually leave the farmland for two- to two-and-half months during the early rainy season. The farm plots where salt has accumulated and used for shrimp culture are thereafter washed by rainfall and are thus prepared for paddy cultivation during the rainy season.

2.35 A survey was carried with brackish shrimp cultivation farmers regarding common practices with respect to extensive, shrimp/paddy (SP) rotation, improved extensive and semi-intensive rotation. (Intensive commercial cultivation was excluded). Based on average gross income and cost of production for brackish shrimp culture, an overall average net income per household was found to be 73,354,000 VND/household with an average area of 2.0 ha/household. Net income ranged from 38,696,000 VND/household for extensive (SP) culture to 112,443,000 VND/household for extensive culture. Note that the highest net income for extensive cultivation occurs at the largest area of the shrimp pond (3.8 ha/household while others are 1.5 – 1.9 ha/farmer).

2.36 In terms of net income per 1.0 hectare unit for the above-mentioned shrimp cultivation, the total average comes to 36,722,000 VND/ha. Income ranges from 26,048,000 VND/ha for extensive cultivation (SP) to 52,031,000 VND/ha for semi-intensive cultivation. Since the net income of extensive cultivation (SP) is a part of total income (additional income is expected from paddy cultivation), it may be lower than other types of cultivation. There is about double the difference between the lowest net income (extensive, SP) and the highest net income (semi-intensive). Cost against the gross income ranges from 29% to 49 %, with an average of 43%.

## 2.8 RELEVANT DEVELOPMENT PLANS AND PROJECTS

2.37 In Mekong delta, the first master plan in the field of water resources development was prepared in 1990. This plan was updated by SIWRP from 2002 to 2005. After the update was completed, SIWRP submitted the Master Plan (SIWRP) to the MARD central office and then to the central government. The Master Plan (SIWRP) was approved in 2006 by the prime minister as Decision 84/2006/QD-TTG. This Master Plan (2006) focused on water resources development mainly for the purpose of agricultural restructuring based on development strategies described in the Socio-economic Development Plan 2005-2010.

2.38 According to SIWRP, by the end of 2009, a total of 53 hydraulic schemes had been implemented out of the 79 hydraulic schemes proposed in the Master Plan (2006). Despite the fact that a total 53 hydraulic schemes had been started, only three schemes had been completed, or 4% of the total. This slow progress was due mainly to funding issues, not only for the construction stages, but also for the design stages. It was estimated by SIWRP that what was disbursed by the central government was only 14% of the total project cost recommended in the Master Plan (2006). Disbursements by provincial governments remained at about 10% of the costs shown in the Master Plan (2006).

2.39 SIWRP started preparing a water resources master plan in 2010 taking into account the effects of climate change covering 4 stages; namely, 2011-2015, 2016-2020, 2021-2030, and 2031-2050. The plan was finalized in August 2011, and submitted to the Headquarters of MARD for its approval. The plan covering the period up to 2020 was approved on September 25, 2012 in Decision No. 1397/QD-TTg. The master plan (2011) examined 3 options in terms of how to deal with the saline intrusion along the Mekong River The plan recommended Option 2 in which three saline prevention gates would be constructed at the Ham Luong, Co Chien and Cung Hau estuaries. Note that these 3 gates are planned for construction after 2020 and, therefore, the present approval does not cover the construction of these gates.

2.40 The projects recommended in the Master Plan (2011) center on hydraulic facilities and works. The Plan covers the period up to year 2050, which is further divided into 4 stages: (1) 2011-2015, (2) 2016-2020, (3) 2021-2030, and (4) 2031-2050. The project cost stage by stage is as follows: US$ 3,771 million for the first stage -2011-2015 increasing to as much as US$ 8,142 million for the third stage - 2021-2030. The total cost is estimated to be US$ 24,758 million. In fact, this investment is very large especially when compared to past investments by the central government, which has allocated about 500 to 600 billion VND per year (US$ 24 – 29 million per year) for whole Mekong Delta region.

2.41 The major donors operating in the Mekong Delta in the field of water resources, agriculture and rural development are WB, ADB, AusAID, IFAD, GIZ, and the Netherlands. The Netherlands is now preparing a regional master plan for the entire Mekong Delta region. WB began a water resources project encompassing rural development covering the southern part of the Delta from Hau River, and ADB is to invest in the northern part of Mekong Delta from the Tien River aiming mainly at mitigating flood damage. From a climate change point of view, the activities of ADB, GIZ and AusAID are directly related to this issue.

# 3. VULNERABILITY ASSESSMENT FOR THE PROJECT AREA

## 3.1 PAST TREND IN CLIMATE AND SEA-LEVEL RISE

3.1 Long term climate data were collected at four stations - Vung Tau, Can Tho, Ca Mau, and Rach Gia – covering the period from 1978 to 2009 or 2010. One clear trend evident at all four stations is a long term increase in mean, mean-maximum and mea- minimum temperatures. The rate of increase is about 0.7$^o$ Celsius, about 1.0$^o$ Celsius, and about 1.0$^o$ Celsius for annual mean, annual mean-maximum and annual mean-minimum temperatures over the 30 year period in question. This trend appears to correspond to global warming.

3.2 The amount of sunshine recorded at the three stations (Can Tho, Ca Mau and Rach Gia) from 1978 to 2009/2010, has gone from about 3 000 hours to 2 500 hours per annum. There is an obvious trend: over the last 30 years, the approximate amount of sunshine hours per annum has gone down by about 500 hours, a 20 % decrease. This may be linked to increased rainfall, meaning there is more cloud over these stations. (In fact, rainfall at Ca Mau and Rach Gia stations shows a steady increase. Though there was a decrease at Can Tho between 1978 and 2010 there is still an increasing trend evident over the longer period e.g. 1910 – 2010).

3.3 With respect to evaporation recorded at the 4 stations of Vung Tau, Can Tho, Ca Mau and Rach Gia from 1978 to 2009/2010, the annual values range from about 800 to 1,400 mm, and sometimes reaches as high as 1,600 mm. The trend is somewhat mixed, however. Two stations - Vung Tau and Can Tho - show an increasing trend while the other two stations - Ca Mau and Rach Gia - show a decreasing trend. Temperatures are increasing and sunshine hours are decreasing. The former contributes to increasing evaporation and the latter to decreasing evaporation. Because of these conflicting influences the trend in evaporation is not clear.

3.4 On the rainfall recorded over the period 1978 – 2010 at five stations - Can Tho, Ca Mau, Rach Gia, My Tho and Vung Tau - it was shown that the annual rainfall at the three stations of Ca Mau, Rach Gia, and My Tho has been increasing while rainfall at the other two stations has been decreasing, though there are fluctuations year by year. Note that though Can Tho station shows a decreasing trend between 1978 and 2010, it is still showing a long-term increase over the period 1910 – 2010. The rainy season shows a similar trend with the same three stations showing an increase and the other two stations showing a decrease. Looking at October rainfall, the maximum monthly rainfall at four stations (except for Can Tho) shows an increasing trend.

3.5 There are water level stations in the East Sea and West Sea as well as along the Mekong River, e.g. Vung Tau (East Sea), Rach Gia (West Sea), and Can Tho, which is located at about 80 km inland from the estuary. The recorded period covers the period from 1982 to 2011 for Vung Tau and Rach Gia and from 1982 to 2009 for Can Tho. It has been noted that all three stations show a continuously increasing trend. The increase for the two stations of Vung Tau and Rach Gia comes to approximately 15 cm over the recorded period of about 30 years. This means that the sea levels for the both East and West Seas has been increasing by approximately 5 cm per decade.

## 3.2 CLIMATE CHANGE PREDICTION

3.6 With reference to a climate change simulation by GCM and PRECIS, the mean annual temperatures in the future are expected to rise based upon predictions related to the stations at Ca Mau and Ho Chi Minh City. The area of least temperature rise lies in the north-western area of the Mekong Delta including Kien Giang Province. Mean temperature are expected to increase continuously, though the increase for climate change scenario B1 seems to show a decrease towards 2100. Mean annual temperature is expected to rise by about 1$^o$ Celsius by 2050 for the three scenarios of A2, B1 and B2 against the average temperature figures for the base period of 1980 and 1999, and by 1.4$^o$ Celsius to as much as 2.7$^o$ Celsius degree by 2100, depending on the climate change scenario.

3.7 Monthly temperature tends to increase more during the rainy season than the dry season. By 2050 rainy season temperatures are expected to increase by about 1.2$^o$ Celsius, 1.3$^o$ Celsius and 1.4$^o$ Celsius for the scenarios B1, B2 and A2. By 2100, the increases will be about 1.6$^o$ Celsius, 2.5$^o$

Celsius, and 3.2 $^{o}$ Celsius, respectively. One unique tendency is that there is a drop in temperature increase during the rainy season in August. During the dry season, the temperature increase is very small, especially between February and April. The increases by 2050 is expected to be about 0.6 $^{o}$ Celsius, 0.7 $^{o}$ Celsius, and 0.8 $^{o}$ Celsius for the scenarios B1, B2 and A2 respectively.

3.8 Rainfall simulations predict an overall rainfall increase over the Mekong Delta (using the northern part of the delta where Dong Thap province is located, as a base point). It is predicted that Ben Tre province to Soc Tran province via Tra Vinh province will have more rainfall in the future along the coastal zone, while the inland areas of Tien Giang, Ben Tre and the whole of Ca Mau provinces will have a smaller increase in rainfall. The annual rainfall simulation shows a general trend indicating that that the higher green gas emission, the more increased rainfall is likely to occur, and vice versa. Scenario A2 shows that the highest rainfall increase will be by about 3% a year by 2050 and by over 7% by 2100. For the B1 low green gas emission scenario, the increase is smaller than the others and the increase percentage after 2070 is very small.

3.9 With regards to seasonal rainfall changes, during the dry season the change is in the negative range, meaning that in the future dry season rainfall will be less than in the past. On the other hand, during the rainy season monthly rainfall is projected to increase in future. The increase during the rainy season shows up in two periods i.e. in July and October. July is still in the early part of the rainy season while October is near the end of rainy season. In October, where the highest amount of monthly rainfall is usually recorded, monthly rainfall is predicted to increase by 15%, more than 20% and more than 30% by 2100 for the three scenarios B1, B2 and A2 respectively. It can be said that, generally in the future, it is predicted that rainfall will tend to increase especially at the end of rainy season.

3.10 With regards to the rise in sea-level, the high green gas emission scenario - A2 - shows the biggest sea level rise at 31 cm a year by 2050 and by as much as 103 cm a year by 2100. Scenario B1 shows the lowest seas level rise; 27 cm a year by 2050 and 70 cm a year by 2100. Scenario B2 shows a somewhat medium rise of 28 cm a year by 2050 and 79 cm a year by 2100. The trend is exponential for all three scenarios, meaning that increases in sea level become greater towards 2100. Sea level rise by province does not differ much and the difference between provinces is only about 5 cm even in 2100.

3.11 The Mekong River Commission (MRC) has carried out simulations on future Mekong River discharges under climate change Scenarios B2 and A1, covering up to the year 2050. With respect to the dry season, (not considering future water resources development projects) discharges become bigger at the beginning of the dry season (end of March) than the average discharge between 1991 and 2000. The simulated discharges tend to be almost the same as the average discharges for 1991 - 2000. Looking at the rainy season discharges, not considering any development projects, the simulated discharges do not show a clear tendency to increase, or to be less than the 1991 – 2000 average discharge until the peak period of mid-September. However, after having reached a peak around mid-September, the simulated discharges tend to exceed the past average discharge.

3.12 With respect to future discharges, considering the many water resource development projects in the catchment area, the dry season’s discharge shows an increasing trend. The simulated discharge during the driest periods of March and April is about 4,000 $m^3/s$ while the average discharge between 1991 and 2000 was only 2,300 – 2,400 $m^3/s$. This implies that there might be a possibility, should the future development projects in the catchment area be realized, that the dry season discharge down river of Kratie station could increase by as much as 70% (from around 2,350 to 4,000 $m^3/s$). The reason for this excessively large increase is the effect of hydro-power dams which release large quantities of stored water during the dry season.

## 3.3 VULNERABILITY ASSESSMENT

3.13 There is a direct relationship between temperature and crop yield. Extremely high temperatures during the vegetative growth periods are known to reduce tiller numbers and the plant height of paddy, and negatively affect panicle and pollen development. This causes a reduction of paddy yield potential. Based on statistical data, it is indicated that as the temperature rises, there is a yield reduction as reflected in the following formula; $y= -0.042x^2 + 2.404x – 29.09$ ($R^2$=0.41). This indicates that there is approximately 0.57 ton/ha yield reduction for every 1.0$^o$ Celsius temperature increase within the temperature range of 31 – 33 Celsius degrees.

3.14 Given this correlation and the present yield of winter – spring paddy which is about 4.5 to 4.9 tons/ha by province will start decreasing as the temperature goes up. Under climate change Scenario B2, where 0.9$^o$ – 1.4$^o$ (1.6$^o$ – 2.6)$^o$ Celsius temperature rise is expected by the year 2050 (2100), the yield may be reduced to 3.8 – 4.2 (3.2 – 3.8) tons/ha by 2050 (2100) depending on the province. This yield reduction corresponds to a 12 – 18 (22 – 29) % yield loss by 2050 (2100). Total production of the winter – spring paddy for the Project area is now about 4 million tons and this total production reduces to 3.4 (3.0) million tons by 2050 (2100). This means a 15 (25) % loss by year 2050 (2100) compared to present figures.

3.15 As the sea level rises as a result of climate change, one of the main impacts will be that most coastal areas will be greatly affected by saline intrusion. The areas most affected by saline intrusion are the provinces of Bac Lieu and Ca Mau where large areas of land will receive around 20 g/l (20,000 PPM). Bac Lieu and Ca Mau provinces are located far from the Mekong River which means that they have difficulty obtaining fresh water from the River, especially in the case of Ca Mau. Also, these two provinces have long coastlines that will be directly affected by a rise in sea level.

3.16 The provinces least affected by saline intrusion may be Tien Giang and Kien Giang, though they contain relatively large areas of land that will be affected in the smaller saline ranges, such as less than 0.5 g/l (500 PPM). The upstream parts of Tien Giang province extend into the mid parts of the Delta, where the lands are relatively high and, therefore, less affected by saline intrusion. For Kien Giang province, the existing sluice gates are operational and will prevent saline intrusion.

3.17 Fruit and paddy are the two main crops largely damaged by saline intrusion in terms of monetary value. Paddy shows the biggest monetary loss in Soc Trang and Kien Giang provinces while Tien Giang, Ben Tre, Tra Vinh, Ca Mau are the provinces where the fruit crop will be most affected. The predicted loss of fruit in Ben Tre province especially ranges from 3 - +7 trillion VND, depending on the level of increase of sea levels. For all the 7 provinces, fruit shows the biggest monetary damage as a result of saline intrusion, followed by paddy. The damage for the vegetable and forest industries are comparatively small. On the cost of damage by province, Ben Tre province shows the biggest loss (approximately 4 – 9 trillion VND), which is due to the loss of valuable fruit production, followed by Soc Trang, Ca Mau, Kien Giang and Tra Vinh.

3.18 Climate change will increase future rainfall, thereby causing deeper and long lasting inundation. Flood inundation levels will peak in September and October. As severe flooding is expected to occur in the upper-most reaches of the Mekong Delta, such as in Dong Thap and An Giang provinces. Along the coastal areas, the level of flooding will not be as severe as that in the upper reaches of the Delta. However, since Kien Giang province is located upstream of the Delta, bordering An Giang province, this province tends to be affected more when compared to other coastal provinces. In addition, the upper reaches of Tien Giang province will also be affected by flooding since this area receives not only Mekong flood discharge water but also runoff water coming from Dong Thap province.

3.19 The most affected crops by inundation in terms of percentage are vegetables, followed by paddy, fruit and shrimp. Forestry is the least affected industry and will suffer almost no damage, even following a 100 cm rise in sea level. Fruit is usually more susceptible to inundation than paddy. However, in most cases fruit plants are planted in relatively high ground, while paddy is planted in low lying areas. This is the reason why paddy is more affected by flooding than fruit.

3.20 As previously mentioned, vegetables are most affected by inundation in terms of percentage decrease. However, in terms of monetary value, the most affected production/area is either fruit or shrimp, and sometimes paddy. Because the land reserved for vegetables is not large in the Delta, the percentage of damage or loss in terms of monetary value is not as big as for other types of crop. Tien Giang and Ben Tre are famous fruit producing areas and these provinces will be most affected in respect of any decline in fruit production figures. Where paddy production is concerned, Kien Giang province where the most paddy fields are located, will suffer the greatest loss in terms of monetary value.

3.21 On the change in production/area by inundation in terms of percentage by province, Kien Giang province is the most affected - except for the ‘Present’ case - followed by Tien Giang. The other five provinces show more or less same damage percentage. In terms of monetary change (damage), Kien Giang province again shows the biggest loss till year 2080, which is due to the loss of vast areas of paddy production, followed by Tien Giang until the year 2050. By 2100, Ca Mau, Soc Trang and also Bac Lieu provinces will show bigger losses as in these provinces shrimp farming will be greatly reduced when the sea level rises by 100 cm.

3.22 Combining the damage by saline intrusion in the dry season and the damage caused by inundation in the rainy season, the percentage loss by 2050 against the annual value (annual production) of paddy, vegetables, fruit, forestry and shrimps ranges from 20% to 50%, with an average of 30% for the severest case of DY 1998 discharge for dry season and FY 2000 discharge for the rainy season. The provinces that will suffer the least loss in terms of percentage are Bac Lieu and Ca Mau while the provinces that will suffer the largest losses are Kien Giang, followed by Tien Giang.

3.23 On the aggregated loss in monetary value by saline intrusion and by flood inundation, the largest losses will occur in Kien Giang province up until 2080 as a result of reduced paddy production during by the rainy season caused by flooding. Other provinces affected will be Soc Trang, Ben Tre, Ca Mau, Tien Giang, so on so forth. Bac Lieu appears to be the least affected province (until 2080) in terms of value loss. In the severest case (DY1998+FY2000), predicted losses by 2050 ranges from 3,600 billion VND (Bac Lieu) to 12,000 billion VND (Kien Giang) Losses occurring by 2050 estimated under future scenarios B2 and A2 are 1,900 billion VND (Bac Lieu) and to 8,600 billion VND (Kien Giang).

## 4. MASTER PLAN FORMULATION: PLANNING

4.1 In view of the impacts from climate change, it has also been agreed in the Scope of Work prior to the commencement of this Project, to present ‘Climate Change Adaptation Solutions’ for sustainable agriculture and rural development in the coastal areas in the Mekong Delta as the main objective of this Project. Taking into consideration the development vision in the Project area – the future scope of the development – the main objective of the proposed project is to ensure that the “Population’s livelihood and life are sustained by adapting to and coping with climate change based upon a variety of structural and non-structural development interventions”.

4.2 To formulate any master plan, there should be a guiding principle that will help to determine the development strategies that will be used to achieve the aforementioned development vision. Planning under climate change is always associated with a certain level of uncertainty about the future.

Furthermore, the Mekong River's flow into the Mekong Delta will vary greatly depending on developments upstream by Vietnam's neighboring countries. Keeping these facts in mind, the following five guiding principles are given to achieve the above proposed development vision; namely, 1) NO Regret Investment, 2) Flexibility in planning and investment, 3) Balanced structural and non-structural intervention, 4) Priority setting in all associated projects, and 5) Establishment of early warning systems (saline intrusion).

4.3 A time framework should be drawn up, consisting of short, medium and long term goals, when preparing any development plan. To define short, medium and long term time frames, the Master Plan should refer to the existing development plans including the national socio-economic development plan as well as the climate change-related framework in Vietnam. Short-term goals should cover the period from 2013 to 2020, Medium term goals from 2021 to 2030, and Long-term goals from 2031 to 2050, a total of 38 years.

4.4 Summing up all the work done in the workshops together with contributions by the JICA Team, a prioritized development framework is presented below together with project/program descriptions in a simplified project design matrix (PDM). The development framework can be used as a guide when the Vietnamese government carries out development activities in the coastal areas of the Mekong Delta. The framework can also work as a development platform so that all stakeholders can make a concerted effort to work together to develop the coastal areas of the Mekong Delta in the context of climate change.

4.5 Setting priorities refers, firstly, to climate change issues provided by the seven provinces and based on the issues identified at village level workshops. Setting priorities also refers to the projects recommended by the provinces as well as those projects recommended in the SIWRP master plan (2011). Note that those projects are not only related to climate change. Taking all these issues into consideration, the most common issues of concern are saline water intrusion, drought, and rising sea-levels (causing the erosion of sea dykes, inundation and/or flooding at high tide or after heavy rainfall) or changing rainfall patterns which exacerbate inundation and increased temperatures.

4.6 A framework can be presented in several ways. In this report at a tree structure is used starting with the development vision which cascades down to prioritized climate change issues, an adaptation and/or coping strategy and finally the project/ program. Priority issues are identified in order of importance as Saline Water Intrusion, Drought, Rising Sea levels, Flooding, Changing Rainfall Patterns and increased Temperatures, which are all related to climate change and are arranged in order of importance from the top down within the framework. In addition 'Common Issues' are placed at the bottom of the framework. Such projects deal with cross cutting issues, e.g. water management and rural improvement, etc..

4.7 Following the projects/ programs presented in the framework, there is a matrix table showing the following symbols - '●', '◎', and '○', which identify highest, next highest, and high priorities in order of importance. This matrix shows which projects/ programs should be carried out in which provinces and at what priority. The prioritization in the matrix is done by cross cutting from top to bottom by the province. The development framework further covers; 1) the type of the project/program either Structural or Non-structural, 2) the project implementation period, and 3) project cost. Note that project costs are preliminary since the projects/programs are presented at master plan level.

# 5. PRIORITY PROJECT IDENTIFICATION

5.1 In selecting priority projects, the following criteria should be considered as Priority Projects; 1) priority be set in accordance with those projects proposed in the framework, 2) should primarily refer to those projects already identified/planned by the relevant provinces as priority project, 3) should primarily be models, which represent measure(s) of adaptation to and/or coping with issues induced by climate change, 4) should be planned in view of examining not only the structural measures, but also the non-structural measures, and 5) should be viable in financial and economic terms, and also justified from different viewpoints, i.e. technical soundness, institutional soundness, and environmental soundness.

5.2 Priority projects are firstly long listed and then short listed for the feasibility study. The projects are classified into 2; structural and non-structural projects. The structural projects are further sub-divided into 2; sub-sector targeted projects and regional (area specific) projects. This Master Plan Project proposes the following projects as long listed priority projects; namely, 6 structural projects and 3 non-structural projects, and the 6 structural projects are further categorized in 2 sub-sector targeted projects and 4 regional (area specific) projects. Of the 9 long listed projects, this Master Plan project further recommends the underlined 4 projects, 2 for structural projects and 2 for non-structural projects, as short listed priority projects;

*Sub-sector targeted Project (Structural):*

1) <u>*Saline Intrusion Prevention Sluice Gate Construction Project (Sub-sector approach)*</u>
2) *Seashore Protection and Improvement Project (Sub-sector approach)*

*Regional Project (Structural):*

3) *North Ben Tre Polder Area Improvement Project*
4) <u>*Tra Vinh Fresh Water Recruitment Project*</u>
5) *Bac Lieu Coastal Area Water Management Project*
6) *Ca Mau Flow Mobilization Project (including water management non-structural measure)*

*Non-structural Project:*

7) <u>*Cropping System Improvement Program toward Climate Change Adaptation*</u>
8) <u>*Capacity Development Project for Flow Water Management in Mekong Delta*</u>
9) *Sustainable Shrimp Culture Promotion Program (focusing on paddy-shrimp rotation)*

5.3 The Saline Intrusion Prevention Sluice Gate Construction Project has been given the highest priority amongst all the projects in the MP framework. Also, this project can be a major component of many regional projects aimed at saline water prevention, e.g. the North Ben Tre Polder Area Improvement Project. There are still a large number of water gates that need to be constructed to prevent saline intrusion. These gates were identified during the government officers' workshop as priority projects for the provinces. Therefore, the Saline Intrusion Prevention Sluice Gate Construction Project shall be selected as a short-listed priority project, which will undergo a feasibility study during the next stage.

5.4 Tra Vinh Fresh Water Recruitment Project involves two components, namely: 1) the construction of three sluice gates to prevent saline water intrusion, and 2) a canal extension/ enlargement scheme to recruit fresh water from an upstream area that is still free from saline intrusion. The first component corresponds to the above short-listed sub-sector project (sluice gate construction). The fresh water recruitment scheme, one of the two major components, is given top priority in the second most important issue - Drought (or lack of fresh water) in the MP framework. Fresh water recruitment will be required in a number of cases where saline water prevention measures are put in place. Therefore, as a model for freshwater recruitment, the Tra Vinh Fresh Water Recruitment Project has been selected as one the short-listed priority projects.

5.5 The Cropping System Improvement Program in respect of Climate Change Adaptation constitutes one of three programs identified in the framework. The major one is the crop calendar adjustment/improvement program (No.7 in the master framework), which falls in the project group that has been placed as a top priority issue with regards to saline intrusion. Also, this major project is not only fourth on the master plan framework but is also in 23rd and 24th positions on the list. As a result, the Crop System Improvement Program in respect of Climate Change Adaptation is now short-listed as a more comprehensive program. The Capacity Development Project for Flow Water Management in the Mekong Delta (No.8) covers the entire Project area, and is meant to help with the fine-tuning of measures to adapt to and/or cope with the impacts of climate change over the entire Project area. It was therefore selected as one of the non-structural short-listed projects.

# 6. In-DEPTH STUDY

6.1 Based on the selected priority issues, coupled with identified priority projects, an in-depth study was conducted in order to understand typical issues associated with climate change. A total of six studies have been carried out such as; 1) The best-suited polder improvement plan to cope with saline intrusion in North Ben Tre, 2) fresh water recruitment for Tra Vinh paddy areas, 3) water management for the Bac Lieu centre and its coastal area, 4) flow mobilization in the tranquil water areas of the Ca Mau peninsula, 5) the best-suited sea dyke types that can be adapted to the local situation, and, 6) the sustainability of extensive to semi-intensive (family level) shrimp cultures.

6.2 In the study of the best-suited polder improvement plan for north Ben Tre area, it was found that embankments and gates were essential in order to prevent both saline intrusion and flooding. The best place for fresh water intake was also selected at the most upstream polder on the Tan Phu and Ben Ro rivers taking into account the salinity level and intake volume to be required. In March and April, however, water supply from the Tan Phu and Ben Ro could hardly meet the demand in the design year (which was a 15% probability). Where there is insufficient water, volumes should be increased by pumping stored water from canals.

6.3 The study of fresh water recruitment for the Tra Vinh paddy areas from Vinh Long province indicated that fresh water resources in Tra Vinh were very limited. Water recruitment from the upstream area is therefore essential, especially in the dry season and there are two options to increase the amount of water in the Tra Vinh province; 1) to utilize sluices which are to be constructed in Tra Vinh province along the Mekong River, and 2) to recruit fresh water from Vinh Long, an upstream province. Regarding the former choice, some of planned sluices can help to take in fresh water when this is available in the Mekong River. When water level of the Mekong River is higher than the water level in the Tra Vinh canal systems, the gates can function as intake valves. They can keep fresh water in the canals when the water level of Mekong river is lower than the canal water level.

6.4 The study on water management for the Bac Lieu centre and its coastal area has indicated that changing the crop pattern does little to decrease fresh water demand under the complicated land use presently operating. This is because; 1) a decrease of saline content in paddy areas affects water quality (saline content) in neighboring shrimp farming areas. 2) Allowing saline water to flow into shrimp areas requires the substitution of extra fresh water from the main canal. 3) Some civil works are required to stop saline water intrusion into fresh water areas. Conversely, changing the crop pattern in a large area would decrease fresh water demand, provided that hydraulic pumps and mechanisms were controlled by gates and embankments.

6.5 Water circulation is considered as one of interventions to reduce shrimp diseases in the water tranquil areas of the Ca Mau peninsula. The study of the Ca Mau flow mobilization Project (including water management as a non-structural measure) has revealed that the correct operation of gates can increase the flow mobilization (water circulation), thereby contributing to the reduction of shrimp diseases. A rise in sea level would be favorable for shrimp cultivation because there would be more saline water than is presently available. It was found, however, that a rise in sea level risks reducing flow mobilization (water circulation) capacity. In other words, a rise in sea level caused by climate change might, to some extent, off-set the benefits of sluice gate operations.

6.6 Three typical zones were identified in the study on the best-suited sea dyke types for the local situation. Zone 1 is the estuary areas of the Mekong River where sedimentation rather than erosion is the dominant feature. In this zone, a combination of concrete structures and mangrove vegetation are recommended to protect the coastline. Zone 2 is located in erosion-prone areas from areas in Soc Trang to the Ca Mau peninsula where concrete and rock structures are recommended for coastline protection. Zone 3 is located in the West Sea where the sea is calm. In this area, mangrove forest is recommended as coastline protection.

6.7 It was discovered during the study on the sustainability of extensive to semi intensive shrimp cultures that about one third of farmers have suffered great losses in shrimp cultivation in 2011-2012 due to an outbreak of diseases (e.g. AHDNS). Multiple regression analysis has indicated that food supply can be considered to be a key factor where obtaining a good yield is concerned in semi-intensive shrimp farming with correlation “R = 0.86”. This obvious correlation could not be found in extensive shrimp farming; however a similar tendency could be seen in fertilizer use in respect of semi-intensive farming. The food cycle starts with fertilizer, followed by phytoplankton, followed by zooplankton, and then shrimp.

# 7. CONCLUSION AND RECOMMENDATIONS

7.1 This Master Plan concludes that the implementation of the recommendations contained herein would be the most appropriate and comprehensive approach to cope with and adapt to the climate change taking place in the Mekong Delta, especially in respect of agricultural and rural development for the seven coastal provinces. The Government should, therefore, embark on the development of the coastal provinces in question, guided by this Master Plan.

1) The Development Plan has incorporated the voices of the concerned stakeholders such as provincial DARD officers, provincial peoples’ committee members, community members, leaders and local authorities, etc. The stakeholders have analyzed not only each area’s situation, but also through the process of planning, obtained consensus with regard to issues such as identifying, prioritizing and confronting difficulties, identifying climate change-related issues, and the prioritization thereof, etc. Situational analysis was also carried out, mainly from quantitative point of view where data were available. The results of these analyses were used to explain the various issues to stakeholders to ensure that they understood where the Project Area stood and how it compared with other parts of Mekong Delta, and other regions of Vietnam. Using this participatory approach has contributed to making the Development Plan comprehensive and responsive to the needs of stakeholders.

2) The development framework presented in this Report can be used as a guide for the central and provincial offices when they try to carry out development activities in the coastal provinces of Mekong Delta. This framework provides concrete developmental components, prioritizes climate change issues by area (province) and suggests which what projects should be carried out and with what level of priority. In addition, any organization which works in the coastal areas of the Mekong Delta can refer to the framework in order to understand where to make their development intervention and with what priority. In this way, the frameworks can also work as a development platform based on which all the concerned development partners can make a

concerted effort to address areas of concern. The framework explains to the developmental stakeholders, who are the people most in need in the Project area and will help to avoid a misallocation of funds. This information will help to accelerate the development process as a whole.

7.2 During the process of drawing up this Master Plan establishment project, the JICA Team encountered a number of issues that have led to the recommendations presented below. However, as is the case with continuous processes, these recommendations are by no means exhaustive and may need to be changed or modified, depending upon prevailing conditions. Nevertheless, it is believed that the issues covered here will have to be pursued:

1) The central MARD together with SIWRP should introduce the Master Plan to other provinces/regions in Vietnam, especially to other coastal provinces/regions facing the threat of climate change. This is because the JICA team thinks that other provinces/regions would also benefit from by introducing a new approach regarding how to adapt to and/or cope with the impact of climate change. In fact, one of Vietnam's characteristics is its 3, 400km coastline, implying that many other provinces will be affected by climate change e.g. a rise in sea level. As this Master Plan provides concrete responses to the impacts emanating from climate change its recommendations should be introduced to other provinces/regions so that they can improve their development plans/activities.

2) There should be a coordinating committee tasked with the job of implementing the Master Plan. The coordinating committee should be composed of representatives from all the seven coastal provinces together with SIWRP. In fact, project proposals in Vietnam are usually prepared at provincial DARD individually, and submitted to the central government through the provincial people's committee. From the view point of balanced development and fund allocation among the concerned provinces, coordination should start at the project proposal preparation stage. One example is the saline intrusion sluice gates construction project, which is given the highest priority in the Master Plan framework. There are number of sluice gate construction plans within the seven coastal provinces, but without the proper coordination these construction projects may not be implemented as a priority. To avoid this, an inter-province coordinating committee should be established to ensure the Master Plan is put into practice within all the provinces.

3) Although the Master Plan provides concrete development projects and programs and implementation timeframes, implementation should always be flexible. The Master Plan was prepared taking into consideration the future impacts of climate change, which are still uncertain in some respects. In fact, even within the climate change scenarios, there are primarily 4 scenarios presented in the IPCC Fourth Assessment Report (2007). It is hard to forecast which scenario is the most accurate, since there are many unpredictable factors such as population growth, economic growth, government structure, social values, and patterns of technological change, etc. Consequently, there remains some uncertainty when forecasting the effects of climate change. For this reason the Master Plan should be reviewed every year and modified accordingly.

4) In conjunction with issue No. 3) above, the future discharge of the Mekong River is also uncertain. There are completed and on-going hydroelectric power schemes built or being built in the upper catchment area and also number of other development plans include hydropower dam construction. (In China, for example, four large scale dams have been constructed and at 10 more are in the planning stage, as of 2011). These developments in the upper catchment area will greatly influence the flow pattern of the lower Mekong River. The dams store flood water

during the rainy season and release it during the dry season, increasing the flow of the Mekong River. This increased flow will push back sea water intrusion and saline damage may not occur as forecast. Given this background, this Master Plan should be reviewed to take into account to not only the effects of climate change but also changes to the Mekong River discharge regime.

5) NO Regret Investment is therefore always recommended in developments related to climate change. As previously mentioned, the future status of the Mekong River flow involves some uncertainty. The sea level will rise and this can be predicted with some accuracy and this will cause saline intrusion into the Mekong River. However, saline intrusion is also dependent on the flow regime of the river. Therefore, should development in the upper reaches of the river lead to an augmentation of the dry season flow, then saline intrusion may not as severe as predicted. Given this uncertain future, investing in tidal prevention barrages at the estuaries of the Mekong River, may be a waste of money. Taking this point into account, it is not recommended that large scale development occurs at only in one place as this might result in ‘regret’ investment. This Master Plan, therefore, does not include such large scale investment, but is composed of a number of small and medium scale projects, including non-structural measures. The structure of the Plan itself therefore is flexible and can be modified/changed.

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**COMPOSITION OF THE REPORT**

**<u>MAIN REPORT MP (English Version, Vietnamese Version, Japanese Version)</u>**

**MAIN REPORT PP (English Version, Vietnamese Version, Japanese Version)**

**APPENDIXES (English Version)**

**ACRONYMS AND ABBREVIATIONS**

| | |
|---|---|
| ADB | Asian Development Bank |
| AHDNS | Acute Hepatopancreatic Degenerative Necrotic Syndrome |
| AMSL | Above Mean Sea Level |
| AusAID | Australian Agency for International Development |
| B/C | Benefit Cost Ratio |
| CP | Counterpart |
| DARD | (Provincial) Department of Agriculture and Rural Development |
| DONRE | Department of Natural Resources and Environment |
| DPC | District People's Committee |
| EU | European Union |
| ERR | Economic Rate of Return |
| FAO | Food and Agriculture Organization |
| FY | Fiscal Year |
| GDP | Gross Domestic Products |
| GOJ | Government of Japan |
| GOV | Government of Vietnam |
| GCM | Global Climate Model (or General Circulation Model) |
| GSO | General Statistical Office |
| HDI | Human Development Index |
| IAS | Institute of Agricultural Science for Southern Vietnam |
| ICB | International Competitive Bidding |
| IDA | International Development Association |
| IDMC | Irrigation and Drainage Management Company |
| IMC | Irrigation (and Drainage) Management Company, under DARD |
| IMF | International Monetary Fund |
| IMHEN | Institute of Metrology, Hydrology and Environment |
| IPCC | Intergovernmental Panel on Climate Change |
| IPM | Integrated Pest Management |
| IRR | Internal Rate of Return |
| IWMI | International Water Management Institute |
| JICA | Japan International Cooperation Agency |
| KfW | Kreditanstalt für Wiederaufbau (German government-owned development bank) |
| MARD | Ministry of Agriculture and Rural Development |
| MBV | Monodon Bacuro Virus |
| MDG | Millennium Development Goal |
| M&E | Monitoring and Evaluation |
| MKD | Mekong Delta |
| MOF | Ministry of Finance |
| MONRE | Ministry of Natural Resources and Environment |
| MPI | Ministry of Planning and Investment |
| MRC | Mekong River Commission |
| NACA | Network of Aquaculture Centres in Asia-Pacific |
| NCB | National Competitive Bidding |
| NPK | Nitrogen, Phosphate, Potassium |

| | |
|---|---|
| NPV | Net Present Value |
| O&M | Operation and Maintenance |
| PCR | Polymerase Chain Reaction |
| PRA | Participatory Rural Appraisal |
| PRECIS | Providing Regional Climates for Impacts Studies (a regional climate model system) |
| PCM | Project Cycle Management |
| PPC | Provincial People's Committee |
| RCM | Regional Climate Model |
| RIA No.2 | Research Institute for Aquaculture, No.2 (located in Ho Chi Minh City) |
| SIWRP | Southern Institute of Water Resources Planning (the CP organization) |
| SIWRR | Southern Institute of Water Resources Research |
| SWOT | Strengths, Weaknesses, Opportunities, and Threats |
| Sub-NIAPP | Sub-national Institute of Agricultural Planning and Projection |
| GIZ | (Deutsche) Gesellschaft für Internationale Zusammenarbeit |

**UNIT CONVERSION**

| | | |
|---|---|---|
| 1 meter (m) | = | 3.28 feet |
| 1 kilometer (km) | = | 0.62 miles |
| 1 hectare (ha) | = | 2.47 acres |
| 1 acre | = | 0.405 ha |
| 1 inch (in.) | = | 2.54 cm |
| 1 foot (ft.) | = | 12 inches (30.48 cm) |
| 1 ac-ft | | 1233.4 cum |

**CURRENCY EQUIVALENTS (AS AT DECEMBER 2012)**

| | | |
|---|---|---|
| US$ 1.00 | = | VND 21,053 (TTB) |
| US$ 1.00 | = | 82.11 Japanese Yen (TTB) |
| VND 1.00 | = | 0.0039 Yen |

**VIETNAM FISCAL YEAR**

January 1 to December 31

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# MAIN
# REPORT

# CHAPTER 1 RATIONALE AND GOAL OF THE PROJECT

Submitted herewith is the Final Report compiled according to the Scope of Works (SW) and the attached Minutes of Meetings (MM) on the "Project for Climate Change Adaptation for Sustainable Agriculture and Rural Development in the Coastal Mekong Delta in Vietnam (the Project)" signed between the Southern Institute for Water Resources Planning (SIWRP), the Government of Socialist Republic of Vietnam, and the Japan International Cooperation Agency (JICA) on April 28, 2011.

This final report covers all the issues that the JICA Team has undertaken since the inception of the Project up till the completion. The issues incorporated in the report among others are results of situation analysis of the Project area, prediction of climate change for Mekong Delta, vulnerability assessment for the Project area on the climate change, development framework with long list of potential projects/programs and master plan, result of in-depth study, priority project identification, feasibility examination of the priority projects, and conclusion and recommendations, etc.

## 1.1 Rationale of the Project: Role of the Delta and the Challenges

Vietnam, which is the second largest rice exporter country, is now aiming at becoming an industrial country by 2020. An industrial area located in the southern part of the country, where Ho Chi Minh City lies as its center, is now like a locomotive leading the economic growth. The Mekong Delta is therefore expected to undertake a role of providing enough stable food to the industrial urban areas as well as being a source of providing good labor forces. The Government is, to this end, making every effort to achieve a balanced economic development in order not to widening the wealth gap between rural population and urban population.

There is a global issue, i.e., climate change, which in most cases entails global warming. Global warning raises sea water level as is well known. Therefore, the Mekong Delta where the altitude is just over the sea level is believed to be greatly affected. Not just waiting for the consequences, the Government has embarked on a programme to cope with the climate change. The program is called National Target Program to Respond to Climate Change (NTP-RCC) with a target year of 2020.

Climate change adaptation is now on the table in each and every sector, including the agriculture and rural development sector. An Action Plan Framework was already established covering the agricultural and rural development sector (2008-2020), and thus the Government urges the concerned authorities of agriculture and rural development sector to formulate a tangible development plan which can cope up, or otherwise to live alongside, with the climate change. With this background, the Project for Climate Change Adaptation for Sustainable Agriculture and Rural Development in the Coastal Mekong Delta was commenced at the beginning of August, 2011.

## 1.2 Objectives of the Project

The objective of the Project is, as stated in the SW, to present 'Climate Change Adaptation Solutions' for sustainable agriculture and rural development in the coastal areas in the Mekong Delta. Towards this end, this Project is carried out in partnership with the SIWRP, the Ministry of Agriculture and Rural Development (MARD), and incorporates the views of concerned stakeholders such as relevant departments under MARD, regional and field offices of MARD, and local communities. The process of the Project centers on the following which themselves are the outputs of the Project:

1) Climate change impact prediction (mid to long term, e.g. 2020-2050) and assessment are conducted,
2) Climate change adaptation Master Plan is formulated, based on which priority project plans area recommended, and
3) Through the Project activities, SIWRP's capacity for climate change adaptation planning and

implementation for the sector of agriculture and rural development is strengthened.

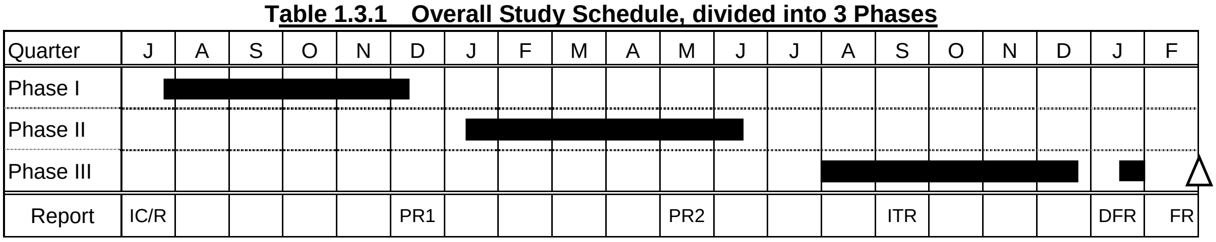
The Government of Vietnam has so far conducted series of simulations on the climate change. The Government has also formulated and implemented plan(s) in the sector of agriculture and rural development. However, both activities have been conducted more or less independently. What is urged is therefore to establish a development plan which is oriented to climate change adaptation in the sector of agriculture and rural development.

This Project shall, therefore, fully utilize existing achievements, e.g. simulation results, existing plans in the implementation pipeline and/or under implementation, lessons from the past and on-going projects. The achievements so far made replenish the process of formulating the development plan oriented to climate change adaptation. On top of that, working together with the counterpart personnel as well as engaging Vietnamese experienced resources facilitate the smooth and effective implementation of the relevant activities.

## 1.3 Scope and Schedule of the Project

To attain the objectives, this Project is carried out in a phasing manner divided into three: Phase 1 deals mainly with situation analysis of the project area and vulnerability assessment on climate change; Phase 2 continues the vulnerability assessment, and undertakes the implementation of in-depth study, draft master plan formulation and the identification of priority projects, and Phase 3 undertakes a feasibility level study for the priority projects and presents the final version of the Master Plan upon getting feedbacks from all the relevant stakeholders. Following are the overall schedule of the Project and the scopes agreed upon in the SW:

**Table 1.3.1 Overall Study Schedule, divided into 3 Phases**




Where; IC/R: Inception Report, PR: Progress Report, ITR: Interim Report, DFR: Draft Final Report, FR: Final Report

1) To prepare climate change adaptation master plan by upgrading and supplementing existing master plans and by integrating the effects of climate change by carrying out following activities:
   - 1.1) Review and evaluation of existing project/action plans,
   - 1.2) Consolidation of information, including agriculture, hydro-meteorology, oceanography and socio-economic data,
   - 1.3) Review of mid to long-term (2020-2050) impact predictions of climate change by utilizing existing climate change and hydrological modeling,
   - 1.4) Assessment of vulnerability in the field of agriculture and rural development caused by salinity intrusion, lack of fresh water, inundation, acid water and coastal erosion,
   - 1.5) Proposal and evaluation of climate change adaptation based on: 1) suggestions for climate change adaptation options based on the result of climate change and hydrodynamic models, 2) evaluation of climate change adaptation by hydrodynamic models, 3) suggestions of structural measures and non-structural measures, and
   - 1.6) Implementation of in-depth study, through which climate change options will be examined and verified more in depth. The purpose of the in-depth study is to suggest methods for concrete planning and design for the climate change adaptation master plan. Planning for water resource management at the grass-roots level in various cropping areas to take measures against flood, drought, acid water and salinity intrusion, will also be conducted.

2) To prepare priority project plans based on the master plan proposed, for which principal issues such as the objectives, size of the projects, outcomes and operational structures will be considered.

### 1.4 Counterpart Organization

The responsible organization of this Project is the Ministry of Agriculture and Rural Development (MARD), while the implementing counterpart organization is the Southern Institute for Water Resources Planning (SIWRP). SIWRP has been engaged in carrying out surveys, simulation and analysis, environmental assessment, and establishing plans in the sector of water resources development in the Mekong Delta area. There are about 100 staff working in different 10 departments, one of which runs climate change simulations, called Center for Climate Change and Adaptation.

### 1.5 The Project Area

Mekong Delta covers Can Tho city and 12 Provinces. The provinces targeted by this Project are 7 provinces among these 12 provinces; Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau and Kien Giang. The total Project area is 24,631km$^2$, about 61% of the total area of Mekong Delta (40,519 km$^2$) [1]. The population of the 7 provinces is estimated at about 9 million, which shares about 52% the total population of 17.3 million of the Mekong Delta (2010) and population density comes to 366 persons/km$^2$, a relatively high density as compared to the national average of 263 persons per km$^2$.

**Table 1.5.1 Area and Population of the Project Area**

| Province/ Region | Area, km$^2$ | Population (2010) | Pop. Density Persons/km$^2$ |
|---|---|---|---|
| Tien Giang | 2,484 | 1,677,000 | 675 |
| Ben Tre | 2,360 | 1,256,700 | 532 |
| Tra Vinh | 2,295 | 1,005,900 | 438 |
| Soc Trang | 3,312 | 1,300,800 | 393 |
| Bac Lieu | 2,502 | 867,800 | 347 |
| Ca Mau | 5,332 | 1,212,100 | 227 |
| Kien Giang | 6,346 | 1,703,500 | 268 |
| Total Project Area | 24,631 | 9,023,800 | 366 |
| Total Mekong Delta | 40,519 | 17,272,200 | 426 |
| Whole Country | 331,051 | 86,927,700 | 263 |

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office)

### 1.6 Relevant National Program on the Climate Change

There is an over-arching program established in Vietnam to adapt to and/or cope with the climate change; National Target Program to Respond to Climate Change (NTP-RCC). It has the target year of 2020. Under the NTP-RCC, there are relevant development sector action plan frameworks, also established in the rural and agriculture sector in Vietnam. It is called Action Plan Framework of Rural and Agriculture Sector (2008-2020).

#### 1.6.1 National Target Program to Respond to Climate Change (NTP-RCC)

NTP-RCC was approved by the prime minister on December 2, 2008, and the strategic objectives are to assess climate change impacts on sectors and regions in specific periods and to develop feasible action plans to effectively respond to climate change in the short-term and long-term period to ensure sustainable development of Vietnam. The standing agency is the Ministry of Natural Resources and Environment, which is in charge of collaboration with relevant agencies and institutions.

The NTP-RCC maintains that tasks to respond to climate change must be integrated into development strategies, programs, plans, planning in all the sectors and at all levels; into legal documents and policy institutions; into development of legal documents and their implementation. The NTP-RCC is planned to implement over the country in three phases such as; first phase (2009-2010) as starting-up stage, 2) second phase (2011-2015) as implementation stage, and 3) third stage (after 2015) as

[1] Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam)

development stage.

To achieve the objectives, there are 9 concrete tasks e.g. assessment of climate change extent and impacts, identification of measures to respond to climate change, awareness raising and human resources development, enhancement of international cooperation, etc. Of them, Task-8 urges relevant authorities to develop their own Action Plan of the ministries, sectors, and localities to respond to the climate change. Given the Task-8, MARD has also formulated the Action Plan covering rural and agriculture sector in responding to the climate change.

### 1.6.2 Action Plan Framework of Rural and Agriculture Sector (2008-2020)

Responding to the Task-8 in the Target Program to Respond to Climate Change (NTP-RCC), MARD has formulated the Action Plan Framework for Adaptation and Mitigation of Climate Change of the Agriculture and Rural Development Sector Period 2008 – 2020. The general objective is to enhance capability of mitigation and adaptation to climate change to minimize its adverse impacts and to ensure sustainable development of the agriculture and rural development sector.

Pursuing the general objective, there are 7 specific objectives; 1) develop a policy integrating climate change in sectoral development programs, 2) develop an action plan and propose support policies for the climate change affected regions, 3) strengthen capacity of research and forecast of climate change, 4) strengthen international cooperation, 5) develop human resources, 6) enhance awareness of relevant stakeholders, and 7) ensure equal benefit sharing for rural communities in implementing climate change mitigation and adaptation.

Since it is an action plan, there is a list of concrete activities to respond to the climate change. Activities are summarized in 5 areas as; 1) conduct the communication and information program to disseminate knowledge and experiences to enhance people’s awareness on climate change impacts, 2) develop human resources and conduct studies to develop and consolidate scientific foundation for providing solutions for climate change mitigation and adaptation, 3) develop policies integrating climate change in sectoral development program, 4) promote international cooperation in mitigation and adaptation, and 5) carry out priority activities for implementing mitigation and adaptation.

In connection with above 5) ‘carry out priority activities for implementing mitigation and adaptation’, there are some concrete project plans such as; 1) strengthening of standing office’s capacity (office of climate change adaptation chaired by the department of personnel), 2) formulation of national standard and technical criteria, 3) conduct of research and planning programs for climate change adaptation and mitigation, 4) tree planting program for wave protection of sea dyke system, 5) upgrading of water resource system, dyke protection system, storm and flood control system, 6) rural infrastructure consolidation program, and 7) establishment of disaster management support organizations. Most of them are now under implementation either by the government or in collaboration with concerned donors.

# CHAPTER 2 THE PROJECT AREA

This Chapter 2 presents status of the Project area from different point of views. At first, the spatial setting of the project area is described together with demography, and followed by meteorology and hydrology, major rural infrastructure such as rural roads, irrigation and drainage network, and rural water supply, and then the people's major livelihood i.e. agriculture inclusive of fruit production, and aquaculture. In addition, projects planned or being carried out by the Government and donors are briefly presented.

## 2.1 Spatial Settings, Demography, Economy and Positioning

### 2.1.1 Spatial Settings

The Project area, 7 coastal provinces, is located along the coastal line of the Mekong Delta as is called. The delta falls in the most southern part of Vietnam, bordering on Cambodia at its upstream, or north-western, side. The Delta area lies immediately to the south-west of Ho Chi Minh City, roughly forming a triangle stretching from My Tho in the east to Chau Doc and Ha Tien in the northwest, down to Ca Mau and the East Sea at the southernmost tip of Vietnam, and including the island of Phu Quoc about 70 km westwards away from the northern tip of Kien Giang province. The land stretches from 08 degree 20 minutes to 11 degree 00 minutes (237 km) in north latitude and from 103 degree 50 minutes to 106 degree 45 minutes (290 km[1]) in its east longitude.

The Mekong Delta is a flood plain and thus presents generally very flat topography. It is classified as flat area with the majority having an average elevation only from 0.7 to 1.2 m except for some hills in the north-western delta province of An Giang. Along the border with Cambodia, the terrain varies from 2.0 to 4.0 m, and then gradually lowers into the central plains with an elevation from 1.0 to 1.5 m, and then only 0.3 to 0.7 m in the coastal areas. Given this very low altitude especially near the coastal area, sea water tends to intrude during low water season, say, from January to May.

### 2.1.2 Area, Population and Population Density

The Project area covers 7 coastal provinces among the total 12 provinces of the Mekong Delta. Table 2.1.1 summarizes the area and demography by province in the Mekong Delta and also by regions in Vietnam. Figure 2.1.1 shows the area and population by province in the Mekong Delta, while Figure 2.1.2 depicts population density and Figure 2.1.3 compares the population density with other regions in Vietnam.

As indicated, provincial population in the Project area varies from 867,800 being the minimum in Bac Lieu to about 1.7 million being the maximum in Kien Giang while the area from 2,295 $km^2$ to as much as 6,346 $km^2$. Total population of the Project area arrives at 9.02 million, sharing about 52% of the whole Mekong Delta population, while the total area comes to 24,631$km^2$ equivalent to about 61% of the total Mekong Delta area. Dividing the population by area gives population density, which is 366 persons/$km^2$. This population density is relatively high, for example, as compared with the national average of 263 persons per $km^2$. High population density implies high carrying capacity of the land endorsed with high productivity.

As for the population growth ratio, it is not high ranging from only 0.05% in Ben Tre province to 1.28 % in Bac Lieu province with an average of 0.51% for the whole Project area. The population growth ratio of whole Mekong Delta arrives at 0.42% close to that of the Project area. On the other hand, most of the population growth ratios of other regions surpass that of Mekong Delta. Only those of North Central and Central Coastal area are the exception. Nationwide population growth ratio

[1] Excluding Phu Quoc island, the mainland delta extends over an distance of about 230km from west-east direction.

comes to a higher one, i.e. 1.05%. As compared to other areas, population growth ratio of the Mekong Delta is obviously low.

The relatively low population growth ratios of the Project area as well as for the Mekong Delta may be attributed to high out-migration trend of the people. As indicated in the most right column of Table 2.1.1, net-migration for the Project area is as high as -10.1 % and that of Mekong Delta is -8.4%. It may be suggested that the population in the Mekong Delta are moving out to urban and industrial areas, e.g. Ho Chi Minh city as well as to an industrial area of Binh Duong province located north from Ho Chi Minh city.

**Table 2.1.1 Land and Demography of the Project Area as compared with Other Areas**

| Province/ Region | Rural Districts | Population (2010) | Area, km2 | Pop. Density, P/km2 | Pop. Growth Rate, % | Net-migration |
|---|---|---|---|---|---|---|
| Tien Giang | 8 | 1,677,000 | 2,484 | 675 | 0.25 | -0.2 |
| Ben Tre | 8 | 1,256,700 | 2,360 | 532 | 0.05 | -12.9 |
| Tra Vinh | 7 | 1,005,900 | 2,295 | 438 | 0.27 | -4.1 |
| Soc Trang | 10 | 1,300,800 | 3,312 | 393 | 0.59 | -10.0 |
| Bac Lieu | 6 | 867,800 | 2,502 | 347 | 1.28 | -10.6 |
| Ca Mau | 8 | 1,212,100 | 5,332 | 227 | 0.41 | -27.3 |
| Kien Giang | 13 | 1,703,500 | 6,346 | 268 | 0.89 | -8.7 |
| Total/Average: the Project Area | 60 | 9,023,800 | 24,631 | 366 | 0.51 | -10.1 |
| An Giang | 8 | 2,149,500 | 3,537 | 608 | 0.09 | -8.3 |
| Can Tho | 4 | 1,197,100 | 1,402 | 854 | 0.71 | -1.7 |
| Hau Giang | 5 | 758,600 | 1,601 | 474 | 0.09 | -6.9 |
| Vinh Long | 7 | 1,026,500 | 1,479 | 694 | 0.14 | -13.4 |
| Dong Thap | 9 | 1,670,500 | 3,375 | 495 | 0.23 | -6.7 |
| Long An | 13 | 1,446,200 | 4,494 | 322 | 0.69 | -3.5 |
| Total/Average: Mekong Delta | 106 | 17,272,200 | 40,519 | 426 | 0.42 | -8.4 |
| Red River Delta | 95 | 19,770,000 | 21,063 | 939 | 0.77 | 0.5 |
| N. Midlands & Mountain | 119 | 11,169,300 | 95,339 | 117 | 0.87 | -3.9 |
| N. Central & Central Coastal | 140 | 18,935,500 | 95,885 | 197 | 0.42 | -5.7 |
| Central Highlands | 52 | 5,214,200 | 54,641 | 95 | 1.66 | -0.3 |
| South East (including HCM) | 41 | 17,272,200 | 40,519 | 426 | 2.95 | 19.9 |
| Whole Country | 553 | 86,927,700 | 331,051 | 263 | 1.05 | - |

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam)

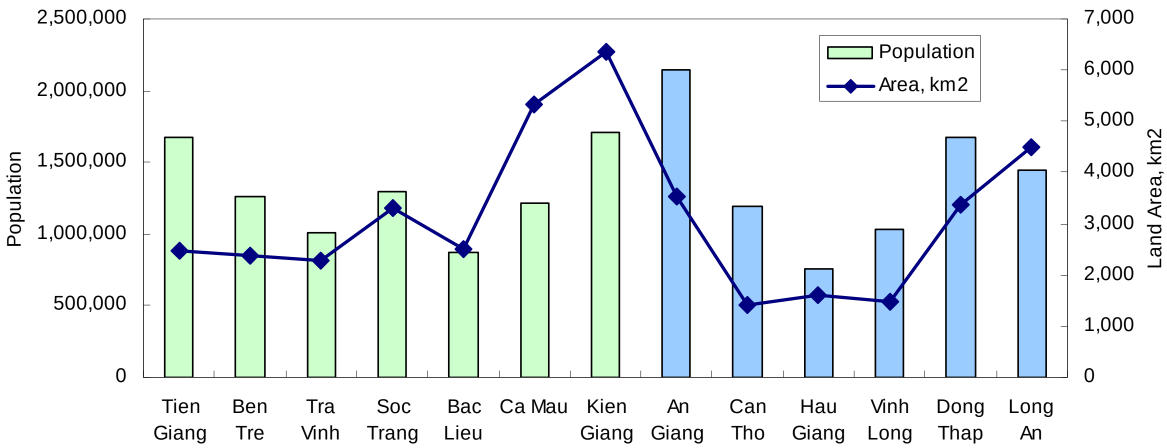



**Figure 2.1.1 Population and Land Area by Province in the Mekong Delta**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam)

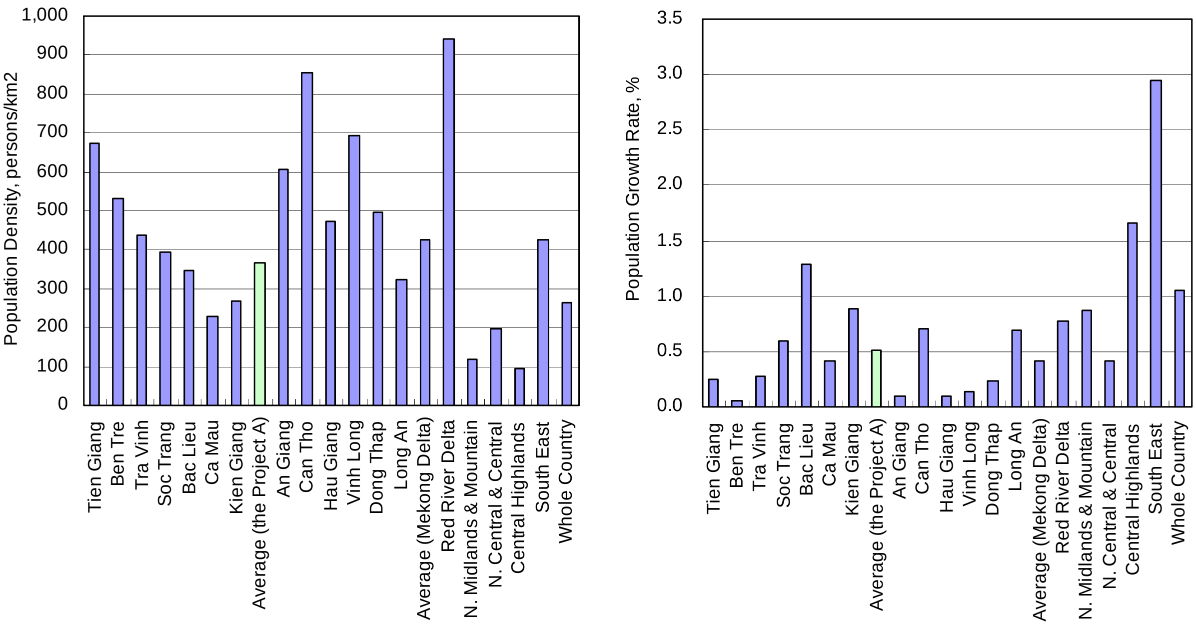



**Figure 2.1.2 Population Density (Left) and Population Growth Ratio (Right) by Province in the Mekong Delta and by Region in Vietnam**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam)

### 2.1.3 Economy and Gross Production

Mekong Delta's economy is agriculture-dominated. Figure 2.1.3 shows the share of GDP in 2009 by sector for the Project area as compared with whole Mekong Delta and also with whole country. As is shown, the Project area's overall economic structure is; 48% by primary sector, 23% by secondary sector, and 29% by tertiary sector. The share of the primary sector, represented mainly by agriculture and aquaculture, in the Project area is higher than that of Mekong Delta, 41%, and by far higher than that of whole country, which is only 21%.

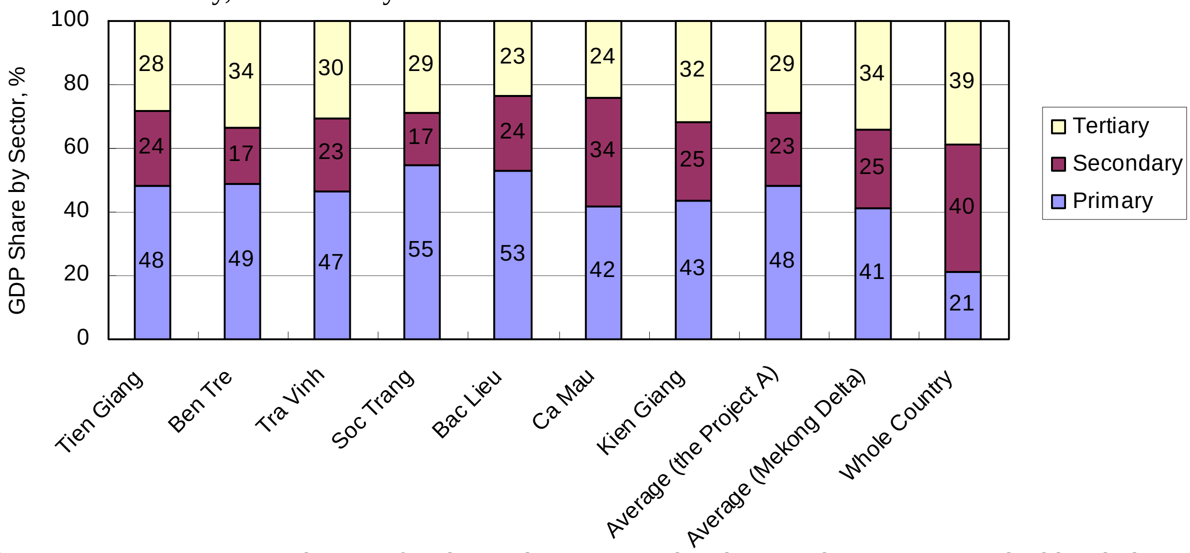



**Figure 2.1.3 GDP Structure in 2009 for the Project Area and Mekong Delta as Compared with Whole Country (Data 2009)**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam), Provincial Statistical Offices

Figure 2.1.4 shows the trend of GDP growth ratios for the Project area as compared with whole Mekong Delta and whole country estimated at constant 1994 prices. At a glance, the Project area and whole Mekong Delta have been achieving higher growth ratios than whole country in 2000s. The growth ratio of the whole country has been about 5 – 8 % per annum while those of the Project area and Mekong Delta have been much higher, e.g. over 10% in most of the provinces. The province showing the lowest growth ratio in the Project area is Ben Tre; nevertheless the growth ratio has been more than 6% for the last 10 years.

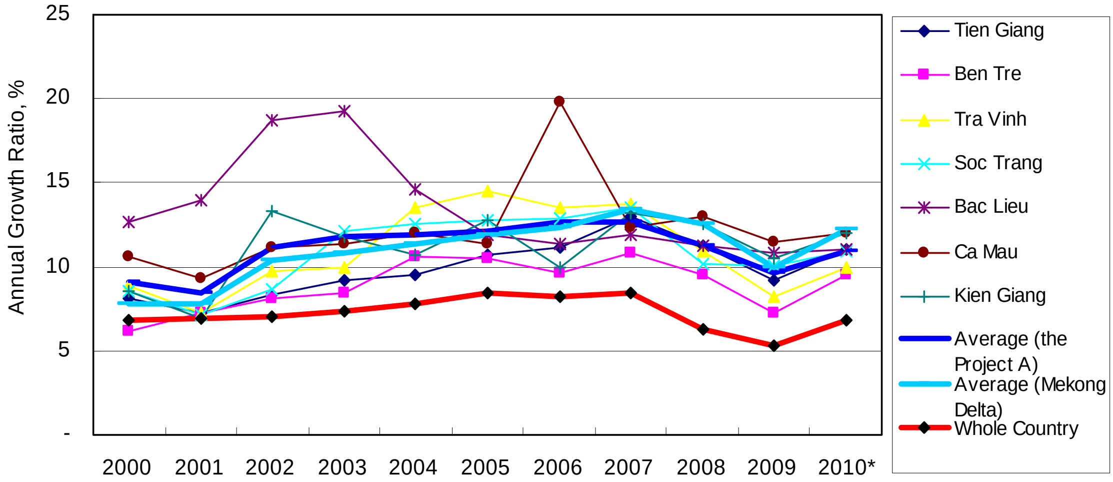



**Figure 2.1.4 Trend of GDP Growth Ratio by Project Area and Mekong Delta as Compared with Whole Country (Data 2009)**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam), Provincial Statistical Offices

Figure 2.1.5 summarizes GDP per capita at year 2009 by Mekong Delta's province with national average. Kien Giang province shows the highest GDP capita within the Project area, US$ 1,286, which is higher than the national level of US$ 1,127. On the other hand, Tra Vinh province shows the lowest GDP per capita within the Project area, which is US$ 801. The average GDP per capita for the Project area comes to US$ 987 while that of Mekong Delta dose US$ 1,040. Both of them are in fact lower than that of national average. It implies that though we can see robust agriculture and aquaculture production in the Project area as well as Mekong Delta, there are fewer secondary and tertiary industries except for Can Tho area whereby fewer value added economic activities, leading to lower GDP per capita as compared to the national level.

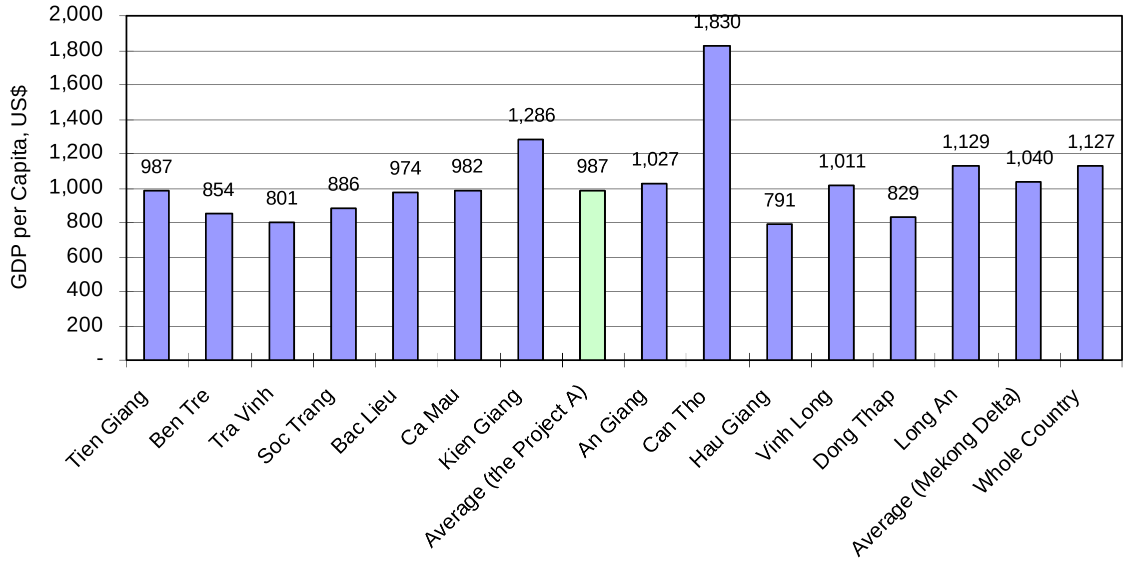



**Figure 2.1.5 GDP Per Capita in 2010 for the Project Area and Mekong Delta as Compared with Whole Country (Estimated at constant 1994 Prices with Exchange Rate of 11,045 VND/US$)**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam), Provincial Statistical Offices

### 2.1.4 Positioning of the Project Area and Mekong Delta in the National Context

Mekong Delta is well known as the Rice Bowl of Vietnam, producing more than half of the total paddy production of the Country. Not only paddy but also other products are very much generated in this delta. Figure 2.1.6 summarizes the positioning of the Project area as well as Mekong Delta by showing such shares to the national level as; land, population, agricultural output, paddy production, livestock possessing, wood production and aquaculture production. It shows that the Project area and Mekong Delta show large shares in terms of agriculture and aquaculture productions to the national level.

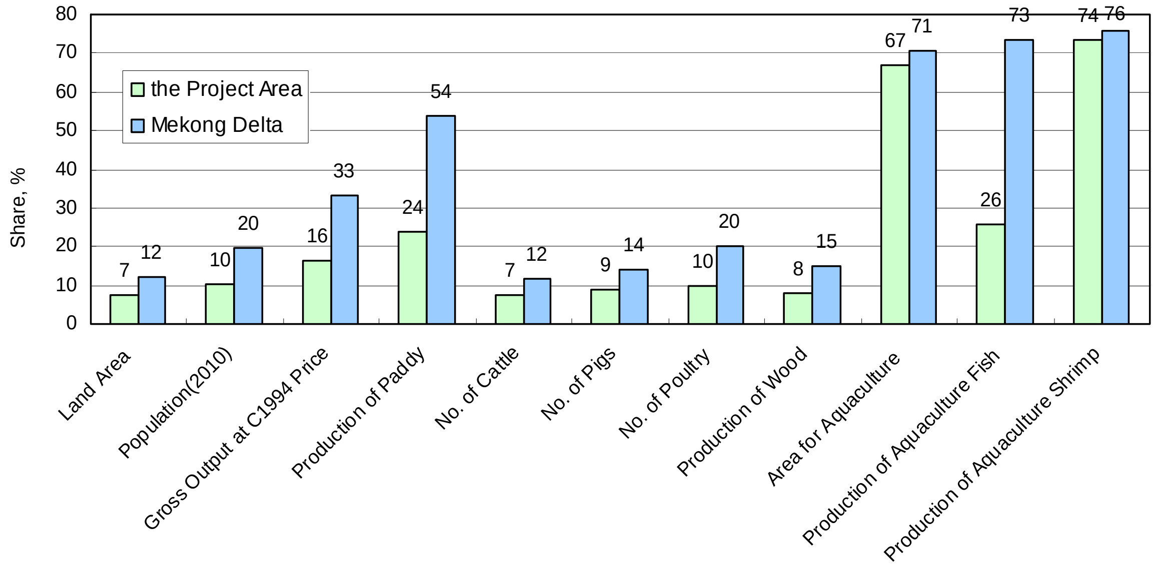



**Figure 2.1.6 Shares of the Project Area and Mekong Delta to the National Level Production for Agriculture, Livestock, Wood and Aquaculture**

Source: Statistical Year Book of Vietnam 2010 (General Statistics Office of Vietnam)

From the above figure, it is known that the land of the Project area shares 7% of the whole national land while that of Mekong Delta occupies 12% of the national. Gross output for agricultural sector shares 16% and 33% for the Project area and Mekong Delta respectively, showing larger production shares than the shares of land and population. Paddy production shows much higher share in the national production, e.g. 24% and as much as 54% by the Project area and Mekong Delta respectively. Mekong Delta is well known as Rice Bowl of Vietnam, which is well illustrated in the production share.

No noticeable shares can be seen in the livestock number and wood production as one may say that the shares are just comparable to that of land area and that of population. On the other hand, we can see very high shares in the aquaculture sector of the Project area and Mekong Delta. In fact, area of aquaculture shares 67% and 71% for the Project area and Mekong Delta respectively to the national aquaculture area. The share of aquaculture shrimp in the Mekong Delta, and also in the Project area, reaches as high as over 70%. Though the Project area and the Mekong Delta are well known as highly agricultural production area, they furthermore indicate much higher shares in aquaculture sector.

## 2.2 Meteorology and Hydrology

### 2.2.1 Temperature

Air temperature in Mekong Delta shows relatively high value as compared to other parts of Vietnam and its annual average over Mekong Delta is about 27$^{o}$C (see Figure 2.2.1); annual accumulation of daily average air temperature is stable over years and it counts at about 9,800$^{o}$C. Generally, it means that annual air temperature in the eastern area is a little lower than that of the coastal and southwest areas (except Vung Tau) by about 0.4 $^{o}$C or more. The highest mean annual air temperature within the Mekong Delta shows up in Rach Gia with 27.6$^{o}$C while the lowest is 26.7$^{o}$C in Ca Mau (refer to the Figure 2.2.1).

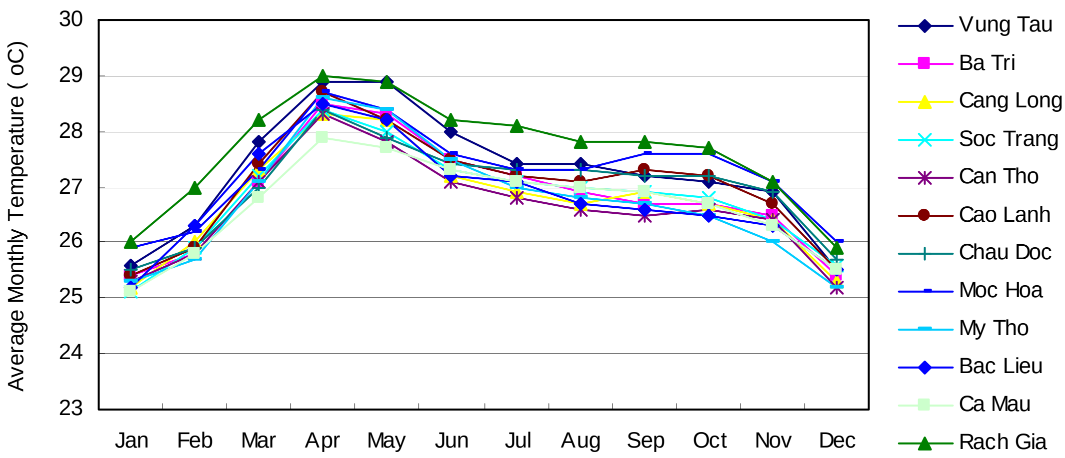



**Figure 2.2.1 Average Monthly Air Temperature at Major Locations in Mekong Delta**

Source: Southern Institute for Water Resources

Note; Record periods are different by station; mostly 1978 – 2010

The highest monthly average air temperature ranges between 28°C and 29°C; and April, just prior to the onset of rainy season, is the hottest month and December and January show the coldest air temperature in a year. It is only about 3.0°C difference between the highest and the lowest average monthly air temperature at the same place (refer to Figure 2.2.1). The maximum monthly air temperature sometimes rises to 31°C - 38°C, and then, the minimum average monthly air temperature descends to as low as 22°C - 26°C. Average daily air temperature usually fluctuates in a range between 6°C and 10°C by station.

### 2.2.2 Rainfall

In the Mekong Delta, rainfall stations are distributed quite evenly through the region. Meteorological data are available mostly after 1978, 3 years after the end of the war when the IMHEN started systematic data collection. Two seasons can be distinguished in a year; rainy season is from May to November and dry season is from December to April. A mean annual rainfall varies from 1,300 to as much as 2,300 mm dependent on the place.

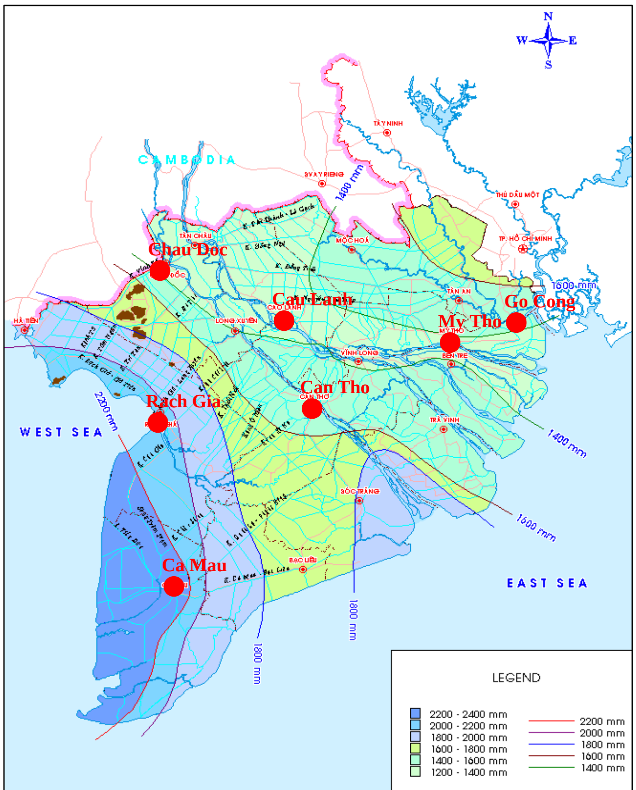



**Figure 2.2.2 Annual Average Rainfall Counters**

Source: SIWRP

The maximum annual rainfall is recorded at Phu Quoc Island, located about 80km westward from the northern tip of Kien Giang province, with 3,067 mm while that of mainland shows lower values, for example, 2,366 mm in Ca Mau. Northeast and internal areas have less annual rainfall; it is around 1,350 mm (such as 1,349 mm at My Tho, 1,360 mm at Chau Doc, 1,356 mm at Cao Lanh and 1,544 mm at Can Tho) as shown in the Figure 2.2.2.

A rainfall data probability analysis shows that a total amount of the annual rainfall in the Mekong Delta with 75% probability ranges between 1,200 and 1,400 mm or sometimes more. The highest rainfall at 75% probability shows up along western peripheral of Ca Mau - Rach Gia area with over 1,800 – 2,000 mm; while the lowest one is observed at Go Cong in Tien Giang province with only 900 – 1,000 mm.

Figure 2.2.3 shows the mean monthly rainfall for the major 18 stations in the Mekong Delta. As is shown, the mean monthly rainfall starts rising from May and keeps increasing, and then it peaks in October. After October, it starts descending quickly, and the minimum mean monthly rainfall shows up in February. From this monthly rainfall distribution, it can be observed that about 90 % of the total annual rainfall is in the rainy season; and thereby the rain in the dry season shares only about 10%.

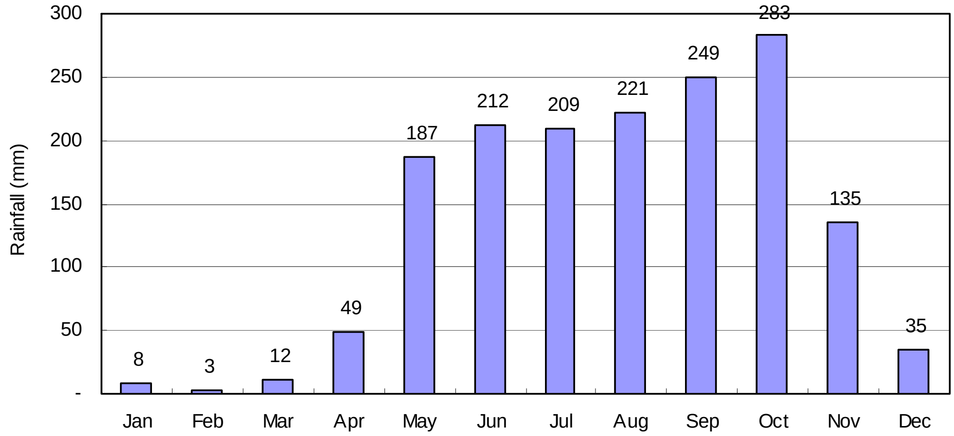



**Figure 2.2.3 Major 18 Stations' Monthly Average Rainfall in Mekong Delta, mm/month**

Source: Southern Institute for Water Resources Planning

### 2.2.3 Water Resources

Water resource in the Mekong Delta is of course the Mekong River, which is also a key regional resource in Southeast Asia for not only agriculture sector but also fisheries and power generation sectors. The River is the world's 8th largest in discharge, annual discharge of 400 billion cubic meter, 12th largest in length (4,350km), and 21st largest in drainage area (795,000 km$^2$). Note that the 400 billion cum was estimated as the annual mean discharge based on the average daily discharges recorded at Kratie station established in Cambodia from 1985 to 2010, and other data were derived from 'Flood and Salinity Management in the Mekong Delta, Vietnam, Le Anh Tuan, Chu Thai Hoanh, Fiona Miller and Bach Tan Sinh'.

It is a major trans-boundary river, originating in the Tibetan Highlands with an altitude of over 5,000m. The Mekong flows through gorges in Lancang area in China's Yunnan Province, and then passes through Myanmar, Laos, Thailand, Cambodia and then finally into Vietnam.

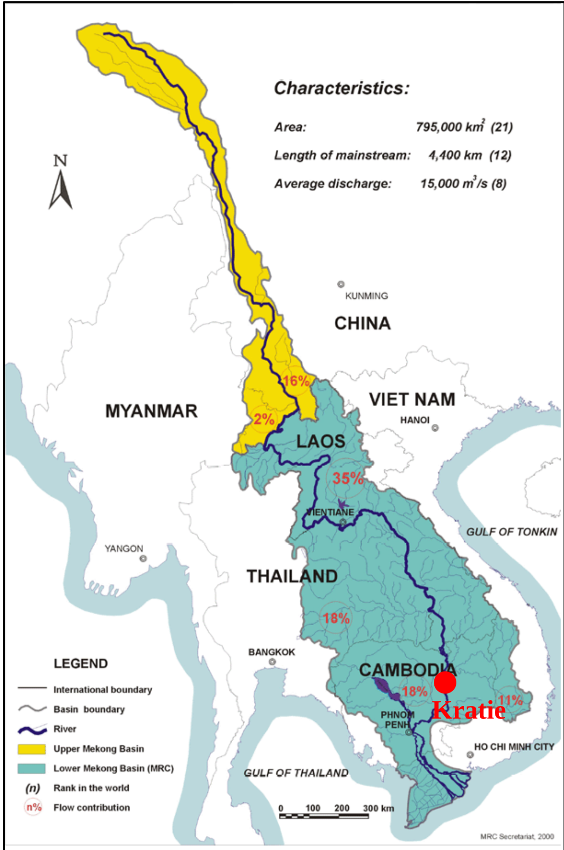



**Figure 2.2.4 Map of the Mekong River Basin**

Source: MRC, 2000

The Mekong meets Tonle Sap River at a point of west of Phnom Penh, and then is divided into the Tien and Hau Rivers. The River discharge at Tan

Chau station on the Tien River is 3-5 times larger than that of Chau Doc station on the Hau River. The Vam Nao, which connects both rivers 20 km downstream of Tan Chau and Chau Doc stations, conveys water from the Tien River to the Hau River, augmenting the flow of Hau River downstream from this point.

The Tien River branches into six tributaries and the Hau River into three tributaries and together they form what is called in the Vietnamese language the “Nine Dragons” (Cuu Long). With these 9 estuaries and also a dense canal network, the Mekong Delta shows very much complicated hydraulic network. The development of the dense canal network started about 300 years ago, and through the French colonial era to date, extensive canal network with some control gates have been established.


**Figure 2.2.5 Map of the Lower Reaches of Lower Mekong River Basin (After Kratie Station)**

Flood season starts from July and ends in December, and during this period the areas from the Tonle Sap River in Cambodia to the East Sea of Vietnam are covered with water. A large part of the Delta, especially upstream and midstream parts of the Delta, is very much inundated from both the overflow from the Mekong River and rainfall while downstream of the delta is less affected by floods. Due to the effect of the tropical monsoon, flood flows are about 25-30 times greater than those of dry season which takes place between March and April.

The flooded area ranges from 1.2 to 1.4 million ha in years of low and medium flooding, and goes up to around 1.9 million ha in years of high flooding[2]. It is reported by MARD that about 50 % of the Mekong Delta experiences flooding and these areas are also susceptible to serious damages by floods about every 5 years. The floods are associated with prolonged deep inundation, causing river bank erosion and transportation difficulties, which altogether disrupt economic activities to a greater extent.

On the other hand, during dry season sea water intrusion takes place and saline water comes to upstream from all the estuaries of the Mekong tributaries. During the dry season, the flow discharges in the Mekong River are at their lowest, especially in March and April, and the saline water intrudes into the lower to as far as mid parts of the Mekong Delta. All the coastal provinces are thus susceptible to saline intrusion during dry season. It is reported by MARD that approximately 1 million ha of agricultural lands are affected by tidal flooding and 1.7 million ha (about 45% of the delta area) by salinity intrusion[3].

[2] Flood and Salinity Management in ht Mekong Delta, Vietnam, Le Anh Tuan, Chu Thai Hoanh, Filna Miller, and Bach Tan Sinh.
[3] Flood and Salinity Management in ht Mekong Delta, Vietnam, Le Anh Tuan, Chu Thai Hoanh, Filna Miller, and Bach Tan Sinh.

### 1) Discharge and Water Level

Mekong River Commission (MRC) has been monitoring water level of the Mekong River at different places and converting them into discharge. Among the monitoring stations, Kratie is located about 300 km upstream from the border with Cambodia. Though this Kratie is located deep in Cambodian territory, it hydrologically represents the starting point of lower parts of the Lower Mekong Basin, from which flood and inundation takes place. It means that simulation models undertaking Mekong Delta's flood inundation as well as saline intrusion should start from this point of Kratie. With this fact, discharge data at Kratie has often been referred to in many literatures and simulation.

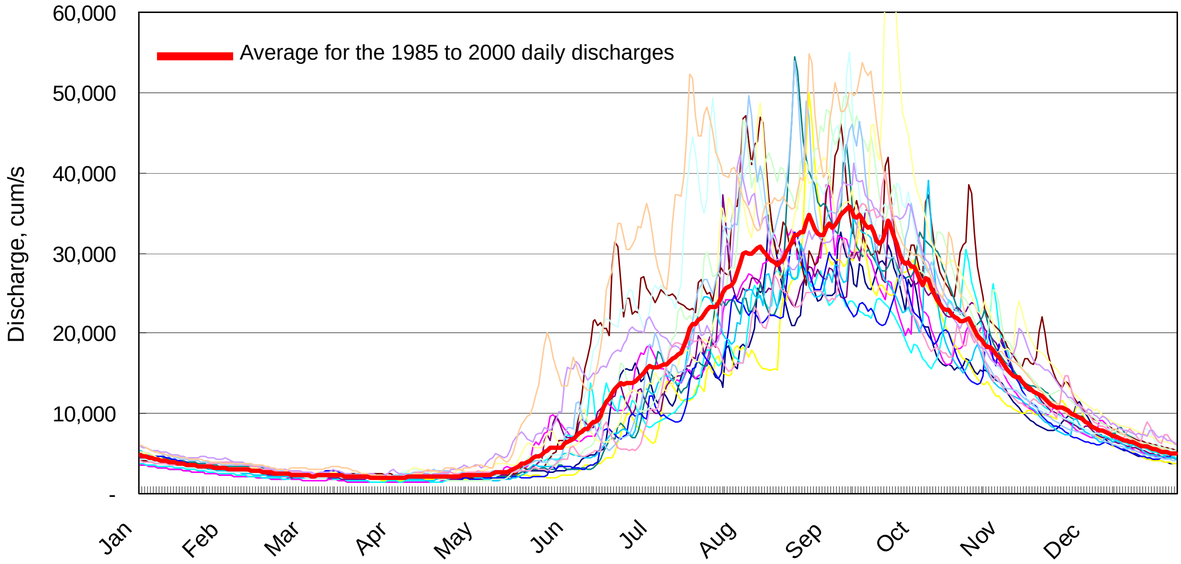



**Figure 2.2.6 Daily Discharge Data Recorded at Kratie Station from 1985 to 2000**

Source: Mekong River Commission

Note; Thick line shows the average of the discharge from 1985 to 2000

Figure 2.2.6 shows the long term daily discharge data from 1985 to 2000 at the Kratie station with the thick line being the average. As is shown, flood season starts from June, or sometimes from late May, and ends in December. During the peak flood season, the daily discharge goes over 30,000 cum/s, and in some years it reaches 40,000 cum/s and sometimes even over 50,000 cum/s. As for the average discharge during the flood season, it starts going over 30,000 cum/s from around mid August and stays there, being more than 30,000 cum/s, till late September. The average discharge peaks at around 35,000 cum/s in early September.

On the other hand, dry season's discharge remains very low. At the beginning of January, the daily discharge marks around 5,000 cum/s and continuously decreases towards the end of dry season. The average daily discharge goes down to less than 3,000 cum/s in February, and further down to less than 2,000 cum/s from late March to early April. After that, the reverse starts in as early as April, but the discharge in April still stays just over 2,000 cum/s. In May, the average daily discharge is now increasing quickly, starting from about 2,300 cum/s at the beginning of May and goes to 6,500 cum/s at the end of the same month.

There are 2 gauging stations in the upper most reaches of Mekong River within the Vietnamese territory near the border with Cambodia; Tan Chau on Tien River and Chau Doc on Hau River as aforementioned. These gauging stations monitor water levels at every hour interval, and can estimate daily discharges based on rating (Q-H) curves established for the river sections with the daily averaged water level. However, the estimation of discharges during the dry season is greatly influenced by back-water effect; namely, whether the measurements are taken during a rising or falling stage on the hydrograph. Thus, quality of the discharge data during the dry season may not be as accurate as those estimated at an upstream station, like the one at Kratie station.

With this in mind, Figure 2.2.7 and Figure 2.2.8 show the water levels at Tan Chau and Chau Doc stations respectively for a period of 31 years from 1980 – 2010. Water level stays very low in April and May; the average daily water level goes down to lower than 0.5 meter AMSL at Tan Chau station in April and that of Chau Doc to lower than 0.4 meter AMSL while from May the water level starts rising towards the peak of the flood season, which is October. In October, the average water level reaches as high as about 4.0 meter at Tan Chau station and about 3.5 meter at Chau Doc station.

It is said by hydrologists as; 1) a low flood during the flood peak season in Tan Chau is less than 4.0 m, 2) moderate floods during the flood peak season are between 4.0 and 4.5 m, and high floods during the flood peak period go more than 4.5 m. In the 31 years from 1980 to 2010 shown in the figures, there were 9 years that the water level went up more than 4.5 m. The maximum water level occurred in 2000, which reached 5.04 m.

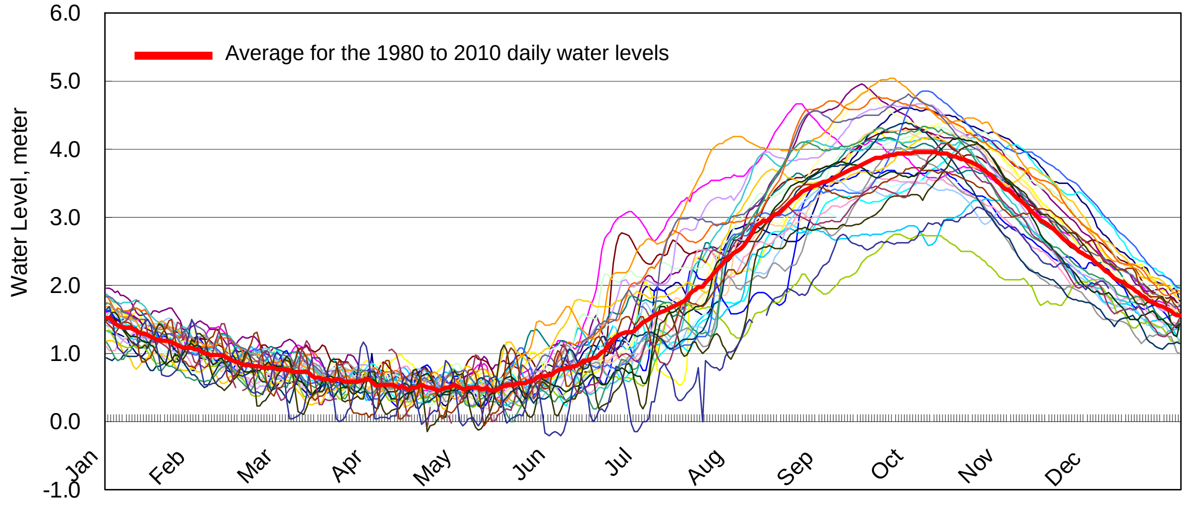



**Figure 2.2.7 Daily Water Level Data Recorded at Tan Chau Station from 1980 to 2010**

Source: Mekong River Commission

Note; Thick line shows the average of the water level from 1980 to 2010.

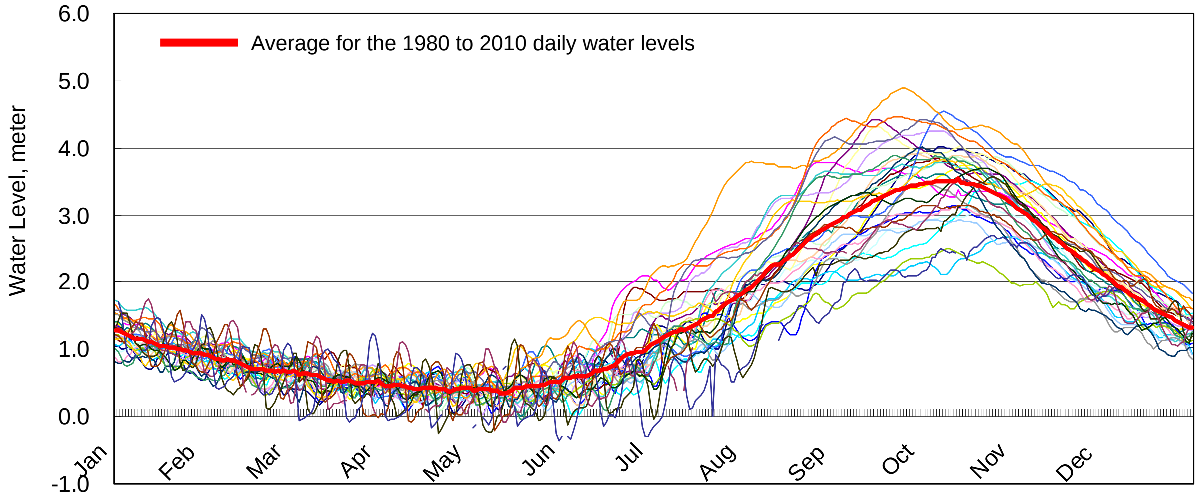



**Figure 2.2.8 Daily Water Level Data Recorded at Chau Doc Station from 1980 to 2010**

Source: Mekong River Commission

Note; Thick line shows the average of the water level from 1980 to 2010

Figure 2.2.9 shows the discharges for the both stations and Figure 2.2.10 shows the summated discharges for the 2 stations for years from 2000 – 2008 except for 2007. The discharges are very different between the 2 stations: much more flow in Tan Chau station than Chau Doc station. While the flood season's discharge at Tan Chau station goes over 20,000 cum/s, the discharge at Chau Doc station remains at around 7,000 cum/s. Totaling the both discharges, the average peak discharge during flood season arrives at about 28,000 cum/s. This discharge is lower than that of Kratie (about 35,000 cum/s), and this is because of the existence of the Great Lake in Cambodia. During flood seasons, a great deal of river water reverses to the Great Lake via Tonle Sap River.

Instead, the Great Lake discharges the stored water back into the Mekong River during dry season. This discharge from the Great Lake augments the dry season flow at Tan Chau and Chau Doc stations. As demonstrated in the hydrographs in Figure 2.2.10, the total discharge of the 2 rivers at the beginning of January is about 10,000 cum/s while that of Kratie station is only about 5,000 cum/s, about half of it. During the driest season, April and May, the total discharge of the 2 rivers stays at around 3,000 cum/s, while that of Kratie station drops to about 2,000 cum/s (about two-third). It means that the Great Lake works in mitigating the flood magnitude in Mekong Delta during flood seasons while augmenting the freshwater during the dry seasons.

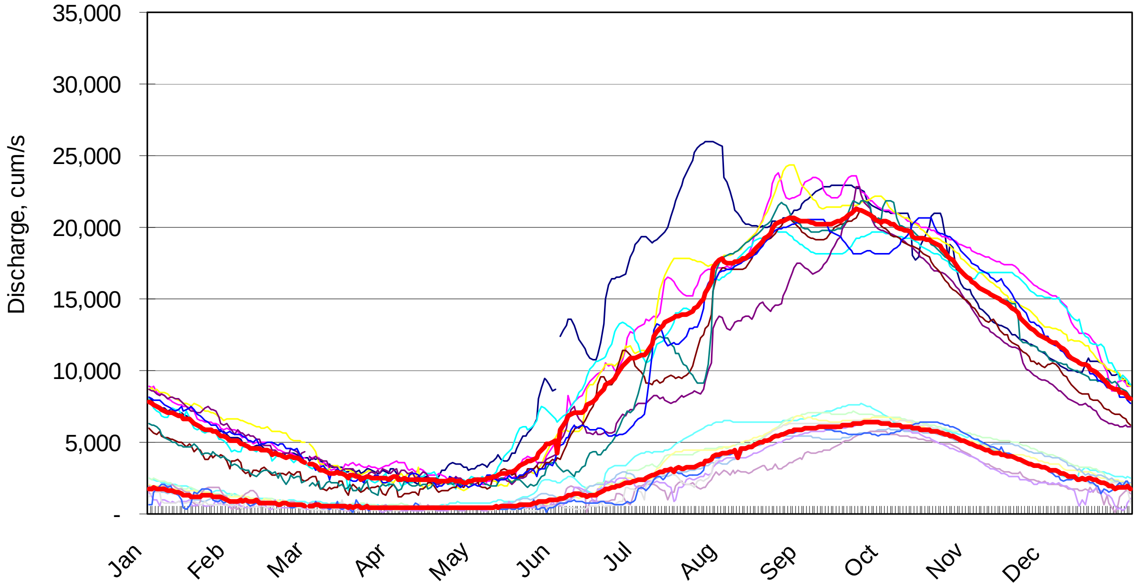



**Figure 2.2.9 Daily Discharge at Tan Chau Station and Chau Doc Station**

Source: Mekong River Commission

Note; Lower group lines are for Chau Doc station, upper group lines are for Tan Chau station, and the bold lines show respective average discharge.

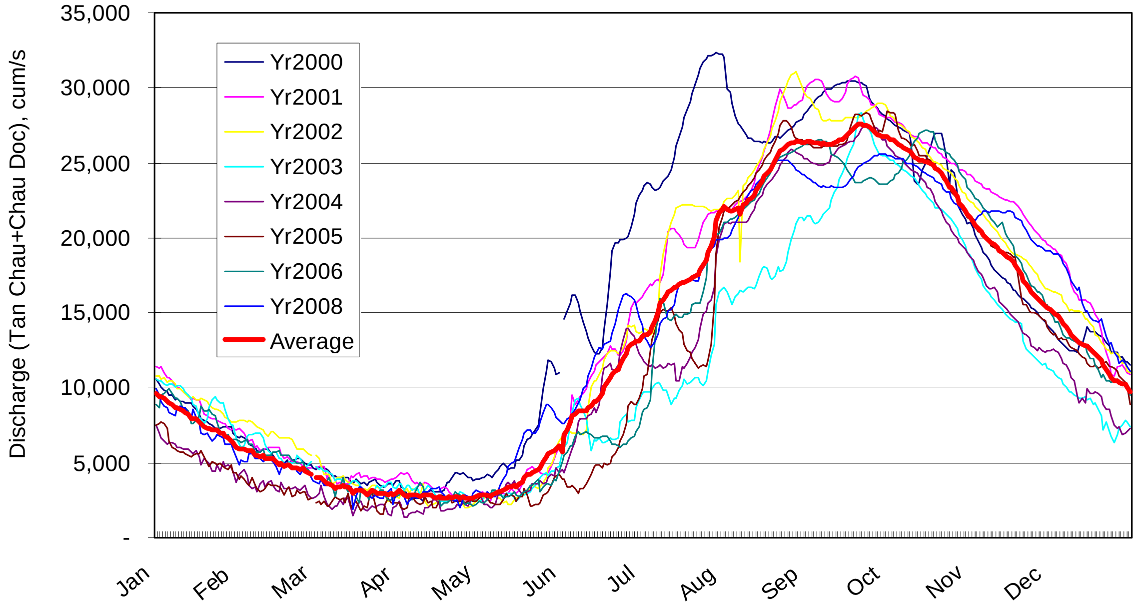



**Figure 2.2.10 Summed Daily Discharge for Tan Chau and Chau Doc Stations**

Source: Mekong River Commission, Note; Bold line show the average discharge.

## 2.3 Major Rural Infrastructure

### 2.3.1 Waterway

The Mekong Delta waterway network carries seagoing and inland traffic, including some cargo traffic from Vietnam to Cambodia. Domestic waterway traffic is highly dense in the whole delta area. Hundreds of waterways varying in size (for vessels from 10 to 600 tons) interlace in this area; such as rivers, rivers' tributaries, constructed canals, and natural creeks. Most waterways have natural favorable conditions for navigation.

It is counted that a total navigable length in the Delta arrives at approximately 4,785 km. The waterway network connects major cities each other, e.g., Phnom Penh, Kampong Cham[1], Ho Chi Minh City, My Tho[2], Vinh Long, Cao Lanh[3], Can Tho and Long Xuyen[4] and East Sea, and then it plays a vital role in the economy and human life of the area. There are three types of inland navigation in the Mekong Delta: local movement by 10 - 15 ton boats; inter-city movement by 15-600 ton ships; and inter-country movement by 600 - 3,000 ton barges or barge convoys, normally comprising one tugboat and three barges of 250 to 300 tons each (source: UN 2001)[5].

#### 1) History of the Development

Natural stream flow of river water and tide have created a dense array of waterways in the Mekong Delta, and it functions as a network of natural irrigation channel, drainage and navigation. The first long distance waterway was constructed during the era of Phu Nam Country (1$^{st}$ - 7$^{th}$ century) at the place between Rach Gia bay to Oc Eo and Angkor Borei in Cambodia with a length of about 70 km. After this, a strong developer for Mekong Delta came in 18$^{th}$ century; Nguyen dynasty quite aggressively carried out canal construction in Mekong Delta starting with Vung Gu canal, which connected Vung Gu and My Tho. The main purpose was for navigation with width; 32m, depth; 4m, and width of embankment road; 13m. In addition, 9 large scale canals were also constructed during the era of Nguyen dynasty (source: SIWRP).

After having conquered west region (1867) of Mekong Delta, French started canal construction for the purposes of navigation and agricultural development. Consequently, more than 100 numbers of large scale canals were constructed in Mekong Delta by the time of World War II. At the area between Tien and Hau Rivers, Tra On canal (1875, Vinh Long) was the first canal to exploit the fertile delta. In Ca Mau Peninsula area, Cai Con canal was one of the major and large canals to facilitate area development in the early development stage of years during 1880-1890. Canal construction in Long Xuyen Quadrangle area was carried out in the period of 1918-1930; Rach Gia – Ha Tien canal was the first one and it runs parallel with seashore line of West Sea. Vinh Te canal (1897, length 45 km, width 10 m) was the first canal to exploit the area of Plain of Reeds area (source: SIWRP).

It was recorded that the period from 1890 to 1936, about 1,360 km of main canals, 2,500 km of auxiliary canals, and thousands kilometer of small canals were constructed in total. Along with the development of canal network, paddy field area had been increased by a total area of 1,689,000 ha from 1890 to 1930 and annual accumulated sown area had counted at as much as 2,452,000 ha in 1930. Likewise, population in the Delta had increased about three-fold from 1890 to 1930 and it reached to 4.5 million at that time (source: SIWRP).

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1 Phnom Penh is the capital of Cambodia and Kampong Cham is located about 90km north of Phnom Penh.
2 My Tho is the capital of Tien Giang province.
3 Cao Lanh is the capital of Dong Thap province.
4 Long Xuyen is the capital of An Giang province.
5 "Guidelines for the Harmonization of Navigation Rules and Regulations, Volume 1. Aids to Navigation", UNITED NATIONS, New York, 2001

After the Second World War and French colonial period until 1975, there was some development on canal network extension in the Delta. Cai San canal system (1956, Can Tho province – Kien Giang province, width 6m and depth 4m) had developed a total length of 159 km with 17 canals, and had commanded an area of 270,000 ha in Ca Mau Peninsula area. The canals were aimed at supporting livelihood for about 42,000 migrations to settle. In the Plain of Reeds area, Tham Thu canal was constructed in early 1970s in order to introduce fresh water to a factory in Go Cong of Tien Giang province with pumps at Tham Thu station. Some areas along the canals received benefit of irrigation by this system (Source: SIWRP).

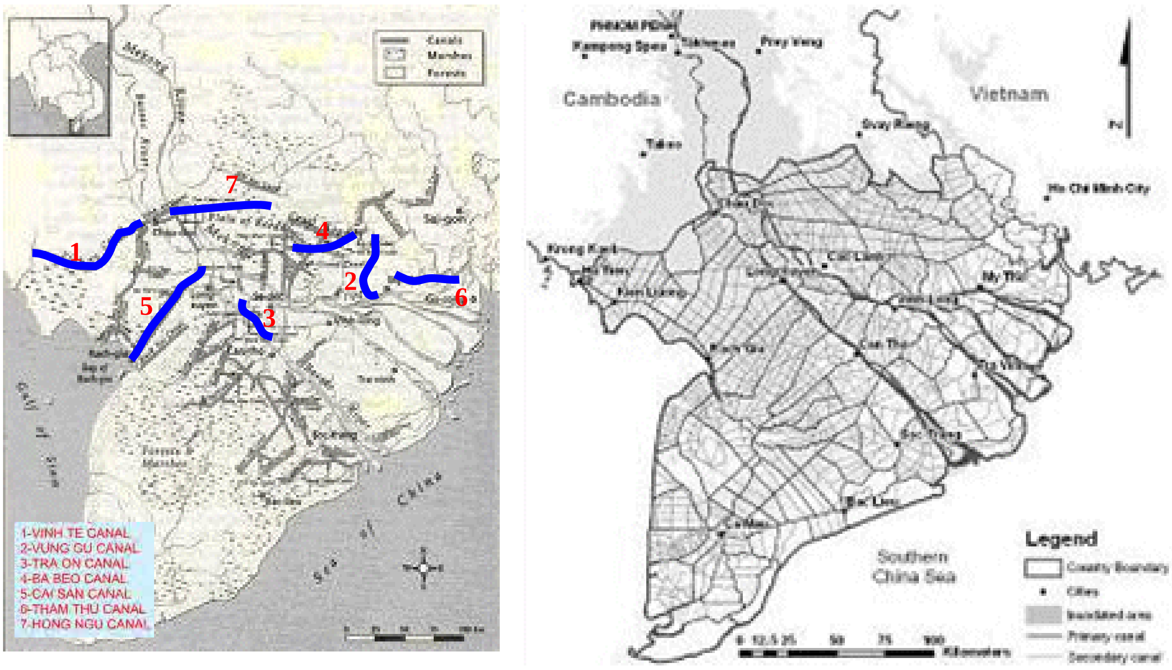


**Figure 2.3.1 Canal Systems in French Colonial Period (Left) and the Present Time (Right)**

Source: Southern Institute for Water Resources Planning

Some canal improvement works and small canal (level 2 and 3) construction were carried out after Vietnam War (1975) until Doi Moi (1985). Some sluices and pumping stations were also installed in this period. Hong Ngu canal (1985, Dong Thap province) was constructed in this period. From 1986 to 1995, secondary canal systems were developed mainly for flood control. Water flow system improvement was carried out during this period such as; canal dredging for fresh water supply and drainage, sluice gates construction to prevent saline water intrusion. Years from 1996 up to now, waterway system was improved toward flood control, prevention of saline intrusion, and coping with sea level rise (Source: SIWRP).

## 2) Canal Networks

Waterway network in Mekong Delta had been developed for navigation purpose at the beginning period in Nguyen dynasty as aforementioned, and then drainage function and irrigation function were added from those days in French colonial time. In nowadays time, canals provide multifunctional services and are classified into several levels as follows;

**Table 2.3.1 Classification of Canals in Vietnam**

| Canal Type | Main | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| Bottom Width (m) | 15m= < | 10m | 6 – 8m | 2 -3m |
| Bottom Elevation (MSL m) | - 3m | - 3m | - 1.5m | - 1m |

Source: Southern Institute for Water Resources Planning

Classification mentioned above can not always apply to all the canals in Mekong Delta because features of canals differ from one place to the others. Sometimes it is difficult to classify an intermediate type of canal. According to a statistics of SIWRP, total length of canals in Mekong Delta is estimated at over 90,000 km; this length is over twice circles of the Globe. Canal network in each area is summarized by type[6] as follows (for the areas, refer to Figure 2.3.2);

**Table 2.3.2 Canal Networks in Mekong Delta (Data Source: SIWRP)**

| Canal Type | Whole Mekong | | Plain of Reeds | | Long Xuyen Quadrangle | | Ca Mau Peninsula | | Trans Bassac | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Project | L (Km) | Project | L (Km) | Project | L (Km) | Project | L (Km) | Project | L (Km) |
| | | Density (km/km$^2$) | | Density (km/km$^2$) | | Density (km/km$^2$) | | Density (km/km$^2$) | | Density (km/km$^2$) |
| Area(km$^2$) | | 38,143 | | 8,131 | | 4,989 | | 16,922 | | 8,101 |
| Main Canal | 133 | 3,190 | 45 | 1,068 | 20 | 450 | 36 | 633 | 32 | 1,039 |
| | | 0.08 | | 0.13 | | 0.09 | | 0.04 | | 0.13 |
| Canal Level 1 | 1,015 | 10,961 | 343 | 3,116 | 44 | 606 | 428 | 5,294 | 200 | 1,945 |
| | | 0.29 | | 0.38 | | 0.12 | | 0.31 | | 0.24 |
| Canal Level 2 | 6,556 | 26,894 | 2,187 | 6,742 | 1,100 | 3,100 | 3,297 | 13,689 | 1,072 | 3,363 |
| | | 0.71 | | 0.83 | | 0.62 | | 0.81 | | 0.42 |
| Canal Level 3 | 35,640 | 50,019 | 3,400 | 7,200 | 1,213 | 4,274 | 7,467 | 16,692 | 24,773 | 21,853 |
| | | 1.31 | | 0.89 | | 0.86 | | 0.99 | | 2.70 |
| Total | 43,344 | 91,064 | 5,975 | 18,126 | 2,377 | 8,430 | 11,228 | 36,308 | 26,077 | 28,200 |
| | | 2.39 | | 2.23 | | 1.69 | | 2.15 | | 3.48 |

Source: Southern Institute for Water Resources Planning
Note: Trans Bassac means the area located in between Tien and Hau Rivers.

Trans Bassac, the area between Tien River and Hau River, is represented with much more waterway density (3.48 km/km$^2$) than that of other areas, which is mainly composed of Level 3 canals. Vinh Long province is known as confluence area between river flow and tidal water, and thus 2-way water flow, back and forward, in this area has created many natural channels than other areas. Level 3 canals in this area are therefore developed from natural canals and its density, 2.70 km/km$^2$, shows rather high value than other areas (0.86 – 0.99 km/km$^2$).


**Figure 2.3.2 Location of the 4 Hydraulic Areas**
Source: Southern Institute of Water Resources Planning

On the other hand, Long Xuyen Quadrangle, northern part of An Giang and Kien Giang provinces, shows less density of waterway network. There is a hilly area at the northern part of An Giang province, so that canal network was hardly developed in this hilly area. In addition to this, large scale drainage canals were developed and renovated in recent years in order to drain flood water from Mekong River to the West Sea during rainy season.

Water level change in Mekong Delta differs by place; downstream side water level fluctuates more than that of upstream side influenced by tidal fluctuation. There is difference of mean water level amplitude with two times or more by areas between upper part and downstream part of the Mekong Delta. Observed water level amplitudes in April 2008 are shown below, from which one can see about 1 meter fluctuation at the most upstream parts of Mekong Delta, and about 1.5 m to 2.0 m at around mid parts of the Delta, and more than 2.0 m to over 2.5 m at the downstream parts of Mekong Delta;

[6] Usually in statistics, the main canals and level 1 canals are counted as main canals, and level 2 canals and level 3 canals are grouped together into level 2 canals. According to SIWRP, construction of medium and small scale canals is required for the purpose of improving drainage capacity.

**Table 2.3.3 Observed Mean Water Level Amplitude in April 2008**

| Tien River | Tan Chau | Cao Lanh | My Thuan | My Tho | Vam Kenh |
|---|---|---|---|---|---|
| Amplitude (cm) | 100 | 150 | 185 | 218 | 236 |
| Hau River | Chau Doc | Long Xuyen | Can Tho | Dai Ngai | My Thanh |
| Amplitude (cm) | 115 | 147 | 195 | 265 | 250 |

Source: Southern Institute for Water Resources Planning

### 3) Waterway Freight

Feature of freight logistics in Mekong Delta is quite different from other areas of Vietnam. Vietnam can be divided into total 6 areas; from the north "Red River Delta", "Northern midland and mountain", "North central and central coast", "Central highland", "East Sea", and "Mekong Delta". In 2009, share percentage of waterway freight is less than 30% by the areas other than Mekong delta, while that of Mekong Delta shared as much as about 70% of the total freight as shown in Figure 2.3.3 (the figures do not include air cargo, and based on road and waterway freights only). Basically, development in Mekong Delta started with canal development often by utilizing natural channels as waterway, and man-made waterways had then been added by the Government and by private sectors. Projects for road network construction together with bridges have been implemented in the Delta; yet waterways are still major infrastructure for freight logistics in the delta area.

Table 2.3.4 shows the freight and freight traffics in Mekong Delta. As shown in the table, freight road remained 9,999,000 tones in 2009 while that of freight water way arrived at 17,012,000 tons, which is about 1.7 times more by waterway. As for freight traffic in terms of ton-kilometer, fright traffic road in 2009 was 790 million ton-km while that of waterway reached at as much as 1,721 million ton-km, more than 2 times larger for the latter. Looking into the unit freight distance, that of road was 79 km per one-ton freight while waterway ferried 101 km per one-ton freight in 2009. Thus, it can be said that the waterways are quite important transportation infrastructure in Mekong Delta.

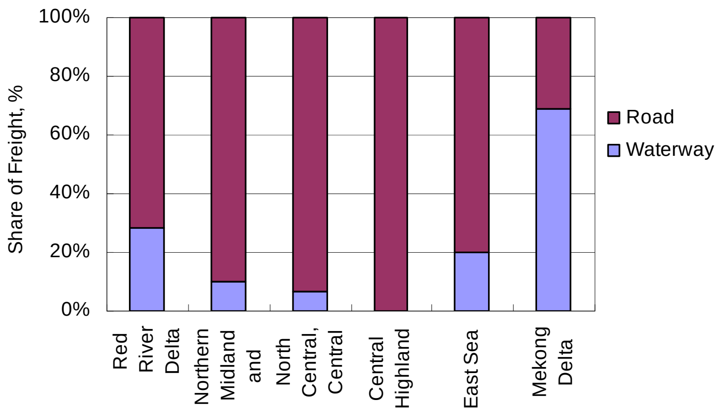


**Figure 2.3.3 Share of Freight in Six Areas of Vietnam**
(Sources: Statistical Year Book, Vietnam, 2010)

**Table 2.3.4 Freight and Freight Traffics in Mekong delta**

| Items | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Freight Road (X1,000 t) | 7,543 | 8,668 | 8,638 | 9,480 | 9,999 |
| Freight Traffic Road (X 1,000,000 t km) | 574 | 617 | 623 | 686 | 790 |
| Freight Waterway (X 1,000 t) | 14,518 | 15,439 | 15,646 | 15,692 | 17,012 |
| Freight Traffic Waterway (1,000,000 t km) | 1,398 | 1,472 | 1,425 | 1,426 | 1,721 |
| Freight Ratio (Waterway/Road) | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 |
| Freight Traffic Ratio (Waterway/Road) | 2.4 | 2.4 | 2.3 | 2.1 | 2.2 |
| Unit Freight Distance Road (FTkm/FT, km) | 76.1 | 71.2 | 72.1 | 72.3 | 79.0 |
| Unit Freight Distance Waterway (FTkm/FT, km) | 96.3 | 95.3 | 91.1 | 90.9 | 101.2 |

Source: Statistical Year Book, Vietnam, 2010, Note; FT means Freight Traffic in ton-km and FTkm is Freight ton x km.

## 2.3.2 Road

### 1) Road Network

Road network in Mekong Delta has a total length of about 22,870 km. Road density differs widely by province and/or area with two times or more. The road density in Long An province is 1.109 $km/km^2$

while that of Ca Mau province is only 0.473 km/km$^2$, with an average density of 0.58 km/km$^2$ or 1.27 km/1,000 people. Total 15 national highway routs run in Mekong Delta with a total length of 2,471 km. At provincial road level, there are 127 road routes with 3,400 km of total length, of which about 75% are paved by asphalt-concrete. The remaining stretch, total length of 17,000 km, belongs to communal road and it connects basically between districts and communes, inter-communes, and internal network in communes.

For the roads in the Project area of the coastal 7 provinces, total length of the national roads arrives at 1,388 km, equivalent to 56% of the whole Mekong Delta; the length of provincial road comes to 2,263 km, which shares 66 % of that of Mekong Delta. Total length of district roads is 2,820 km and the data for commune road is not available by province. The density for the 3 levels roads in the Project area shows an average of 0.32 km/km$^2$ with the highest one, 0.57 km/km$^2$ in Tien Giang province while the lowest density in Ben Tre province, 0.16 km/km$^2$, though the data for Kien Giang is not available.

**Table 2.3.5 Class and Road Length in Mekong Delta**

| National Highway (Km) | Provincial Road (Km) | District / Commune Road (Km) | Road Density 1 (Km/Km$^2$) | Road Density 2 (Km/1,000 people) |
|---|---|---|---|---|
| 2,471 | 3,400 | 17,000 | 0.58 | 1.27 |
| Total of Mekong Delta : 22,871 km | | | | |

Source: Southern Institute for Water Resources Planning

**Table 2.3.6 Road Type and its Length of Coastal 7 Provinces in Mekong Delta**

| Province | Area | National Road | | Provincial Road | | District Road | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | (km$^2$) | (Km) | Density (km/km$^2$) | (Km) | Density (km/km$^2$) | (Km) | Density (km/km$^2$) | (Km) | Density (km/km$^2$) |
| Tien Giang | 2,484 | 214 | 0.09 | 388 | 0.16 | 825 | 0.33 | 1,427 | 0.57 |
| Ben Tre | 2,360 | 131 | 0.06 | 172 | 0.07 | 64 | 0.03 | 367 | 0.16 |
| Tra Vinh | 2,242 | 249 | 0.11 | 183 | 0.08 | 322 | 0.14 | 754 | 0.34 |
| Soc Trang | 3,312 | 239 | 0.07 | 409 | 0.12 | 337 | 0.10 | 985 | 0.30 |
| Bac Lieu | 2,582 | 63 | 0.02 | 296 | 0.11 | 587 | 0.23 | 946 | 0.37 |
| Ca Mau | 5,332 | 176 | 0.03 | 515 | 0.10 | 693 | 0.13 | 1,384 | 0.26 |
| Kien Giang | 5,731 | 316 | 0.06 | 300 | 0.05 | NA | NA | NA | NA |
| Total | 24,043 | 1,388 | 0.058 | 2,263 | 0.094 | 2,820 | 0.15 | 5,863 | 0.32 |

Source; Tien Giang) Master plan on social economic 2005, Ben Tre) Ministry of Agriculture and Rural Development 2008, Tra Vinh) Ministry of Agriculture and Rural Development 2010, Soc Tran) Master Plan on social economic 2005, Bac Lieu) Master plan on social economic 2009, Ca Mau) website: Camau.gov.vn, Kien Giang) Master Plan on agriculture 2010

About 65% of national highway is reported to have a risk of inundation during rainy season, of which about 50% are located at shallow inundation areas (0.5 – 1.5 m), 10% are in the medium inundation areas (1.5 – 3.0m), and 5% lie in deep inundation areas (> 3.0 m). It is also said that about 50% of communal roads are located in flood risk areas (Source: SIWRP). Road embankment has dual functions such as; it can protect the areas surrounded by roads from flood while it can also disturb draining flood water. Thus, it is quite complicated for planning and implementation of road construction in lowland areas of the Mekong Delta.


**Figure 2.3.4 Present Trunk Road Network in Mekong Delta**
Source: Impact of Climate Change, Sea Level Rise on Development of Transportation System in Mekong Delta 2010, Ministry of Transportation

### 2) Road Freight

Given dense array of natural and man-made waterways in Mekong Delta, it is quite challenging work to construct road network. Mekong Delta has been developed with the construction of canals over hundred years to date and navigation systems are still dominant freight transportation mean even nowadays. In this regard, utilization of road network in Mekong Delta is not as active as other parts of Vietnam.

An example is the share of the road freight as compared to that of whole country. For example, in Mekong Delta, the share of road freight against that of the whole country's road freight was a mere 5% in 2009 (see Table 2.3.7 below). This is quite contrast to the fact that freight by navigation shared as much as 34% of the whole country's freight in the same year of 2009. Likewise, its increment ratio marked only 139% during the period from 2005 to 2009, which is the lowest increment as compared to those ratios of other regions of the country, e.g. 193% for Red River Delta area.

**Table 2.3.7 Road Freight Transportation in Each Area of Vietnam**

| Freight by Road (1000 t) | 2005 | 2006 | 2007 | 2008 | 2009 | % in 2009 | 2009/2005 |
|---|---|---|---|---|---|---|---|
| Whole Country | 294,718 | 334,836 | 399,595 | 447,548 | 505,412 | 100% | 171% |
| Red River Delta | 89,133 | 102,720 | 131,477 | 148,108 | 172,433 | 34% | 193% |
| Northern Midland and Mountain | 38,660 | 42,098 | 50,024 | 56,340 | 62,393 | 12% | 161% |
| North Central, Central Coast | 85,169 | 94,428 | 101,396 | 113,661 | 128,062 | 25% | 150% |
| Central Highland | 8,801 | 10,814 | 12,944 | 16,164 | 18,971 | 4% | 216% |
| East Sea | 54,579 | 65,083 | 81,783 | 90,094 | 98,041 | 19% | 180% |
| Mekong Delta | 18,377 | 19,694 | 21,971 | 23,181 | 25,511 | **5%** | **139%** |

Source: Statistic Year Book 2010, General Statistics Office

Major reason of the low ratio is the disconnection of road network by rivers and canals. At present many trucks and cars have to be conveyed by ferry between major ports in Mekong River. Under such situation, function of road freight transportation is quite limited to only inland areas of each province. Therefore, bridge construction will greatly contribute to completing road network and whereby facilitate land transportation in Mekong Delta such as in the case of Can Tho bridge between Vinh Long province and Can Tho province over Hau River.

### 2.3.3 Water Supply

There are four major sources for domestic water supply system in Mekong Delta as follows; about 19% of the population is provided with domestic water from water supply station, which is the most stable water supply system, 26 % by drilling wells for which the depth usually goes more than 100m to sometimes 150m, 22 % by shallow wells dug by the owners, and still 33 % of the population depend on rainwater. In fact, rainwater is one of the safe water sources, yet the difficulty shows up as coming to the end of dry season. As approaching the end of dry season, they run shortage of the stored rain water whereby they have to go for channel water in most cases.

**Table 2.3.8 Resources of Water Supply System in Mekong Delta**

| Source of Water | Water Supply Station | Drilling Well | Shallow Well | Rain Water | Total |
|---|---|---|---|---|---|
| (%) | 19.0 | 26.4 | 22.0 | 32.6 | 100 |
| Population | 2,580,000 | 3,590,000 | 2,990,000 | 4,430,000 | 13,600,000 |

Source: Southern Institute for Water Resources Planning

National Target Program on Water and Sanitation for rural areas (1999-2005) and rural water program of UNICEF have remarkably resolved water problems in the rural areas of Mekong Delta. It is estimated that, as at 2006, 65% of population can access safe water, which is higher rate comparing to national average of 62%. Remaining populations obtain water from local wells or surface water from channel networks; about 60% of people in rural area use these types of water supply system.

It is said that water in Mekong Delta always faces risks in quality from sea water intrusion, solid materials of erosion, chemicals, fertilizers, industrial wastes, household effluent, etc. However, water quality tests so far carried out have not shown contaminated results for domestic purposes. There are, however, difficulties in water supply, for example, people in coastal area have limitations to access water. They rely on groundwater, rainwater and surface water. The surface water from rivers and canals is affected by sea water intrusion; yet those who do not have well have to use it due to the limitation of the other water sources.

History of groundwater development in Mekong Delta started in early 1940's. There are four major aquifers composed of stratums of Pleistocene, Pliocene, and Miocene. By developing these aquifers, there are nowadays about 465,000 numbers of groundwater supply wells and total discharge of them is estimated at about 1.3 million $m^3$/day (source: SIWRP) within the whole Mekong Delta (see Table 2.3.9). The wells are found, however, to be concentrated in mainly 5 provinces as shown in Figure 2.3.5. By province, Kien Giang province has the greatest number of groundwater works as 96,950 followed by Tra Vinh and Bac Lieu while Tien Giang province has the least number of works as 1,165 only within the costal provinces.

**Table 2.3.9 Current Groundwater Development Works in Mekong Delta**

| No | Provinces/cities | Number of works | Discharge ($m^3$/day) |
|---|---|---|---|
| 1 | Tien Giang | 1,165 | 129,114 |
| 2 | Ben Tre | 2,063 | 6,683 |
| 3 | Tra Vinh | 88,923 | 147,301 |
| 4 | Soc Trang | 50,111 | 100,090 |
| 5 | Bac Lieu | 88,741 | 63,681 |
| 6 | Ca Mau | 67,185 | 134,657 |
| 7 | Kien Giang | 96,950 | 328,970 |
| | Total above | 395,138 | 910,496 |
| 8 | An Giang | 4,971 | 71,917 |
| 9 | Can Tho | 22,643 | 64,638 |
| 10 | Hau Giang | 29,656 | 50,045 |
| 11 | Vinh Long | 6,263 | 11,545 |
| 12 | Dong Thap | 2,767 | 44,188 |
| 13 | Long An | 3,487 | 169,956 |
| | Grand Total | 464,925 | 1,322,785 |

Source: Southern Institute for Water Resources Planning

Quality of groundwater is in good condition but much utilization of groundwater may cause land settlement and sea water intrusion especially along the coastal areas. It occurred at Bangkok bay due to industrial water pumping from the aquifers. Total capacity of groundwater resource is estimated at about 86 million $m^3$/day according to SIWRP information. However, heavy development of the groundwater in future may increase risks on it.

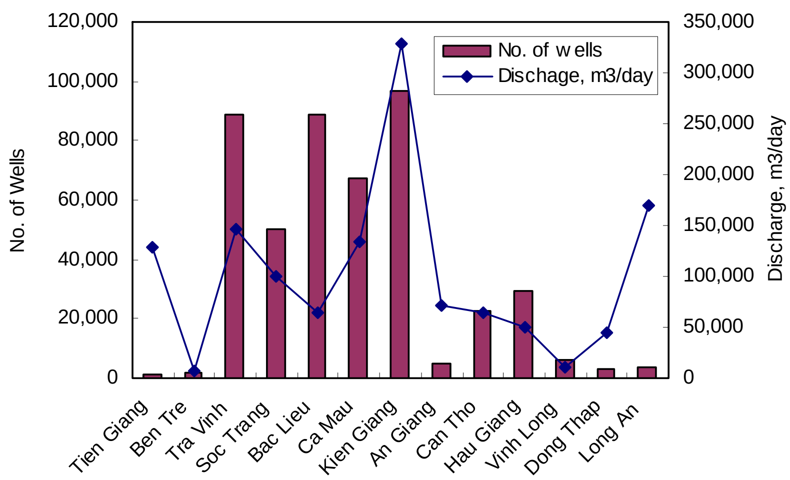


**Figure 2.3.5 No. of Wells and Discharges by Province**

Source: Southern Institute for Water Resources Planning

## 2.4 Agriculture in the Project Area

Agriculture in the Mekong Delta is quite diversified. So-called “rice bowl” of rice production area is featured by strategic combinations of paddy, fruit trees, and aquaculture depending on specific conditions of agro-ecological environment. One of those diversified farming systems is repeated production of paddy: two to three times of paddy productions a year. This sub-chapter discusses the agriculture in the Project area as well as for the Mekong Delta by large.

### 2.4.1 Diversified Agriculture

In the upper and mid parts of the Mekong Delta, the agriculture centers on paddy production. There used to be one paddy crop area over such flooded areas as Plain of Reed, composed of Dong Thap and Long An provinces, and Long Xuyen Quadrangle composed of An Giang province and northern part of Kien Giang province. However, provided with irrigation and drainage canals and also flood protection dykes surrounding farm lands, the areas have been turned into 2 paddy cropping farm lands coupled with introduction of new varieties of paddy, mainly short maturity variety.

From the mid part of Mekong Delta, the magnitude of flood becomes less since the flood water after getting into Vietnam territory is dispersed over huge extent of the Delta. Thus, paddy cultivation can be more intensified, and in and around the areas between the 2 big tributaries of Mekong River; Tien and Hau Rivers, there are lots of areas where farmers practice 3 times paddy cultivation in a year.

The best environment for paddy production where farmers can practice 3 times cultivation, though, cannot extend further down to the coastal areas. Coastal areas are affected by sea water intrusion whereby paddy cultivation is limited mostly during rainy season only. However, there is another type of farming in this coastal area. An example is a combination of paddy production and aquaculture especially shrimp, which is seen in many places of the Project area.

In the coastal areas of Mekong Delta, e.g., the Project area, there are vast ranges of areas where seasonal salinity intrusion takes place. In such areas, brackish-water shrimp culture is run during the dry season and then paddy production is organized in the rainy season in the same farm plot. In this system, brackish water shrimp production and fresh water paddy production are alternately carried out in the same farm plot. Further along the coastal areas where fresh water is hardy available, brackish shrimp culture becomes dominant throughout year.

One may say it seems impossible or not recommendable for the alternate culture between paddy and brackish shrimp in a same plot. However, it is manageable and actually being done in the vast extent of the Project area, given the seasonal saline intrusion during dry season while abundant precipitation coupled with the increased water level of Mekong river during rainy season—salinity can be washed away or leached out by fresh water in the rainy season. Thus, farmers orchestrate different types of crops/commodities given the availability of brackish/fresh water, technical competency, and financial capability.

Furthermore, combination is not just paddy and brackish shrimp. It includes fresh water shrimp and fish as well. In such areas where relatively abundant fresh water is available, fresh-water shrimp/fish and paddy are produced at the same time at the same place. In this management, surrounding of the paddy field is dug much deeper than central part of the field, more than 1m deep. While paddy is planted in the central part of the paddy field, shrimp/fish is cultivated in the deep water of the surrounding. By combining the two commodities, environment especially water quality, can be kept better for shrimp/fish culture and the expected profitability can also be kept higher.

### 2.4.2 Agriculture Land Use

#### 1) Overall Land Use

As aforementioned, the agriculture in the Project area and Mekong Delta by large is diversified. The land use is consequently quite diverse. By and large, double and triple cropping of paddy is dominant in the upper-middle delta especially along the Rivers, while brackish fishery stretches out along the coastal areas including the Project area. Those major two patterns of land use are further diversified by the different types of forest areas (protective, productive, reforestation etc.), annual crops (mostly fruits), and freshwater fishery (in this classification, shrimp culture is included in “fishery”).

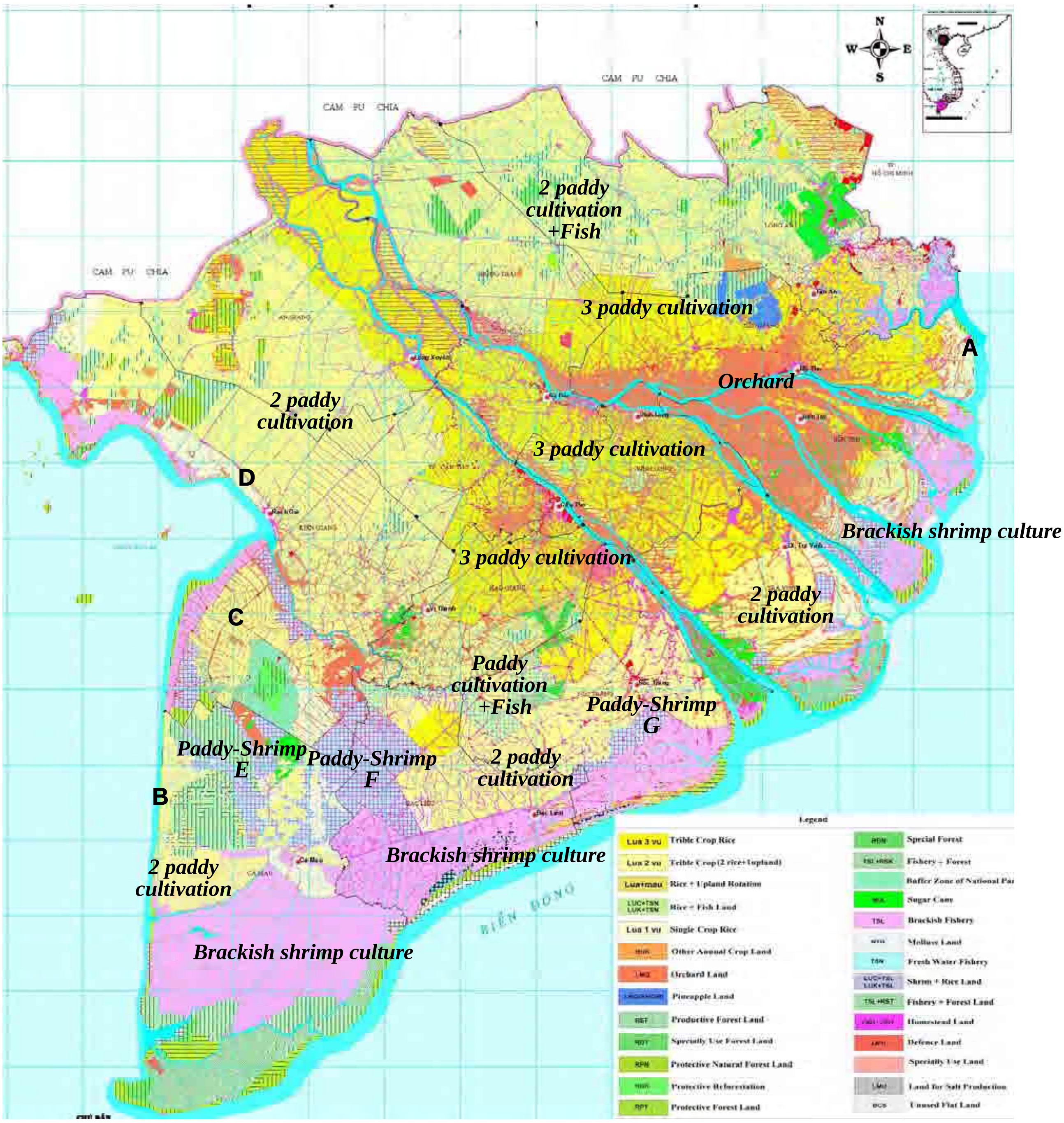


**Figure 2.4.1 Land Use Map of the Mekong Delta as at Year 2008**
Source: SIWRP based on the land use data provided by sub-NIAPP

As seen in the Land Use Map of Figure 2.4.1, brackish shrimp culture is extensively practiced along the coastal areas of Mekong Delta except for some places e.g. coastal areas of Tien Giang province (refer to location ‘A’ in Figure 2.4.1), western parts of Ca Mau Peninsula (refer to locations of ‘B’ and ‘C’), and central coastal part of Kien Giang (refer to ‘D’). In these areas, there are sluice gates already in place, which prevent saline water from coming into the farm lands. With those sluice gates, farmers still can cultivate paddy though some farmers express that they prefer shrimp culture as it is more profitable.

Moving into some inland areas from the coastal brackish shrimp areas, paddy-shrimp alternate cultivation in a year can be seen; paddy cultivation during rainy season while brackish shrimp culture during dry season. This alternate culture between paddy and shrimp is dominant in Ca Mau province (refer to ‘E’), Bac Lieu province (refer to ‘F’) and Soc Trang province (refer to ‘G’), and to lesser extent it is observed in Tra Vinh and Ben Tre provinces. In these areas, by utilizing the saline water during dry season rather than preventing it, this alternate culture has been practiced since late 1980s.

The largest area of this alternate culture is seen in northern part of Bac Lieu province. This area can barely receive fresh water from Hau River (southern tributary of Mekong River) due to the fresh water shortage in the River during dry season despite the fact that there is a long distance canal, called Quan Lo – Phung Hiep, stretching to as far as Ca Mau center. Saline intrusion from East Sea comes as far upstream as this ‘paddy-shrimp’ culture area (refer to ‘F’) during the dry season making possible the shrimp culture. On the other hand, fresh water from Hau River pushes back the saline water during rainy season, thus farmers change to paddy cultivation during the rainy season.

Going into further inland areas or upstream sides along the Mekong River, now dominant cropping is the paddy cultivation. In most of these areas, farmers there practice 2 times paddy cultivation and in the limited areas along and around the Mekong River, they enjoy 3 times paddy cultivation. There is another dominant farming practice, which can be seen in Ben Tre province and Tien Giang province. There are extensive orchard farm lands in upstream and mid parts of Ben Tre province and southern parts of Tien Giang province. The fruits are marketed in the local area and to the Ho Chi Minh city, and then further to abroad, according to interviews to the farmers.

### 2) Agricultural Land Use

Referring to the statistical data for Rural, Agricultural and Fishery Census (2006), difference of land use types in each province is clarified. As shown in Figure 2.4.2, ratio of agricultural land use in the Project area as well as Mekong Delta is much higher than other areas of the Country. While 55% and 63% of the area is used for agricultural purposes in the Project area and Mekong Delta respectively, only 29% is used in the whole Country, which is far greater than any other regions including the Red River Delta (36%).

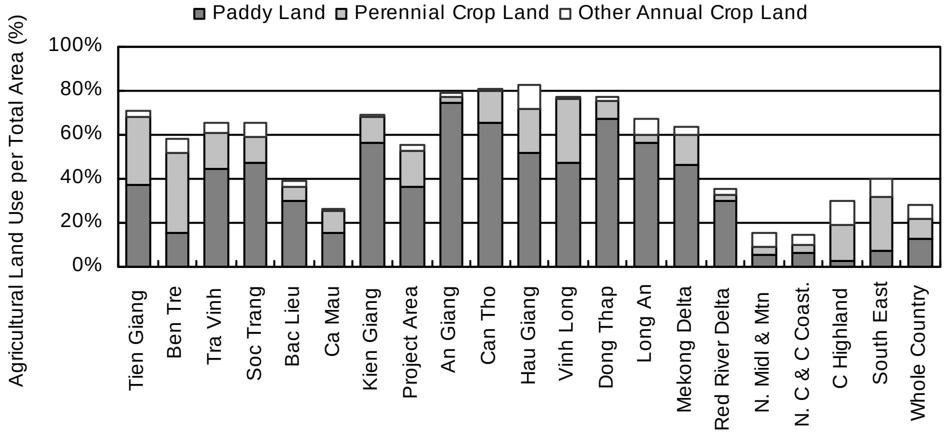


**Figure 2.4.2 Agricultural Land Use per Total Land Area (%))**

Source: Rural, Agricultural and Fishery Census, Data in 2006

Among the provinces in the Project area and also in the Mekong Delta, there are also some variations. At glance is that the share of agriculture land in the Project area is relatively smaller than those of Mekong Delta's other provinces which are mostly located in upper reach of the delta. This is because of the availability of fresh water essential for agriculture more in the upper provinces of the delta. The share of the agricultural land use in most of the provinces ranges from around 50% to 80%, while Bac Lieu and Ca Mau, coastal 2 provinces, resulted in only 39% and 27%. It probably reflects the large aqua-cultural area for those two provinces.

Looking at the percentage of land uses in paddy, perennial crops and other annual crops per agricultural land of each province, there are also some geographical differences. As shown in Figure 2.4.3, percentages of paddy in the Project area (66%) and in the whole Mekong Delta (75%) are first of all higher than that of whole Country (44%), which is after that of the Red River Delta (83%). Among the provinces of the Project area, Kien Giang (83%) was the highest in the paddy land, which was followed by Bac Lieu (75%) and Soc Trang (73%). On the other hand, paddy area of Ben Tre (27%) was quite limited followed by Tien Giang (53%), suggesting that the most agricultural areas in Ben Tre, also followed by Tien Giang province, are now planted with perennial cops i.e. fruits.

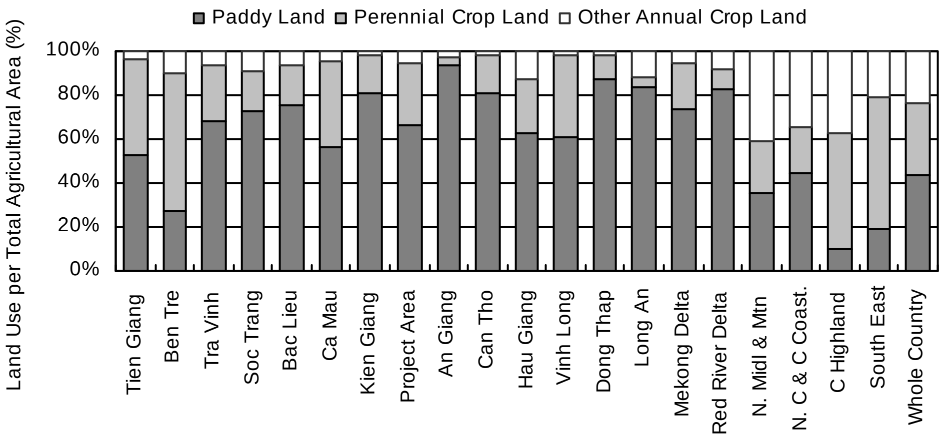


**Figure 2.4.3 Agricultural Land Use per Total Agricultural Area (%)**

Source: Rural, Agricultural and Fishery Census, Data in 2006

### 2.4.3 Cropping Calendar

Cropping systems in the Project area and Mekong Delta are quite diverse and highly sophisticated. There are several combinations of various crops including paddy, upland crops, and aquaculture. As for the cropping calendar of paddy, there are four major seasons: winter-spring, summer-autumn, autumn-winter and spring-summer in an order of popularity in terms of planted areas. Among the four cropping seasons, summer-autumn paddy (May-Aug) and winter-spring paddy (Dec-Feb) constitute the major part of paddy production in the Project area. A typical cropping in the coastal areas is the combination with brackish shrimp culture as aforementioned. Typical cropping patterns in the Project area are illustrated in Table 2.4.1:

Paddy production is organized with various combinations in accordance with the availabilities of irrigation water, fresh water and schedule of other crops or commodities (e.g. brackish shrimp, fresh water shrimp, and freshwater fish). Two cropping of winter-spring (dry season) paddy and summer-autumn (rainy season) paddy can be organized only where irrigation water is available for the dry season. In some cases, three cropping of paddy can be also possible in such areas of northern part of Soc Trang province near Hau River and upper part of Tra Vinh province.

In rain-fed areas where irrigation water is barely available, paddy is planted only during the rainy season. In this case, if the area is heavily flooded toward mid to end of rainy season, only summer-autumn paddy (early rainy season paddy) is cultivated once while in areas not affected by flood, summer-autumn paddy and autumn-winter paddies are commonly cultivated. The latter means that there are two-paddy cropping in a rainy season, which is the majority in the Project area.

**Table 2.4.1 Major Cropping Calendar in Project Area**

| Land Use Type | Month (Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec) | Remarks |
|---|---|---|
| **Irrigated land use** | | |
| 2 paddy crops (WS-SA) | WS, SA, WS | Shallow flooded areas |
| 2 paddy crops (WS-SA) + Fish | Fish | Shallow flooded areas |
| 3 paddy crops (WS-SA-AW) | WS, SA, AW, WS | Shallow flooded areas |
| Perennial crops (e.g. fruits) | Planting | Shallow flooded areas |
| **Rainfed land use** | | |
| 1 paddy crop | SA | Saline intrusion areas |
| 1 paddy crop + fish | Fish | Saline intrusion areas |
| 2 rainfed paddy crops (SA-AW) | SA, AW | Saline intrusion areas |
| 1 paddy crop (SA) - Shrimp | Shrimp, SA, Shrimp | Saline intrusion areas |
| Shrimp culture (1 or 2 crops) | Shrimp 1st, Shrimp 2nd | Saline intrusion areas |

WS: Winter - Spring paddy; SA: Summer-Autumn paddy; AW: Autumn - Winter paddy
Source: Southern Institute of Agricultural Planning and Investment (2011)

In cultivating 2 paddy crops in a rainy season from May to November, farmers may face water shortage toward end of the rainy season. To avoid the water shortage, they carry out transplanting of 30 to 45 days nurseries into the main field for the 2nd paddy crop (Note that direct seeding is the common practice in the Mekong Delta). In cases, some farmers use even 60 days nurseries which have grown more than 40 cm height. This practice shortens the growing period of the 2nd paddy in the main field, and whereby they could accommodate 2 times paddy cultivation in a rainy season.

In such areas along the coastal region where salinity intrusion takes place, rain-fed paddy production is often combined with shrimp culture. Surprisingly, in dry season, paddy field is filled with saline water for shrimp culture and then after a certain time for leaching of salinity by fresh water, i.e. rainfall, paddy is planted in the same plot during rainy season. The farm plots used for the shrimp-paddy culture are enclosed with high embankment. In most cases, the farm plots are enclosed with about 1.5 meter height dyke in order to keep water depth enough for shrimp culture. In addition, trench is made along the inner side of the dyke whereby shrimp can stay in the deeper zone during hot hours of day.

Salinity is usually seen as a harmful feature to paddy production and it is often prevented by dikes and sluice gates. Yet, some farmers have chosen the way to adapt to this kind of extreme environment rather than coping against it by introducing brackish shrimp culture during dry season. Though shrimp culture entails high risk of diseases when the culture continues intensively without consideration on environment, it can fetch better income than paddy cultivation in most cases. As a result, those farmers who have introduced brackish shrimp culture can maximize its profitability.

### 2.4.4 Paddy Production

The major agriculture production in the Project area and the Mekong Delta is paddy. The paddy production by province in the Mekong Delta is shown in Figure 2.4.4. It has been on an increasing trend and in 2010 the total production reached 9,618,000 tons for the Project area and 21,570,000 tons for the Mekong Delta in total. In the same year 2010, the paddy production of the whole County was

39,989,000 tons. It means the Project area produced 24% of the country's production and that of Mekong Delta shared as much as 54%.

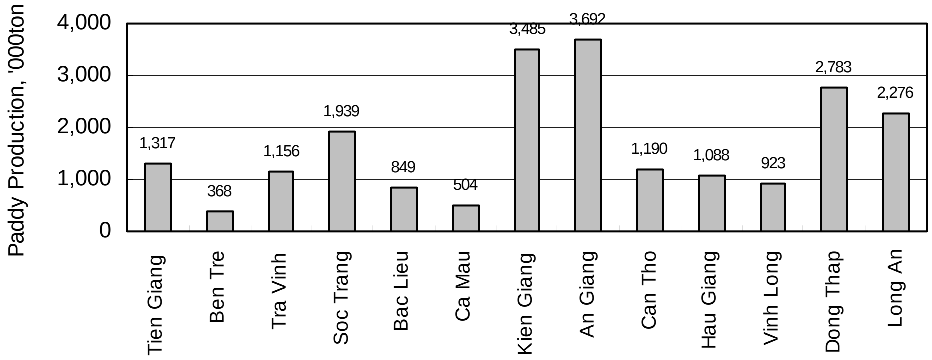


**Figure 2.4.4 Paddy Production by Province in the Mekong Delta**

Source: Statistical Year book 2010, GSO

Looking at the provincial production of 2010, Kien Giang produced by far paddy in the Project area, which is in fact 2nd largest production in the Mekong Delta after An Giang. The 3rd biggest production was made in Dong Thap province. Kien Giang, An Giang and Dong Thap provinces are located in the most upper reach of the Mekong River within Vietnam. On the other hand, coastal provinces have relatively less production. For example, Ben Tre province shows the least production by 368,000 tons, followed by Ca Mau (504,000 tons) and then Bac Lieu (849,000 tons), which are all in line with the land use pattern.

Furthermore, Figure 2.4.5 shows production of paddy per capita as compared with other regions of the County. As shown in the figure, the highest paddy producing province per capita in 2010 is Kien Giang, 2,046 kg/capita or 164% of the Mekong Delta's average, while the least paddy producing province is Ben Tre with 293 kg/capita or 23% of the Mekong Delta's average, followed by Ca Mau province (416 kg/capita, 33% of Mekong Delta's average). The low production in Ben Tre can be explained by a fact that the farmlands in the province have already devoted for fruit production. In Ca Mau province, saline intrusion takes place to a great extent thereby paddy cultivation is difficult.

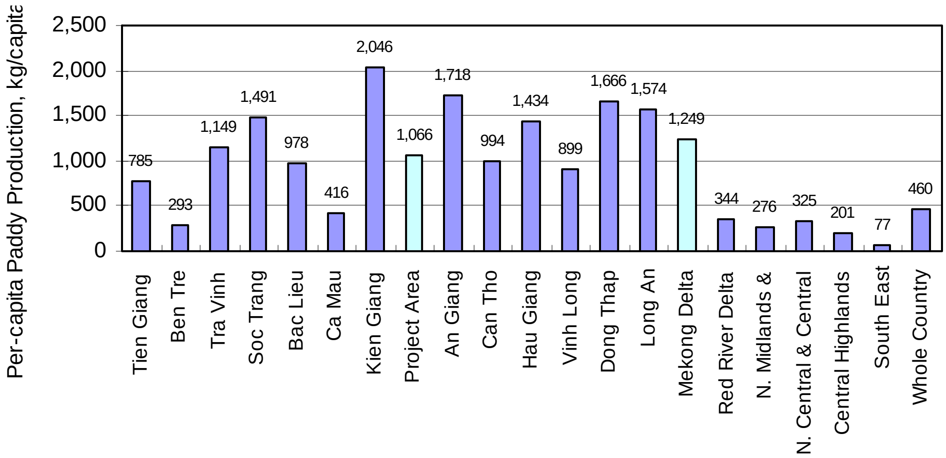


**Figure 2.4.5 Production of Paddy per Capita by Province**

Source: Statistical Year book 2010, GSO

National average of the paddy production per capital is 460 kg. Even that of Red River Delta arrives only at 344 kg. On the other hand, the paddy production per capita comes to 1,066 kg and 1,249 kg for the Project area and the Mekong Delta respectively. This comparison shows how large amount of paddy the Mekong Delta is producing, contributing much to the nation's staple food self-sufficiency as well as for export of paddy. In fact, a typical adult consumes about 150 kg of milled rice per annum, which is approximately equivalent to 250 kg of paddy (60% conversion to milled rice). With this simple estimation, it can be said that the Country has a huge export potential for rice and it comes from Mekong Delta.

More detailed statistical data on paddy production by season are available. As shown in Figure 2.4.6, production of paddy in the Project area is in an increasing trend, notwithstanding some stagnation in area planted. In particular, summer-autumn production and winter-spring production have been increasing in the past two decades, while the production of autumn-winter paddy is in a decreasing trend. In fact, yield has been increasing for all the seasons' paddies including autumn-winter paddy. It means that the decline of the autumn-winter paddy production is due to the decrease of planted area.

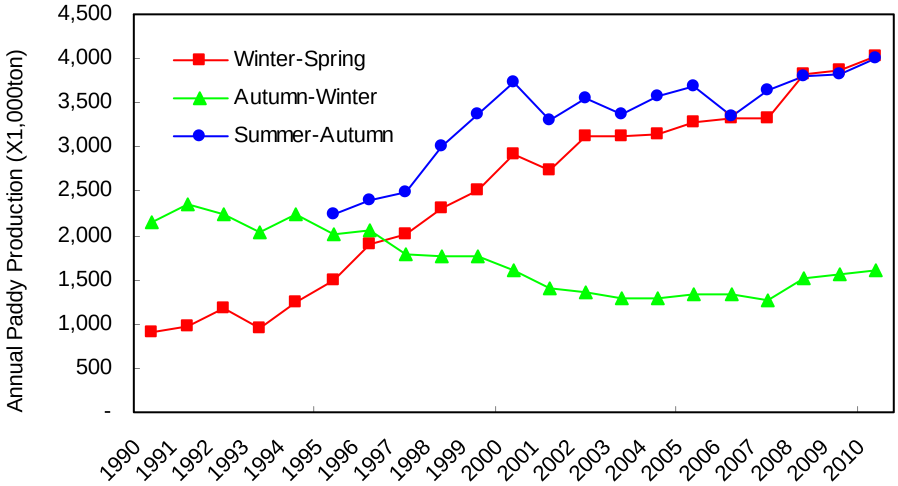


**Figure 2.4.6 Paddy Production in Coastal Seven Provinces**
Source: Statistical Year Book of Vietnam (1995-2011)

Figure 2.4.7 shows the yield of paddy for three different seasonal categories. All the three categories show basically increasing trends in the past two decades. Especially winter-spring paddy has kept the highest yield as compared to other two categories, which recorded 6.4 ton/ha in 2010 as an average of seven coastal provinces. General trend of increase in production is probably attributed mainly to the introduction of improved varieties and increase in the use of chemical fertilizer. A series of interviews made to some farmers revealed that about 200-400 kg/ha of chemical fertilizer is applied in the area, which is quite high level of application in accordance with an available standard[1].

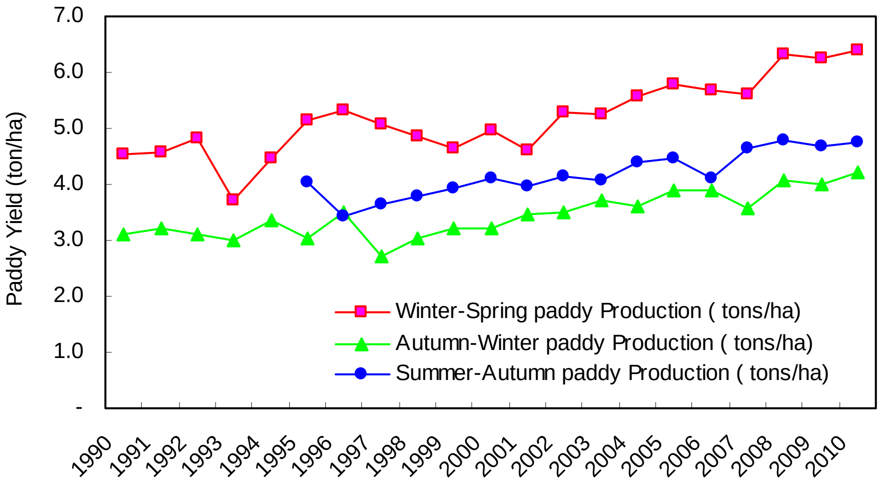


**Figure 2.4.7 Yield of Paddy in Coastal Seven Provinces**
Source: Statistical Year Book of Vietnam (1995-2011)

[1] In the Philippines, it is recommended to apply 275 to 300kg/ha of chemical fertilizer to achieve 5-6 ton/ha (Quick guide for fertilizing transplanted rice in Laguna, DA, PhiRice, OPAg, IRRI, May, 2009).

### 2.4.5 Farm Land Holding

Figure 2.4.8 summarizes the average farm production area per farm household (2006) and Figure 2.4.9 indicates the share of the farm household by the farm scale as compared with those of other regions of Vietnam. From Figure 2.4.8, it is known that the average farm production area in the Project area and also in the Mekong Delta is rather bigger than the national average. The averages are 1.21 ha and 1.20 ha for the Project area and Mekong Delta respectively while that of national level is only 0.81 ha. Among the provinces in the Projects area, Tien Giang and Ben Tre provinces show rather smaller average areas by 0.63 ha and 0.58 ha respectively while Kien Giang shows the biggest area, 2.49 ha.

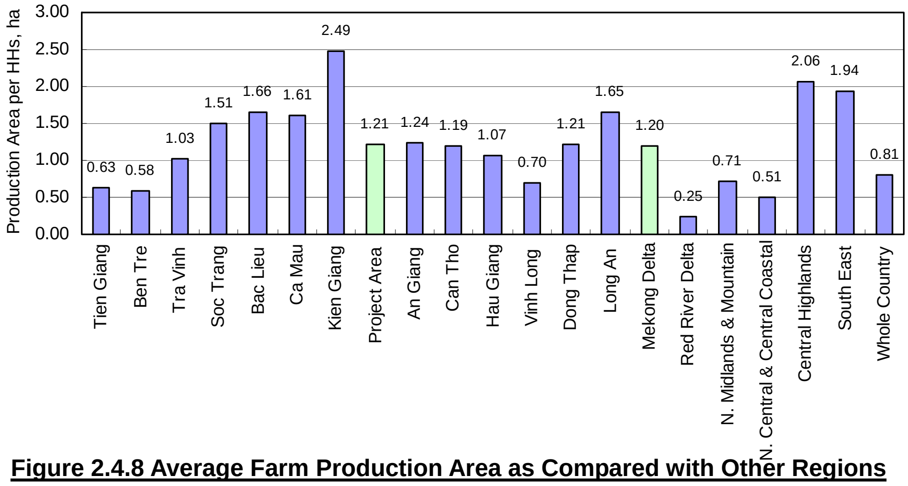


**Figure 2.4.8 Average Farm Production Area as Compared with Other Regions**

Source: Rural, Agricultural and Fishery Census, Data in 2006

With regard to the farm production area size, Tien Giang and Ben Tre provinces show that the share of the farm households whose lands are less than 0.2 ha comes to about a quarter percentage while the average share of the farm households in the Project area is about 19%. Note that Ca Mau province shows the highest share, 35%, in the households whose farm lands are less than 0.2 ha. However, the average farm production area of this Ca Mau is 1.61 ha, not small in the Project area. This may imply that few farmers may have very big farm lands, raising the average size despite the fact that there are many number of smallholder farmers. Bac Lieu and Kien Giang provinces show relatively bigger shares in the farm households whose production lands are more than 2.0 ha, resulting in rather bigger average farm land area.

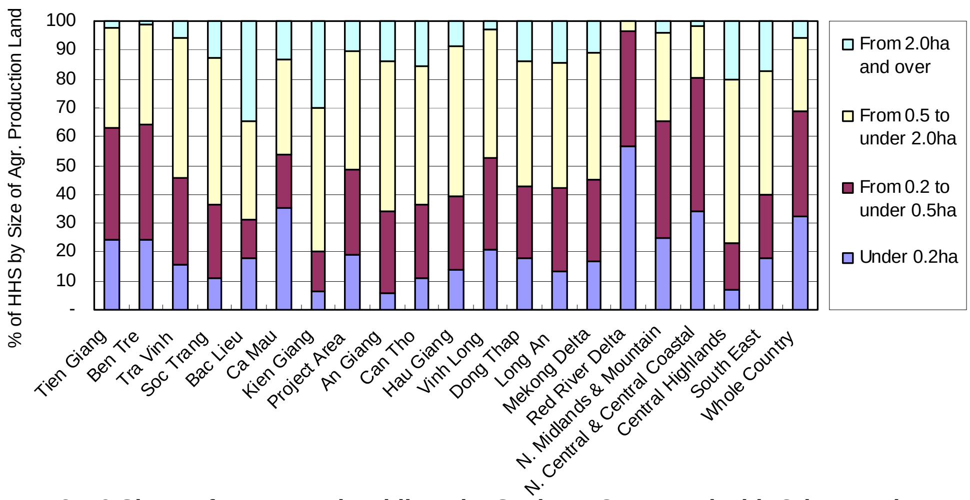


**Figure 2.4.9 Share of Farm Land Holdings by Scale as Compared with Other Regions**

Source: Rural, Agricultural and Fishery Census, Data in 2006

## 2.5 Aquaculture in the Project Area: Shrimp Culture

Aquaculture in the Mekong Delta has been a common aspect of daily life of the people, and in addition commercial aquaculture started rapidly developing in the mid to late 1980's with the introduction of Doi Moi. In the 1990's, the rapid expansion of shrimp farming received much attention from overseas but in recent years, various types of aquaculture system have developed for both the domestic and oversea markets. This sub-chapter discusses the aquaculture in the Project area as well as for the Mekong Delta.

### 2.5.1 Aquaculture Production by Province

Overall coastal areas of the Delta are characterized as brackish shrimp (Penaeus monodon) cultivation area under the condition that saline water intrusion takes place. In the coastal areas nearer to Ho Chi Minh (HCM) city, various types of cultivation systems are in operation. In Ben Tre and Tien Giang provinces, for example, the cultivation of mollusks such as clams (*Meretrix spp*) and blood cockles (*Anadara sp*) are becoming very significance.

On the other hand, freshwater aquaculture has flourished in the mid and upper parts of Mekong Delta. The upper parts of the Hau and Tien Rivers are becoming *Pangasius* cultivation areas. Initially in An Giang and Dong Thap provinces, the cultivation of Mekong catfish, *Pangasius spp*., was started in the late 1990's. The central parts of the Delta, such as Can Tho province, are introducing this export-oriented *Pangasius* cultivation but the areas placed under heavy floods still depend on other freshwater fish mostly for the domestic markets.

Table 2.5.1 summarizes the aquaculture production in the Mekong Delta as compared with other parts of the Country, and Figure 2.5.1 illustrates per-capita aquaculture production of fish and Figure 2.5.2 depicts the brackish shrimp aquaculture production. As is well illustrated, the aquaculture production of the Mekong Delta by far surpasses the production of other regions. In fact, the overall aquaculture production by Mekong Delta (1,940,181 tons) shares as much as 72% of the national production (2,706,752 tons).

**Table 2.5.1 Aquaculture Production (2010) in the Mekong Delta as Compared with Other Regions**

| Province/ Region | Aquaculture Production, ton | Per-capita Aquaculture Production, kg | Aquaculture Production of Fish, ton | Per-capita Aquaculture Production of Fish, kg | Aquaculture Production of Shrimp, ton | Per-capita Aquaculture Production of Shrimp,kg |
|---|---|---|---|---|---|---|
| Tien Giang | 120,188 | 72 | 87,925 | 52 | 12,833 | 7.7 |
| Ben Tre | 168,148 | 134 | 122,150 | 97 | 30,485 | 24.3 |
| Tra Vinh | 82,777 | 82 | 53,824 | 54 | 20,944 | 20.8 |
| Soc Trang | 98,493 | 76 | 37,490 | 29 | 60,830 | 46.8 |
| Bac Lieu | 143,725 | 166 | 65,370 | 75 | 68,003 | 78.4 |
| Ca Mau | 235,550 | 194 | 117,216 | 97 | 103,900 | 85.7 |
| Kien Giang | 97,673 | 57 | 46,637 | 27 | 34,765 | 20.4 |
| Project Area | 946,554 | 105 | 530,612 | 59 | 331,760 | 36.8 |
| An Giang | 279,773 | 130 | 276,941 | 129 | 916 | 0.4 |
| Can Tho | 172,360 | 144 | 172,331 | 144 | 22 | 0.0 |
| Hau Giang | 44,430 | 59 | 43,482 | 57 | 15 | 0.0 |
| Vinh Long | 135,181 | 132 | 135,089 | 132 | 16 | 0.0 |
| Dong Thap | 331,373 | 198 | 327,757 | 196 | 1,727 | 1.0 |
| Long An | 30,510 | 21 | 23,751 | 16 | 6,661 | 4.6 |
| Mekong Delta | 1,940,181 | 112 | 1,509,963 | 87 | 341,117 | 19.7 |
| Red River Delta | 406,280 | 21 | 309,573 | 16 | 16,422 | 0.8 |
| N. Midlands & Mountain | 67,909 | 6 | 65,673 | 6 | 367 | 0.0 |
| N. Central & Central Coastal | 177,397 | 9 | 86,725 | 5 | 71,292 | 3.8 |
| Central Highlands | 20,603 | 4 | 20,252 | 4 | 68 | 0.0 |
| South East | 94,382 | 5 | 67,379 | 4 | 21,030 | 1.2 |
| Whole Country | 2,706,752 | 31 | 2,058,465 | 24 | 450,364 | 5.2 |

Source: Statistical Year Book of Vietnam (2011)

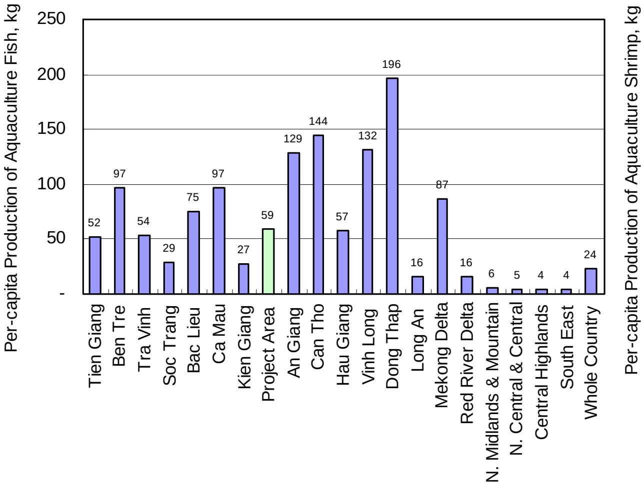


**Figure 2.5.1 Per-capita Production of Aquaculture Fish (2010)**

Source: Statistical Year Book of Vietnam 2010, GSO

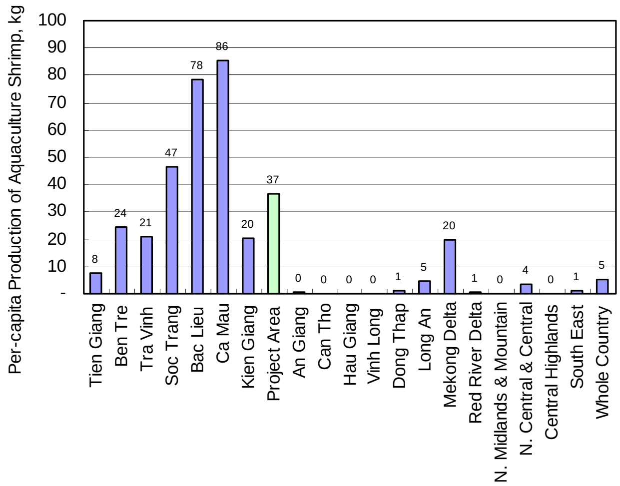


**Figure 2.5.2 Per-capita Production of Aquaculture Shrimp (2010)**

Source: Statistical Year Book of Vietnam 2010, GSO

With regards to the aquaculture production of fish, the intensive production areas can be seen in the upper-mid parts of Mekong Delta, and yet the Project area still produces total 530,612 tons of aquaculture fish. Per-capita production of aquaculture fish in the Project area is estimated at 59 kg as shown in the Figure 2.5.1, which is far bigger than the national per-capita production of 24 kg only. Note that the population employed in estimating the per-capita production is the total number of people in the respective provinces or regions (not the population engaged in the aquaculture).

As is well known, the aquaculture shrimp production in the Project area by far exceeds those of other regions including mid-upper parts of Mekong Delta. The total production of aquaculture shrimp in 2010 was 331,760 tons while that of national level was 450,364 tons. It means the Project area produced as much as 76%, three-quarters of the national production. Per-capita production of the aquaculture shrimp arrives at 36.8 kg while those of other provinces and regions remain less than 5 kg per capita only.

### 2.5.2 Shrimp Culture by Category

In the coastal area of Mekong Delta, a lot number of shrimp culture firms can be seen. Shrimp culture had started in the early 1970's in brackish water area. At that time, however, yield of the production was said to be only about 100 kg/ha with extensive farming method[2]. The shrimp production in Vietnam started increasing rapidly in 2000's in contrast to the black tiger shrimp production in Thailand. In Thailand, black tiger shrimp culture had become popular in mid 1980's, and in the 1990's the production had reached a peak. However, with devastative negative impacts on the natural environment, the Thai government had restricted the culture, and instead white leg shrimp has become popular.

As the production of Thai black tiger shrimp had decreased, the production of the black tiger in Vietnam started increasing on the contrary. The production of the black tiger shrimp in Vietnam started increasing since early 2000s as indicated in Figure 2.5.3. The production of black tiger shrimp in Vietnam has come to around 300,000 tons per annum in year 2008. Most of the production came from the coastal areas of Mekong Delta, which is the Project area. In recent years, white leg shrimp is cultivated in Vietnam but still the black tiger shrimp is the major species, unlike the trend in Thailand.

[2] R. E. Turner (1977); "Intertidal Vegetation and Commercial Yield of Penaeid Shrimp", Transactions of the American.

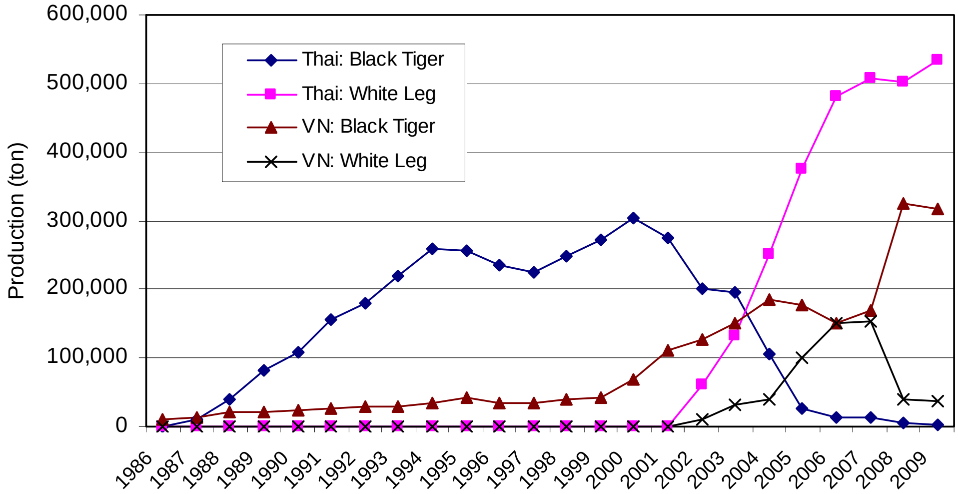


**Figure 2.5.3 Trend of Shrimp Production in Vietnam and Thailand**
Source: FAOSTAT (2011)

Shrimp culture in Vietnam is divided into two major categories: intensive and extensive, and those may further be divided into four: intensive, semi-intensive, improved extensive and extensive, although they have some variations. In the coastal Mekong Delta, intensive and semi-intensive shrimp culture shares only 10% in terms of the area cultivated as indicated in Figure 2.5.4; remaining one are all for extensive systems including improved extensive according to Research Institute for Aquaculture No.2[3].

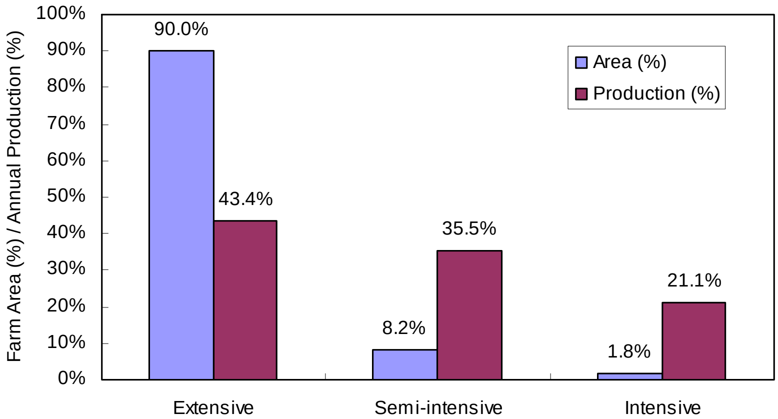


**Figure 2.5.4 Shares in Area Cultivated and Production of Shrimp by Category**
Source: The Status, Challenge and Perspective of Black Tiger Shrimp (Penaeus monodon) Farming in the Mekong Delta, Vietnam, Research Institute for Aquaculture No.2, MARD, 2008

Extensive system has less impact to environment, although it on the other hand results in quite low productivity. According to records by Research Institute for Aquaculture No.2[4], annual yield of the shrimp production under the extensive system is estimated at around 200-300kg/ha. On the other hand, production of the semi-intensive system reaches 1.5-3.0 ton/ha and the intensive system comes to as high as 5.0-7.0 ton/ha and even more.

As shown above, while the extensive system shares 90% of the total cultivated area in the Mekong Delta, it shares only 43% in terms of the production. On contrast, the semi-intensive system, which shares only 8.2% of the area, produces 35.5% of the production. Similarly, while the intensive system shares only 1.8% of the area, it produces 21.1% of the total production, that is, "intensive" systems produce nearly half of the production with only 10% of the land.

[3] The Status, Challenge and Perspective of Black Tiger Shrimp (Penaeus monodon) Farming in the Mekong Delta, Vietnam, Research Institute for Aquaculture No.2, MARD, 2008
[4] The Status, Challenge and Perspective of Black Tiger Shrimp (Penaeus monodon) Farming in the Mekong Delta, Vietnam, Research Institute for Aquaculture No.2, MARD, 2008

Today, Research Institute for Aquaculture No.2 recommends an improved extensive system, in which no food is applied and shrimps are cultivated in a low population density. For the food of shrimps, fertilizer is applied, which is to increase the population of planktons in the water as a food for shrimp. In this system, deterioration of water quality is rarely observed whereby environment is kept sound.

### 1) Extensive Shrimp Culture

In extensive system, post larvae are released at a low density of abut 1-2 shrimp only per square meter. There is no clear production cycle for the extensive system. Instead, shrimp is periodically harvested, once a month for example, and at this time, small shrimps are released into the pond. Post larvae are also released periodically to supplement the deficit caused by the harvest. As those arrangements are done periodically and with no concrete measurement, actual population density is hardly monitored.

Extensive shrimp cultivation system is sometimes combined with paddy production. In this kind of system, shrimp is cultivated only in the dry season when saline intrusion takes place. In this system, as the period available for shrimp culture is limited, post larvae are released only one time at the beginning of the dry season in most cases. After they have harvested the shrimp at end of dry season, they usually leave the farm land for two to two and half months during the early rainy season. The farm plots where salt has been accumulated with shrimp culture are therefore washed by rainfall, becoming ready for paddy cultivation.

According to some interviews made to shrimp farmers[5], costs of fertilizer and post larvae shares a range of about 30% of the total expenditure. By subtracting the cost from the sale, farmers can fetch net profit of about 20 million VND to 40 million VND per ha from this extensive shrimp culture. This net profit of 20 to 40 million VND is about the same to twice as much as what one hector of paddy cultivation can fetch in net profit. Thus, if no disease occurs, shrimp culture even if it is extensive one can be more profitable than paddy production.

### 2) Intensive and Semi-intensive Shrimp Culture

As for the intensive shrimp culture systems, it is recommended by Research Institute for Aquaculture No.2 to do only one time cultivation per year. However, it was revealed that many shrimp farmers do twice per year for more income earning. According to the Institute, the intensive culture requires quite a high investment for feeds, purification of polluted water, and replacement of dead shrimps, and thus more farmers run for the semi-intensive system, which require relatively low investment.

Typical profiles of semi-intensive and intensive systems are summarized in Table 2.5.2 in comparison with those of extensive shrimp culture. As shown in the table, for the intensive systems, investment cost shares 40-60% of gross income, in which the cost of feed shares the most (usually a range of about 70% of total cost). The net profits for the semi-intensive and intensive are in fact quite high as exampled by a comparison with the net profit of extensive culture; about 3 times more for the case of semi-intensive and more than 10 times or even over 30 times in case of intensive culture depending on the level of the intensiveness.

**Table 2.5.2 Typical Profile of Semi-Intensive and Intensive Systems**

| Category | Initial Population Density | Average Yield | Gross Income, VND/ha | Net Profit, VND/ha |
|---|---|---|---|---|
| Semi-Intensive | 10 – 15 shrimps/m$^2$ | 1.5 – 3.0 ton/ha | 175 – 500 million | 75 – 100 million |
| Intensive | 20 – 30 shrimps/m$^2$ | 5.0 – 7.0 ton/ha | 600 – 1,200 million | 325 – 650 million |
| Extensive | 1 – 2 shrimps/m$^2$ | 200 – 300 kg/ha | 30 – 60 million | 20 – 40 million |

Source: The Status, Challenge and Perspective of Black Tiger Shrimp (Penaeus monodon) Farming in the Mekong Delta, Vietnam, Research Institute for Aquaculture No.2, MARD, 2008, Interviews to Shrimp Culture Farmers

[5] The interviewees were conducted in August and September in 2011 to 20 shrimp culture farmers in Ca Mau, Bac Lieu, Soc Trang, Ben Tre provinces.

## 2.6 Household Economy by Questionnaire Survey

Household questionnaire survey was conducted targeting different livelihood farmers, mainly paddy cultivation farmers, fruit cultivation farmers and shrimp cultivation farmers including shrimp-paddy rotational cultivation. The survey was carried out as follows in years 2011 and 2012, and their household economy from the major livelihood is examined in this sub-chapter;

**Table 2.6.1 Summary of Farmers Household Economy Questionnaire Survey**

| Major Livelihood | Sample No. | Remarks |
|---|---|---|
| Paddy farmers (1st questionnaire)<br>Paddy farmers (2nd questionnaire) | 68<br>50<br>(total 118) | Carried out in Ben Tri district of Ben Tre province and Cang Long district of Tra Vinh province for the 1st questionnaire.<br>For those farmers who are to resettle by May Phop canal extension project in Tra Vinh province for the 2nd questionnaire. |
| Fruit farmers | 100 | Carried out in Tien Giang (72 samples) and Ben Tre (28 samples) provinces, totaling 100 samples |
| Shrimp farmers | 281 | 6 villages covering shrimp mono-culture (extensive, improved extensive, semi-intensive) and shrimp-paddy rotation culture. |

Source: JICA Project Team

### 2.6.1 Paddy Farmers' Household Economy

Economic nature of paddy cultivation by typical household was identified based on the sampled data. First of all, average data for area harvested, production, farm gate price, and gross income were estimated based only on valid data that have complete information for area, production and cost, that is, such data that lack either one of those information had been omitted from the estimation. For example, any sample which have cost data without production data were not included. Based on a total of 139 paddy production valid data[6], weighted average of all the information had been calculated.

### 1) Paddy Production and Gross Income

As shown in Table 2.6.2, the average size of area harvested per season per farmer was 0.74 ha, which accounts only for 47% of the entire farm plot per household (1.57ha/HH). The size of paddy field does not change much by cropping season (0.73ha to 0.76ha). In this size of paddy field, an average of 4.86 ton/ha of production were harvested, in which the highest yield was marked in Summer-Autumn season (5.39 ton/ha), while the lowest was during Autumn-Winter season (4.27 ton/ha). This yield tendency by season is a little different from overall trend of entire Project area where Winter-Spring paddy shows the highest yield (see Figure 2.4.7). The W-S paddy yield for the sampled households came second after that of S-A paddy, due probably to effect of saline intrusion, water shortage, etc.

**Table 2.6.2 Production and Estimated Gross Income from Paddy Cultivation per Season per Household**

| Cropping Season | Area Harvested | Yield | Production | For Seed | For Selling | For Home | Farm Gate Price | Gross Income (Financial) | Gross Income (Economic) |
|---|---|---|---|---|---|---|---|---|---|
| | (ha) | (ton/ha) | (kg) | (kg) | (kg) | (kg) | (VND/kg) | (VND) | (VND) |
| SA Paddy | 0.74 | 5.39 | 3,974 | 69 | 3,541 | 364 | 6,365 | 21,480,000 | 24,125,000 |
| AW Paddy | 0.76 | 4.27 | 3,256 | 26 | 2,662 | 568 | 6,591 | 17,961,000 | 21,933,000 |
| WS Paddy | 0.73 | 4.79 | 3,483 | 38 | 2,971 | 474 | 6,398 | 18,940,000 | 22,202,000 |
| **Total. Ave.** | **0.74** | **4.86** | **3,596** | **46** | **3,088** | **462** | **6,445** | **19,588,000** | **22,838,000** |
| | | | **100%** | **1%** | **86%** | **13%** | | | |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: Income was estimated as a weighted average, not by the horizontal calculation in the table.
SS (Spring-Summer) Paddy was excluded from the data as it has only one valid sample
Total average was estimated based on the weighted average of all the valid data, not the average of above figures
Financial: Based on the amounts which were sold out. Economic: Based on the amounts which were produced.

6 Since a farmer paddy household produces 2 – even 3 times paddies, the valid data set of paddy is larger than the number of farm households.

As per season per household, an average of 3,596 kg of paddy per season were produced, of which 3,088 kg, or 86% of the production, were sold out; 46 kg (1%) were kept as seeds for next season; and 462 kg (13%) were consumed at home. A weighted average of farm gate price of paddy was 6,445 VND/kg ranging from 6,365VND/kg for S-A paddy to 6,591VND/kg for A-W paddy. Based on the production and price data, gross cash income from selling (referred to as 'financial value') and from production (referred to as 'economic value') were estimated[7]. The estimated average gross income in financial value (from selling) per one cropping season was 19,588,000 VND/household, and the gross income in economic value (from entire production) was found at 22,838,000 VND/household.

Note that above production data are as per paddy season and not for as per household since typical paddy farmer household cultivates paddy at least 2 times a year and sometimes even 3 times per year. Table 2.6.3 summarizes how many times typical paddy farmers cultivate paddy. Out of the 68 valid samples, 55 samples cultivate 3 times paddy per year (81%), 10 samples do 2 times paddy per year (15%), and the rest of 3 samples do only one-time paddy cultivation. It means an average typical paddy farmers cultivate as many as 2.76 times paddy cultivation in a year, composed of 0.88 times for S-A paddy, 0.93 times for A-W paddy and 0.96 times for W-S paddy.

**Table 2.6.3 Paddy Cropping by Season per Farmer**

| Total No. of Samples | 3 Cropping | 2 Cropping | | | | 1 Cropping | | | | G. Total | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA+AW+WS | SA+AW | AW+WS | WS+SA | Total | SA | AW | WS | Total | | |
| 68 | 55 | 0 | 8 | 2 | 10 | 3 | 0 | 0 | 3 | 68.0 | 2.76 |
| 100% | 81% | 0% | 12% | 3% | 15% | 4% | 0% | 0% | 4% | 100% | |
| SA | 55 | | | 2 | 2 | 3 | | | 3 | 60 | 0.88 |
| AW | 55 | | 8 | | 8 | | | | 0 | 63 | 0.93 |
| WS | 55 | | 8 | 2 | 10 | | | | 0 | 65 | 0.96 |
| | | | | | | | | | | Total | 2.76 |

Source: Questionnaire Household Survey, JICA Study Team (2011)

Given the paddy cropping data per year by a typical average paddy farmer, Table 2.6.4 examines how much annual production is produced and how much gross incomes are generated by a typical average paddy farmer who cultivate 2.76 times paddy per year. The typical average farmer cultivates a total of 2.05 ha of paddy, out of which total 9,943 kg is produced and 54 million VND in financial term and 63 million in economic term are generated.

**Table 2.6.4 Production and Estimated Gross Income from Paddy Cultivation per Year per Farmer**

| Cropping Season | Cropped Area | Yield | Production | For Seed | For Selling | For Home | Farm Gate Price | Gross Income (Financial) | Gross Income (Economic) |
|---|---|---|---|---|---|---|---|---|---|
| | (ha) | (ton/ha) | (kg) | (kg) | (kg) | (kg) | (VND/kg) | (VND) | (VND) |
| SA Paddy | 0.65 | 5.39 | 3,506 | 61 | 3,124 | 321 | 6,365 | 18,952,941 | 21,286,765 |
| AW Paddy | 0.71 | 4.27 | 3,019 | 24 | 2,466 | 526 | 6,591 | 16,640,338 | 20,320,279 |
| WS Paddy | 0.69 | 4.79 | 3,328 | 36 | 2,840 | 453 | 6,398 | 18,104,412 | 21,222,500 |
| **Total. Ave.** | **2.05** | **4.86** | **9,943** | **127** | **8,537** | **1,277** | **6,445** | **54,155,059** | **63,140,353** |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: Refer to Table 2.6.2.

Table 2.6.5 shows same data set as above-mentioned but on basis of unit 1.0 ha area, which will be referred to in carrying out economic analysis for a project targeting paddy production area. One (1) ha of paddy field produces an average of 4,859 kg of paddy ranging from 4,266 kg for A-W paddy to 5,309 kg for S-A paddy. With the prevalent farm gate prices, gross income per hector in financial term arrives at 26 million VND ranging from 23 – 29 million VND while the gross income in economic term comes to 31 million VND ranging from 29 – 33 million VND.

[7] Note that the gross incomes indicated in the table were not calculated by a simple multiplication of averaged price and production but the average of individual data.

**Table 2.6.5 Production and Estimated Gross Income from Paddy Cultivation per 1.0 ha**

| Cropping Season | Area Harvested | Yield | Product'n | For Seed | For Selling | For Home | Farm Gate Price | Gross Income (Financial) | Gross Income (Economic) |
|---|---|---|---|---|---|---|---|---|---|
| | (ha) | (ton/ha) | (kg) | (kg) | (kg) | (kg) | (VND/kg) | (VND) | (VND) |
| SA Paddy | 1.00 | 5.39 | 5,390 | 94 | 4,803 | 494 | 6,365 | 29,134,540 | 32,722,103 |
| AW Paddy | 1.00 | 4.27 | 4,266 | 34 | 3,488 | 744 | 6,591 | 23,533,518 | 28,737,857 |
| WS Paddy | 1.00 | 4.79 | 4,792 | 52 | 4,088 | 652 | 6,398 | 26,060,417 | 30,548,752 |
| **Total. Ave.** | **1.00** | **4.86** | **4,859** | **62** | **4,173** | **624** | **6,445** | **26,470,270** | **30,862,162** |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: Refer to Table 2.6.2.

### 2) Cost of Labor/Outsourcing and Input for Paddy Cultivation per Cropping Season

Table 2.6.6 summarizes an average total cost of labor and out-sources for paddy cultivation based on a total of 82 valid responses. In the table, cost was estimated based on simple average of all the 82 samples item by item, some of which may have no disbursement at all. As a result, cost of such items that farmers rarely disburse became to be smaller than usually disbursed; for example, cost of "soil pudding" was approximately 765,000 VND for those who actually out-sourced it, while the average cost of all the responses came to 9,329 VND, suggesting less farmers out-sourced soil pudding.

For comparison, "typical cost" of the table shows an average of only the responses that have actual disbursement (excluding zero value) with the number of responses which have values more than zero. It should also be noted that there are multiple items used for establishment of paddy: "seeding (broadcast), seeding (in row) and transplanting. It does not mean that the model farmer disburses for all the three items, but maybe one or two items of them. Therefore the table indicates typical averaged picture of entire respondents.

**Table 2.6.6 Labor and Outsourcing Costs for Paddy Cultivation per Household**

| Item | Cost (VND) | % | Typical Cost (Reference) | No. of Responses |
|---|---|---|---|---|
| Land Cleaning | 346,098 | 3.9% | 1,351,429 | 21 |
| **Plowing** | **1,530,195** | **17.0%** | 1,872,776 | 67 |
| Saline Leaching | 7,805 | 0.1% | 640,000 | 1 |
| Soil Pudding | 9,329 | 0.1% | 765,000 | 1 |
| *Seeding (broadcast)* | 695,144 | 7.7% | 1,540,589 | 37 |
| *Seeding (in row)* | 301,476 | 3.4% | 1,648,067 | 15 |
| *Transplanting* | 121,951 | 1.4% | 3,333,333 | 3 |
| Fertilizer Application | 191,512 | 2.1% | 3,140,800 | 5 |
| Pesticide/fungicide Application | 49,390 | 0.5% | 810,000 | 5 |
| Herbicide Application | 8,902 | 0.1% | 243,333 | 3 |
| Weeding | 140,244 | 1.6% | 1,045,455 | 11 |
| **Harvesting** | **3,600,841** | **40.1%** | 3,645,296 | 81 |
| Threshing | 789,512 | 8.8% | 1,471,364 | 44 |
| **Transporting (farm to dry yard)** | **934,024** | **10.4%** | 1,781,163 | 43 |
| Drying/ packing | 30,488 | 0.3% | 625,000 | 4 |
| Transporting (dry yard to market) | 10,976 | 0.1% | 300,000 | 3 |
| Water Fee | 201,311 | 2.2% | 1,500,682 | 11 |
| Land Tax | 16,098 | 0.2% | 660,000 | 2 |
| **Total Cost of Labor/Out Source (Rounded)** | **8,985,000** | **100.0%** | | **82** |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: Cost of each item represents the average of all the responses including those which were not born (zero value)
Instead, typical cost shows the average of only those which were actually born excluding zero value.
Only total cost is rounded to the nearest thousand.
"No. of responses" shows the number of responses that have values more than zero, which were applied to estimate "typical cost."

Now, the total cost for labor and out-sources was estimated on average 8,985,000 VND per cultivation per paddy farmer based on a total of 82 valid responses. As of the share of each item to the total cost of labor and out-sourcing, cost of harvesting shares the most with 3,600,841 VND or 40.1% of the total cost, which is followed by plowing with 1,530,195 VND (17.0%) and transporting from farm to dry yard (10.4%). Those three items share 67% of the total labor and out-sources cost as a simple average of 82 responses.

Table 2.6.7 summarizes the average cost of inputs applied to paddy cultivation by cropping season per farmer. As shown in the table, there are a total of five main types of inputs used for paddy cultivation: urea, compound, compost, pesticide/fungicide, and herbicide. As a whole, the total cost of inputs was averaged to be 4,117,000 VND per cultivation ranging from 3,686,000 VND of W-S paddy to 4,479,000 VND of A-W paddy. Among all, the cost of urea shared 51% of the total input costs (2,081,000 VND). The second biggest cost was compost (20%).

In the Mekong Delta, it is common to cultivate paddy twice or even three times a year, leading to a higher risk on deterioration of soil condition. In this setting, one of the issues that enable the rice cultivation sustainable is the periodical flood that brings necessary nutrition to the paddy field (30% of the valid responses receives periodical flood according to the questionnaire survey). In addition, it was found that farmers use compost for paddy cultivation—implying that farmers already recognize the difficulty in continuing paddy cultivation without application of organic matters.

**Table 2.6.7 Cost of Inputs for Paddy Cultivation per Household**

| Cropping Season | Urea | Compound | Compost | Pesticide/ Fungicide | Herbicide | Total Cost of Input | Cost of Labor & Outsource | Total Cost for Production |
|---|---|---|---|---|---|---|---|---|
| | (VND) | (VND) | (VND) | (VND) | (VND) | (VND) | (VND) | (VND) |
| SA Paddy | 2,071,000 | 654,000 | 822,000 | 385,000 | 252,000 | 4,184,000 | 8,985,000 | 13,169,000 |
| AW Paddy | 2,372,000 | 763,000 | 858,000 | 290,000 | 197,000 | 4,479,000 | 8,985,000 | 13,464,000 |
| WS Paddy | 1,808,000 | 649,000 | 753,000 | 290,000 | 186,000 | 3,686,000 | 8,985,000 | 12,671,000 |
| **Average** | **2,081,000** | **686,000** | **811,000** | **325,000** | **214,000** | **4,117,000** | **8,985,000** | **13,102,000** |
| | **51%** | **17%** | **20%** | **8%** | **5%** | **100%** | | |
| | **16%** | **5%** | **6%** | **2%** | **2%** | **31%** | **69%** | **100%** |

Source: Questionnaire Household Survey, JICA Study Team (2011)

As already shown in Table 2.6.7, a total cost of paddy production was estimated by cropping season, although the cost of labor was estimated by common data applicable to all the cropping seasons. The total amount was found 13,102,000 VND on average, ranging from 12,671,000 VND of W-S paddy to 13,464,000 VND of A-W paddy. The difference among the cropping seasons was caused probably by the amount of inputs applied, or it is just within a range of error.

Among the total cost, cost of labor and outsourcing shares 69% (see the bottom raw of the Table 2.6.7), while the cost of inputs shares 31%. Large portions of labor works are already mechanized in the area, but if the cost of labor would increase in future, cost structure of paddy cultivation would largely be affected. In fact, share of agriculture sector in the labor force structure of the Mekong Delta had lost 7% in 2011, which in turn shifted into industry (+3.5%) and services (+3.5%) due to the structural change of the economy.[8]

### 3) Net Income from Paddy Cultivation

Estimated net income from paddy cultivation per season is summarized in Table 2.6.8 based on a total of 139 valid responses. As shown in the table, with the gross cash incomes and also the total cost of production aforementioned, net income per season per farmer is now estimated at 6,486,000 VND at financial value and 9,736,000 VND at economic value based on an average area of 0.74 ha. If the

[8] "The economic transition and migration of Vietnam and the Mekong Delta region (December 2011)" http://mpra.ub.uni-muenchen.de/36387/1/MPRA_paper_36387.pdf. In the reference, it was mentioned that structural change in labor force was however much milder than the change in the share of agriculture in GDP.

economic income is converted into the value for the unit 1.0 ha paddy area, the net income comes to 13,122,000 VND ranging from about 11 million VND to 15 million VND by season.

**Table 2.6.8 Estimated Net Income from Paddy Cultivation per Season per Farmer**

| Cropping Season | Area Harvested | Gross Cash Income (Financial) | Gross Cash Income (Economic) | Total Cost | Total Net Income (Financial) | Total Net Income (Economic) | Total Net Income/ ha (Economic) |
|---|---|---|---|---|---|---|---|
| | (ha) | (VND) | (VND) | (VND) | (VND) | (VND) | **(VND)** |
| SA Paddy | 0.74 | 21,480,000 | 24,125,000 | 13,169,000 | 8,311,000 | 10,956,000 | **14,860,000** |
| AW Paddy | 0.76 | 17,961,000 | 21,933,000 | 13,464,000 | 4497000 | 8,469,000 | **11,097,000** |
| WS Paddy | 0.73 | 18,940,000 | 22,202,000 | 12,671,000 | 6269000 | 9,531,000 | **13,114,000** |
| Total. Ave. | **0.74** | **19,588,000** | **22,838,000** | **13,102,000** | **6,486,000** | **9,736,000** | 13,122,000 |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: SS Paddy had only one valid sample; therefore, it was excluded from the calculation.
Total average was estimated based on the weighted average of all the valid data, not the average of above figures.
Financial: Based on the amounts which are sold out.
Economic: Based on the amounts which are produced.

Table 2.6.9 estimates the net income from paddy cultivation per year per typical average farmer. As shown in the table where a typical average farmer cultivates a total area of 2.05 ha by an average of 2.76 cultivations per year, the farmer generates about 54 million VND and 63 million VND in financial and economic terms respectively. Subtracting the cost for the 2.76 times paddy cultivation of about 36 million VND, net income per year per farmer arrives at 17,901,000 VND in financial term and 26,871,000 VND in economic term.

**Table 2.6.9 Estimated Net Income from Paddy Cultivation per Year per Farmer**

| Cropping Season | Area Harvested | Gross Cash Income (Financial) | Gross Cash Income (Economic) | Total Cost | Total Net Income (Financial) | Total Net Income (Economic) | Remarks |
|---|---|---|---|---|---|---|---|
| | (ha) | (VND) | (VND) | (VND) | (VND) | (VND) | |
| SA Paddy | 0.65 | 18,952,941 | 21,286,765 | 11,619,706 | 7,333,235 | 9,667,059 | |
| AW Paddy | 0.71 | 16,640,338 | 20,320,279 | 12,474,000 | 4,166,338 | 7,846,279 | |
| WS Paddy | 0.69 | 18,104,412 | 21,222,500 | 12,111,985 | 5,992,426 | 9,110,515 | |
| **Total. Ave.** | **2.05** | **54,063,000** | **63,033,000** | **36,162,000** | **17,901,000** | **26,871,000** | |

Source: Questionnaire Household Survey, JICA Study Team (2011)
Note: Refer to Table 2.6.8.
Note: Total average was estimated based on the weighted average of all the valid data, not the average of above figures.
Financial: Based on the amounts which are sold out.
Economic: Based on the amounts which are produced.

### 2.6.2 Shrimp Farmers' Household Economy

A household questionnaire survey had been carried out for shrimp culture in a total of six villages (communes) of three provinces namely Ca Mau, Bac Lieu, and Soc Trang. There were a total of 147 valid responses that maintained complete data for both farmland area and cost of production. According to the farmers' responses, the questionnaire survey found out there are such 4 categories of shrimp culture as extensive, extensive (shrimp-paddy; SP), improved extensive, and semi-intensive.

The three categories, aside from extensive (shrimp-paddy; SP), of extensive, improved extensive and semi-intensive were in fact reported by farmer themselves based on their own definition. Generally speaking, extensive culture means that it does not provide artificial feed but most of the cases in fact provided it at least to some extent, and as expected almost all the improved extensive cases did so. Thus, since the category is very much dependent on the farmers' perspective and most of the both cases provided artificial feed, there is in fact not much difference between the two categories of extensive and improved extensive in the answers of the questionnaire.

#### 1) Area Cultivated

Table 2.6.10 summarizes average sizes of farmland dedicated for shrimp culture per household by type of aquaculture. As an overall average of all types of culture, area per household reached 2.0 ha/household. Of the total responses, 137 responses were given to brackish shrimp culture with the average size of 2.0 ha/household. For freshwater shrimp culture and the rotation of brackish and fresh cultures, responses were only three (1.3 ha/household) and seven (2.0 ha/household) respectively.

**Table 2.6.10 Area of Farmland per Household by Type of Aquaculture**

| Category | Brackish | | Fresh | | Brackish and Fresh | | Total Average | |
|---|---|---|---|---|---|---|---|---|
| | Area (ha/HH) | No. of Samples | Area (ha/HH) | No. of Samples | Area (ha/HH) | No. of Samples | Area (ha/HH) | No. of Samples |
| Extensive | **3.8** | 14 | | | | | 3.8 | 14 |
| Extensive (SP) | **1.5** | 38 | 1.3 | 3 | 2.0 | 6 | 1.6 | 47 |
| Improved Extensive | **1.9** | 30 | | | | | 1.9 | 30 |
| Semi Intensive | **1.7** | 55 | | | 1.8 | 1 | 1.7 | 56 |
| **Average** | **2.0** | **137** | **1.3** | **3** | **2.0** | **7** | **2.0** | **147** |

Source: Questionnaire Shrimp Survey, JICA Study Team (2012)
Note: Samples were selected only from the ones which have cost data.

## 2) Gross Income from Shrimp Culture

Amount of production and gross income from shrimp culture became available for brackish culture (for fresh culture, however, enough number of responses was not obtained). As shown in Table 2.6.11, an average production of shrimp was found 768 kg/household with a total of 126 valid responses, for which complete set of production and cost data including items are available, ranging from 307 kg/household for extensive (SP) to 1,030 kg/household for semi-intensive cultures.

An average unit price was 158,000 VND/kg, which also ranged from 144,000 VND/kg for semi-intensive to 183,000 VND/kg for extensive cultures; the average unit price for extensive system was higher than that of semi-intensive system. It was partly, if not all, caused by the size of shrimp. For extensive system, average number of shrimp per kg was 31 shrimps as compared to 40 shrimps for semi-intensive—size of individual shrimps is bigger than that of semi-intensive. Then, an average size of shrimp was found 35 shrimp/kg.

As a result, an average gross income reached 129,778,000 VND/household (2.0 ha/household), which actually ranged from 54,202,000 VND/household for extensive (SP) to 187,057,000 VND/household for extensive. Although the level of gross income for extensive culture is bigger than other categories, it basically attributes to the bigger size of its aquaculture land, 3.8 ha/household being much bigger that the others ranging from 1.5 to 1.9 ha/household. In fact, an average gross income per hectare for extensive system was not so much higher than the others. Instead, it was the highest for semi-intensive culture, 101,642,000 VND/ha. As a total average of all categories, an average gross income per hectare reached 64,968,000 VND/ha.

**Table 2.6.11 Production and Gross Income from Brackish Shrimp Culture**

| Category | Brackish | | | | | | |
|---|---|---|---|---|---|---|---|
| | Production (kg) | Unit Price (000VND/kg) | Size (shrimp/kg) | Gross Income (000VND) | No. of Samples | Farmland (ha/HH) | Gross Income/ha (000VND) |
| Extensive | 981 | 183 | 31 | 187,057 | 14 | 3.8 | 48,950 |
| Extensive (SP) | 307 | 163 | 33 | 54,202 | 38 | 1.5 | 36,486 |
| Improved Extensive | 867 | 156 | 31 | 141,088 | 30 | 1.9 | 73,791 |
| Semi Intensive | 1,030 | 144 | 40 | 169,112 | 44 | 1.7 | 101,642 |
| **Total/Average** | **768** | **158** | **35** | **129,778** | **126** | **2.0** | **64,968** |

Source: Questionnaire Shrimp Survey, JICA Study Team (2012)

## 3) Cost of Production

Cost of brackish shrimp culture is summarized in Table 2.6.12. As shown in the table, an average cost of shrimp production was found 56,424,000 VND/household for an average farm size of 2.0

ha/household. It actually ranged from 15,506,000 VND/household for extensive (SP) to 82,543,000 VND/household for semi-intensive culture. Among all the main cost items, the biggest portion was shared by food (34%), which was followed by 19% of the larvae (baby/egg) and others (20%). Note that, however, a couple of samples accounted all the cost for "others" as some shrimp farmers could not specify the cost items, leading the average cost of "others" to be bigger than what it actually is.

In terms of the cost per unit area, the total average reached 30,083,000 VND/ha, ranging from 9,517,000 VND/ha for extensive (SP) to 45,250,000 VND/ha for semi-intensive. The cost of semi-intensive, which is the highest one, is therefore corresponding to about as 4 - 5 times high as that of extensive (SP) shrimp culture which is the lowest one. In general, the more the intensity of the system is, the higher the cost of production is as well expected.

**Table 2.6.12 Cost of Production for Brackish Shrimp Culture**

| Category | Cost of Brackish Shrimp Culture (000VND/Household) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baby/egg | Medicine | Food | CaCO3 | Labor | Fertilizer | Others | Total | No. of Sample | Shrimp Area (ha/HH) | Cost Per ha |
| Extensive | 9,400 | 10,471 | 42,979 | 1,807 | 6,514 | 1,271 | 2,171 | 74,614 | 14 | 2.65 | 28,118 |
| Extensive (SP) | 7,028 | 716 | 3,113 | 1,259 | 1,559 | 1,057 | 775 | 15,506 | 44 | 1.63 | 9,517 |
| Improved Ext. | 13,303 | 2,867 | 32,183 | 2,237 | 5,633 | 1,400 | 1,567 | 59,191 | 30 | 1.92 | 30,850 |
| Semi-Intensive | 12,853 | 18,944 | 19,503 | 1,316 | 1,500 | 2,043 | 26,384 | 82,543 | 56 | 1.82 | 45,250 |
| **Total/ Average** | **10,831** | **9,201** | **19,419** | **1,538** | **2,867** | **1,533** | **11,035** | **56,424** | **144** | **1.88** | **30,083** |
| | **19%** | **16%** | **34%** | **3%** | **5%** | **3%** | **20%** | **100%** | | | |

Source: Questionnaire Shrimp Survey, JICA Study Team (2012)

### 4) Net Income from Shrimp Culture

Based on average gross income and cost of production for brackish shrimp culture, net income is estimated as shown in Table 2.6.13. First, net income per household is summarized on the left side of the table, and net income per hectare is shown on the right side of the table. An averaged net income per household was found 73,354,000 VND/household with an average area of 2.0 ha/household. The net income ranged from 38,696,000 VND/household for extensive (SP) culture to 112,443,000 VND/household for extensive culture. Note that its highest net income for the extensive cultivation is, as aforementioned, attributed to the largest area of the shrimp pond (3.8 ha/household while others are 1.5 - 1.9 ha/farmer)

**Table 2.6.13 Net Income from Brackish Shrimp Culture**

| Category | Net Income per Household (000VND) | | | | Net Income per Hectare (000VND) | | | | % of Cost |
|---|---|---|---|---|---|---|---|---|---|
| | Gross Income | Total Cost | Net Income | No. of Sample | Area of Shrimp (ha/HH) | Gross Income | Total Cost | Net Income | |
| Extensive | 187,057 | 74,614 | 112,443 | 14 | 3.8 | 48,950 | 19,525 | 29,425 | 40% |
| Extensive (SP) | 54,202 | 15,506 | 38,696 | 38 | 1.5 | 36,486 | 10,438 | 26,048 | 29% |
| Improved Ext. | 141,088 | 59,191 | 81,897 | 30 | 1.9 | 73,791 | 30,957 | 42,834 | 42% |
| Semi Intensive | 169,112 | 82,543 | 86,569 | 44 | 1.7 | 101,642 | 49,611 | 52,031 | 49% |
| **Average** | **129,778** | **56,424** | **73,354** | **126** | **2.0** | **64,968** | **28,246** | **36,722** | 43% |

Source: Questionnaire Shrimp Survey, JICA Study Team (2012)

In terms of net income per hectare, the total average reached 36,722,000 VND/ha. It ranged from 26,048,000 VND/ha for extensive (SP) to 52,031,000 VND/ha for semi-intensive. Since the net income of extensive (SP) is a part of total income (additional income is expected from paddy cultivation), it may be natural to be lower than the others. In between the lowest net income (extensive, SP) and the highest net income (semi-intensive), there is about 2 times difference. As for the share of the cost against the gross income, it ranged from 29% to 49 % with the average of 43%.

## 2.6.3 Fruit Farmers' Household Economy

A household questionnaire survey had been carried out in late 2011 for fruit culture in a total of eight villages (communes) of five districts under two provinces of Ben Tre and Tien Giang. There are a total of 100 samples (households), for which such data as area cultivated, quantity and kind of fruit trees, production, farm gate price, and gross income and cost were interviewed.

### 1) Fruits Produced and Fruit Farmers

Average size of fruit cultivated area per household came to 0.64 ha, and 91% of the valid responses have fruit farm area less than 1 ha. As shown in Table 2.6.14, relatively large numbers of fruit farmers cultivated sapodilla, durian, rambutan, longan and star apple by its order. The average number of trees per farmer is 82 trees regardless of what fruit trees are cultivated. Note that since farmers who cultivate pomelo (3), bellfruit (1) and mandarin (1) answered only the kind of fruits and number of trees but not other questionnaire items, those relevant data were omitted from the following analysis;

**Table 2.6.14 No. of Farmers and No. of Trees by Fruit**

| Fruit | No of Farmers | Total No of Trees | Average No. of Trees |
|---|---|---|---|
| Sapodilla | 34 | 2,462 | 72 |
| Durian | 25 | 1,984 | 79 |
| Rambutan | 20 | 1,751 | 88 |
| Longan | 21 | 1,943 | 93 |
| Star apple | 18 | 550 | 31 |
| Coconut | 9 | 404 | 45 |
| Orange | 5 | 1,430 | 286 |
| Lemon | 8 | 1,000 | 125 |
| Pomelo | 3 | 150 | 50 |
| Mangosteen | 2 | 122 | 61 |
| Bellfruit | 1 | 70 | 70 |
| Mandarin | 1 | 15 | 15 |
| Total/Average | 147 | 12,161 | 82 |

Source: Questionnaire Fruit Survey, JICA Project Team (2011)

Figure 2.6.1 shows the relationship between total number of farmers by fruit and the total number of trees also by kind. General trend is, of course, the more number of farmers who cultivate the fruit, the more total number of the fruit trees one finds in the area. However, for star apple and coconut, the numbers of trees are obviously smaller than what are expected by the number of farmers. It may imply that the spacing of star apple and coconut may be wider than the other fruits. On the other hand, orange and lemon show relatively lots numbers of trees as compared to the numbers of farmers, implying these trees may be planted in a narrower spaces than other fruits.

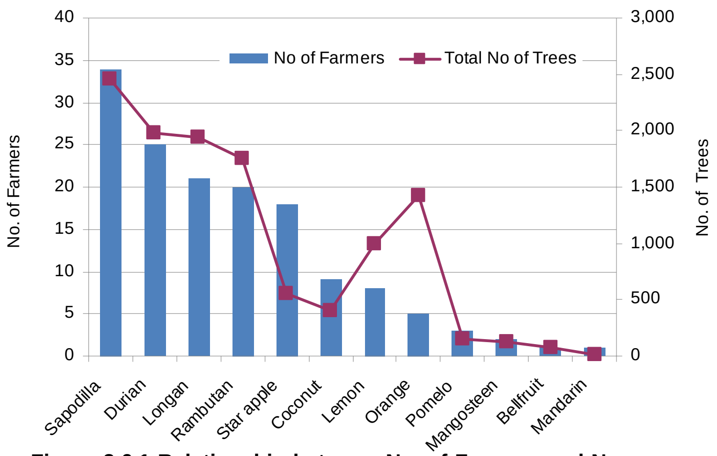


**Figure 2.6.1 Relationship between No. of Farmers and No. of Trees by Fruit**., Source JICA Project Team

### 2) Gross Production and Gross Income

Table 2.6.15 shows the total annual production by fruit and average production per year per farmer by fruit. The most produced fruit is sapodilla, 344,441 kg by 37 farmers, followed by rambutan of 255,950 kg by 25 farmers, 125,943 kg of durian by 26 farmers, longan of 77,830 kg by 21 farmers. In terms of average production per farmer, what comes first is rambutan (10,238 kg), followed by sapodilla (9,309 kg), durian (4,844 kg), coconut (3,865 kg), longan (3,706 kg), etc. On the other hand, the least production per farmer is for mangosteen, only 350 kg, followed by orange (1,010 kg), lemon

(2,013 kg). Average annual production per farmer by all the fruits arrives at 4,256 kg.

**Table 2.6.15 Production by Fruit**

| Category | Coconut | Durian | Longan | Lemon | Orange | Ram-butan | Sapodilla | Star apple | Mango-steen | Total Avg |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Production(kg) | 34,781 | 125,943 | 77,830 | 16,100 | 5,050 | 255,950 | 344,441 | 47,549 | 700 | 100,927 |
| Avg Production / Farmer, kg | 3,865 | 4,844 | 3,706 | 2,013 | 1,010 | 10,238 | 9,309 | 2,972 | 350 | 4,256 |
| No. of Farmers | 9 | 26 | 21 | 8 | 5 | 25 | 37 | 17 | 2 | 150 |

Source: Questionnaire Fruit Survey, JICA Project Team (2012)

Table 2.6.16 summarizes farm gate prices per kg by fruit, generally showing 2 groups of fruits in terms of farm gage price; higher or lower. The highest farm gate price per kg shows up in star apple, followed by mangosteen, and durian. These three fruits show much higher farm gate price per unit weight of kg as compared to other fruits, more than double value. In general, per-farmer production for these fruits is relatively lower than the others, especially in case of mangosteen (see Figure 2.6.2). On the contrary, sapodilla and rambutan are much produced as per farmer, whereby those farm gate prices tend to be lower.

**Table 2.6.16 Farm Gate Price by Fruit, '000 VND/kg**

| Category | Coconut | Durian | Longan | Lemon | Orange | Ram-butan | Sapodilla | Star apple | Mango-steen |
|---|---|---|---|---|---|---|---|---|---|
| Farm Gate Price (,000VND/kg) | 5.01 | 21.38 | 9.44 | 6.38 | 7.31 | 8.62 | 9.75 | 27.80 | 26.00 |

Source: Questionnaire Fruit Survey, JICA Project Team (2011)

Given the farm gate prices by fruit, Table 2.6.17 estimates gross income with its total production by fruit and gross income as per farmer by fruit. Upper part of the table shows the former estimation and the lower row indicates the latter estimation by fruit. In terms of gross income with its total production by fruit, durian shows the highest gross income, followed by sapodilla, and rambutan. As for gross income per farmer by fruit, what comes first is star apple (4,574,535 VND/farmer), followed by mangosteen (4,550,000 VND), durian (4,240,236 VND), rambutan (3,530,062 VND), so on so forth. As indicated, these 4 fruits of star apple, mangosteen, durian and rambutan give much higher gross income than others.

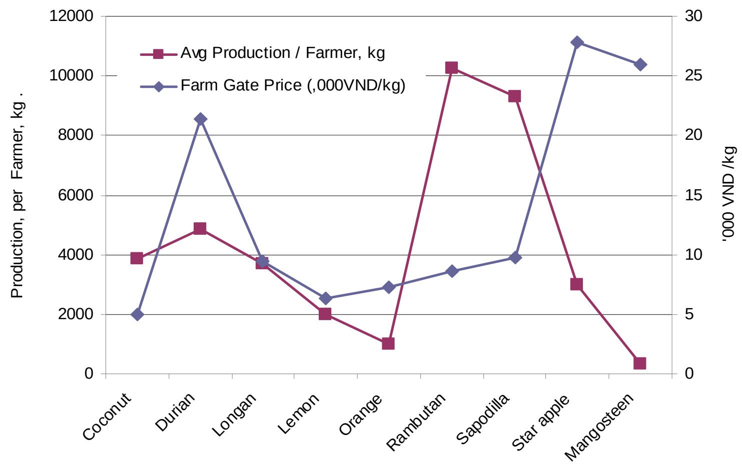


**Figure 2.6.2 Production/Farmer and Farm Gate Price by Fruit**
Source JICA Project Team

**Table 2.6.17 Gross Income by Fruit for Total Production and as per Farmer, (VND)**

| Category | Coconut | Durian | Longan | Lemon | Orange | Ram-butan | Sapodilla | Star apple | Mango-steen |
|---|---|---|---|---|---|---|---|---|---|
| Sum (VND) | 19,346,027 | 106,005,907 | 34,971,613 | 12,832,875 | 7,386,130 | 88,251,560 | 90,802,020 | 77,767,087 | 9,100,000 |
| Per Far-mer | 19,346 | 4,240,236 | 1,248,986 | 1,604,109 | 1,477,226 | 3,530,062 | 2,522,278 | 4,574,535 | 4,550,000 |

Source: Questionnaire Fruit Survey, JICA Project Team (2011)

### 3) Cost of Fruits Cultivation

Table 2.6.18 shows the recurrent cost for fruit cultivation per year for a typical average farmer. As a whole, the total cost of fruit cultivation per year came to 20,668,392 VND per fruit farmer. Among all, the cost of fertilizer shared 40% (18,950,109 VND) of the total input cost, followed by harvest (19%), chemicals (14%), pruning (5%), watering (4%), and transportation (3%). Fertilizer and chemicals, the major agricultural input, shares as much as 54%.

**Table 2.6.18 Recurrent Cost Incurred for Fruit Cultivation per Farmer per Year (VND)**

| Category | Fertilizer | Chemicals | Pruning | Watering | Harvest | Transpor-tation | Other labor | Total |
|---|---|---|---|---|---|---|---|---|
| Sum (VND) | 18,950,109 | 6,473,584 | 2,627,352 | 1,891,007 | 8,931,677 | 1,591,583 | 7,285,000 | 20,668,392 |
| No. of Samples | 130 | 98 | 21 | 100 | 58 | 27 | 22 | 457 |

Source: Questionnaire fruit Survey, JICA Study Team (2012)

Table 2.6.19 shows the recurrent cost now required by fruit per farmer (Note that the cost is not per unit area but as per farmer only as cultivated area by fruit is not available in this survey). As shown in the table, the highest recurrent cost of fruit cultivation shows up in rambutan, 25,160,160 VND per farmer, which is followed by sapodilla (21,407,657 VND per farmer), durian (15,086,364 VND per farmer), lemon (7,652,000 VND per farmer), etc.

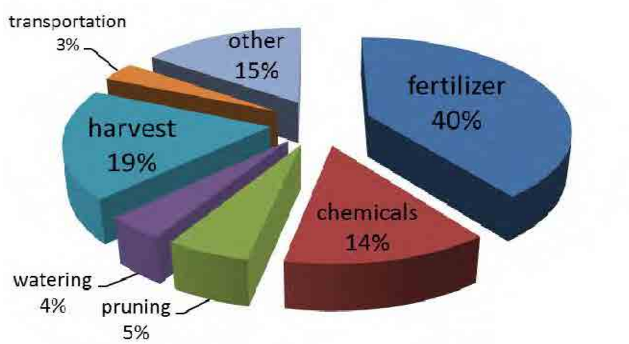


**Figure 2.6.3 Recurrent Cost by Item**

Source: Questionnaire Survey, JICA Project Team (2011)

**Table 2.6.19 Recurrent Cost Incurred for Fruit Cultivation per Farmer by Fruit (VND)**

| Fruit | Coconut | Durian | Longan | Lemon | Orange | Ram-butan | Sapodilla | Star apple |
|---|---|---|---|---|---|---|---|---|
| Sum (VND) | 276,000 | 15,086,364 | 6,386,533 | 7,652,000 | 4,149,200 | 25,160,160 | 21,407,657 | 5,624,750 |
| No. of Samples | 5 | 22 | 15 | 5 | 5 | 25 | 28 | 12 |

Source: Questionnaire fruit Survey, JICA Study Team (2012)

Aside from the aforementioned recurrent cost, fruit cultivation needs an establishment cost composed of land preparation, seedling, transplantation, etc. Table 2.6.20 shows the establishment cost by work per typical average farmer. As shown in the table, land preparation needs the highest cost of about 5 million VND per farmers which shares as much as 66% of total cost, followed by seeding (12%), and transportation (9%).

**Table 2.6.20 Establishment Costs by Work per Farmer**

| Category | Land Preparation | Seedling | Transplanting | Others | Remarks |
|---|---|---|---|---|---|
| Cost, VND | 5,081,538 (66%) | 921,099 (12%) | 715,533 (9%) | 1,025,156 (13%) | |
| No. of Samples | 78 | 122 | 12 | 15 | |

Source: Questionnaire fruit Survey, JICA Study Team (2012)

The establishment cost is a one-time investment over fruit productive years. The productive year ranges in general from 10 years to as long as 50 years[9] theoretically or under well-controlled management. However, practically there is a difficulty for fruit trees in the Mekong Delta to last over 10 years due mainly to disease (especially green disease prevalent nowadays). Therefore, according to interviews to farmers, the establishment is assumed to take place every 10 years regardless of the

[9] For example, economic productive year is estimated at 10 years for papaya, 20 years for lemon, 30 years for coconut, 30 years for orange, 40 years for durian, 50 years for rambutan and as long as 100 years for mango tree Source; FAO, JIRCAS Nes No.57, 2009 (Durian), Rambutan and Pili Nuts (Potential Crops for Hawai, Francis T. Zee, 1993)

variety of fruit. It means depreciation cost for the establishment is distributed over 10-year period, which, together with above recurrent cost, consists of all the required cost per annum.

Table 2.6.21 shows the establishment cost by fruit divided by 10 year depreciation period. Note that the establishment cost is not per unit area but as per farmer only (cultivated area by fruit is not available in this survey). As shown in the table, the highest establishment cost of fruit is durian, 2,745,652 VND per farmer, which is followed by rambutan (1,619,455 VND per farmer), star apple (1,075,028 VND per farmer), coconut (1,071,000 VND per farmer), etc.

**Table 2.6.21 Establishment Costs for Fruit Cultivation per Depreciation (10 years) per farmer**

| Category | Coconut | Durian | Longan | Lemon | Orange | Ram-butan | Sapodilla | Star apple | Mango-steen |
|---|---|---|---|---|---|---|---|---|---|
| Sum (VND) | 1,071,000 | 2,745,652 | 853,800 | 72,583 | 198,500 | 1,619,455 | 753,724 | 1,075,028 | 270,000 |
| No. of Samples | 29 | 87 | 59 | 18 | 16 | 82 | 112 | 46 | 2 |

Source: Questionnaire fruit Survey, JICA Study Team (2012)

### 3) Net Income from Fruit Cultivation

Table 2.6.22 summarizes establishment cost depreciated over 10 years, recurrent cost, gross income, cost share in the gross income, net income as per typical average farmer and by fruit. Note that since this survey could not gain planted area by fruit but only by a total area of the fruit garden owned by each interviewed farmer where in most cases more than one fruit is cultivated, each fruit item can be estimated only in terms of farmer household who cultivates the fruit but not by unit area of each fruit.

As shown in the table, a typical average farmer earns a gross profit of about 90 million VND with a total cost of 29.54 million VND composed of the depreciated establishment cost (8.9 million VND) and the recurrent cost (20.7 million VND). Subtracting the total cost from the gross profit gives a net profit, which comes to 60.4 million VND per typical farmer with an average fruit area of 0.64 ha. The net profit as per one unit hector of fruit area is therefore estimated at as much as 94.43 million VND.

By fruit, though unit area of cultivation is not counted, durian bears the most profit per farmer, which net profit is 89.17 million VND, followed by rambutan (82.4 million VND), star apple (71.1 million VND), sapodilla (68.6 miullion VND), coconut (15.5 million VND), and so on so forth (Note that since mangosteen does not have recurrent cost, it was omitted in estimating the net profit).

**Table 2.6.22 Cost, Gross Profit and Net Income per Farmer By Fruit**

| Fruit | Area of Fruits Production | Establishment Cost/10yrs | Annual Recurrent Cost | Gross Income per HH | Cost Share | Net Income per HH | Gross Income per hectare | Net Income per hectare |
|---|---|---|---|---|---|---|---|---|
| | ha | VND | VND | VND | (%) | VND | VND/ha | VND/ha |
| Average | 0.64 | 8,869,242 | 20,668,392 | 89,975,000 | 33% | 60,437,366 | 140,585,938 | 94,433,384 |
| Coconut | - | 1,071,000 | 2,760,000 | 19,346,027 | 20% | 15,515,027 | - | - |
| Durian | - | 2,745,652 | 15,086,364 | 106,005,907 | 16% | 89,173,891 | - | - |
| Longan | - | 853,800 | 6,386,533 | 34,971,613 | 21% | 27,731,280 | - | - |
| Lemon | - | 72,583 | 7,652,000 | 12,832,875 | 60% | 5,108,292 | - | - |
| Orange | - | 198,500 | 4,149,200 | 7,,386,130 | 59% | 6,446,701 | - | - |
| Rambutan | - | 1,619,,455 | 25,160,160 | 88,251,560 | 29% | 82,353,166 | - | - |
| Sapodilla | - | 753,724 | 21,407,657 | 90,802,020 | 24% | 68,640,639 | - | - |
| Star apple | - | 1,075,028 | 5,624,750 | 77,767,087 | 9% | 71,067,309 | - | - |
| Mangosteen | - | 270,000 | - | 9,100,000 | - | - | - | - |

Source: Questionnaire fruit Survey, JICA Study Team (2012)

## 2.7 Development Plans and Projects in the Project Area

This sub-chapter discusses development plans and projects relevant to the Project area. There are 2 master plans covering whole Mekong Delta; 1) Water Resources Master Plan 2006, 2) Water Resources Master Plan in the Context of Climate Change (2011), both of which were prepared by SIWRP. Aside from the 2 major master plans, there is an on-going master plan study which aims at formulating Mekong Delta Plan in collaboration with Netherlands. There are on-going and to-be-appraised projects in the Mekong Delta, which altogether are briefed below:

### 2.7.1 Water Resources Master Plan (2006 approved), SIWRP

Concerning Mekong Delta, first master plan in the field of water resources development was prepared in 1990, and then it had been updated by SIWRP from 2002 to 2005. Upon the update completed, SIWRP submitted the Master Plan (SIWRP) to the MARD central office and then to the central government. The Master Plan (SIWRP) was approved in 2006 by the prime minister with Decision 84/2006/QD-TTG. This Master Plan focused on water resources development mainly for the purpose of agriculture sector’s restructuring based on development strategies upheld in the Socio-economic Development Plan 2005-2010 (so-called national development plan 2006-2010).

The Master Plan (2006, SIWRP) presented 3 development options as:

1) Option 1 was formulated based on the Socio-economic Development Plan 2005-2010, in which main development sectors were agriculture and aquaculture, and development trend was the same as present; hence hydraulic system especially flood control facilities had to ensure stable livelihood and life of the people and facilitate farming restructuring in Mekong Delta. There were 7 flood protection areas with the area of 295,000 ha in this Option 1.
2) Option 2 had a higher socio-economic development targets in comparison to the Option 1. The development of hydraulic system included such main infrastructure as ring-dyke along 2nd class (secondary) canals to protect farm lands from early flood, hydraulic facilities for the purpose of restructuring/diversifying agriculture and facilities to maintain sustainable development in coastal areas, and flood control system for the bordering areas with Cambodia. The areas to be protected from floods were proposed at about 900,000 ha including shallow flood areas as well as the areas recommended in Option 1.
3) Option 3 was similar to the Option 2 but in the context of increased water demands in the upper regions out of Vietnam territory, and the option added the installation of a ring-dyke to protect Mekong Delta including Cambodian territory also taking into account sea level rise by 25 cm.

Based on economic analysis, the Master Plan recommended Option 1 for water resources development in Mekong Delta for the near future (by 2010), and further Option 2 to highly meet the objectives of the Socio-economic Development Plan 2005-2010. The total project cost was estimated at about 41,351 billion VND (20,562 billion for hydraulic facilities) and 101,814 billion VND (32,398 billion for hydraulic system) for Option 1 and Option 2 respectively. In US$ term, with the exchange rate of 15,855 VND per US$ recorded at July 1, 2005[1], the project costs were US$ 2.608 billion (US$ 1.297 billion for hydraulic facilities) and US$ 6.422 billion (US$ 2.043 billion) for Option 1 and Option 2 respectively (see Table 2.7.1).

On the other hand, the benefit from the projects proposed in the mater plan arrived at 1,595 billion VND (US$ 101 million) and 9,573 billion VND (US$ 604 million) for Option 1 and Option 2 respectively. The internal rate of returns were thus estimated at 13.0 % and 16.3 % respectively, higher than the opportunity cost of Vietnam, which is 12 % according to the World Bank. BC ratios were 1.07

[1] http://www.xe.com/ict/?utm_source=internal&utm_medium=TL&utm_content=NOGEO&utm_campaign=ICT_HistRates_QuickLinksOutput

and 1.28 for the both cases respectively, narrowly over 1.0.

**Table 2.7.1 Project Cost and Economic Return in the Master Plan (2006)**

| No. | Item | Option 1 | Option 2 | Option 3 | Remarks |
|---|---|---|---|---|---|
| I. | Total cost (billions VND) | 41,351 | 101,814 | 101,814 | Structure in Option 3 is in Cambodia, whereby the cost not included in the Option 3. |
| 1. | Hydraulic system | 20,562 | 32,398 | 32,397 | |
| 2. | Transport system (embankment included) | 12,155 | 60,782 | 60,782 | |
| 3. | Residential protection/ resettlement | 8,634 | 8,634 | 8,634 | |
| II. | Economic Evaluation | | | | |
| 1. | NPV (billions VND) | 1,595 | 9,573 | | |
| 2. | IRR (%) | 13.0 | 16.3 | | |
| 3. | B/C | 1.07 | 1.28 | | |

Source: Water Resources Master Plan (2006 approved), SIWRP

With the master plan approved, the central government has made investments in the construction of hydraulic facilities, construction of main canals or 1st class canals, embankments to protect farm lands as well as people's life from river flooding and seashore erosion, bank protections, and construction of sluice gates while provincial governments have invested in 2nd class (secondary) canals. Canals lower than the 2nd class, so-called infield infrastructure, have been invested by local beneficiary people.

According to SIWRP, by the end of 2009, a total of 53 works had been put under implementation out of 79 hydraulic works which were proposed in the master plan. Despite the fact that total 53 hydraulic works had been started, there were only 3 works completed sharing only 4% of the proposed whole 79 projects. The completed construction works were mostly bank protections for urban areas from inundation, flooding, and sea level rising.

The lugged progress was due mainly to funding issues not only for construction stage but also for designing stage. In fact, the fund available for project planning and designing stages is normally lower than what is actually required. Therefore, some survey requirements usually have to be cut down; thus the project documents are not well articulated for project appraisal. Typical example could be the under-estimation of project cost. The estimated project cost in the Master Plan was in fact much lower than what was actually required for construction. In many cases, the project cost estimated remained only 25-30% and in cases even only 10% of the actually required project cost (Source: SIWRP).

Further, lack of investment fund at the central government as well as at the provincial government was another difficulty. It was estimated by SIWRP that what was disbursed by the central government was only 14% of the project cost recommended in the master plan (2006), and the fund disbursed by provincial government remained only about 10% of what was planned in the master plan (2006).

### 2.7.2 Water Resources Master Plan in the Context of Climate Change (2011), SIWRP

SIWRP started preparing a water resources master plan in 2010 taking into account the effects of climate change. The plan was finalized in August 2011, and submitted to the Headquarters of MARD for its approval. The plan covers up to year 2050, divided into 4 stages of 2011-2015, 2016-2020, 2021-2030, and 2031–2050. The plan was approved on September 25, 2012, yet covering up to year 2020 only by the Decision No. 1397/QD-TTg.

The plan examined 3 options in terms of how to deal with the saline intrusion back along the Mekong River. Option 1 is to construct no tide prevention gate at the estuaries of Mekong River, Option 2 is to construct a total of 3 saline prevention gates in Ham Luong, Co Chien and Cung Hau estuaries (see Figure 2.7.1), and Option 3 to construct another 4 gates at estuaries (see circles in Figure 2.7.1). In fact, Option 3 aims at controlling all the Mekong River's estuaries by tide prevention sluice gate. Note that all such prevention gates are planned to construct after year 2020, and therefore the current approval does not make the construction effective yet.

The master plan recommends the Option 2 whereby there will be 3 tide prevention sluice gates at the 3 estuaries of Ham Luong (2021-2030), Co Chien (2021-2030) and Cung Hau (2031-2050) rivers, which are all tributaries of Tien River of Mekong. For other tributaries of Mekong River where there is no tide prevention gate, saline intrusion is to be prevented by sluice gate to be constructed at each end point of the canals and streams draining from inland areas out to the Mekong tributaries. It means that as the sea water intrudes upstream influenced by sea level rise over time in the context of climate change, the sluice gates are to be installed one by one towards upstream in keeping with the sea water intrusion.

Projects recommended in the master plan center on hydraulic facilities and works such as construction of sea water prevention sluice gates, flood prevention sluice gates, rehabilitation/ strengthening of embankment, enlargement of irrigation and drainage canals, dredging of canals, water supply for irrigation as well as for domestic use, sea and river dykes to cope with sea level rise, and roads combined with embankment, etc.

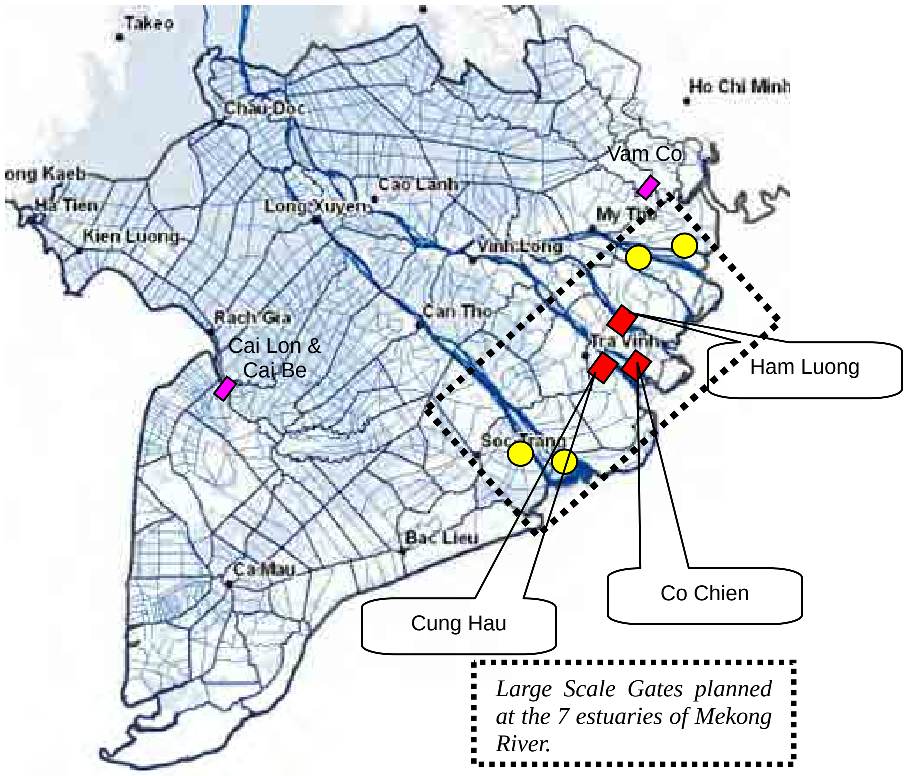


**Figure 2.7.1 Sea Water Prevention Sluice Gates in the Master Plan**

Source: Water Resources Master Plan for the Mekong Delta in the Context of Climate Change and Sea Level Rise, SIWRP

Note: Red squares shows the locations of the 3 sluice gates recommended in the Option 2, and Option 3 further recommends another 4 gates indicated by yellow circles.

The project cost by major work and by stage is summarized below. The project cost by stage is US$ 3,771 million for the first stage of year 2011-2015 to as much as US$ 8,142 million for the 3rd stage of year 2021-2030, totaling to US$ 24,758 million. By category, roads to be constructed with embankment shares the most, reaching US$ 8,015 million for the whole period up to 2050 equivalent to 32.4% and followed by in-field irrigation infrastructure which cost is US$ 5,751 million sharing 23.2%.

**Table 2.7.2 Project Cost by Stage and by Category (Unit: Billion VND, and Million US$)**

| Categories | Stage 1 2011-15 | Stage 2 2016-20 | Stage 3 2021-30 | Stage 4 2031-50 | Total (BVND) | Total (MUS$) | Share (%) |
|---|---|---|---|---|---|---|---|
| 1. Sea Dyke Construction | 114 | 1,543 | 5,785 | 6,626 | 14,068 | 668 | 2.7 |
| 2. River Dyke Construction | 1,566 | 3,928 | 4,728 | 810 | 11,031 | 524 | 2.1 |
| 3. Water Channel + Reservoir | 1,665 | 1,392 | 956 | 615 | 4,628 | 220 | 0.9 |
| 4. Flood Control Facilities | 7,884 | 7,295 | 1,900 | 1,535 | 18,615 | 884 | 3.6 |
| 5. Large Sluices at Mekong*1/ Cai Lon&Cai Be, Vam Co *2 | 3,890 | 11,885 | 23,940 | 26,933 | 66,647 | 3,164 | 12.8 |
| 6. New Constructions | 17,296 | 13,752 | 5,847 | 1,724 | 38,620 | 1,833 | 7.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7. Ongoing Decision QĐ 84/ TTg *3 | 8,954 | 792 | 7,244 | 10,578 | 27,567 | 1,309 | 5.3 |
| **8. In-field Irrigation Infrastructure *4** | **12,426** | **15,533** | **31,066** | **62,132** | **121,157** | **5,751** | **23.2** |
| **9. Roads combined with Embankment** | **0** | **71,729** | **83,715** | **13,387** | **168,831** | **8,014** | **32.4** |
| 10. Prevention of Urban & Residential Areas' Inundation | 25,642 | 18,411 | 6,350 | 0 | 50,403 | 2,393 | 9.7 |
| **Total (BVND)** | **79,438** | **146,259** | **171,531** | **124,340** | **521,567** | **24,758** | 100.0 |
| **Total (MUS$)** | **3,771** | **6,943** | **8,142** | **5,902** | **24,758** | **24,758** | 100.0 |
| Share (%) | 15 | 28 | 33 | 24 | 100 | 100 | |

Source: Water Resources Master Plan in the Context of Climate Change 2011, SIWRP

Note: *1: 3 large scale tide prevention gates planned at the estuaries of Mekong River are included in this work.

*2: Cai Lon Cai Be are also large scale sluice gates, which are planned to construct in Cailon and Caibe rivers (see Figure 2.7.1). The rivers are drainage rivers flowing into West Sea through Kien Giang Province (not tributaries of Mekong River). Vam Co is also a large scale sluice gate planned in Vam Co river flowing through Long An province (this is not a tributary of Mekong River either. For the location, see FOgure 2.7.1).

*3 Decision QD 84/TTg was made on the last Water Resources Master Plan approved in 2006 by the prime minister.

*4 In-field infrastructure means mostly irrigation canals of 3rd class and below thereof. Note that 1st class canal means the main canals and 2nd class is the branch canals directly from the 1st level canals.

In fact, the investment aforementioned is very large especially as compared with the past actual investment from the central government, which was about 500 to 600 billion VND per year (US$ 24 – 29 million per year) for whole Mekong Delta. The annual investment for all the stages (2011-2050) arrives at 13,039 billion VND (US$ 618 million) per year, and the annual investment by stage is 15,888 billion VND (US$ 754 million), 29,252 billion VND (US$ 1,389 million), 17,153 billion VND (US$ 814 million), and 6,217 billion VND (US$ 295 million) for the stage 1, stage 2, stage 3 and stage 4 respectively.

The annual investment for all the stages, 13,039 billion VND (US$ 618 million) per yea, is as much as 22 to 26 times more than what has been actually invested from the central government to the Mekong Delta. The highest annual investment which shows up during the stage-2 period, 29,252 billion VND (US$ 1,389 million), arrives at as much as 50 – 60 times more than the past actual investment. With this in mind, the Master Plan recommends about 80% of the works should be born by local government and also by the beneficiaries. However, even with this 80% arrangement from other than central government, it may still look too ambitious to arrange the remaining 20%.

### 2.7.3 Donor Involvement

There are donors operating in the Mekong Delta in the field of water resources, agriculture and rural development, amongst which the major players are WB, ADB, AusAID, IFAD, GIZ, and Netherlands. Following table summarizes the donors' activities; namely, Netherlands is now preparing Delta Plan which is a master plan for the whole Mekong Delta, WB commenced a project for water resources development and rural development covering southern part of the Delta from Hau River, and ADB is to invest in northern part of Mekong Delta from Tien River aiming mainly at mitigating flood. From the view point of climate change, the activities of ADB, GIZ and AusAID are directly related to this issue.

**Table 2.7.3 Major Donor Activities in the Mekong Delta**

| Donor | Project | Stage | Remarks |
|---|---|---|---|
| Netherlands | Mekong Delta Plan April 2010 - 2012 | TA (Strategic partnership) | Netherlands and Vietnam made an agreement called 'Strategic Partnership Arrangement on Climate Change Adaptation and Water Management in April 2010 by both prime ministers. Till the end of 2012, 4 reference groups were established such as; 1) physical system group, 2) land use group, 3) social and economic group, and 4) governance group, all of which are composed of Vietnamese sides. Also, draft plans were produced in March 2012 for Ver.1 and in November 2012 for |

| | | | |
|---|---|---|---|
| | | | Ver.2. Consultation workshop for the Ver.2 was held in My Tho on December 5, 2012, inviting over 150 stakeholders. The draft plans are of regional economic development where agro-business specialization scenario and also dual node industrialization scenario are recommended. The later scenario upholds thriving diversified economy wherein high-value agro-food business is expected to develop with secondary and tertiary sector activities in designated economic zones. For water resources development sector, no specific projects are yet proposed but conceptual plan only. The conceptual plan presents, as an option, 1) major flood diversion canals in upstream of Mekong Delta to release peal flood into West and East Seas, 2) linking canal between Hau river and Tien river at upper mid point of Delta in order to augment fresh water towards Ca Mau peninsula, and 3) dry season closing of Tien 3 branches in order to prevent saline water intrusion, corresponding to the Option 2 recommended by SIWRP MP (2011). Those water resource related projects are of large scale and therefore they are all planned as mid-long term development option between 2050 and 2100, which have to be reviewed in line with the climate change to take place. |
| World Bank (WB) | Mekong Delta Water Resources Management for Rural Development Project<br>June 2011 – 5 years | Implementation | This project commenced in June 2011 with a period of 5 years implementation. The project covers the area of southern part of Mekong Delta from Hau River with components of rehabilitation of irrigation system, dredging of canals, rehabilitation and strengthening of embankment, and rural water supply. The total investment for the project is US$ 207 million, of which IDA is to provide US$ 160 million. Out of the US$ 160 million, US$ 129 million is to be invested in the rehabilitation of irrigation system including canal dredging, strengthening of embankment, widening of canal, protection of embankment, rehabilitation and renewal of gates, etc. The Project is to rehabilitate total 5 irrigation systems and at the appraisal stage only 3 systems were identified and the remaining 2 will be identified on the course of the implementation. Note that the IDA once invested US$ 106.2 million out of the total project cost of US$ 156.5 million from 1997 to 2007 for the purpose of rehabilitation of 3 irrigation systems, establishment of tertiary level canals and rural water supply. |
| Asian Development Bank (ADB) | 1. Climate Change Impact and Adaptation Study in the Mekong Delta<br>October 2010 – April 2012 | TA | This ADB Technical Assistance (TA) formulated a development plan (conceptual level) for Ca Mau province and Kien Giang province with MONRE being the counterpart organization taking into account the effects of climate change. The TA has carried out simulations in the field of inundation, saline water intrusion, morphology, etc., based on which vulnerability indices for the 2 provinces were established. For the project planning, it is conceptual level and some pilot projects covering not only rural but also urban areas were proposed. This TA was co-financed by ADB with US$ 500,000 and AusAID with US$ 800,000. Note that following this TA, a successor TA was commenced in late 2012, aiming at presenting fundable projects by ADB. |
| | 2. Greater Mekong Sub-region Flood & Drought Risk Management and Mitigation Project | Project appraisal (Dec. 2011) | This project targets Dong Thap province, Long An province and Tien Giang province which are very often hit by flood. The project components are rehabilitation of irrigation systems, strengthening of embankment of canals, establishment of ring embankment for the protection of farm land from flood, etc. In Tien Giang province, there are lots of fruit gardens and the project is expected to protect those gardens. Total project cost is estimated at US$ 90.2 million, of which 61% is meant for civil works and 20 % is for re-settlement of the people to be affected. The project is expected to commence from 2012 and ends in 2016. Note that the target provinces are located in northern part of Mekong Delta whereby no geographical overlap with the above WB project. |
| GIZ | Climate Change and Coastal Ecosystem Programme (CCCEP) | Implementation | A predecessor pilot project, titled Conservation and Development of the Kien Giang Biosphere Reserve Project, was carried out in Kien Giang province from June 2008 to July 2011. The pilot project had rehabilitated coastal areas including locally adaptable fence establishment, reforestation of |

| | | | |
|---|---|---|---|
| | | | mangrove, and capacity development on bio-diversity conservation. With the results, together with funds from AusAID and KfW, the GIZ started the project, 'Climate Change and Coastal Ecosystem Programme', from June 2011 for the period of 5 years. The project targets 5 provinces such as Kien Giang, Ca Mau, Bac Lieu, Soc Trang, and An Giang. Cost sharing arrangement is US$ 24.3 million by AusAID, US$ 14.1 million by GIZ and US$ 25.3 million by KfW. The first two investments are grant while the last one is loan. |
| AusAID | 1. Climate Change Impact and Adaptation Study in the Mekong Delta<br>2. Climate Change and Coastal Ecosystem Programme | Co-financier | As co-financier, AusAID disburses fund to Climate Change Impact and Adaptation Study in the Mekong Delta (ADB TA) and Climate Change and Coastal Ecosystem Programme (GIZ Programme). |
| IFAD | Developing Business with the Rural Poor Programme (Ben Tre)<br>Improving Market Participation of the Poor (Tra Vinh) | Implementation | IFAD carries out community based rural development project, targeting Ben Tre province and Tran Vinh province in the Mekong Delta. The Project in Ben Tre province commenced in 2008 with an investment of US$ 25 million while in Tra Vinh province the project has been implemented since 2007 with US$ 18 million. The project term is 5 years for the both. The modus operandi is that the beneficiary commune is to prepare proposal and submit it to the project committee established at the provincial level, and upon appraisal, disbursement is done to the commune's bank account with which the commune implements the project. About 70% of the investment is disbursed for rural infrastructure such as rural road, rural bridges, water supply, etc., 15% for capacity development and the last 15% for vocational trainings. A typical commune level project is disbursed at an average of about US$ 240,000 while typical village level project is about US$ 60,000. |

Source: JICA Project Team based on interviews and relevant reports such as appraisal reports, project documents, etc.

# CHAPTER 3 VULNERABILITY ASSESSMENT FOR THE PROJECT AREA

This Chapter 3 discusses past trend of climate, future climate change by employing PRECIS[1] model (a high resolution regional climate change simulation model), flood and saline intrusion simulation, and then carries out vulnerability assessment under climate change. At first, past trend of climate data is presented, followed by climate change prediction in future. Then, given the future climate change as well as sea level rise, flood simulation and also saline intrusion simulation are carried out. Based on the simulation results, vulnerability assessment which discusses economic loss caused by the clime change is conducted.

## 3.1 Past Trend in Climate and Sea-level Rise

### 3.1.1 Past Trend in Temperature, Sunshine Hour and Evaporation

Long term climate data were collected at such 4 stations as Vung Tau, Can Tho, Ca Mau, and Rach Gia over a period from 1978 to 2008 or 2009 (for the location, refer to Figure 3.1.1 which includes My Tho for rainfall data). Figures 3.1.2 to 3.1.4 show long term trend of air temperature of 1) annual mean, 2) annual mean maximum and 3) annual mean minimum at the 4 stations of Vung Tau, Can Tho, Ca Mau, and Rach Gia.


Figure 3.1.1 Location of the 4 Meteorological Stations

Annual mean temperature ranges approximately from 26.5 °C to 27.5 °C by station and sometimes goes up over to 28.0 °C. Annual mean maximum temperature shows bigger range of fluctuation by station and so does the annual mean minimum temperature. In general, the annual mean maximum temperature ranges from 31 °C to nearly about 34 °C while the annual mean minimum temperature does 22 °C to over 24 °C.

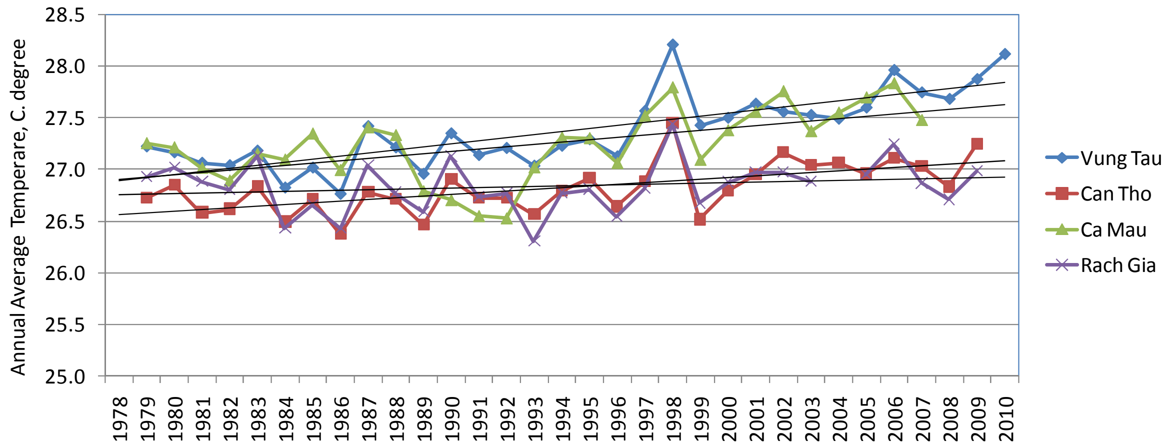


Figure 3.1.2 Annual Mean Temperature at 4 Major Locations in Mekong Delta

Source: Southern Institute for Water Resources, Sub-Institute of Hydrometeorology and Environment

One obvious observation from the long term trend is the increase in all the temperatures of mean, mean maximum and mean minimum and for all the 4 stations. Though these annual mean

[1] PRECIS stands for 'Providing Regional Climates for Impacts Studies', which is a regional climate model system whose resolution is 25-30 x 25-30 km, much higher resolution than GCM.

temperatures fluctuate by year, we can see an increase trend over years for all the 4 station. The rate of increase can be said about 0.7 °C, about 1.0 °C, and about 1.0 °C for annual mean, annual mean maximum and annual mean minimum over the period of about 30 years. This increase trend could be corresponding to global warming.

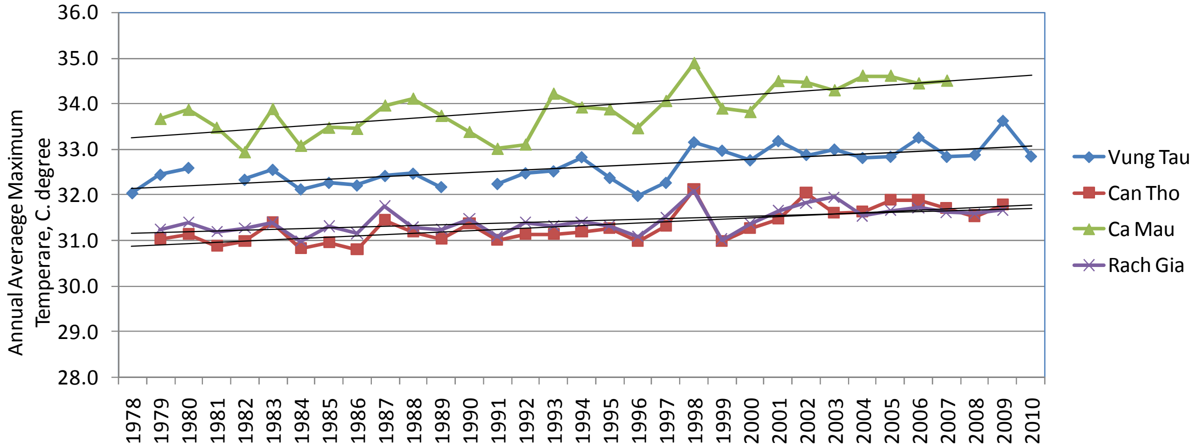


**Figure 3.1.3 Annual Mean Maximum Temperature at 4 Major Locations in Mekong Delta**

Source: Southern Institute for Water Resources, Sub-Institute of Hydrometeorology and Environment

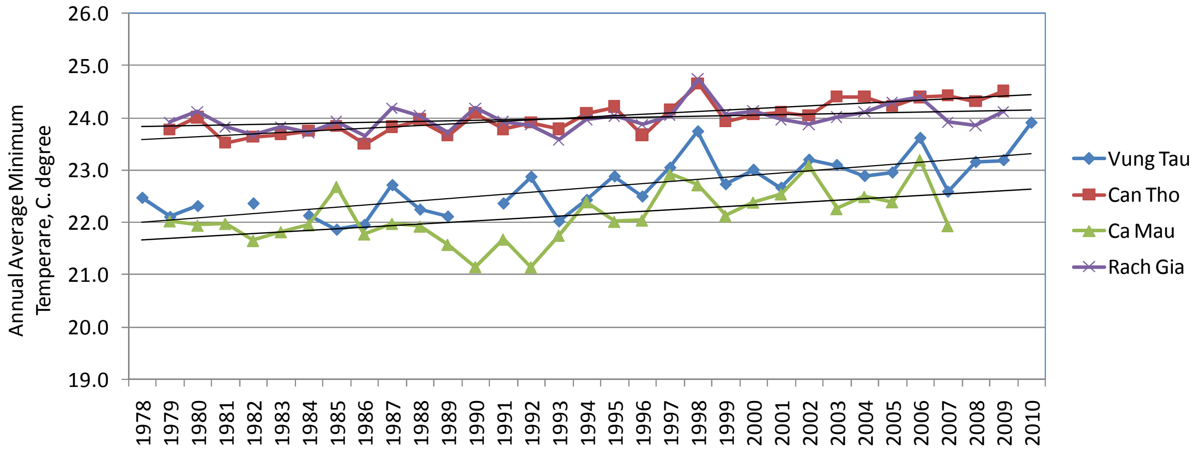


**Figure 3.1.4 Annual Mean Minimum Temperature at 4 Major Locations in Mekong Delta**

Source: Southern Institute for Water Resources, Sub-Institute of Hydrometeorology and Environment

Figure 3.1.5 summarizes annual sunshine hours for 3 stations of Can Tho, Ca Mau and Rach Gia. Sunshine hour does not change among the stations and falls in a range of 2,500 to 3,000 hours per annum. The trend is obvious; it is on a decreasing trend. Over the last 30 years, approximately annual sunshine hour has reduced by about 500 hours, which is about 20 % decrease. This may be corresponding to the increase of rainfall, meaning more cloud over those stations (in fact, rainfall trend for Ca Mau and Rach Gia stations show increase trend. Though Can Tho station shows decrease trend between 1978 and 2010, it is still on the increase trend over longer period of e.g. 1910 – 2010. For the detail see the next section).

Figure 3.1.6 shows evaporation record for the 4 stations of Vung Tau, Can Tho, Ca Mau and Rach Gia. Annual evaporation ranges about 800 to 1,400 mm, and sometimes reaches up to 1,600 mm. The trend is somewhat mixture; 2 stations show increase trend while the other 2 stations show decrease trend. As aforementioned, temperature shows obvious increase trend while sunshine hour does reverse trend, i.e. decreasing trend. The former contributes to increasing evaporation while the latter decreases evaporation. By this opposite influence each other, the evaporation trend may have presented somewhat mixed phenomenon.

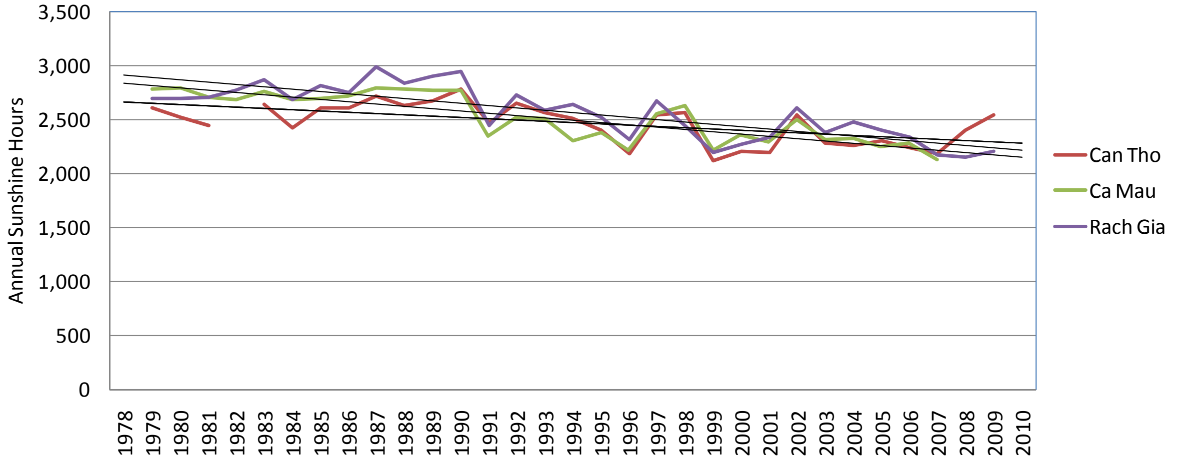


**Figure 3.1.5 Annual Sunshine Hours at 3 Major Locations in Mekong Delta**

Source: Southern Institute for Water Resources, Sub-Institute of Hydrometeorology and Environment

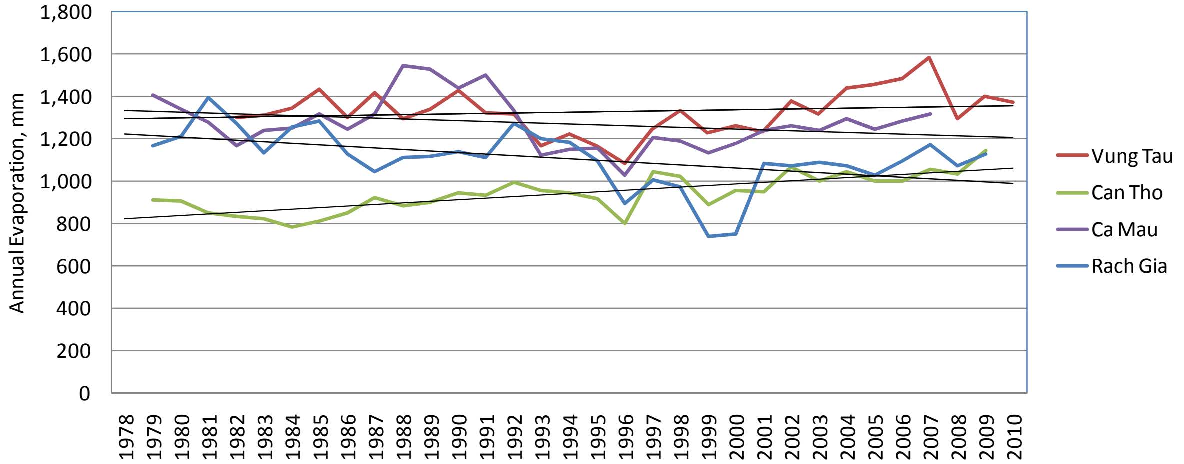


**Figure 3.1.6 Annual Evaporation at 4 Major Locations in Mekong Delta**

Source: Southern Institute for Water Resources, Sub-Institute of Hydrometeorology and Environment

### 3.1.2 Past Trend in Rainfall

Figures 3.1.7 – 3.1.10 show long term trend of rainfall for; 1) annual, 2) rainy season, 3) October which is the peak rainfall month, and 4) dry season for the 5 stations of Can Tho, Ca Mau, Rach Gia, My Tho, and Vung Tau (for the location of the rainfall stations, see Figure 3.1.1). Figure 3.1.7 reveals that the annual rainfalls for the 3 stations of Ca Mau, Rach Gia, and My Tho have been increasing while the rest of the 2 stations show a reverse trend, though there are fluctuations by year.

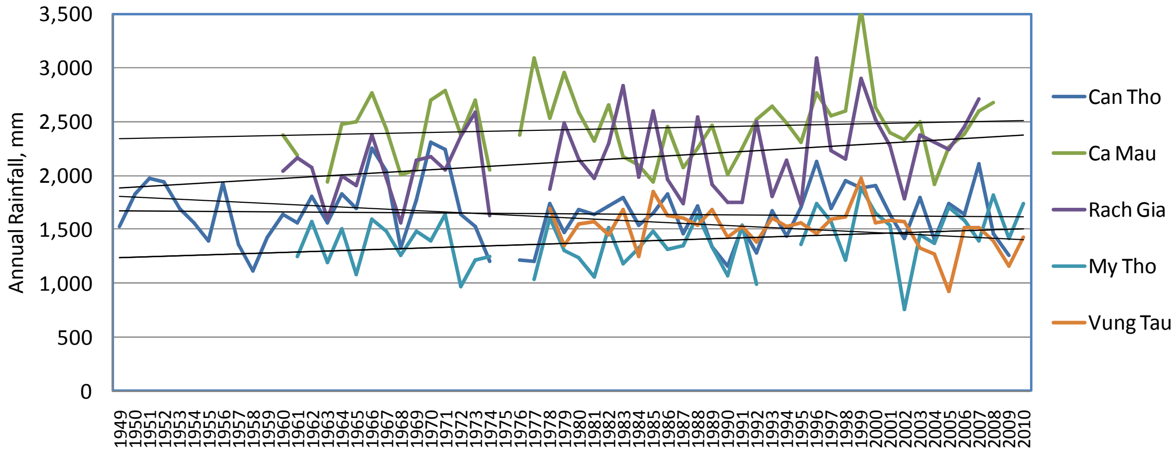


**Figure 3.1.7 Long Term Trend of Annual Rainfall for 5 Stations in Mekong Delta**

Source; Sub-Institute of Hydrometeorology and Environment, SIWRP

Rainy season's rainfall shown in Figure 3.1.8 does the almost same; i.e. 3 stations except for the 2 stations showing increasing trend. Looking into the October rainfall in Figure 3.1.9, 4 stations except for Can Tho show increasing trend. As for dry season's rainfall shown in Figure 3.1.10, increasing trend can be seen for the 4 stations but Vung Tau. The dry season rainfall at Vung Tau shows a little decreasing trend as expressed by a linear regression of Y=-0.107X +65.49.

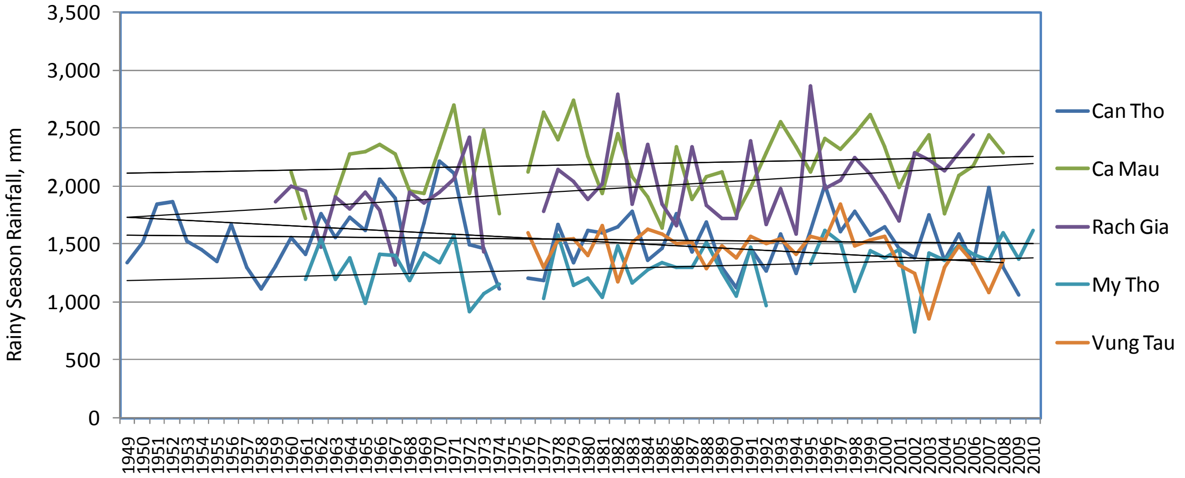


**Figure 3.1.8 Long Term Trend of Rainy Season Rainfall for 5 Stations in Mekong Delta**

Source; Sub-Institute of Hydrometeorology and Environment, SIWRP

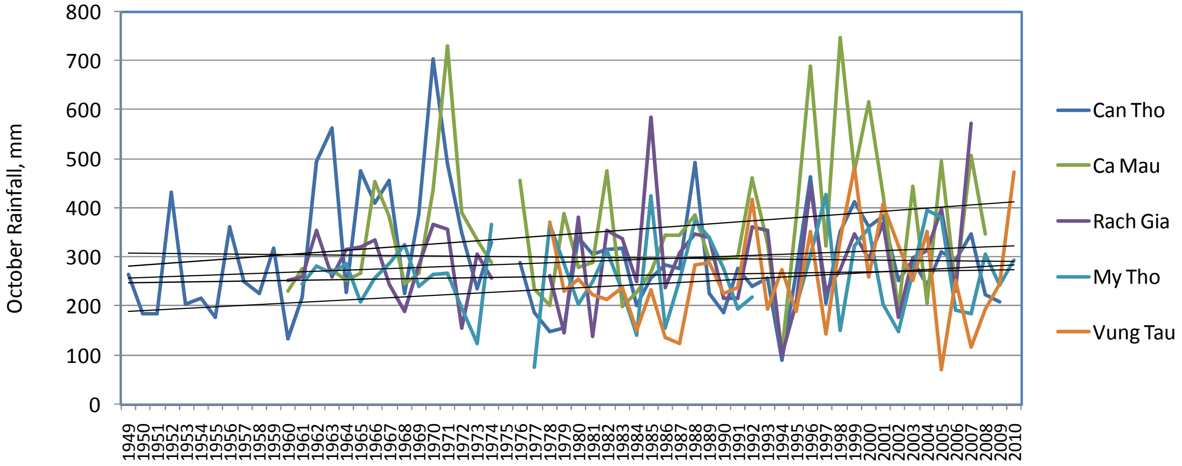


**Figure 3.1.9 Long Term Trend of October Rainfall for 5 Stations in Mekong Delta**

Source; Sub-Institute of Hydrometeorology and Environment, SIWRP

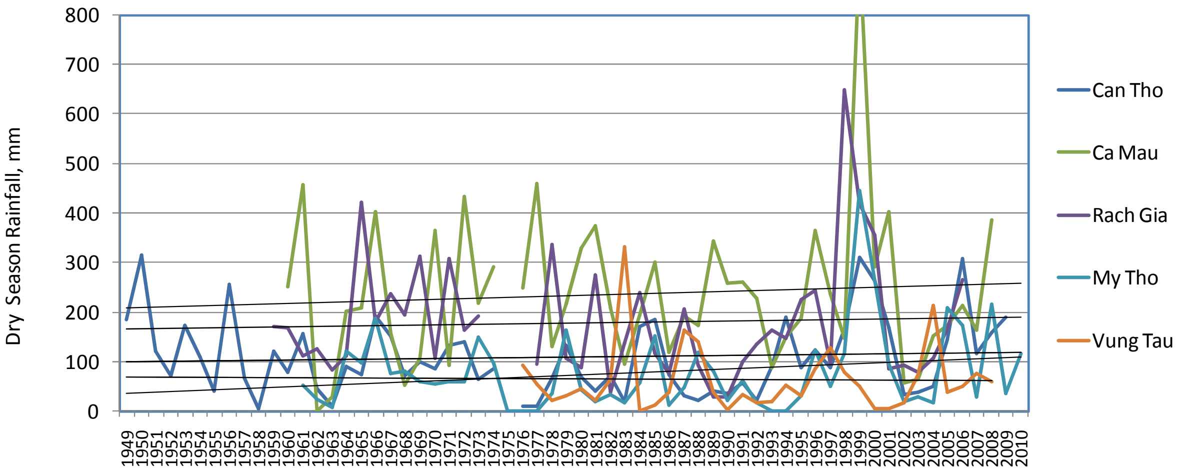


**Figure 3.1.10 Long Term Trend of Dry Season Rainfall for 5 Stations in Mekong Delta**

Source; Sub-Institute of Hydrometeorology and Environment, SIWRP

### 3.1.3 Past Trend in Sea Water Level

There are water level stations in the East Sea and West Sea as well as along Mekong River. Figure 3.1.11 to Figure 3.1.13 show long term trend of mean annual water levels recorded at Vung Tau (East Sea), Rach Gia (West Sea), and Can Tho which is located at about 80 km inland from the estuary. The recorded period covers from 1982 to 2011 for the Vung Tau and Rach Gia and up to 2009 for Can Tho, say about 30 years. As is shown, all the 3 stations show continuous increasing trend, and the sea level rise for Vung Tau and Rach Gia stations arrives at an average of approximately 15 cm over the recorded period of about 30 years (for Can Tho station, it is only 4 cm). It means that the sea levels for the both East and West Seas, including the inland water level, have been increasing with an average sea level rise by approximately 5 cm per decade.

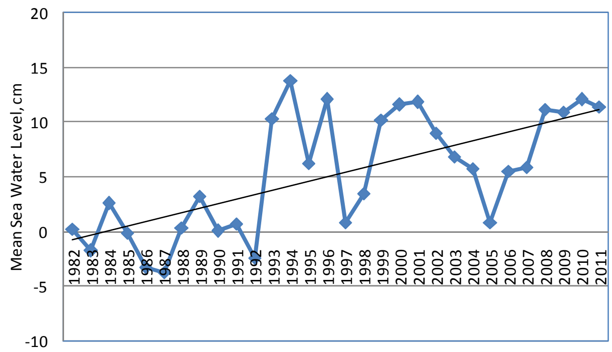


**Figure 3.1.11 Water Level at Vung Tau (East Sea)**

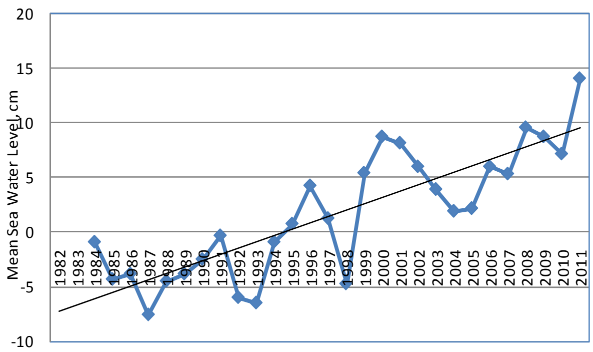


**Figure 3.1.12 Water Level at Rach Gia (West Sea)**

Source; Department of Hydro-meteorology

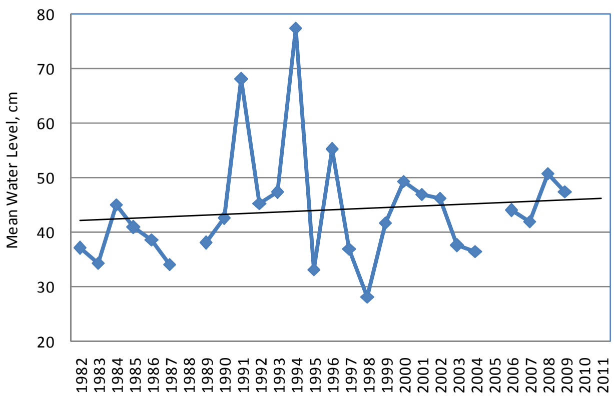


**Figure 3.1.13 Water Level at Can Tho (80km Inland)**

Source; Department of Hydro-meteorology

In fact, IPCC 4th Assessment Report reported that the average sea level rise from 1993 – 2003 was 3.1 cm + & - 0.7 mm by satellite observation, whereby about 4 cm rise at maximum may be suggested, which is corresponding to the 5 cm rise per decade recorded in the above East and West Seas. In other areas of Vietnam, e.g., Hon Dau (Red River Delta area, north Vietnam) shows about 4 cm rise per decade from 1960 – 2005, and Son Tra (Da Nan, central Vietnam) does 2.1 cm rise per decade.

## 3.2 Climate Change Prediction

IMHEN under MONRE had carried out a climate change simulation in 2010 by using Global Climate Model (GCM) and published those simulation results in November 2010. The resolution of GCM was 250 x 250 km, and IMHEN further carried out climate change simulation by using PRECIS model. PRECIS model provides a high resolution climate change regional simulation. IMHEN undertook 3 climate change scenarios of A2, B1 and B2, and presents all the results in the published literatures e.g. Impact of Climate Change on Water Resources and Adaptation Measures.

IMHEN does not mention which scenario out of the A2, B1 and B2 should be applied in Vietnam, and this is because it is dependent upon which development pass the world should undergo, e.g. economic oriented development or environmental friendly oriented development and also pursuing globalization or otherwise localization. This issue cannot be pertinent to Vietnam only but to the whole world. Therefore, the IMHEN does not specify which scenario is the best for Vietnam, but very often the results of the B2 scenario have been referred to in many cases. This may be simply because the results of B2 fall somewhat in between the results of A2 and B1. This JICA Master Plan project refers to the simulation results carried out by IMHEN, and future climate change for the coastal Mekong Delta is briefed below;

### 3.2.1 Temperature

Figure 3.2.1 shows isolines of mean annual temperature rise at year 2050 under climate change Scenario B2 in terms of percentage against the average annual mean temperature of 1980 – 1999. The mean annual temperature in future would rise by having two poles; one in Ca Mau and the other in Ho Chi Minh area. The least temperature rise area lies in north-western area of Mekong Delta including Kien Giang Province.

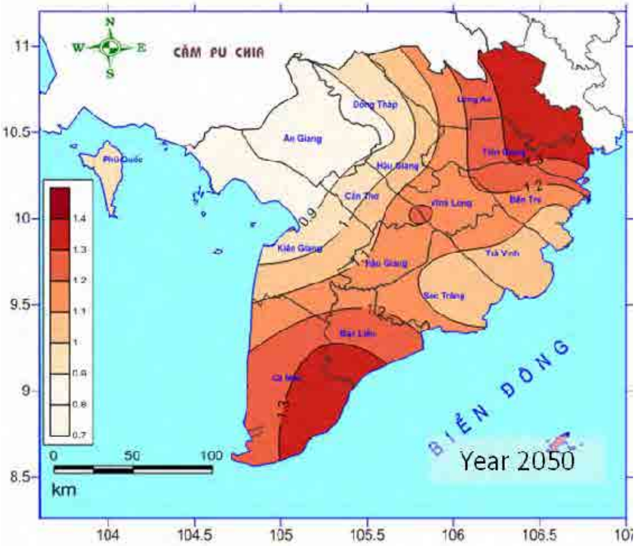


**Figure 3.2.1 Mean Annul Temperature Rise at Year 2050 in Percentage under Scenario B2**

Figure 3.2.2 to Figure 3.2.4 show change of mean annual temperature, mean annual maximum temperature, and mean annual minimum temperature for overall average of Mekong Delta simulated under the 3 scenarios of B1, B2, and A2. The temperature rise was estimated in percentage against the average temperature of the period from 1980 to 1999. As Figure 3.2.2 shows, the mean temperature increases continuously though the increase for scenario B1 seems to curve down toward year 2100. The mean annual temperature is expected to rise by about 1 $^{o}$C in year 2050 for the 3 scenarios and by 1.4 $^{o}$C to as much as 2.7 $^{o}$C in year 2100 depending on the scenario.

For the mean annual maximum temperature, the increase is more than that of mean annual temperature. It shows already more than 1 $^{o}$C increase in year 2020 against the average temperature for the period of 1980 and 1999, nearly about 2 $^{o}$C increase in 2050 and then 2.2 $^{o}$C to 3.2 $^{o}$C increase in 2090. The mean annual minimum temperature shows almost same trend of mean annual maximum temperature.

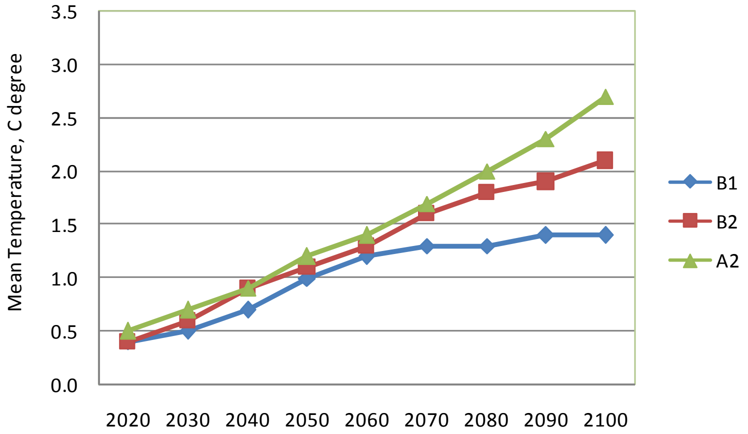


**Figure 3.2.2 Mean Annul Temperature Change in Mekong Delta with 3 Scenarios, Source; PRECIS simulation**

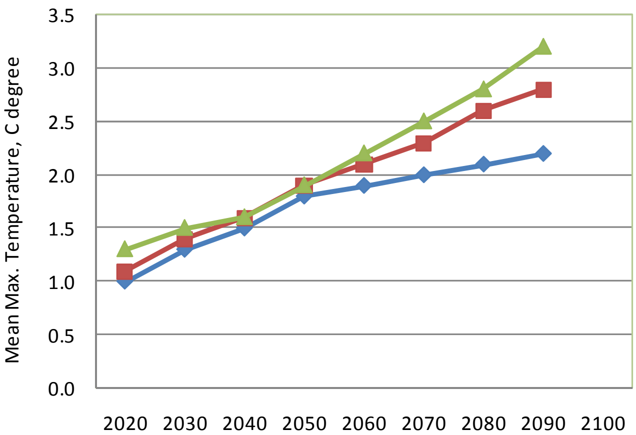


**Figure 3.2.3 Mean Annul Max. Temperature Change in Mekong Delta with 3 Scenarios, Source; PRECIS**

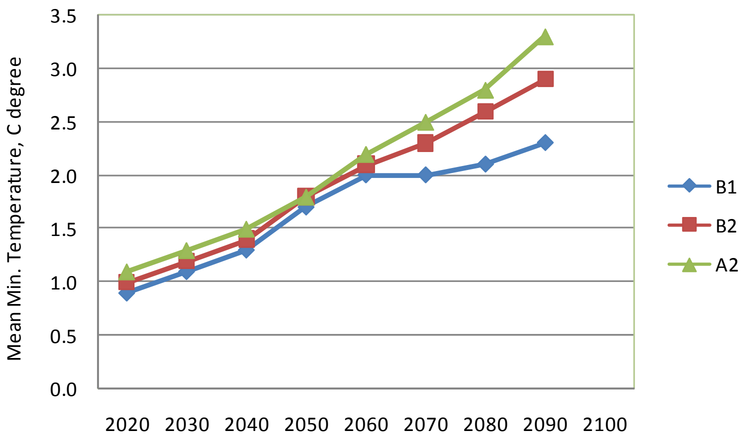


**Figure 3.2.4 Mean Annul Min. Temperature Change in Mekong Delta with 3 Scenarios, Source; PRECIS**

Figures 3.2.5 to 3.2.7 show the change of temperature by province for the 3 scenarios. Figure 3.2.5 shows the mean annual temperature for the scenario B1, low green house gas emission scenario. As it is shown, mean annual temperature shows almost continuous increase trend till year 2060 – 2070, and after that year the increase trend curves down and no more increase shows up after 2080 - 2090.

By province, Ca Mau and Tien Giang show the highest increase trend while Kien Giang facing West Sea shows the lowest increase trend. By year 2050, the mean temperature increases by about 0.8 to 1.2 °C depending on the place and by 2100 the increase reaches 1.1 to 1.7 °C.

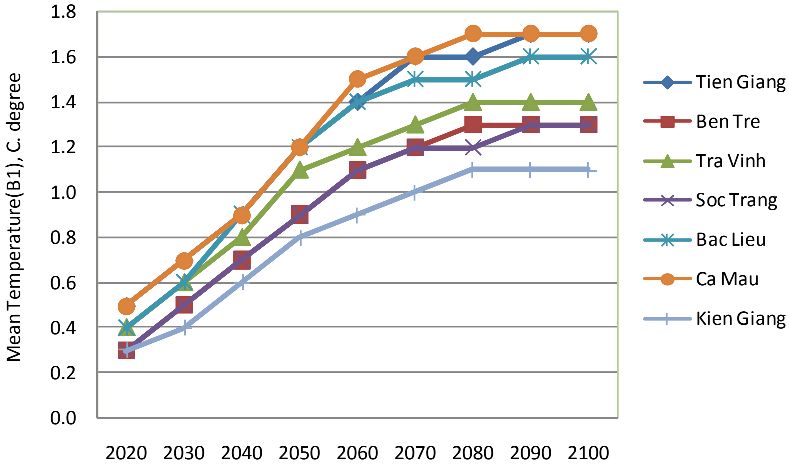


**Figure 3.2.5 Mean Annul Temperature Change under Scenario B1 by Province, Source; PRECIS simulation**

Figure 3.2.6 shows the mean annual temperature change for scenario B2, medium green house emission scenario. It shows almost linear increase trend toward 2100. The increase is about 0.8 °C to 1.4 °C by year 2050 and 1.6 °C to 2.6 °C by year 2100 depending on the place. Mean annual temperature under scenario A2, high green house gas emission scenario, has exponential increasing trend as shown in Figure 3.2.7. The increase by year 2050 reaches 0.9 °C to 1.4 °C and 2.1 to 3.3 by year 2100. Lowest increase shows up in Kien Giang while the highest increase is seen at Ca Mau, followed by Tien Giang, and Bac Lieu.

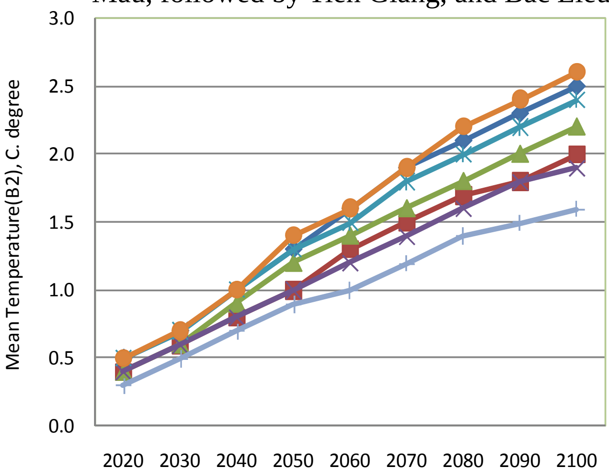


**Figure 3.2.6 Mean Annul Temperature Change under Scenario B2 by Province, Source; PRECIS simulation**

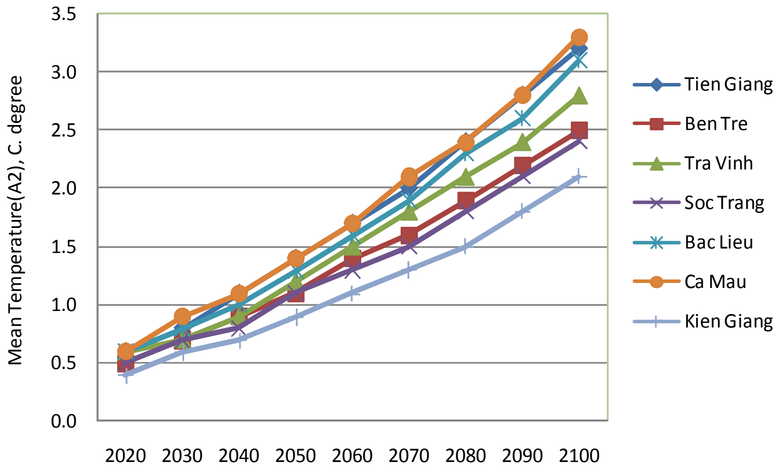


**Figure 3.2.7 Mean Annul Temperature Change under Scenario A2 by Province, Source; PRECIS simulation**

Figures 3.2.8 to 3.2.10 shows monthly temperature change for Mekong Delta under scenario B1, B2 and A2 by year. Temperature tends to increase more during rainy season than dry season. In the rainy season, at year 2050 expected temperature increase is to be about 1.2 °C, 1.3 °C and 1.4 °C for the scenarios B1, B2 and A2. At year 2100, the increase will be about 1.6 °C, 2.5 °C, and 3.2 °C respectively. One thing unique

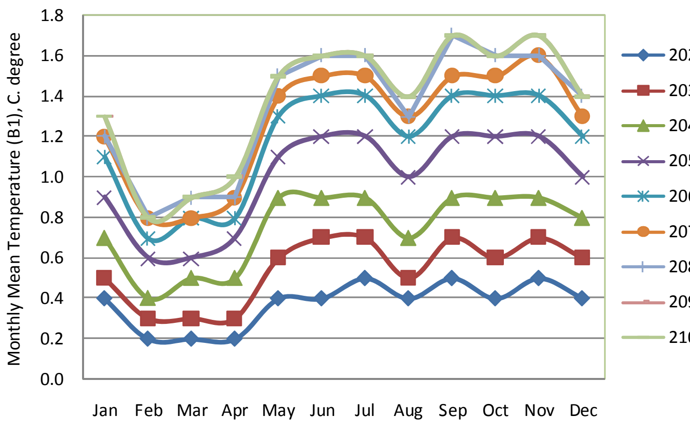


**Figure 3.2.8 Mean Monthly Temperature Change in Mekong Delta under B1, Source; PRECIS simulation**

tendency is that there is a drop during the rainy season temperature increase, which shows up in August.

During dry season, temperature increase is not much especially between February and April. The increase at year 2050 is about 0.6 °C, 0.7 °C, 0.8 °C for the scenario B1, B2 and A2 respectively. At year 2100, the increase becomes more as about 0.9 °C, 1.4 °C, and 1.7 °C for the scenario B1, B2, and A2 respectively. Trend of increase ratio by year is somewhat different by scenario as; less increase ratio toward 2100 for the scenario B1, even increase ratio toward 2100 for the scenario B2 and greater increase ratio toward 2100 for the scenario A2.

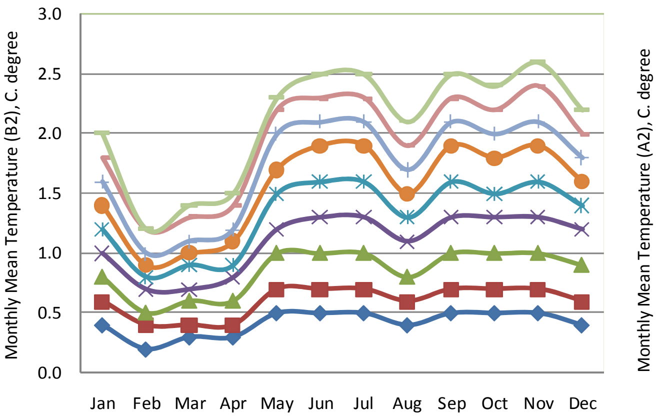


**Figure 3.2.9 Mean Monthly Temperature Change in Mekong Delta under B2, Source; PRECIS simulation**

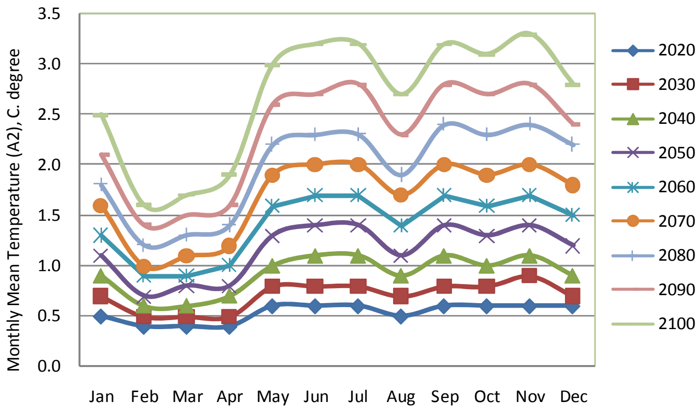


**Figure 3.2.10 Mean Monthly Temperature Change in Mekong Delta under A2, Source; PRECIS simulation**

### 3.2.2 Rainfall

Figure 3.2.11 shows simulated annual rainfall change in percentage at year 2050 under climate change Scenario B2 against the average annual rainfall between 1980 and 1999. The figure shows overall rainfall increase over the Mekong Delta with a pole at northern part of the delta where Dong Thap province is located. It is found that Ben Tre province to Soc Tran province via Tra Vinh province will have more rainfall in future along the coastal zone, while inner parts of Tien Giang, Ben Tre and whole of Ca Mau provinces will have less increase of rainfall.

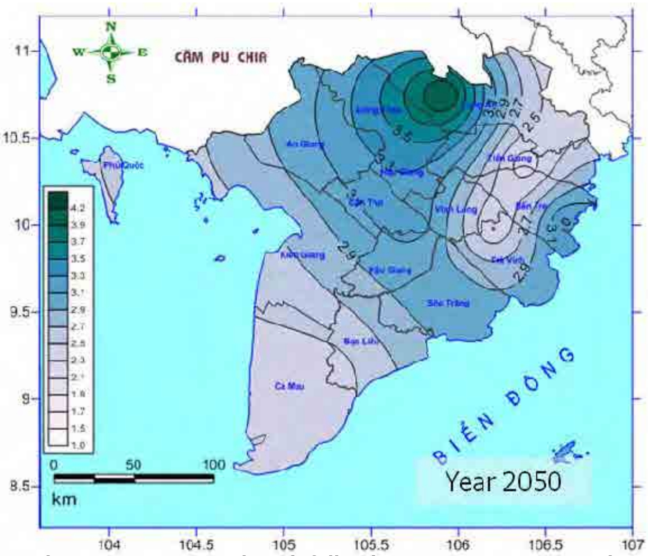


**Figure 3.2.11 Annul Rainfall Change at Year 2050 in Percentage under Scenario B2**

Figure 3.2.12 shows the simulated overall annual rainfall change of Mekong against the average rainfall between 1980 and 1999 under 3 scenarios of B1, B2 and A2. The rainfall is predicted to increase for all the 3 scenarios with a general trend that the higher green gas emission the scenario is the more the rainfall takes place and vice versa. Scenario A2 shows the highest rainfall increase as about 3% at year 2050 and over 7% at the 2100. For the B1 scenario, low green gas emission scenario, the increase trend is smaller than the others and the increase ratio after 2070 is very little.

Figure 3.2.13 shows the annual rainfall change under B1 scenario by province, while Figure 3.2.14 shows that of scenario B2 and Figure 3.2.15 indicates that of scenario A2. Overall trend of the increase is of course similar to those of increases indicated in Figure 3.2.12. The highest rainfall increase can be seen in Ben Tre, followed by Soc Trang, Bac Lieu and Kien Giang while the lowest increase shows up in Tien Giang. Difference between the provinces comes to about 1 % only at year 2050 and it becomes about 1.5 %, 2.0 % and 3.0% for the scenarios of B1, B2 and A2.

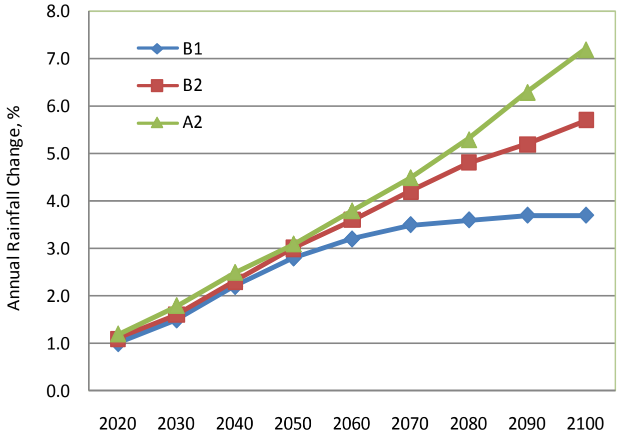


**Figure 3.2.12 Annual Rainfall Change in Mekong Delta under 3 scenarios, Source; PRECIS simulation**

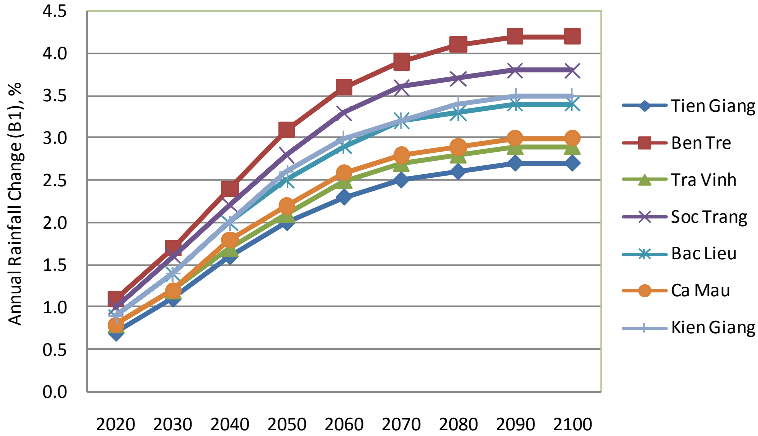


**Figure 3.2.13 Annual Rainfall Change by Province under Scenario B1, Source; PRECIS simulation**

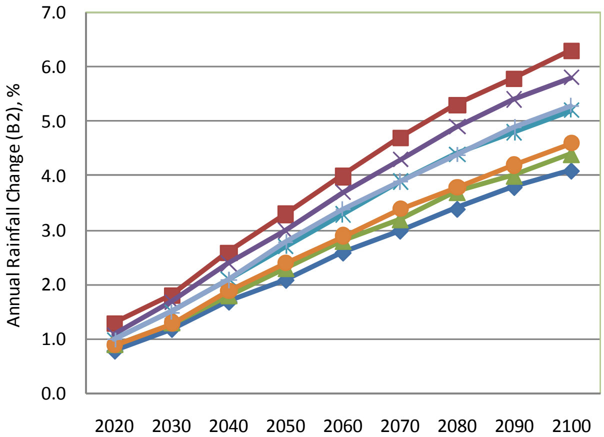


**Figure 3.2.14 Annual Rainfall Change by Province under Scenario B2, Source; PRECIS simulation**

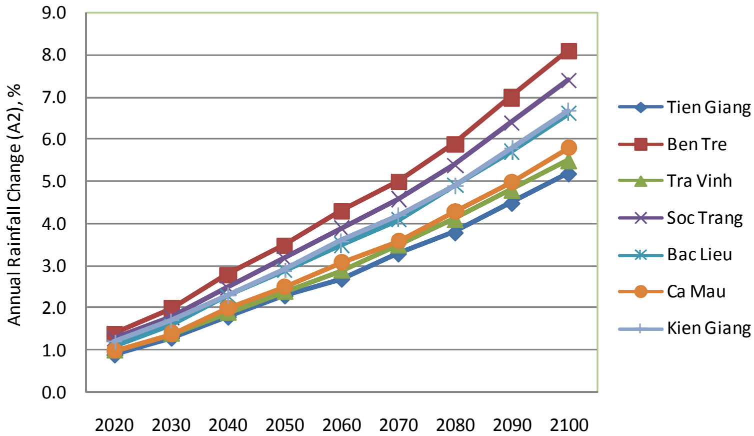


**Figure 3.2.15 Annual Rainfall Change by Province under Scenario A2, Source; PRECIS simulation**

Figures 3.2.16 to 3.2.18 show monthly rainfall change for the 3 scenarios of B1, B2 and A2 against the average monthly rainfall between 1980 and 1999. The change of the monthly rainfall fluctuates by month; during dry season the change falls in a negative range meaning the dry season rainfall in future becomes less than the past. In March, rainfall is expected to decrease by 20%, 30% and nearly about 40% at year 2100 for the scenarios of B1, B2 and A2 respectively.

On the other hand, during rainy season the monthly rainfall is projected to increase in future. The increase during rainy season shows up in July and October. July is still early part of the rainy season while October is almost end of the rainy season where usually the highest amount of monthly rainfall is recorded. In October, monthly rainfall is projected to increase by 15%, more than 20% and more than 30% at year 2100 for the 3 scenarios respectively. It can be said in future, it is projected that the rainfall tends to increase especially at the

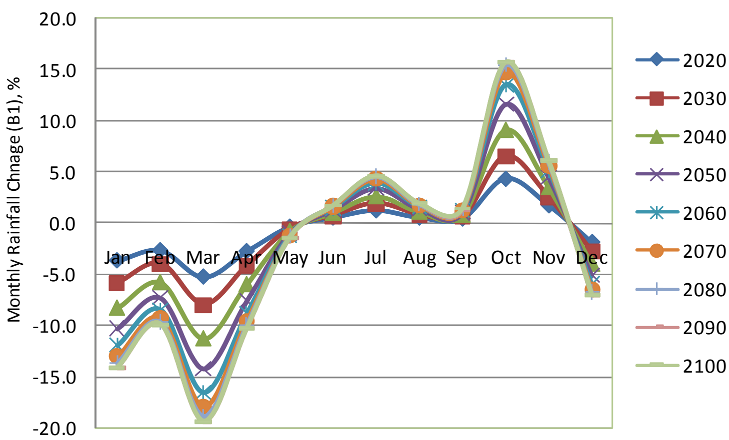


**Figure 3.2.16 Monthly Rainfall Change in Mekong Delta under Scenario B1, Source; PRECIS simulation**

end of rainy season.

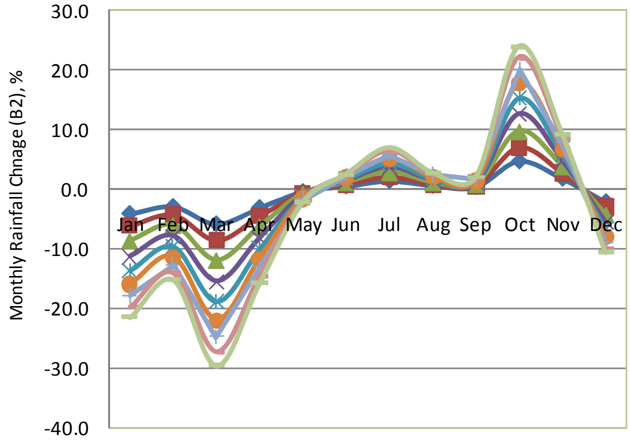


**Figure 3.2.17 Monthly Rainfall Change in Mekong Delta under Scenario B2, Source; PRECIS simulation**

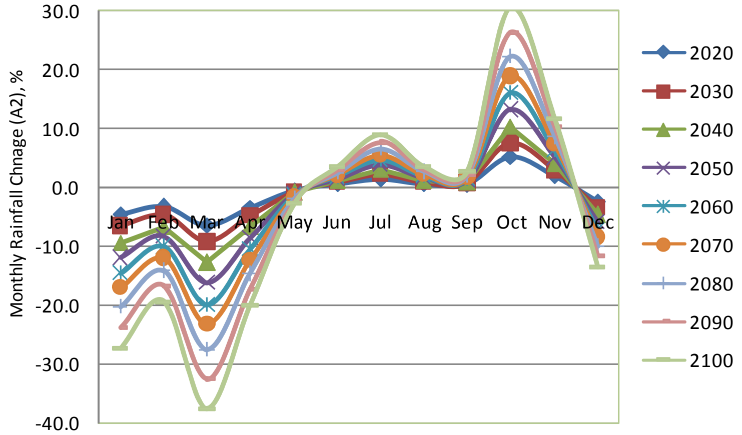


**Figure 3.2.18 Monthly Rainfall Change in Mekong Delta under Scenario A2, Source; PRECIS simulation**

### 3.2.3 Sea Level Rise

Figure 3.2.19 shows the sea level rise of Mekong Coastal area by scenario. It is shown that high green gas emission scenario, A2, shows the biggest sea level rise as 31 cm at year 2050 and as much as 103 cm at year 2100. Scenario B1 shows the lowest seas level rise; 27 cm at year 2050 and 70 cm at year 2100. The trend is somewhat exponential for all the scenarios, meaning that increase ratio becomes more towards 2100. Figures 3.2.20 to 3.2.22 show sea level rise by province for the 3 scenarios respectively. Sea level rise by province does not differ much and the difference between provinces is 5 cm even at the year 2100.

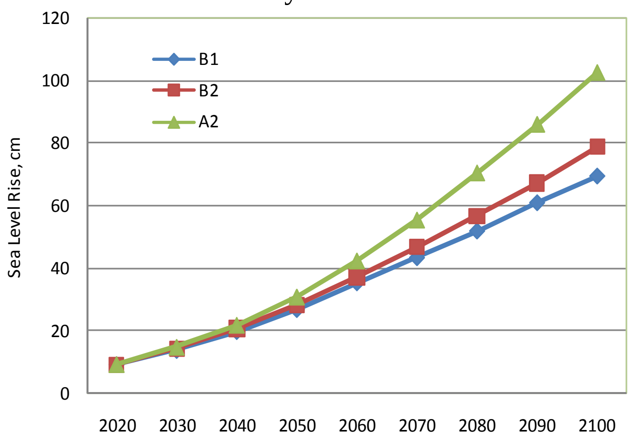


**Figure 3.2.19 Sea Level Rise of Mekong Coastal Area under 3 Scenarios, Source; PRECIS simulation**

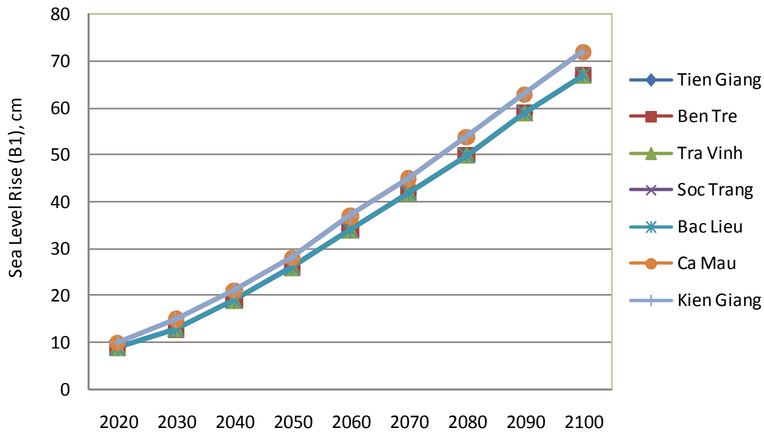


**Figure 3.2.20 Sea Level Rise by Province Under Scenario B1, Source; PRECIS simulation**

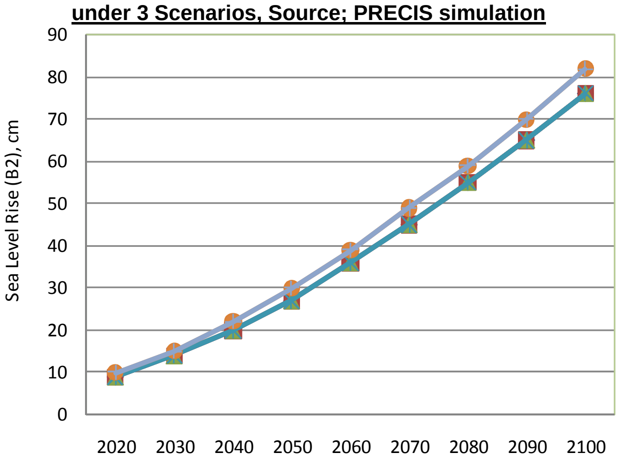


**Figure 3.2.21 Sea Level Rise by Province Under Scenario B2, Source; PRECIS simulation**

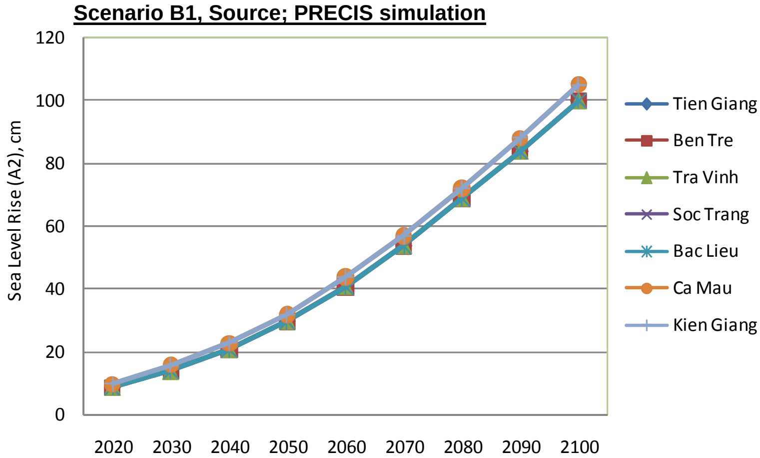


**Figure 3.2.22 Sea Level Rise by Province Under Scenario A2, Source; PRECIS simulation**

### 3.2.4 Mekong River Flow Regime Prediction (MRC)

Mekong River Commission (MRC) has carried out simulation on the future Mekong River discharge under climate change Scenarios of B2 and A1. The simulation covered up to year 2050. Besides, the Commission carried out additional simulation taking into account various number of basin development projects in projecting the future Mekong discharge. MRC considered 2 development Scenarios called; 1) basin development 2020 and 2) basin development 2050, both of which are under climate change scenario B2. The former simply means it considered all the planned water resources development projects to be constructed till 2020 in the Mekong catchment area while the latter all the water resources development projects to be constructed till 2050.

Table 3.2.1 summarizes the monthly average discharges at Kratie station by every 10 years till 2050 under scenarios B2 and A1, and those ones considering water resources development projects till 2020 and also till 2050 in comparison with discharges of year 1998 (driest year), average of 1985 – 2000, and average of 1991 – 2000. In addition, Figure 3.2.23 illustrates the dry season's discharges simulated under scenarios B2 and A1 (refer to thin lines) as compared to the average discharge between 1991 and 2000 shown with the bold line while Figure 3.2.24 shows the discharges of rainy season. Likewise, Figure 3.2.25 and Figure 3.2.26 show the dry and rainy seasons' discharges, respectively, both of which have considered planned development projects in the catchment areas. From those table and figures, following are expected;

1) With respect to dry season as shown in Figure 3.2.23, discharge not considering future water resources development projects becomes bigger from the beginning till the direst season (end of March) than the average discharge between 1991 and 2000. Then, the simulated discharges tend to be almost same as the average discharge of 1991 - 2000. Looking at the rainy season discharge not considering the development projects as shown in Figure 3.2.24, the simulated discharges do not show clear tendency of being bigger or being less than the 1991 – 2000 average discharge till the peak period of mid September. However, after having reached the peak in and around mid September, simulated discharges tend to surpass the average discharge. It may be summarized as the simulated future discharge tends to increase while descending from the peak period towards the mid dry season, and tends to be almost same while ascending from the mid dry season towards the peak rainy season period.

2) With respect to the future discharge considering the water resource development projects in the catchment, the dry season's discharge shows very much increase trend. As illustrated in Figure 3.2.25, the simulated discharge during the driest periods of March and April comes to about 4,000 $m^3/s$ while the average discharge between 1991 and 2000 is only 2,300 – 2,400 $m^3/s$. This implies that there might be a possibility that should the future development in the catchment be realize as planned, the dry season discharge after Kratie station could increase by as much as 70% (from around 2,350 to 4,000 $m^3/s$). The reason why it increases so much is the effect of hydro power dams which releases much amount of stored water during dry season for power generation.

3) For the rainy season discharge considering the planned development projects in the catchment (Figure 3.2.26), the simulated ones tend to be smaller than the average discharge from 1991 to 2000 during the course of ascending towards the peak, and then sometime after the peak period of mid September, the discharges are revered, i.e., simulated ones tend to be bigger than the average. This most probably means that hydro power dams considered in the simulation could work to store the rainy season Mekong River discharge while ascending the hydro-curve, and once after it has reached the peak, the dams start discharging the stored water for generating power.

4) On the Scenarios A1 and B2, there is not much difference between the two simulation results. In some years, discharge simulated under Scenario A1 may be bigger than that of Scenario B2 while

vice versa takes place in other years. Note that simulated discharges in October tend to sharply increase in all the scenarios A1, B2, and those cases considering planned water resources development projects in the catchment. This tendency seems to correspond to the increase of rainfall at the end of rainy season, October (refer to Figures 3.2.16 – 3.2.18.).

**Table 3.2.1 Monthly Average Discharges at Kratie Simulated under Different Scenarios**

| Month | Past Record (average) | | | Scenario B2 (average) | | | | Scenario A2 (average) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 1985-2000 | 1991-2000 | 2011-2020 | 2021-2030 | 2031-2040 | 2041-2050 | 2011-2020 | 2021-2030 | 2031-2040 | 2041-2050 |
| Jan | 3,724 | 3,793 | 4,077 | 4,398 | 4,858 | 5,627 | 4,702 | 4,556 | 5,268 | 5,364 | 5,064 |
| Feb | 3,140 | 2,694 | 2,943 | 2,994 | 3,377 | 3,700 | 3,144 | 3,039 | 3,445 | 3,837 | 3,500 |
| Mar | 2,236 | 2,161 | 2,337 | 2,343 | 2,417 | 2,751 | 2,301 | 2,350 | 2,610 | 2,828 | 2,574 |
| Apr | 2,560 | 2,189 | 2,420 | 1,848 | 2,304 | 2,662 | 2,143 | 2,233 | 2,299 | 2,432 | 2,594 |
| May | 3,057 | 3,988 | 4,303 | 3,399 | 6,976 | 4,996 | 3,459 | 3,897 | 5,707 | 3,151 | 5,450 |
| Jun | 6,286 | 11,472 | 11,602 | 11,360 | 10,931 | 10,788 | 9,803 | 12,161 | 14,330 | 10,526 | 13,791 |
| Jul | 17,040 | 21,222 | 23,418 | 22,297 | 21,245 | 21,097 | 16,571 | 17,681 | 22,251 | 23,923 | 24,983 |
| Aug | 23,472 | 31,173 | 33,138 | 30,760 | 27,829 | 34,238 | 29,045 | 31,101 | 29,557 | 37,908 | 32,662 |
| Sep | 31,178 | 32,587 | 35,236 | 30,994 | 37,302 | 40,168 | 33,430 | 30,134 | 34,934 | 39,331 | 39,117 |
| Oct | 17,946 | 21,851 | 22,296 | 23,942 | 25,013 | 27,121 | 25,180 | 26,081 | 24,822 | 27,586 | 25,435 |
| Nov | 11,585 | 11,927 | 12,209 | 13,986 | 13,892 | 16,983 | 14,111 | 13,984 | 14,282 | 15,726 | 14,840 |
| Dec | 7,569 | 6,471 | 6,784 | 7,595 | 8,461 | 9,500 | 7,792 | 8,059 | 8,490 | 9,080 | 8,428 |
| Month | Past Record | | | Basin Development 2020, B2 | | | | Basin Development 2050, B2 | | | |
| | 1998 | 1985-2000 | 1991-2000 | 2011-2020 | 2021-2030 | 2031-2040 | 2041-2050 | 2011-2020 | 2021-2030 | 2031-2040 | 2041-2050 |
| Jan | 3,724 | 3,793 | 4,077 | 4,695 | 4,800 | 5,212 | 4,767 | 4,658 | 4,762 | 5,150 | 4,745 |
| Feb | 3,140 | 2,694 | 2,943 | 3,795 | 4,086 | 4,036 | 3,878 | 3,806 | 4,085 | 4,048 | 3,887 |
| Mar | 2,236 | 2,161 | 2,337 | 3,499 | 3,618 | 3,697 | 3,499 | 3,592 | 3,730 | 3,835 | 3,634 |
| Apr | 2,560 | 2,189 | 2,420 | 3,541 | 3,891 | 3,926 | 3,727 | 3,638 | 3,936 | 4,011 | 3,803 |
| May | 3,057 | 3,988 | 4,303 | 4,597 | 7,647 | 6,224 | 4,957 | 4,637 | 7,460 | 5,976 | 5,017 |
| Jun | 6,286 | 11,472 | 11,602 | 10,754 | 11,587 | 10,713 | 9,704 | 10,293 | 11,215 | 10,272 | 9,141 |
| Jul | 17,040 | 21,222 | 23,418 | 19,857 | 19,161 | 18,864 | 14,829 | 19,028 | 18,201 | 18,153 | 14,118 |
| Aug | 23,472 | 31,173 | 33,138 | 27,870 | 24,994 | 31,156 | 25,789 | 26,956 | 24,225 | 30,233 | 24,776 |
| Sep | 31,178 | 32,587 | 35,236 | 28,498 | 34,781 | 38,305 | 30,582 | 27,693 | 33,932 | 37,443 | 29,450 |
| Oct | 17,946 | 21,851 | 22,296 | 22,400 | 22,783 | 25,870 | 23,279 | 21,780 | 22,112 | 25,328 | 22,720 |
| Nov | 11,585 | 11,927 | 12,209 | 12,827 | 12,570 | 16,135 | 13,025 | 12,688 | 12,270 | 15,830 | 12,853 |
| Dec | 7,569 | 6,471 | 6,784 | 7,023 | 7,767 | 8,614 | 7,119 | 6,884 | 7,538 | 8,286 | 6,921 |

Source: Mekong River Commission

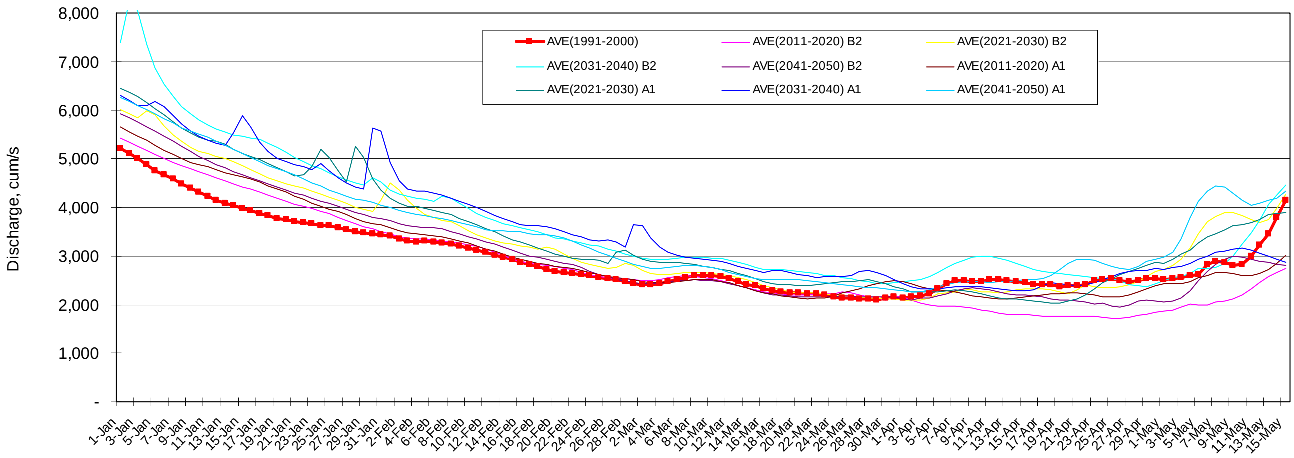


**Figure 3.2.23 Mekong River Discharge at Kratie during Dry Season under Scenarios A1 and B2**

Source; Mekong River Commission

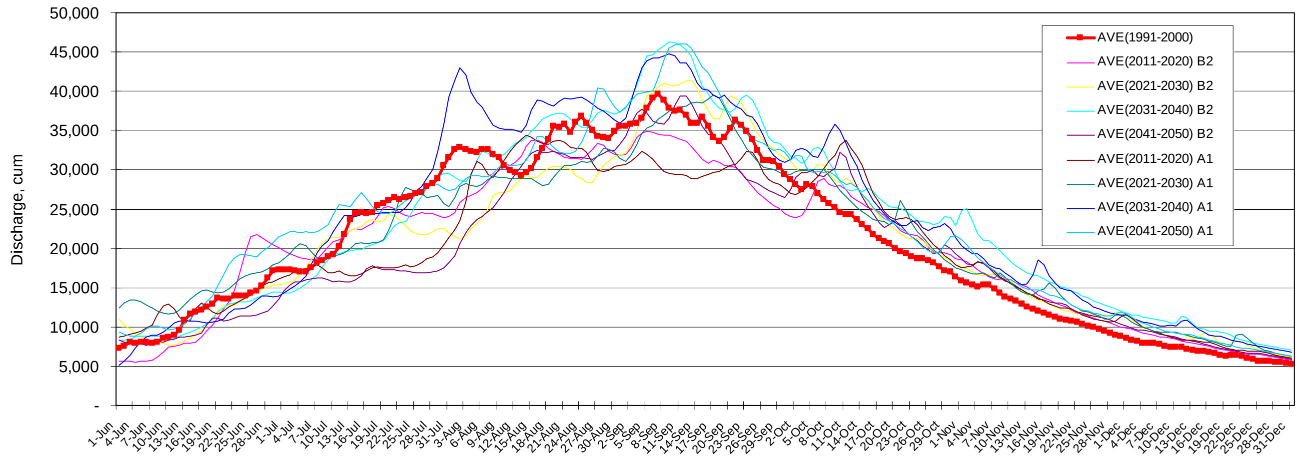


**Figure 3.2.24 Mekong River Discharge at Kratie during Rainy Season under Scenarios A1 and B2**

Source; Mekong River Commission

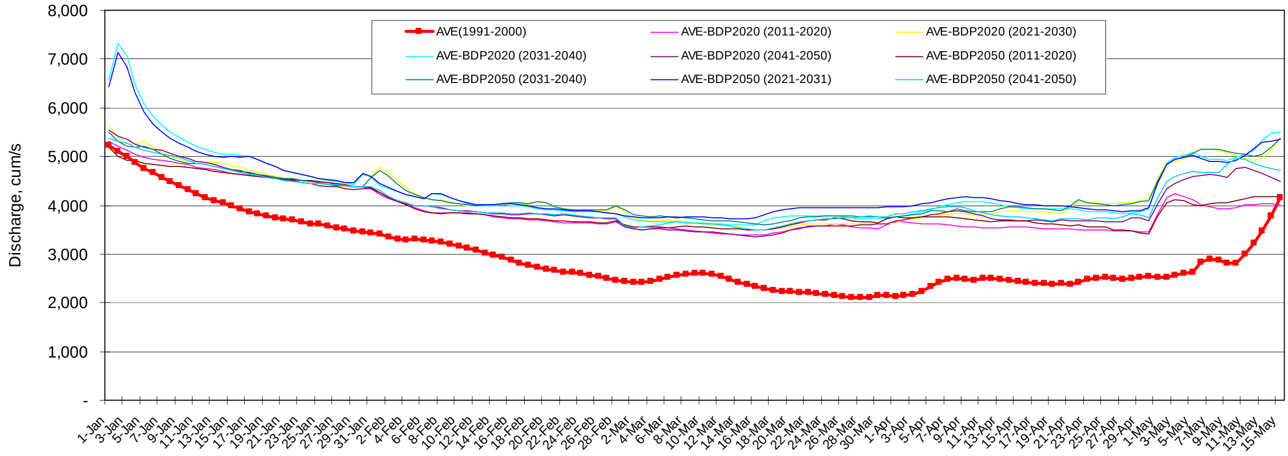


**Figure 3.2.25 Mekong River Discharge at Kratie during Dry Season with Basin Development Projects**

Source; Mekong River Commission

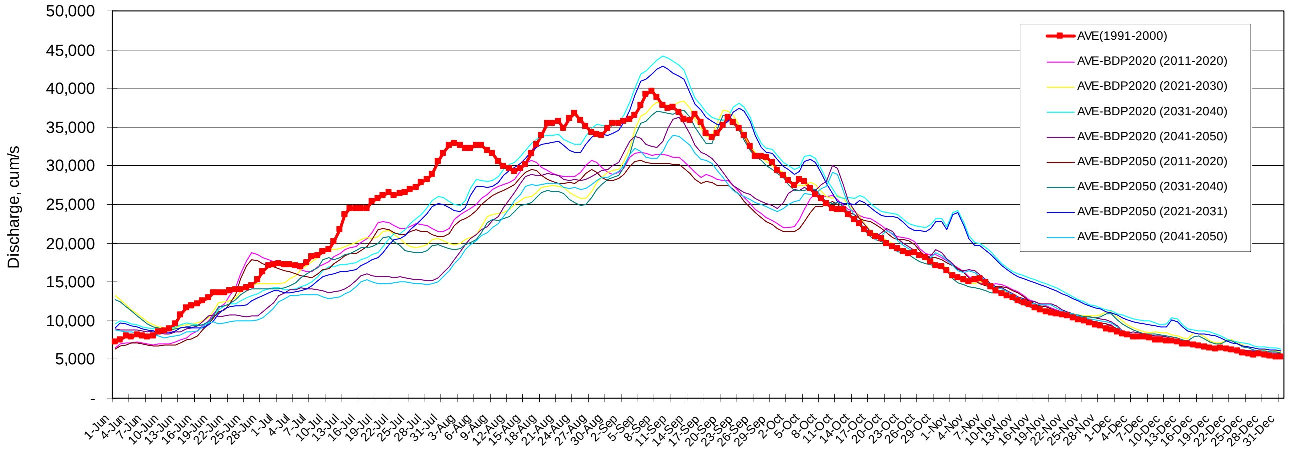


**Figure 3.2.26 Mekong River Discharge at Kratie during Rainy Season with Basin Development Projects**

Source; Mekong River Commission

## 3.3 Vulnerability Assessment on Climate Change Simulation Results

This sub-chapter presents vulnerability assessment for the Project area on the climate change. Climate change prediction in future was elaborated in the previous section, and this sub-section carries out saline intrusion simulation and also flood simulation taking into account sea level rises, Mekong River future discharge, etc. Based on these simulations, firstly yield change, mostly in terms of loss, is to be estimated and whereby loss in economic value will be examined. Finally taking into account the results, vulnerable areas to the climate change are to be identified for the Project area.

### 3.3.1 Impact on Crop Production by Temperature Rise under Climate Change

#### 1) Correlation between Temperature Rise and Paddy Yield

There is a relationship between temperature and crop yield often reported. For example, extremely high temperatures during vegetative growth are well known to reduce tiller number and plant height, and negatively affect panicle and pollen development. This causes reduction of paddy yield potential. High temperature is of particular importance during flowering, which typically occurs at mid-morning. Exposure to high temperature (i.e. greater than 35 Celsius degree) can greatly reduce pollen viability and thereby causes irreversible yield loss because of spikelet sterility.

A research result reported that 1 Celsius degree rise in mean daily temperature reduces major crop yields by 5 - 7 % based on a simulation (Matthews et al., 1997)[1]. The yield reduction is mostly associated with decrease in sink formation, shortening of growth duration and increase in maintenance respiration. Another research result confirmed that rice yield decreases by 10% for each 1 Celsius degree increase in growing-season nighttime temperature of the dry season[2]. Ziska and Manalo (1996) suggested that higher nighttime temperatures could also increase the susceptibility of rice to sterility with a subsequent reduction in seed set and grain yield.

Higher temperature shows up in spring in Vietnam just before the rainy season starts, which means the winter-spring paddy could be affected the most by this high temperature. In this regard, maximum monthly temperature data and winter-summer paddy harvest data (paddy yield) have been collected and those data corresponding to the years[3] shown in Table 3.3.1 have been applied to examine the correlation between the past temperature and the harvest data. This examination established a relationship of how temperature rise, in terms of maximum monthly temperature, affects the yield of winter-spring paddy as shown in Figure 3.3.1.

**Table 3.3.1 Years for Data Applied for Establishing Correlation between Temperature and Yield**

| Province/ Temp. Station | Can Tho | Ca Mau | Rach Gia |
|---|---|---|---|
| Tien Giang | 1995-2001 | - | - |
| Ben Tre | 1994-2003 | - | - |
| Tra Vinh | 1995-2003 | - | - |
| Soc Tran | 1994-2003 | - | - |

1 Climate Change Adaptation through Rice Production in Regions with High Poverty Levels, Reiner Wassmann and Achim Dobermann, IRRI, An Open Access Journal by ICRISAT, Seconded from Research Centre Karlsruhe (IMK-IFU), Germany

2 Rice Production and Global Change: Scope for Adaptation and Mitigation Activities, R. Wassmann, SVK Jagadish, SB Peng, K Sumfleth, Y. Hosen, and BO Sander

3 Basically data were collected from 1976 to the latest ones, mostly up to 2010. At first, all those data were employed to establish the correlation between the temperature and the paddy yield, however this revealed no correlation between the two indexes. This may be explained by a fact that yield is more affected by application of chemical fertilizer rather than temperature fluctuation. Fertilizer application has been increasing especially recent years, say, in 2000s. Since the effect of the chemical fertilizer cannot be segregated due to the lack of fertilizer application data in the published GSO date, this examination instead focused on period wise relationship, whereby such data period of 1994 – 2003 shown in Table 3.3.1 was applied.

| | | | |
|---|---|---|---|
| Bac Lieu | - | 1996-2003 | - |
| Ca Mau | - | 1996-2003 | - |
| Kien Giang | - | - | 1994-2003 |

Source: JICA Project Team with reference to the data availability

The correlation shown in Figure 3.3.1 indicates that as the temperature rises, there shows up yield reduction as depicted by a formula; y= $-0.042x^2 + 2.404x - 29.09$ ($R^2$=0.41). This indicates that there is approximately 0.57 ton/ha yield reduction against 1.0 Celsius degree temperature increase within the temperature range of 31 – 33 Celsius degrees. The reduction of 0.57 ton/ha is equivalent to about 11% reduction in the yield. This reduction, 11% reduction, is similar to what was reported by 'Rice Production and Global Change: Scope for Adaptation and Mitigation Activities, R. Wassmann, SVK Jagadish, SB Peng, K Sumfleth, Y. Hosen, and BO Sander' wherein 10 % reduction was reported.

**2) Damage Loss for Paddy Yield by Temperature Rise**

Given this correlation, future winter – summer paddy production can now be estimated under the climate change temperature rise. Figure 3.3.2 to Figure 3.3.4 show yield change by province, its rate of yield change, and production change by province as well as its summated change, which were all estimated under climate change scenario B2. In addition, Figures 3.3.5 – 3.3.7 show same production changes estimated under temperature rise forecasted with climate change scenario A2. In fact, IMHEN simulated temperature change under scenario B1 as well; however the result shows the least temperature rise, and therefore the result is not taken in this discussion but the 2 bigger change scenarios only, i.e. scenarios B2 and A2. Note that 'present' means the average yield/production from year 2005 to 2000. The following figures indicate such yield changes in future as the temperature goes up;

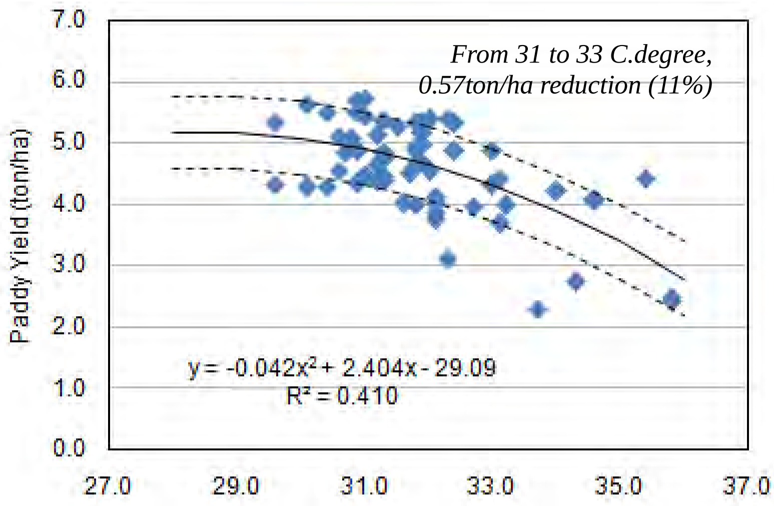


**Figure 3.3.1 Correlation between the Paddy Yield and Maximum Monthly Temperature**
Source; MONRE for meteorological data, DARD for Paddy Yields.

1) Present yield of winter – spring paddy stays at around 4.5 to 4.9 tons/ha by province and this yield starts going down as the temperature goes up in future. Under the climate change scenario B2, where 0.9 – 1.4 (1.6 – 2.6) Celsius degree temperature rise is expected at year 2050 (2100) as compared to the base year 2000, the yield may reduce to 3.8 – 4.2 (3.2 – 3.8) tons/ha at year 2050 (2100) depending on the province (see Figure 3.3.2). This yield reduction is corresponding to 12 – 18 (22 – 29) % yield loss at the year 2050 (2100) depending on the province (see Figure 3.3.3). According to the Figure 3.3.4, total production of the winter – spring paddy for the Project area is now about 4 million tons and this total production reduces to 3.4 (3.0) million tons at year 2050 (2100). This means 15 (25) % loss at year 2050 (2100) could take place as compared with the present production.

2) Under the climate change scenario A2, where 0.9 – 1.4 (2.1 – 3.3) Celsius degree temperature rise is expected at year 2050 (2100) as compared to the base year of 2000, the yield may reduce to 3.7 – 4.2 (2.9 – 3.6) tons/ha at year 2050 (2100) depending on the province (see Figure 3.3.5). This yield reduction is corresponding to 14 – 18 (27 – 36) % yield loss at the year 2050 (2100)

depending on the province (see Figure 3.3.6). According to the Figure 3.3.7, total production of the winter – spring paddy for the Project area which is now about 4 million tons may reduce to 3.4 (2.7) million tons at year 2050 (2100). This means 15 (33) % loss at year 2050 (2100) as compared with the present production. Note that the reduction till 2050 is not much different between the 2 climate change scenarios of A2 and B2 while the change after 2050 towards 2011 tends to be bigger since the PRECIS prediction for A2 scenario shows an accelerated incremental trend towards 2100.

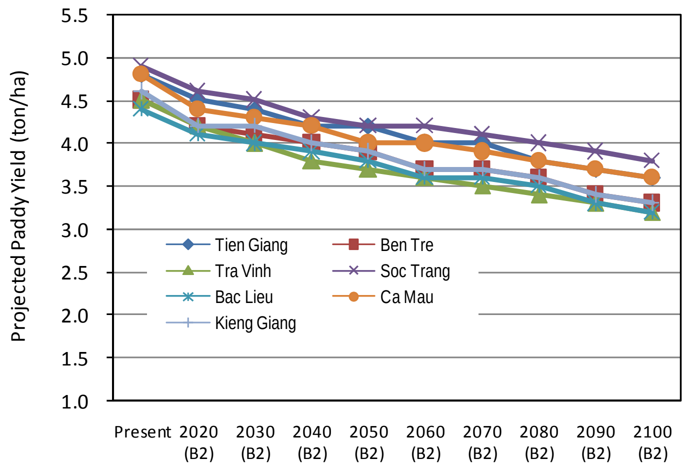


**Figure 3.3.2 Yield Reduction under B2 Scenario**

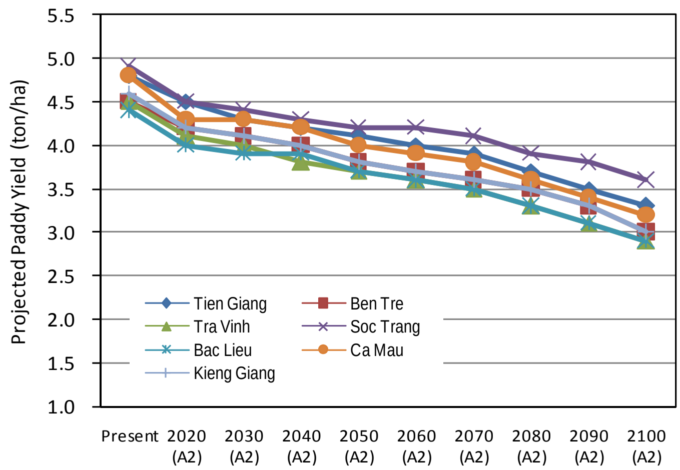


**Figure 3.3.5 Yield Reduction under A2 Scenario**

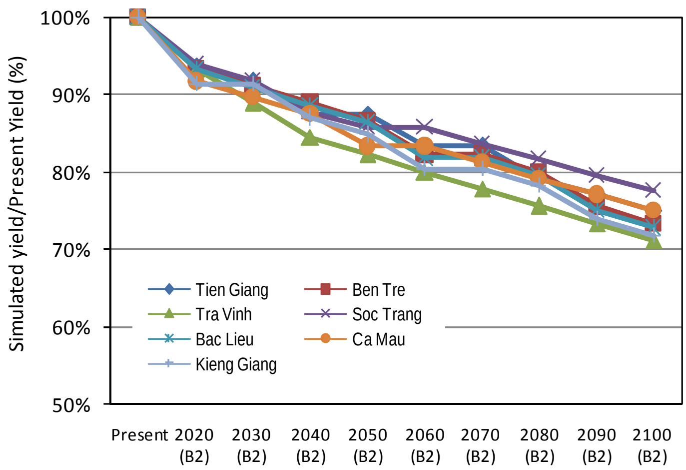


**Figure 3.3.3 Yield Reduction in % under B2 Scenario**

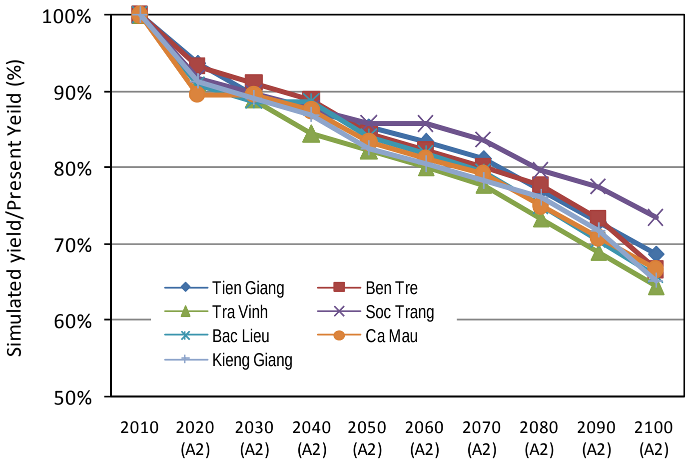


**Figure 3.3.6 Yield Reduction in % under A2 Scenario**

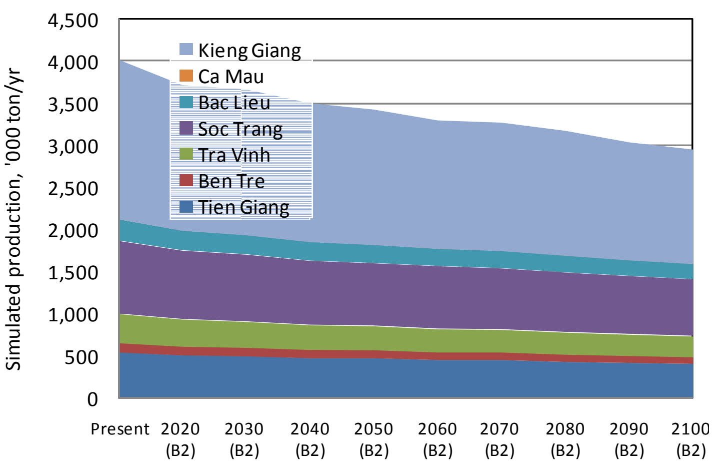


**Figure 3.3.4 Production Reduction under B2 Scenario**

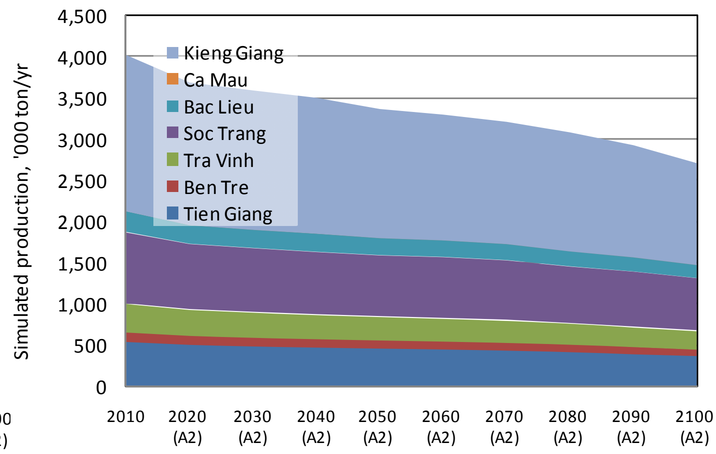


**Figure 3.3.7 Production Reduction under A2 Scenario**

### 3.3.2 Impact on Crop Production by Saline Intrusion under CC

Table 3.3.2 summarizes the simulation cases for saline intrusion. Basically the cases are categorized in 3 groups as; 1) cases with the driest year's Mekong River discharge (1998), 2) cases with projected discharges by MRC including 1991-2000 average discharge, and 3) average projected discharge taking into account future 50 years basin catchment area development where dry season's Mekong flow is to be augmented by as much as 70%. Sea level rises have also been taken into account, e.g., 12 cm. 17 cm, 30 cm, 50 cm and 100 cm corresponding to relevant years and different climate change scenarios.

**Table 3.3.2 Simulation Cases for Saline Intrusion**

| No. | Saline Simulation | Selection of the Discharge | Discharge Scenario | Sea Level Rise, cm | Sea Level Scenario |
|---|---|---|---|---|---|
| 1 | DY 1998 | Year 1998 | - | 0 | |
| 2 | DY 1998 SLR17 | Year 1998 | - | 17 | 2030 B2&A1FI |
| 3 | DY 1998 SLR30 | Year 1998 | - | 30 | 2050 B2 |
| 4 | DY 1998 SLR50 | Year 1998 | - | 50 | 2080 B1 |
| 5 | DY 1998 SLR100 | Year 1998 | - | 100 | 2100 A1FI |
| 6 | DBD 1991-2000 | Average Discharge of 1991-2000 (MRC) | - | 0 | |
| 7 | DPD 2020 B2 | Average Projected Discharge of 2011-2020 | B2 (MRC) | 12 | 2020 B2 |
| 8 | DPD 2030 B2 | Average Projected Discharge of 2021-2030 | B2 (MRC) | 17 | 2030 B2 |
| 9 | DPD 2050 B2 | Average Projected Discharge of 2041-2050 | B2 (MRC) | 30 | 2050 B2 |
| 10 | DPD 85% B2 | Probability 85% Projected Discharge | B2 (MRC) | 30 | 2050 B2 |
| 11 | DPDD 2050 B2 | Average Projected Discharge of 2041-2050* | B2 (MRC) | 30 | 2050 B2 |

Note: *; this discharge is provided by MRC based on Future 50 Years Development Scenario. Source; JICA Project Team

As aforementioned, MRC estimated future Mekong River discharge under climate change scenarios of A1 and B2. In this section, the future Mekong discharges applied is that result for climate change scenario B2, which corresponding to the most referred cases by IMHEN/ Vietnam government, and also this discharge gives a little smaller volume than that of A1 scenario during the dry season, which in turn gives critical simulation condition between the 2 scenarios in terms of examining the magnitude of saline intrusion during the dry season. As per boundary conditions for the simulation, summary is given in the right box (for detail, refer to Appendix).

**Tips of the Boundary Condition for Simulation:**

- ✓ Simulation model covers not only whole Mekong Delta but also some areas along Mekong River up to Kratie station located in Cambodia; the whole area of the model is applied for each simulation.
- ✓ Boundary conditions are given at; Kratie for upstream boundary with hourly water, and for salinity level, coastal 9 stations for downstream boundary with hourly water and salinity level.
- ✓ Model calibrations were made by hourly data of 365days in such specific years as; an average year for 2008, a flood year for 2000, a draught year for 1998.
- ✓ Model calibration in dry season (drought) was conducted in comparison with 12 inland stations; the same magnitude and trend were confirmed between observed hourly but intermittence data and simulation results.
- ✓ Model calibration in rainy season (flood) was conducted in comparison with 23 inland hourly water level stations; thus simulation errors were verified less than 5%.

#### 1) Damage Indexes under Saline Intrusion

Saline intrusion primarily affects crop production, reducing the yield and when the salinity reaches certain level crops can hardly grow. Examination of the impact caused by saline intrusion focuses on paddy being the primary concern, fruit, vegetables and forest (Melaleuca). There are experiments and researches which show relationships between salinity level and the reduction of the yield. Table 3.3.3 summarizes the relationships to be taken into the assessment of damage loss under saline intrusion.

R. S. Ayers and D.W. Westcot (1989)[4] presented tables regarding crop tolerance against saline content in irrigation water and yield loss in percentage for some selected crops including paddy. Saline

[4] R. S. Ayers and D.W. Westcot (1989), Water quality for agriculture, FAO Irrigation and Drainage Paper, 29 Rev. 1, 1989

tolerance of paddy is summarized in Figure 3.3.8 where total yield loss is estimated to take place at 4.9g/L of saline level in irrigation water. Damage index is thus calculated from the average at each range of saline content level in the Table 3.3.3, namely, yield damage at a range of 2.5 – 4 g/L of saline level is estimated at 54% which is the average between 33% (salt content at 2.5g/L) and 75% (salt content at 4g/L), and likewise damage 17% is estimated for the range of salt content 1.0 – 2.5 g/L.

**Table 3.3.3 Damage Index for Saline Water Intrusion**

| No | Items | Salinity Level (g/L: PPT) | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | <0.5 | 0.5 – 1.0 | 1.0 – 2.5 | 2.5 – 4 | 4 – 10 | 10 – 20 | >20 | |
| 1 | Paddy | 0% | 0% | 17% | 54% | 100% | 100% | 100% | FAO |
| 2 | Fruit | 0% | 0% | 19% | 55% | 100% | 100% | 100% | FAO |
| 3 | Vegetable | 0% | 0% | 29% | 71% | 100% | 100% | 100% | FAO |
| 4 | Forest (Melaleuca) | 0% | 0% | 0% | 0% | 50% | 100% | 100% | SIWRP |

Source: JICA Project Team

On the fruit, coastal 7 provinces produce several varieties of fruits, and the major fruits including coconut are summarized in Table 3.3.4. Ayers and Westcot (1989) presented salinity tolerance and potential yield loss for several trees and fruit crops, with which the fruits in the Project area may be categorized into 2 major groups according to the salinity tolerance and further into each 2 groups totaling 4 groups as shown in the bottom row of the table and also by 4 dotted lines in the Figure 3.3.9.

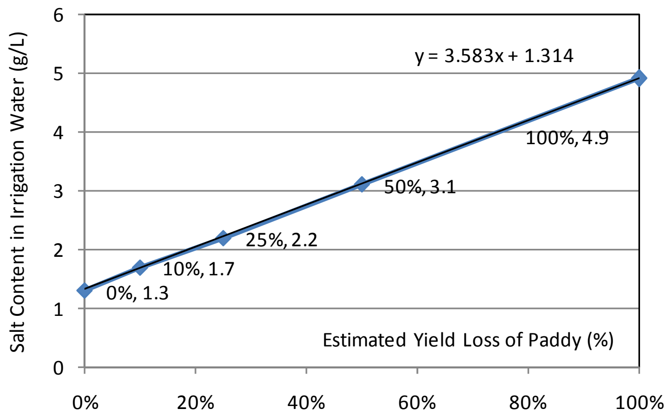


**Figure 3.3.8 Paddy Yield Potential and Irrigation Water Salinity**

Source: Ayers & Wescot (1989), FAO, modified by Study Team

To estimate the loss of fruit production under saline intrusion in the Project area, an average salinity tolerance for all the fruits is employed, which is weighted by economic value for each of the produced amount of fruits. Table 3.3.4 also shows the fruit production and the corresponding economic value estimated based on the farm-gate prices obtained from field surveys and interviews in 2011. The economic value-weighted average salinity tolerance for fruits is now shown by solid line in Figure 3.3.9, which in the aforementioned Table 3.3.3 was proportionally posted in percentage according to the range of salinity.

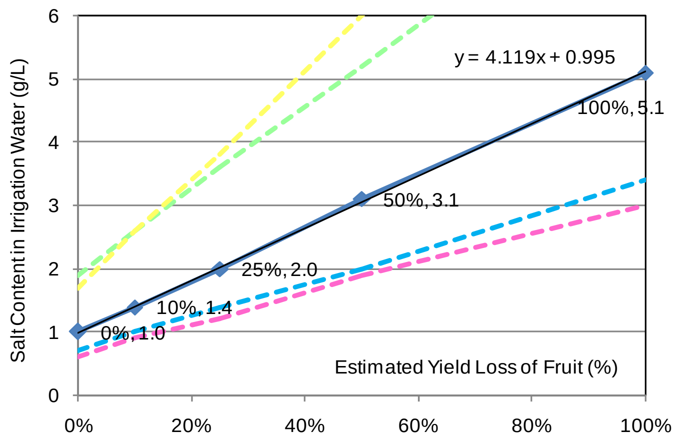


**Figure 3.3.9 Yield Loss and Salt Content in Irrigation Water**

Source: Ayers and Wescot (1989), arranged by Study Team

**Table 3.3.4 Major Fruit (2010) in the Coastal 7 Provinces and their value share (%)**

| 2010 Production | Mangosteen | Durian | Rambutan | Longan | Mango | Banana | Pamelo | Mandarine | Orange | Lemon | Pine Apple | Coconut |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) | (ton) |
| Tien Giang | 0 | 0 | 0 | 118,922 | 0 | 0 | 76,035 | 27,221 | 112,957 | 0 | 193,639 | 82,150 |
| Ben Tre | 11,201 | 15,683 | 67,602 | 62,032 | 10,186 | 36,879 | 33,921 | 20,959 | 35,568 | 20,959 | | 420,100 |
| Tra Vinh | 0 | 0 | 3,637 | 18,357 | 18,333 | 0 | 12,619 | 0 | 41,907 | 0 | 0 | 164,013 |
| Soc Trang | 0 | 0 | 0 | 18,867 | 0 | 0 | 15,276 | 0 | 27,599 | 0 | 0 | 15,032 |
| Bac Lieu | 0 | 0 | 0 | 0 | 3,112 | 19,471 | 0 | 0 | 345 | 0 | 0 | 17,501 |
| CA Mau | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 264 | 26,035 |
| Kien Giang | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89,593 | 30,132 |
| Total | 11,201 | 15,683 | 71,239 | 218,178 | 31,631 | 56,350 | 137,851 | 48,180 | 218,376 | 20,959 | 283,496 | 754,963 |
| Farm Gate Price (VND/kg) | 30,500 | 17,500 | 13,875 | 8,500 | 30,000 | 6,000 | 18,000 | 17,500 | 17,500 | 12,000 | 6,000 | 4,500 |
| Value per year | 3.416E+11 | 2.745E+11 | 9.884E+11 | 1.855E+12 | 9.489+11 | 3.381E+11 | 2.481E+12 | 8.432E+11 | 3.822E+12 | 2.515E+11 | 1.701E+12 | 3.397E+12 |
| Value Share (%) | 2.0% | 1.6% | 5.7% | 10.8% | 5.5% | 2.0% | 14.4% | 4.9% | 22.2% | 1.5% | 9.9% | 19.7% |
| Share by Group (%) | | | | | | 28% | | | | 43% | 10% | 20% |

Source: Statistical Year Book (2010) of; Tien Giang, Ven Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau, Kien Giang

Concerning vegetables, the production in the Project area seems not much, and available statistical data does not show each vegetable production but only total production as vegetable or as vegetable & beans. Therefore, to establish the relationship between the potential loss of vegetable production and the salinity level, simple average for the ones presented by Ayers and Westcot (1989) was applied for such vegetables observed in the Project area. Figure 3.3.10 shows the relationship between the loss of vegetable production and salinity level by vegetable presented by Ayers and Westcot, and the solid line shows the simple average of those vegetables.

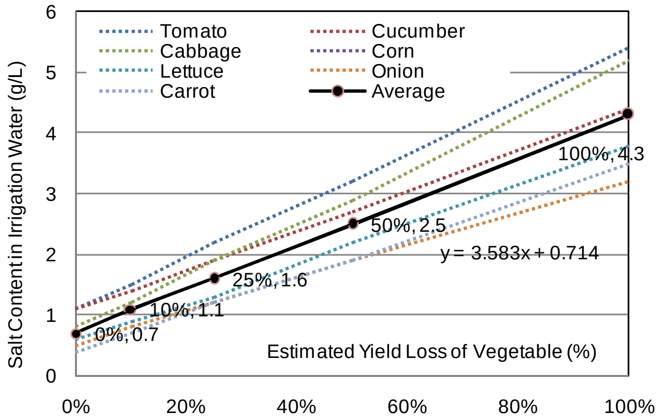


**Figure 3.3.10 Estimated Yield Loss of Vegetable and Salt Content of Irrigation Water**

Source: Ayers and Wescot (1989), modified by Study Team

Melaleuca is one of common indigenous trees in the Mekong Delta and it grows in the regions from Australia to Vietnam. The character of the tree is moderately fast-growing and it can adapt to a wide variety of soils. It has tolerance to acidic and swampy conditions, such that well-growing Melaleuca can be observed in inundated areas. It means it has high water-logging tolerance as well. It is moderately to highly salt-tolerant and the growth is expected to slow down at ECe of 10-15 dS/m level and the survival rate starts going down above 15 dS/m (N Marcar et al, 1995)[5]. 10-15 dS/m of electric conductivity is approximately equal to 6.4-9.6g/L; as a result, a damage loss is set at 50% at the range from 4 to 10g/L, beyond which 100% loss is set.

### 2) Yield Loss and Damages by Saline Intrusion

Figure 3.3.11 to Figure 3.3.14 show the salinity level change by month under the case of dry year (DY) 1998 Mekong River discharge with the 30 cm sea level rise, equivalent to year 2050's expected rise under climate change scenario B2. Also, Figure 3.3.15 to Figure 3.3.18 do the same under the case of year 2050[6] projected Mekong River discharge by MRC under scenario B2. These figures indicate;

1) Most of the coastal areas are affected by large extent of saline intrusion except for Kien Giang province where there are already many saline prevention sluice gates in operation.
2) The province most affected is Ca Mau province as expected, excluding a small area located in western-mid area where paddy fields are well protected by saline prevention sluice gates.
3) Looking at the figures by month, it is obvious that the salinity level hits the peak in April, and with the onset of rainfall from May, it starts descending.
4) The difference between the ones with the DY 1998 discharge and the ones with future projected discharge may be that the saline intrusion level is less extent in case of latter. For example, examining the Ben Tre province, the salinity level in April shows all more than 4 g/l (4,000 PPM) in the former case while there is area showing less than 4 l/g salinity level in case of latter, for the case of future projected Mekong River discharge. This is because the future discharge simulated by MRC shows increase trend than the past, whereby the saline water is pushed down to the sea side by the increased river discharge.

Figure 3.3.19 to Figure 26 show the change of saline affected areas by salinity level and by month for the case of DY 1998 Mekong River discharge with 30 cm sea level rise corresponding to year 2050's

[5] N Marcar et al (1995), Trees for salt-land, a guide to selecting native species for Australia", CSIRO, Australia
[6] The discharge of 2050 was estimated based on the average discharge from 2040 to 2050. Note that MRC's simulation has been done up to year 2050.

expected sea level rise under CC scenario B2. Figure 3.3.27 to Figure 3.3.34 illustrate the same with the Mekong River future discharge of year 2050 under 30 cm sea level rise.

In addition, Figure 3.3.35 to Figure 3.3.42 show the change of saline affected areas for the case of DY 1998 Mekong River discharge with 100 cm sea level rise corresponding to year 2100 under CC scenario A1FI, and further Figure 3.3.43 to Figure 3.3.50 show the results for which all the planned projects in the Mekong catchment area would have been implemented by year 2050. The last case implies that there would be certain extent of increase in the dry season Mekong River discharge since hydropower dams planned will work to augment the dry season discharge. The figures generally show;

1) Least affected province by saline intrusion may be Tien Giang and Kien Giang, for which one can see relatively large areas affected in the smaller saline ranges such as less than 0.5 g/l (500 PPM), as shown in for example Figure 3.3.19 and Figure 3.3.25. Upstream parts of Tien Giang province extend into mid parts of the Delta where the lands are relatively higher, less affected by saline intrusion. For the Kien Giang province, as aforementioned existing sluice gates are operational in such way of preventing saline intrusion.

2) On the other hand, the most affected areas by saline intrusion show up in such provinces of Bac Lieu and Ca Mau where a large extent of areas with more than 20 g/l (20,000 PPM) can be seen. As is well known, Bac Lieu and Ca Mau provinces area located far from the Mekong River whereby there is difficulty of receiving fresh water from the River, especially in case of Ca Mau province. Also, these 2 provinces have long seashore line, directly affected by the sea level rise.

3) There is little difference between the ones with DY 1998 MR discharge and the ones with future projected MR discharge. In some cases, though, less salinity areas tend to show up in latter case, for example as demonstrated by Figure 3.3.22 and Figure 3.3.30 for the case of Soc Trang province where areas least affected by saline show up more in the latter case. This is because future Mekong Discharge simulated by MRC has a tendency to increase especially in the early stages of the dry season, i.e. January and February (refer to Figure 3.2.23).

4) From Figure 3.3.25 to Figure 3.3.42 where 100 cm sea level rise is given, large extent of areas are affected by saline intrusion except for Kien Giang province where saline prevention sluice gates are already set. Even Tien Giang province is affected over large areas and such 3 provinces as Ben Tre, Tra Vinh and Soc Trang would have large extent of saline affected areas.

5) In case that the future development projects in the Mekong River catchment were considered as shown in Figure 3.3.43 to Figure 3.3.50, saline intrusion becomes less as expected. Though Bac Lieu and Ca Mau provinces which are located far from the Mekong River are sill largely affected by saline water, salinity level in other provinces tends to be less.

Figure 3.3.51 to Figure 3.3.58 show change (decrease) in the production of rice and vegetable, and change in the area of fruit and forest according to the level of saline intruded. The figures are summarized for the case of DY 1998 discharge with different sea level rises. On the other hand, Figure 3.3.59 to Figure 3.3.66 show the same production/area change in case of future projected Mekong River discharge with different seas level rises. In the latter case, the estimation covers up to year 2050 only since the future Mekong River discharge is available till year 2050. These figures indicate;

1) Least affected provinces are Tien Giang and Kien Giang as expected by the aforementioned figures. Ben Tre, Tran Vinh, Soc Trang and Bac Lieu provinces will be affected as the sea level rises under the condition where the Mekong River flow is fixed with the DY 1998 discharge. Ca Mau province shows large reduction in the production/area but the trend is not changed according to the sea level rise. In Ca Mau, the area sharing the most is devoted in shrimp culture which is excluded in the discussion here (shrimp culture is assumed not to be affected by saline

intrusion in this simulation). Rice, vegetables, fruit and forest in Ca Mau are cultivated in relatively smaller areas, and the areas not protected can easily be affected and the area protected can remain even under higher sea level rise, resulting in such result shown in Figure 3.3.56.

2) Though there is almost constant reduction in production/area in case of Mekong Discharge being fixed at DY 1998 discharge, quite different trend shows up in cases where future Mekong River discharge is applied as shown in Figure 3.3.59 to Figure 3.3.66. Once after the reduction takes place since the present condition, the reduction in percent change is little changed, rather showing almost same constant level. The reason why the reduction does not change in spite of the sea level being raised may be for the augmented Mekong River discharge. Especially at the early stages of dry season, e.g. January and February, Mekong River discharge is simulated to increase according to MRC. This future augmented Mekong River discharge works in pushing down the saline water whereby no further reduction in production/area took place in future.

3) One may notice that there is already a large extent of reduction even at the present stage in the above simulations. The case of ‘Present’ here means that DY 1998 Mekong River discharge without sea level rise for Figures 3.3.51 to 3.3.58 while average Mekong River discharge from 1991 to 2000 for Figures 3.3.59 to 3.3.66. In both cases, there is already large reduction in the production/area. The reduction in the simulation was so estimated that if there is saline water at certain point, the probable crops in and around the point accordingly would be damaged taking into account the salinity level. It means that in the simulation immediate damage with the salinity level was assumed. However, in the fields farmers may try to avoid saline water in one way or the other, e.g. simply stopping irrigation, utilizing fresh water stored in ditches often seen in fruit gardens, etc. Therefore, the damage or change examined under ‘Present condition’ in the simulation may not well correspond to the actual situation on the ground. In any case, however, the reduction trend according to the year, namely by sea level rise, can be referred.

Figures 3.3.67 to 3.3.74 correspond to Figures 3.3.51 to 3.3.58 while Figures 3.3.75 to 3.3.82 correspond to Figures 3.3.59 to 3.3.66. Those figures show the damage or reduction in terms of monetary value in billion VND. Figures 3.3.67 to 3.3.74 are summarized for the case of DY 1998 discharge with different sea level rises while Figures 3.3.75 to Figure 3.3.82 show the change/reduction in billion VND with future projected Mekong discharge under different seas level rises. These figures indicate;

1) Fruit and paddy are the main 2 crops which are largely damaged in monetary value. Paddy shows the biggest monetary loss in Soc Trang and Kien Giang provinces while fruit in Tien Giang, Ben Tre, Tra Vinh, Ca Mau provinces. Especially the loss of fruit in Ben Tre ranges from 3 trillion to over 7 trillion VND according to Figure 3.3.68 depending on the sea level rise. For all 7 provinces, fruit shows the biggest monetary damage, followed by paddy, and the damage for vegetable and forest are comparatively not much. The areas for vegetable and forest are smaller than those of paddy and fruit whereby the smaller damage in terms of monetary value.

2) The damage shown in Figure 3.3.75 to Figure 3.3.82 has not much changed according to the sea level. This is corresponding to the trend indicated in terms of percentage change in production/area shown in Figure 3.3.59 to Figure 3.3.66.

Figure 3.3.83 and Figure 3.3.84 show the change in production/area in terms of percentage by province. Likewise, Figure 3.3.85 and Figure 3.3.86 indicate the change (damage) in terms of monetary value by province. As shown in these figures, in terms of percentage change, Ca Mau province comes first except for year 2100 case, followed by Ben Tre, Bac Lieu, Soc Trang, and Tra Vinh. In terms of monetary change (damage), Ben Tre province shows the biggest loss, which is due to the loss of valuable fruit production, and followed by Soc Trang, Ca Mau, Kien Giang and Tra Vinh.

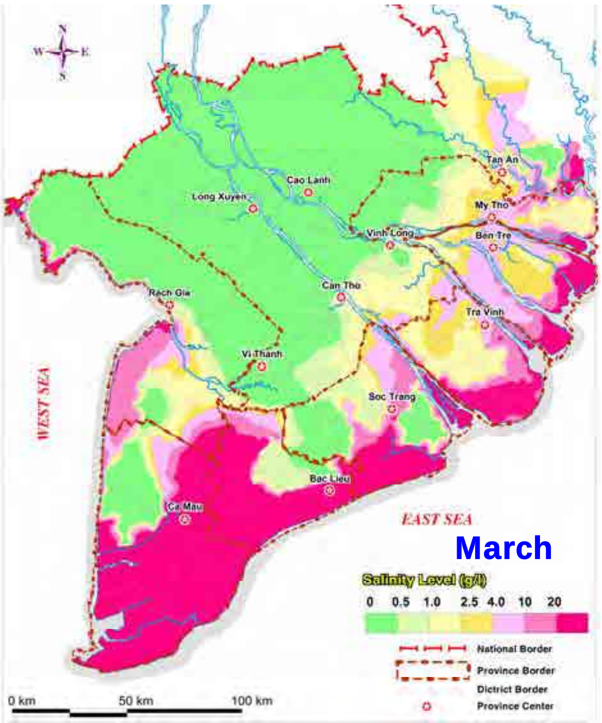


Figure 3.3.11 Salinity Isolines of March for DY 1998 MR Discharge with 30 cm SLR (2050)

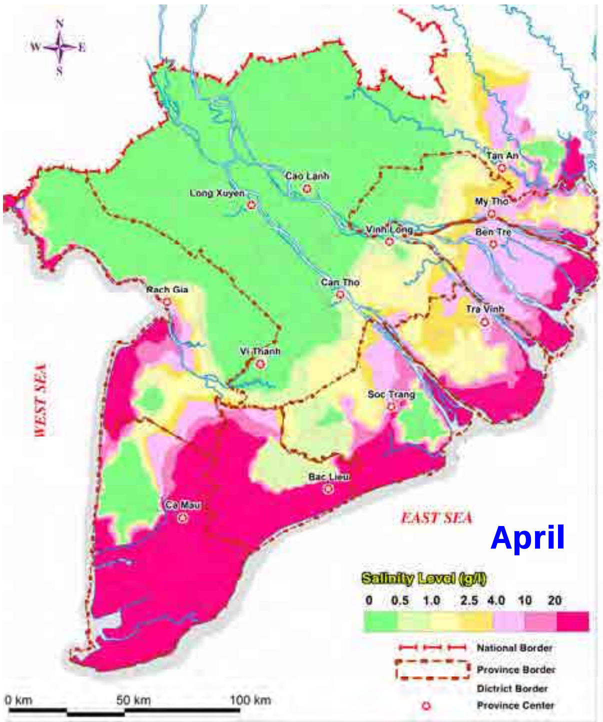


Figure 3.3.12 Salinity Isolines of April for DY 1998 MR Discharge with 30 cm SLR (2050)

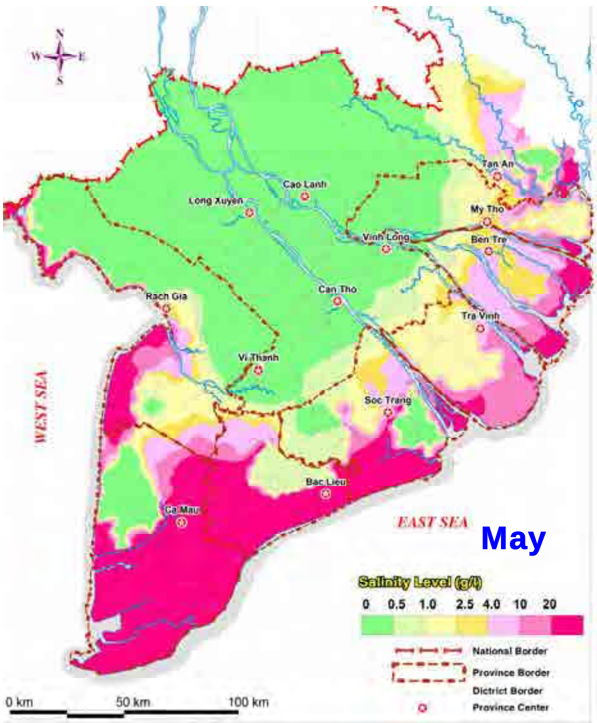


Figure 3.3.13 Salinity Isolines of May for DY 1998 MR Discharge with 30 cm SLR (2050)

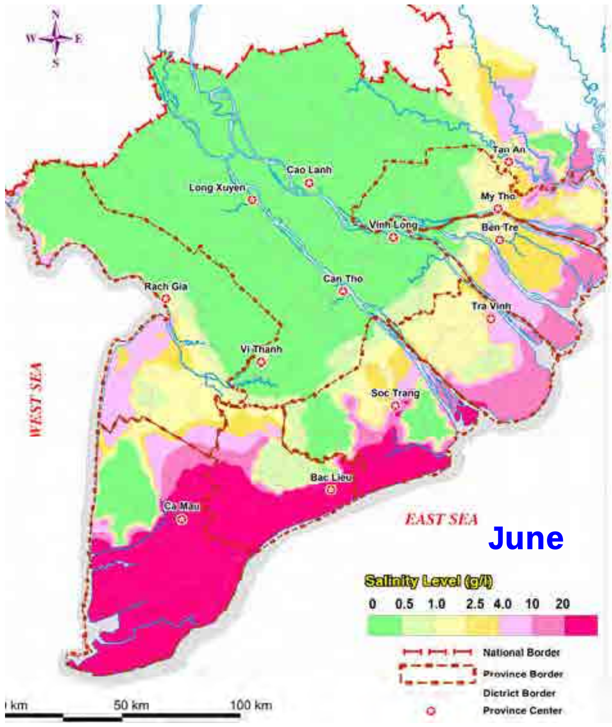


Figure 3.3.14 Salinity Isolines of June for DY 1998 MR Discharge with 30 cm SLR (2050)

Note: Salinity intrusion simulation covers January to July, for which the results only from February to June are presented above with April and May being the severest months.

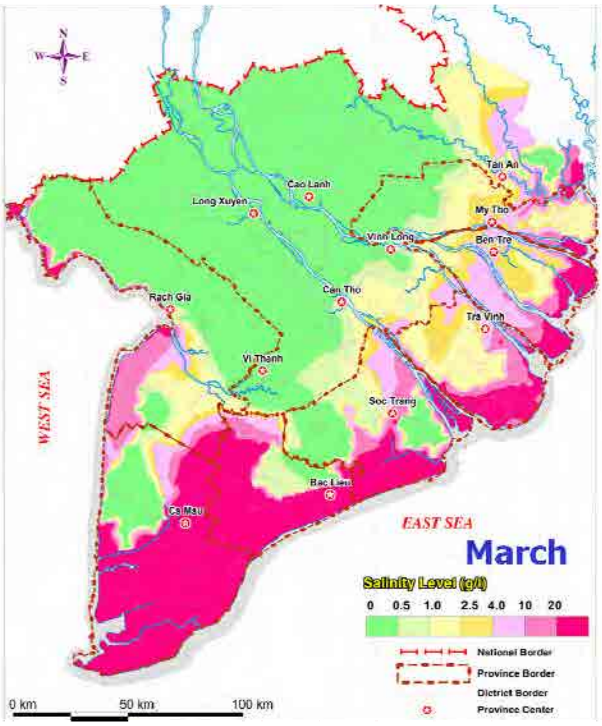


**Figure 3.3.15 Salinity Isolines of March for Scenario B2 with 30 cm SLR (2050)**

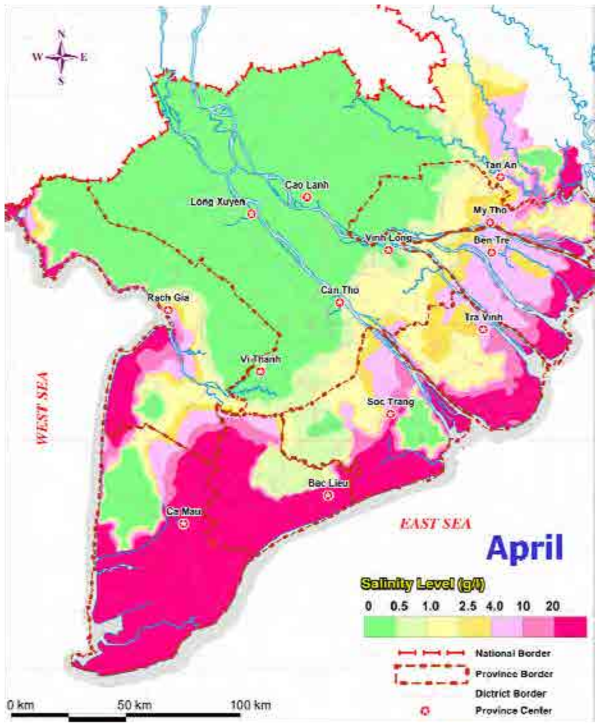


**Figure 3.3.16 Salinity Isolines of April for Scenario B2 with 30 cm SLR (2050)**

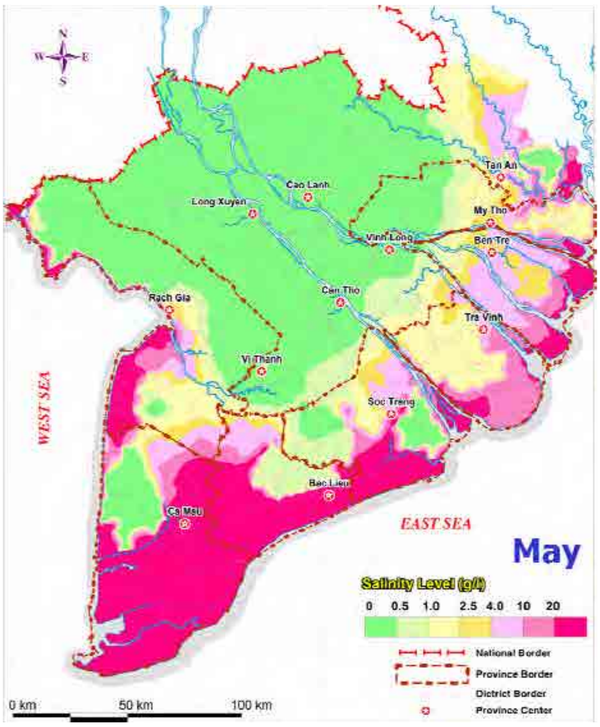


**Figure 3.3.17 Salinity Isolines of May for Scenario B2 with 30 cm SLR (2050)**

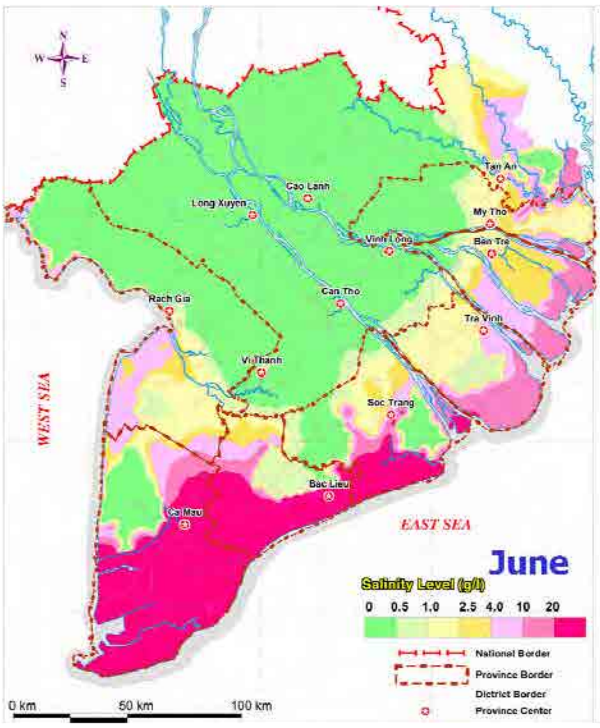


**Figure 3.3.18 Salinity Isolines of June for Scenario B2 with 30 cm SLR (2050)**

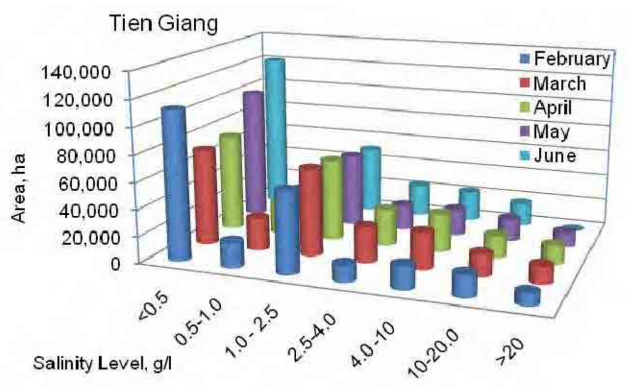


Figure 3.3.19 Saline Area for Tien Giang Province (DY1998 MR Discharge with 30cm SLR, 2050)

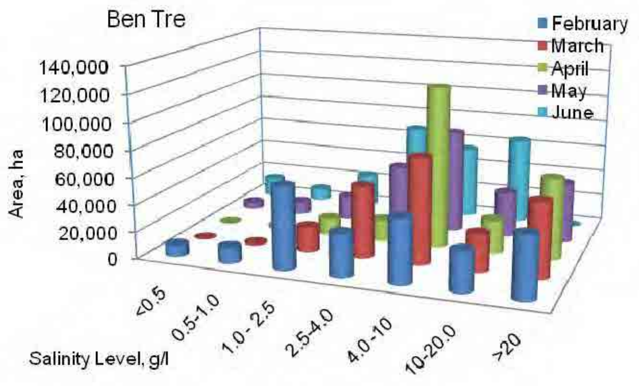


Figure 3.3.20 Saline Area for Ben Tre Province (DY1998 MR Discharge with 30cm SLR, 2050)

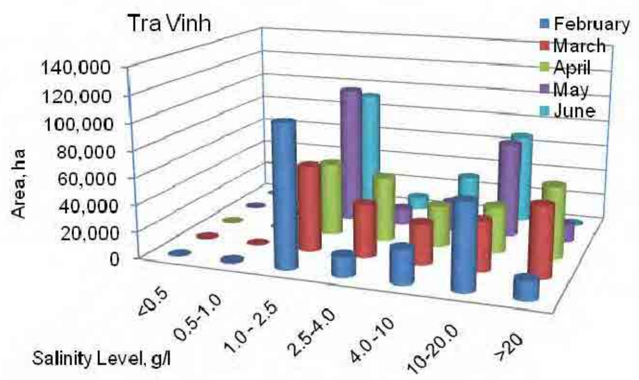


Figure 3.3.21 Saline Area for Tra Vinh Province (DY1998 MR Discharge with 30cm SLR, 2050)

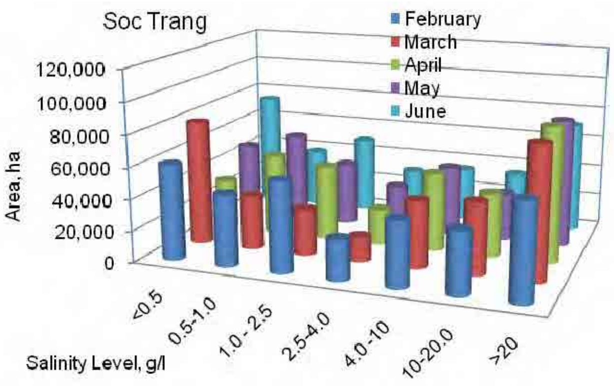


Figure 3.3.22 Saline Area for Soc Trang Province (DY1998 MR Discharge with 30cm SLR, 2050)

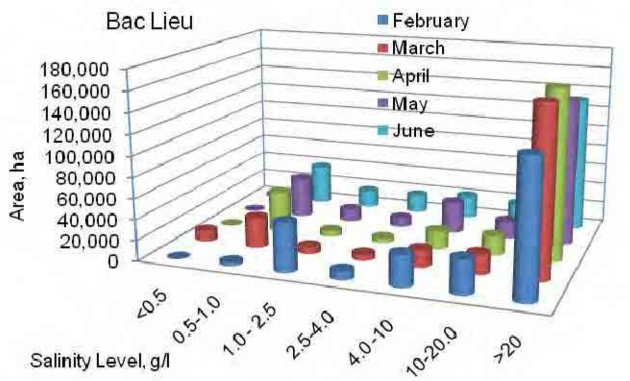


Figure 3.3.23 Saline Area for Bac Lieu Province (DY1998 MR Discharge with 30cm SLR, 2050)

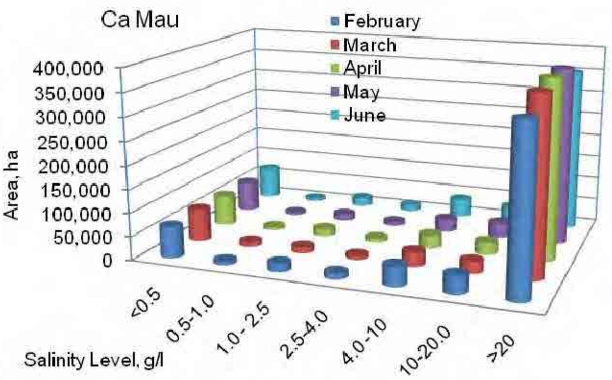


Figure 3.3.24 Saline Area for Ca Mau Province (DY1998 MR Discharge with 30cm SLR, 2050)

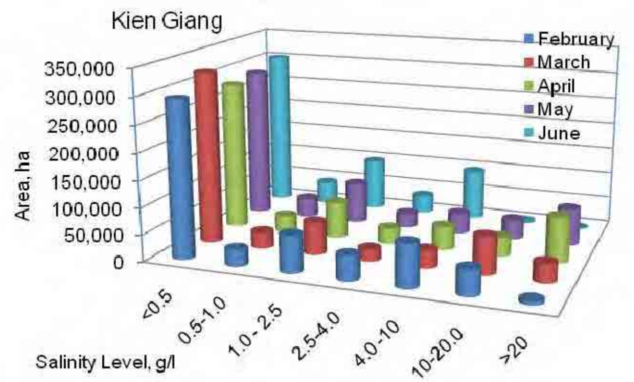


Figure 3.3.25 Saline Area for Kien Giang Province (DY1998 MR Discharge with 30cm SLR, 2050)

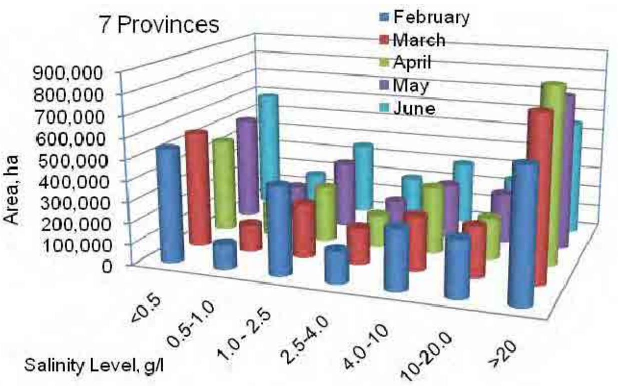


Figure 3.3.26 Saline Area for 7 Provinces (DY1998 MR Discharge with 30cm SLR, 2050)

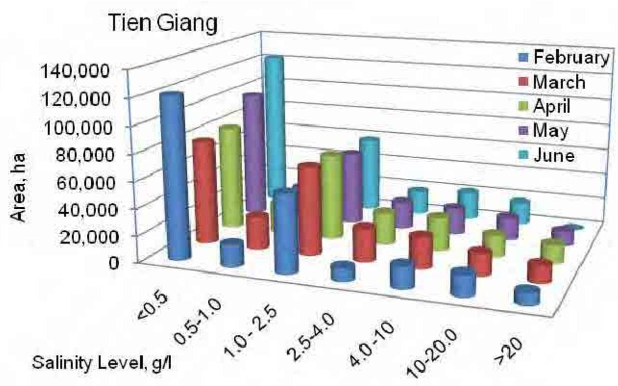


Figure 3.3.27 Saline Area for Tien Giang Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

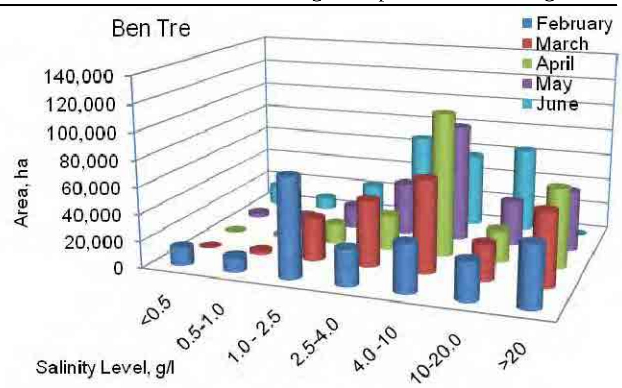


Figure 3.3.28 Saline Area for Ben Tre Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

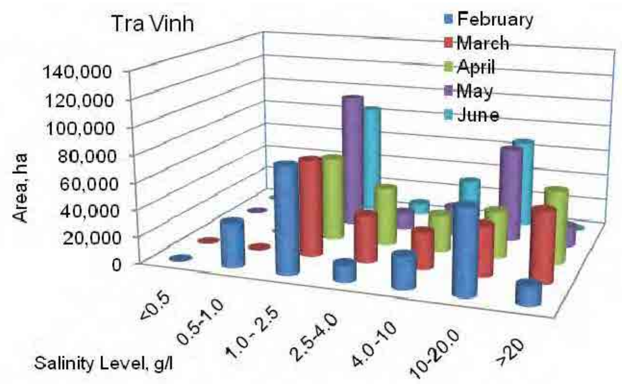


Figure 3.3.29 Saline Area for Tra Vinh Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

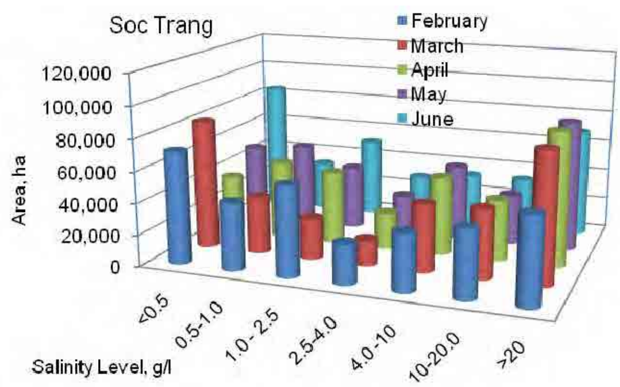


Figure 3.3.30 Saline Area for Soc Trang Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

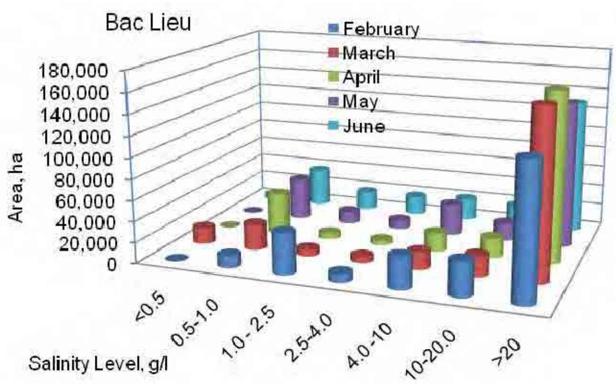


Figure 3.3.31 Saline Area for Bac Lieu Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

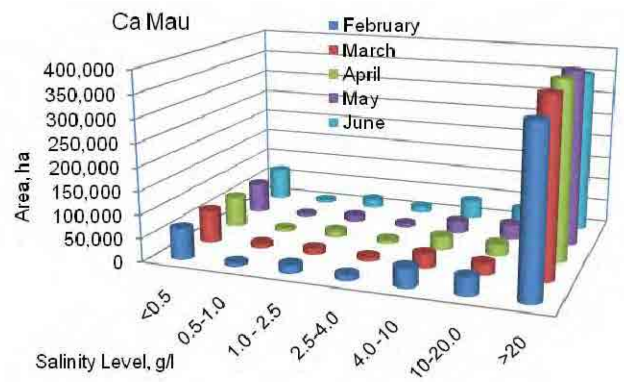


Figure 3.3.32 Saline Area for Ca Mau Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

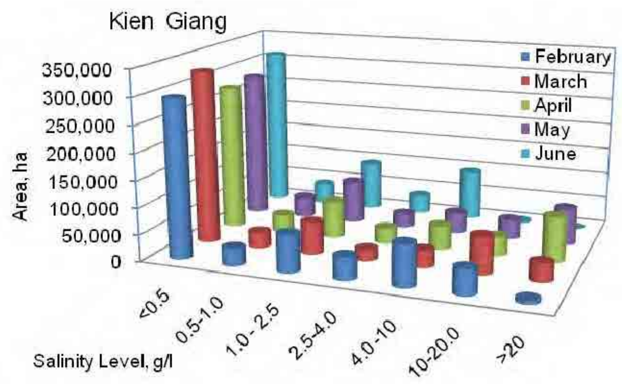


Figure 3.3.33 Saline Area for Kien Giang Province
(Scenario B2 MR Discharge with 30cm SLR, 2050)

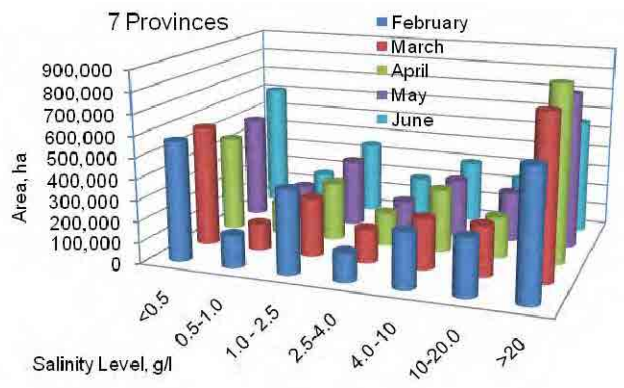


Figure 3.3.34 Saline Area for 7 Provinces
(Scenario B2 MR Discharge with 30cm SLR, 2050)

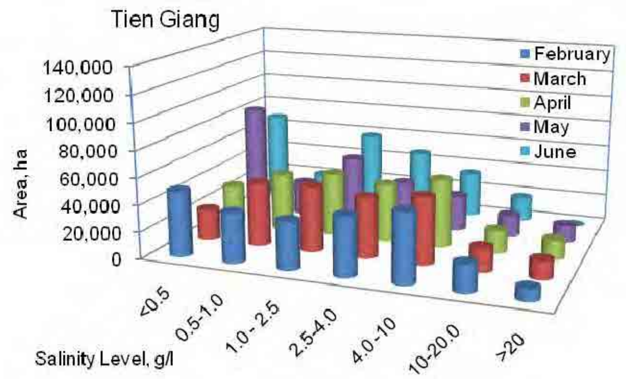


Figure 3.3.35 Saline Area for Tien Giang Province
(DY1998 MR Discharge with 100cm SLR, 2100)

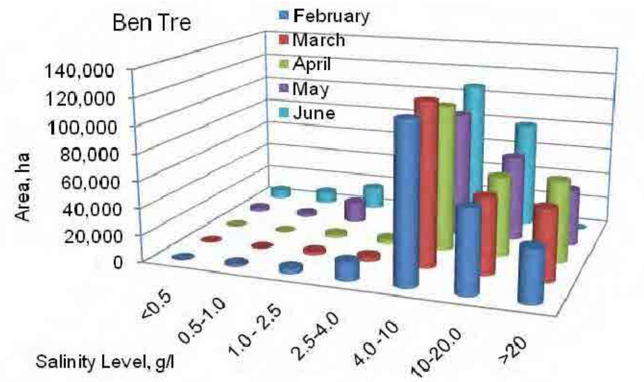


Figure 3.3.36 Saline Area for Ben Tre Province
(DY1998 MR Discharge with 100cm SLR, 2100)

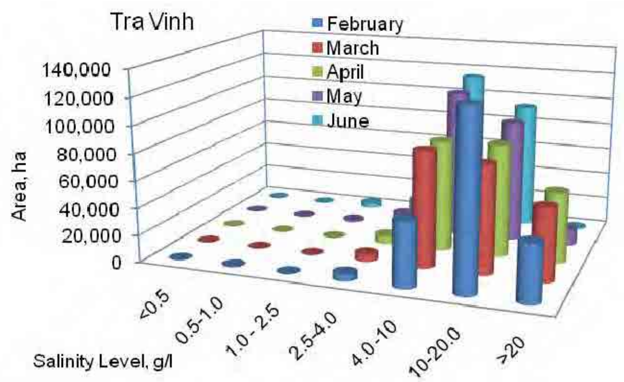


Figure 3.3.37 Saline Area for Tra Vinh Province
(DY1998 MR Discharge with 100cm SLR, 2100)

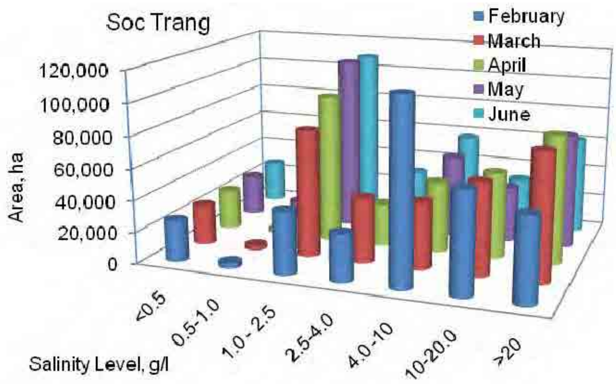


Figure 3.3.38 Saline Area for Soc Trang Province
(DY1998 MR Discharge with 100cm SLR, 2100)

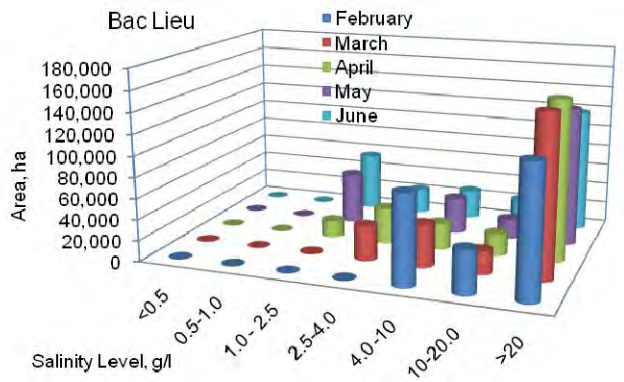


Figure 3.3.39 Saline Area for Bac Lieu Province
(DY1998 MR Discharge with 100cm SLR, 2100)

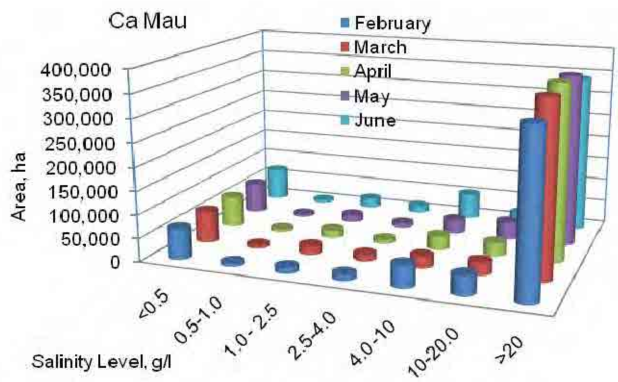


Figure 3.3.40 Saline Area for Ca Mau Province
(DY1998 MR Discharge with 100cm SLR, 2100)

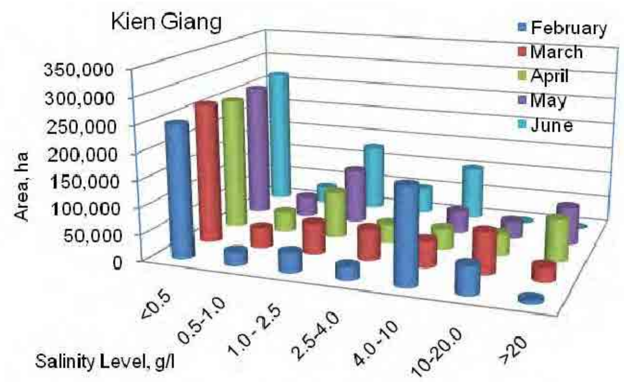


Figure 3.3.41 Saline Area for Kien Giang Province
(DY1998 MR Discharge with 100cm SLR, 2100)

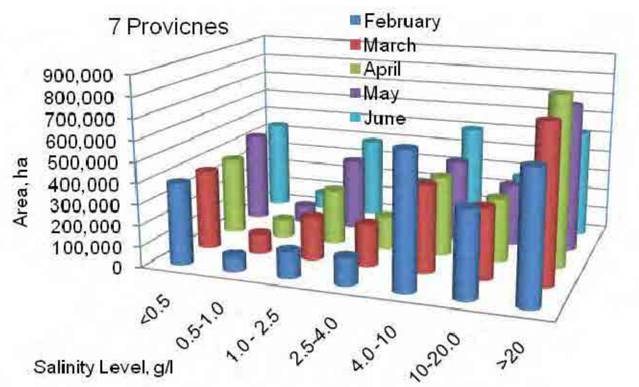


Figure 3.3.42 Saline Area for 7 Provinces
(DY1998 MR Discharge with 100cm SLR, 2100)

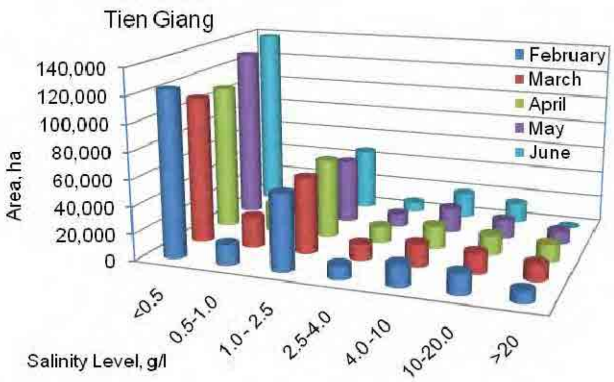


Figure 3.3.43 Saline Area for Tien Giang Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

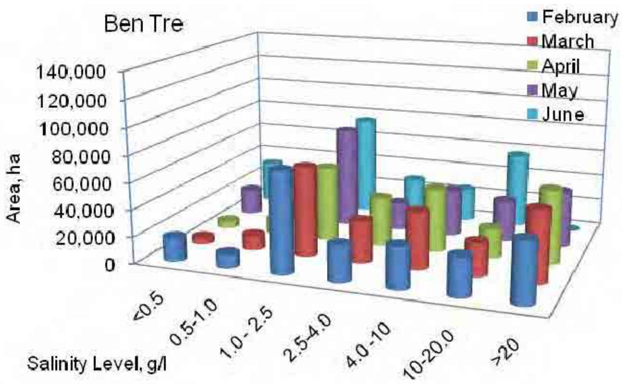


Figure 3.3.44 Saline Area for Ben Tre Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

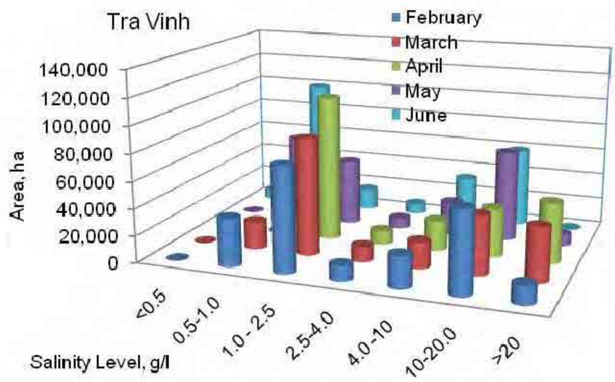


Figure 3.3.45 Saline Area for Tra Vinh Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

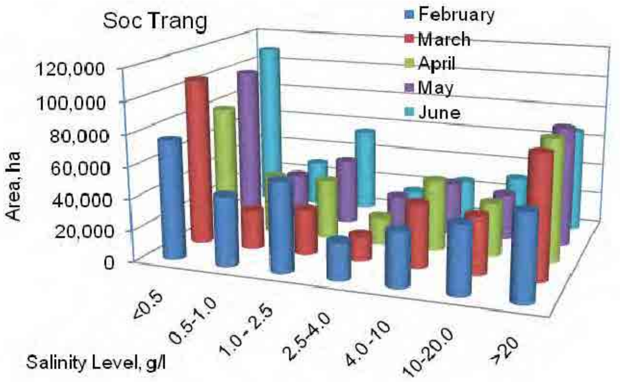


Figure 3.3.46 Saline Area for Soc Trang Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

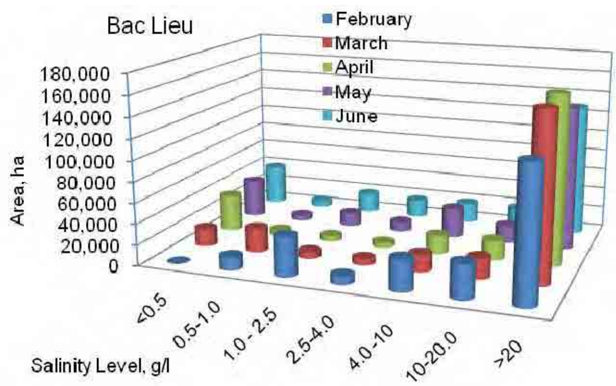


Figure 3.3.47 Saline Area for Bac Lieu Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

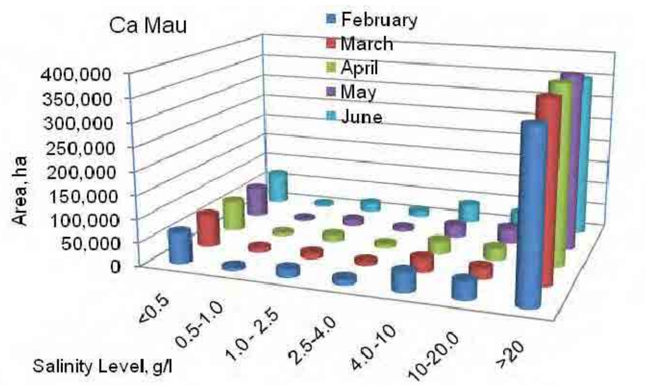


Figure 3.3.48 Saline Area for Ca Mau Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

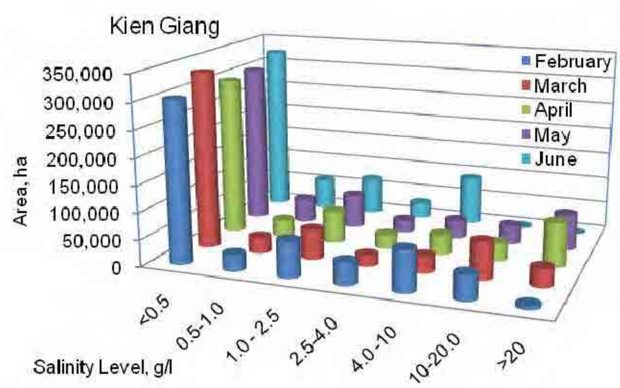


Figure 3.3.49 Saline Area for Kien Giang Province
(Scenario B2 Development Discharge with 30 SLR, 2050)

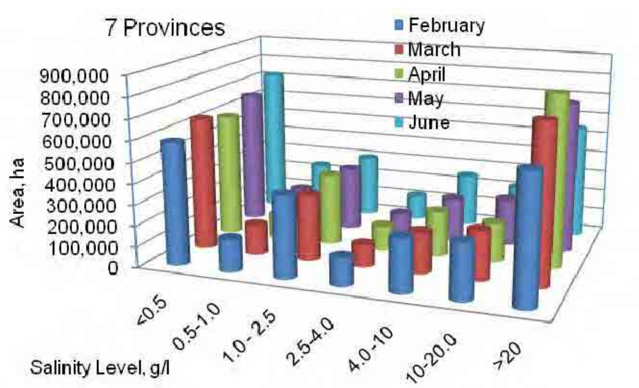


Figure 3.3.50 Saline Area for 7 Provinces
(Scenario B2 Development Discharge with 30 SLR, 2050)

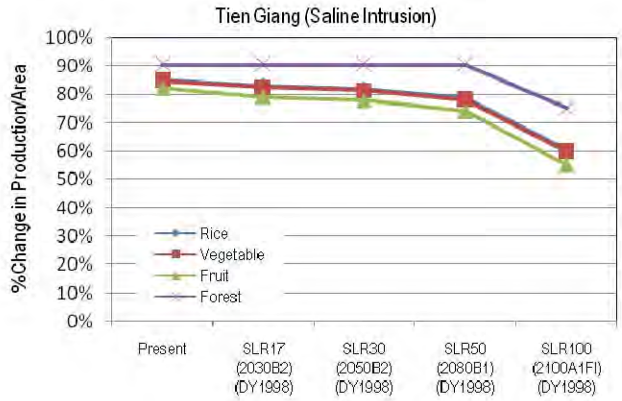


Figure 3.3.51 Production Loss(%) for Tien Giang Province (DY1998 MR Discharge with Different SLR)

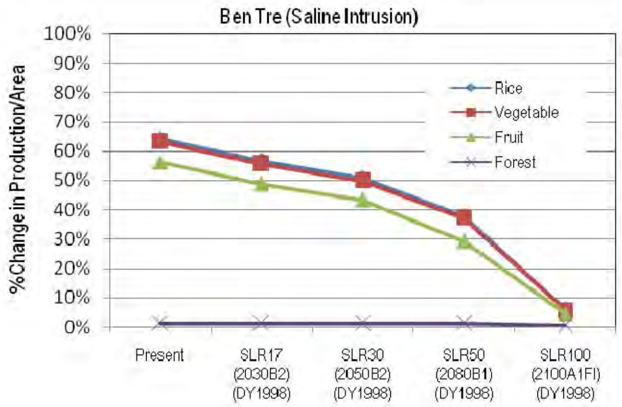


Figure 3.3.52 Production Loss(%) for Ben Tre Province DY1998 MR Discharge with Different SLR)

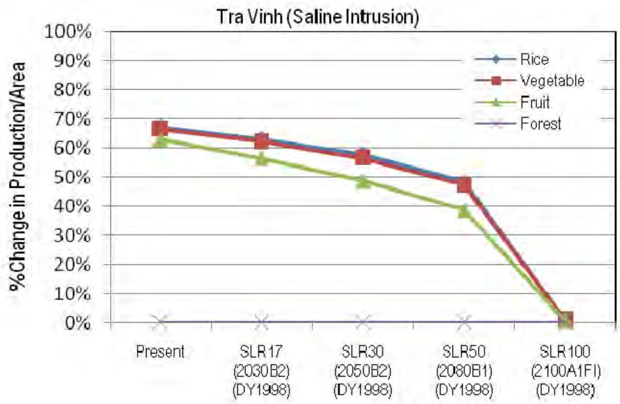


Figure 3.3.53 Production Loss(%) for Tra Vinh Province (DY1998 MR Discharge with Different SLR)

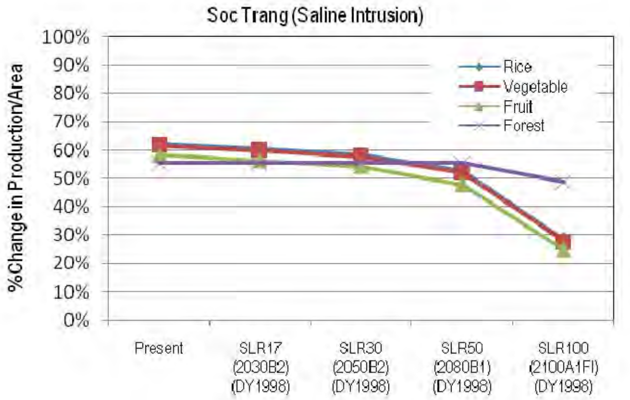


Figure 3.3.54 Production Loss(%) for Soc Trang Province (DY1998 MR Discharge with Different SLR)

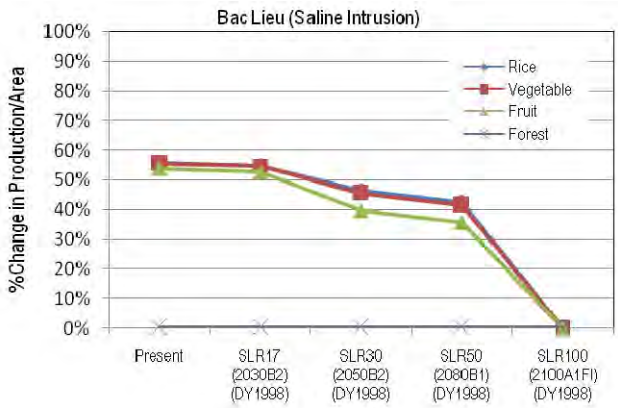


Figure 3.3.55 Production Loss(%) for Bac Lieu Province DY1998 MR Discharge with Different SLR)

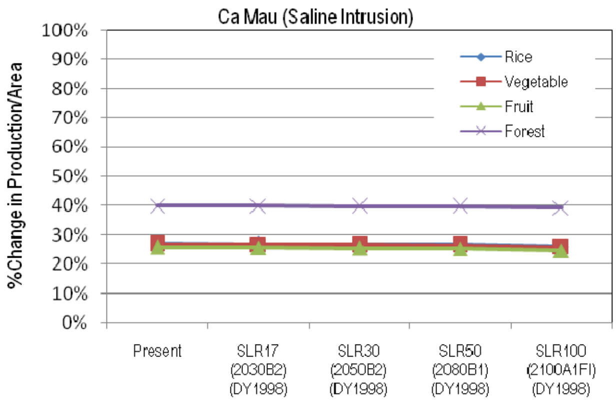


Figure 3.3.56 Production Loss(%) for Ca Mau Province (DY1998 MR Discharge with Different SLR)

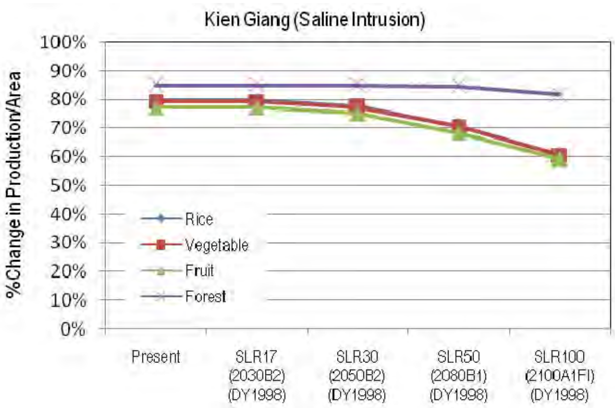


Figure 3.3.57 Production Loss(%) for Kien Giang Province (DY1998 MR Discharge with Different SLR)

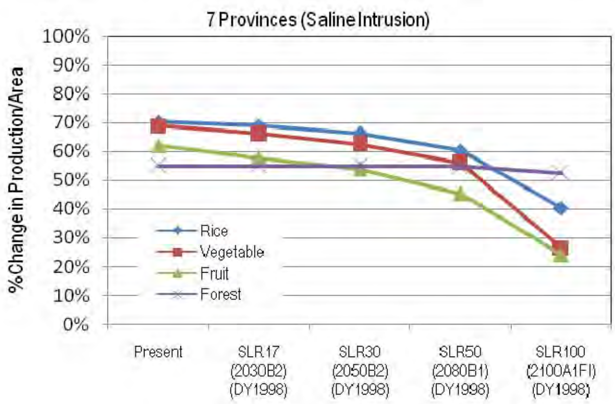


Figure 3.3.58 Production Loss(%) for 7 Provinces (DY1998 MR Discharge with Different SLR)

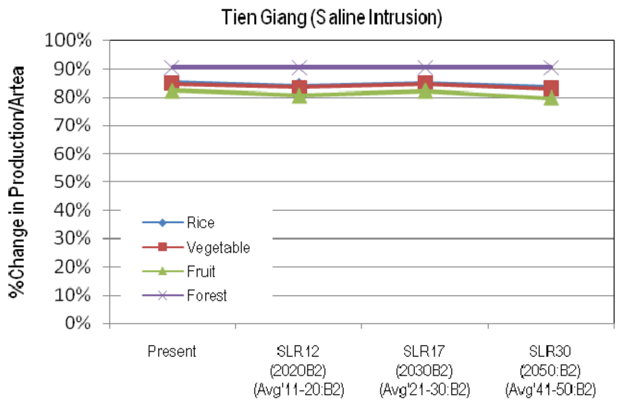


Figure 3.3.59 Production Loss(%) for Tien Giang Province (Scenario B2 MR Discharge with Different SLR)

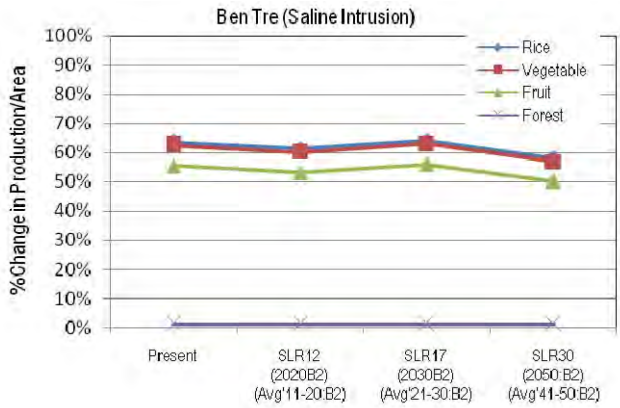


Figure 3.3.60 Production Loss(%) for Ben Tre Province (Scenario B2 MR Discharge with Different SLR)

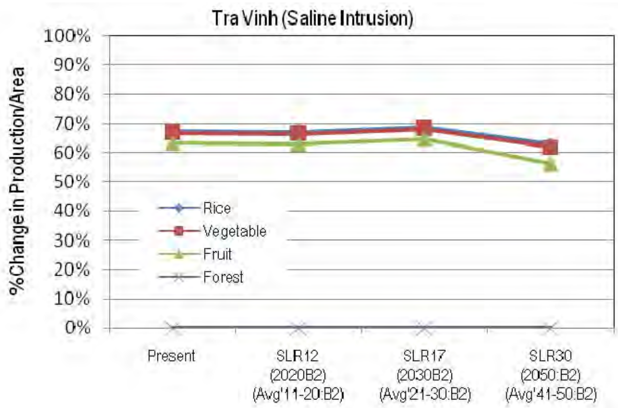


Figure 3.3.61 Production Loss(%) for Tra Vinh Province (Scenario B2 MR Discharge with Different SLR)

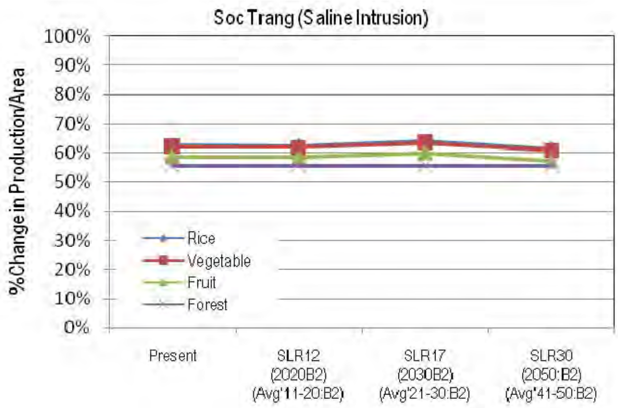


Figure 3.3.62 Production Loss(%) for Soc Trang Province (Scenario B2 MR Discharge with Different SLR)

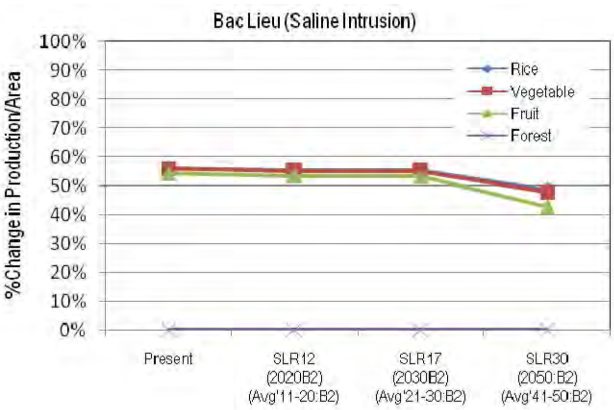


Figure 3.3.63 Production Loss(%) for Bac Lieu Province (Scenario B2 MR Discharge with Different SLR)

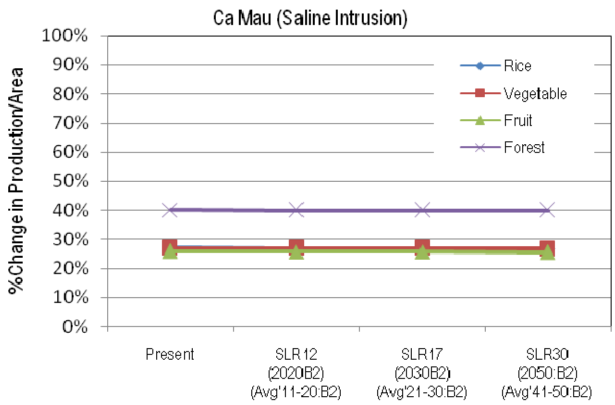


Figure 3.3.64 Production Loss(%) for Ca Mau Province (Scenario B2 MR Discharge with Different SLR)

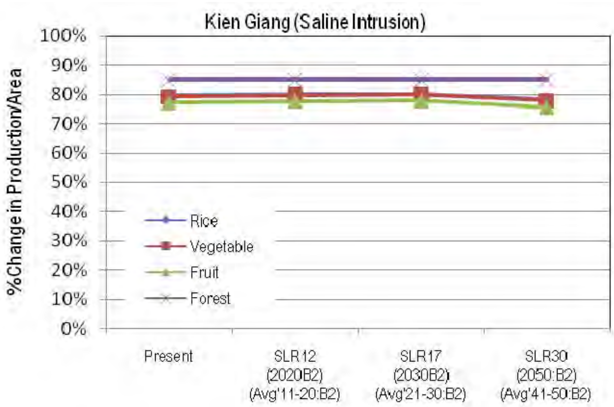


Figure 3.3.65 Production Loss(%) for Kien Giang Province (Scenario B2 MR Discharge with Different SLR)

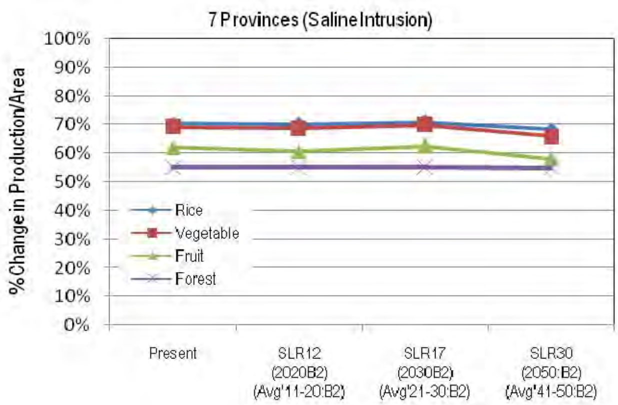


Figure 3.3.66 Production Loss(%) for 7 Provinces (Scenario B2 MR Discharge with Different SLR)

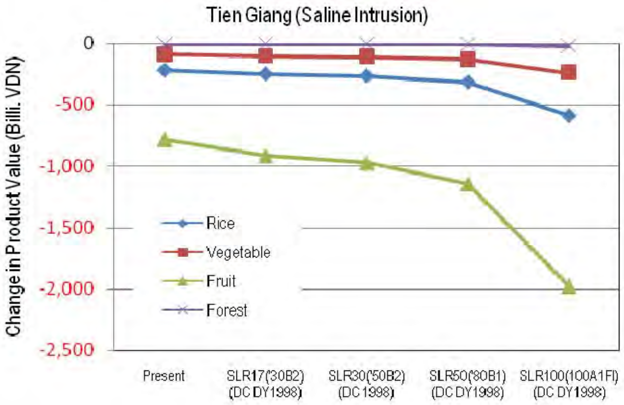


Figure 3.3.67 Production Loss(VND) for Tien Giang Province (DY1998 MR Discharge with Different SLR)

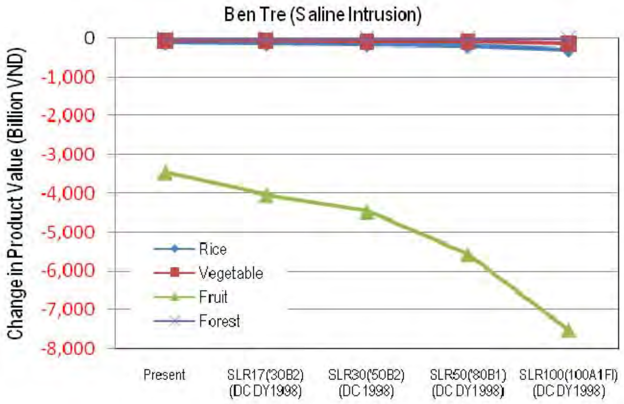


Figure 3.3.68 Production Loss(VND) for Ben Tre Province DY1998 MR Discharge with Different SLR)

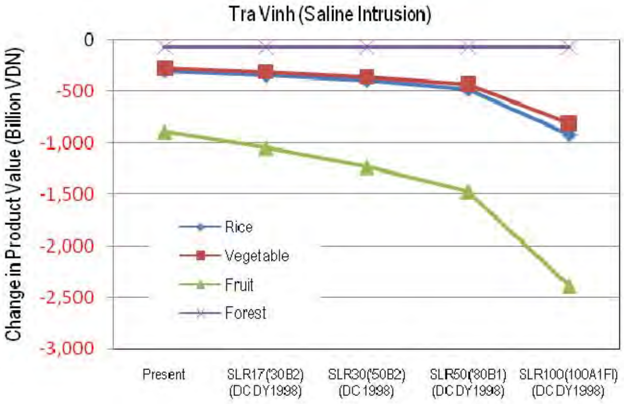


Figure 3.3.69 Production Loss(VND) for Tra Vinh Giang Province (DY1998 MR Discharge with Different SLR)

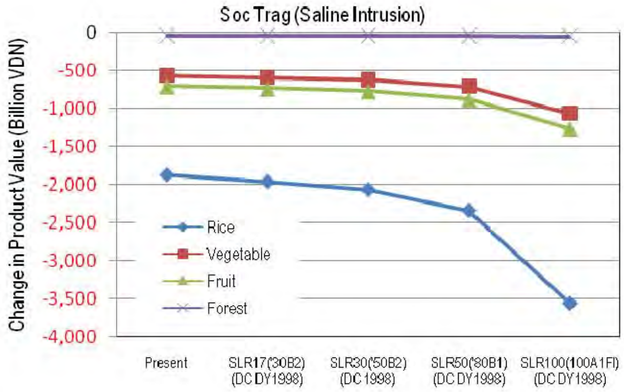


Figure 3.3.70 Production Loss(VND) for Soc Trang Province (DY1998 MR Discharge with Different SLR)

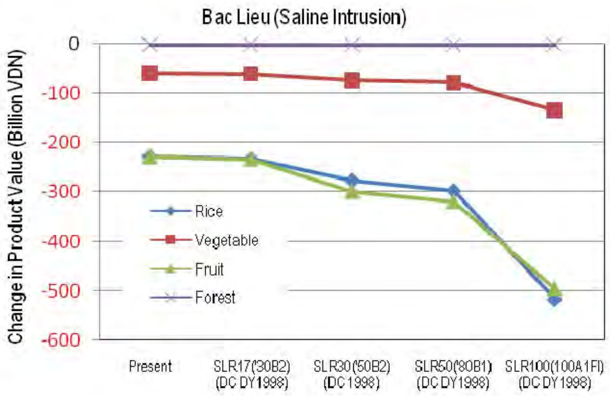


Figure 3.3.71 Production Loss(VND) for Bac Lieu Province DY1998 MR Discharge with Different SLR)

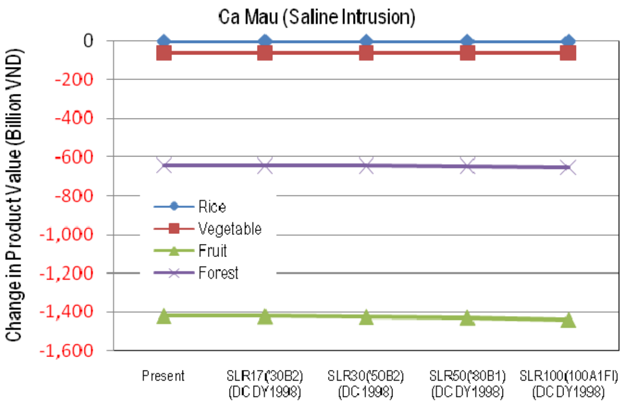


Figure 3.3.72 Production Loss(VND) for Ca Mau Province (DY1998 MR Discharge with Different SLR)

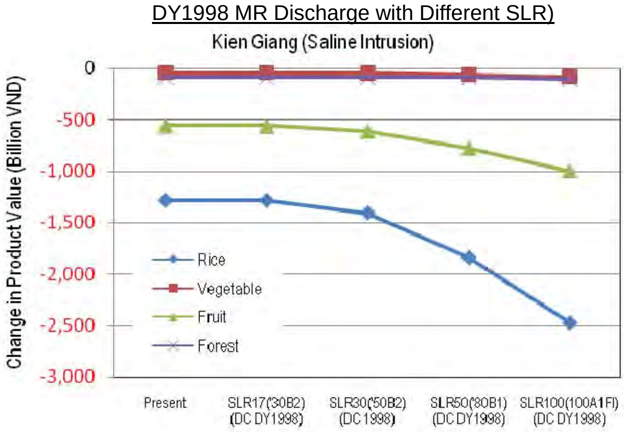


Figure 3.3.73 Production Loss(VND) for Kien Giang Province (DY1998 MR Discharge with Different SLR)

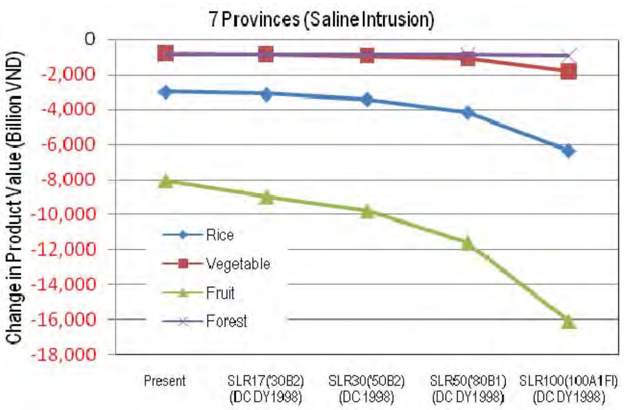


Figure 3.3.74 Production Loss(VND) for 7 Provinces (DY1998 MR Discharge with Different SLR)

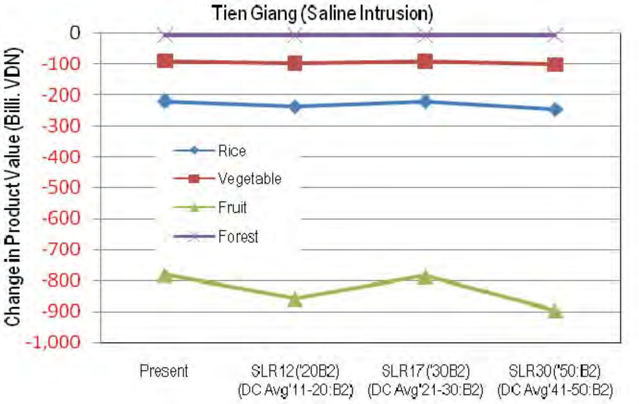


Figure 3.3.75 Production Loss(VND) for Tien Giang Province (Scenario B2 MR Discharge with Different SLR)

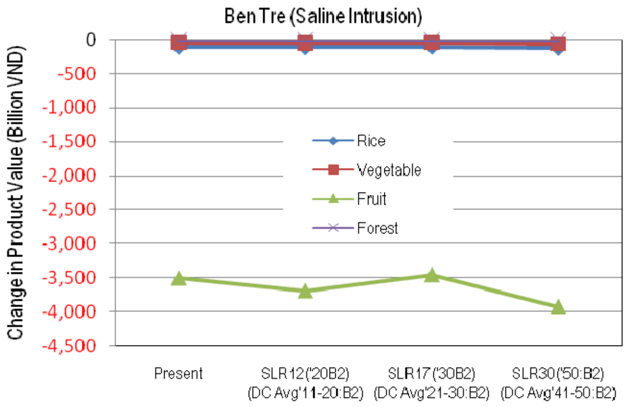


Figure 3.3.76 Production Loss(VND) for Ben Tre Province (Scenario B2 MR Discharge with Different SLR)

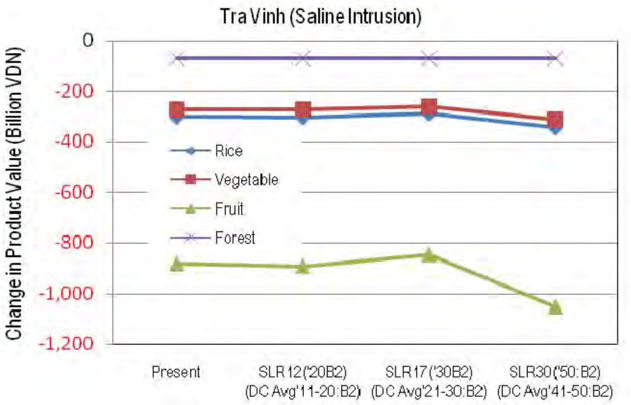


Figure 3.3.77 Production Loss(VND) for Tra Vinh Province (Scenario B2 MR Discharge with Different SLR)

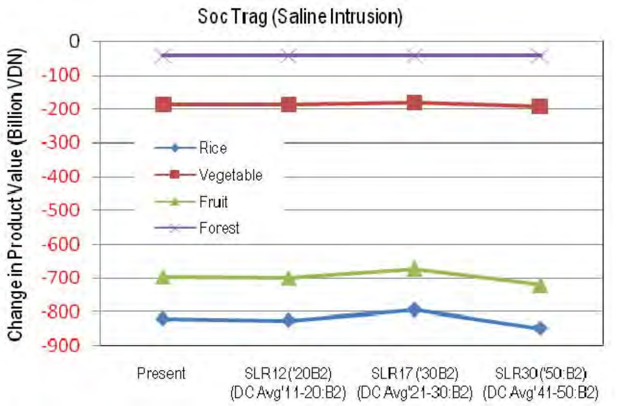


Figure 3.3.78 Production Loss(VND) for Soc Trang Province (Scenario B2 MR Discharge with Different SLR)

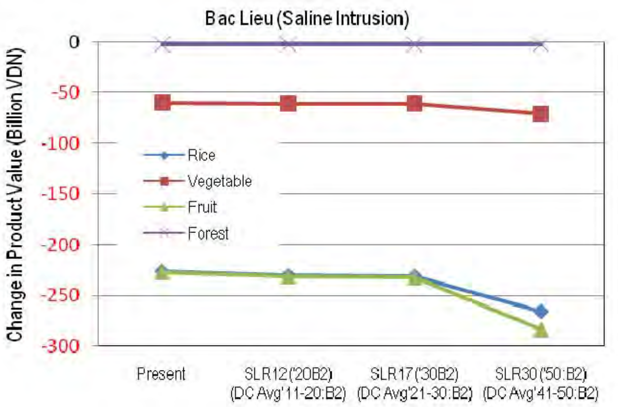


Figure 3.3.79 Production Loss(VND) for Bac Lieu Province (Scenario B2 MR Discharge with Different SLR)

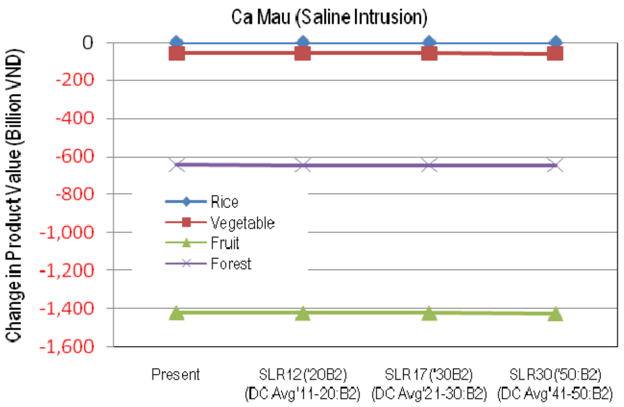


Figure 3.3.80 Production Loss(VND) for Ca Mau Province (Scenario B2 MR Discharge with Different SLR)

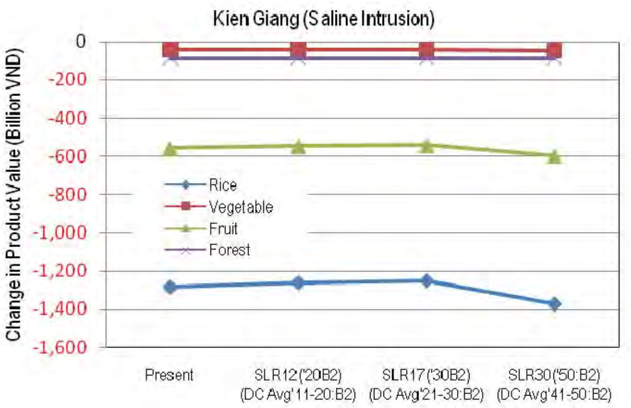


Figure 3.3.81 Production Loss(VND) for Kien Giang Province (Scenario B2 MR Discharge with Different SLR)

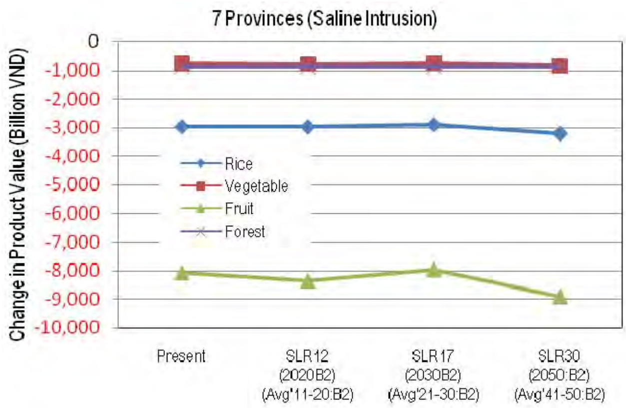


Figure 3.3.82 Production Loss(VND) for 7 Provinces (Scenario B2 MR Discharge with Different SLR)

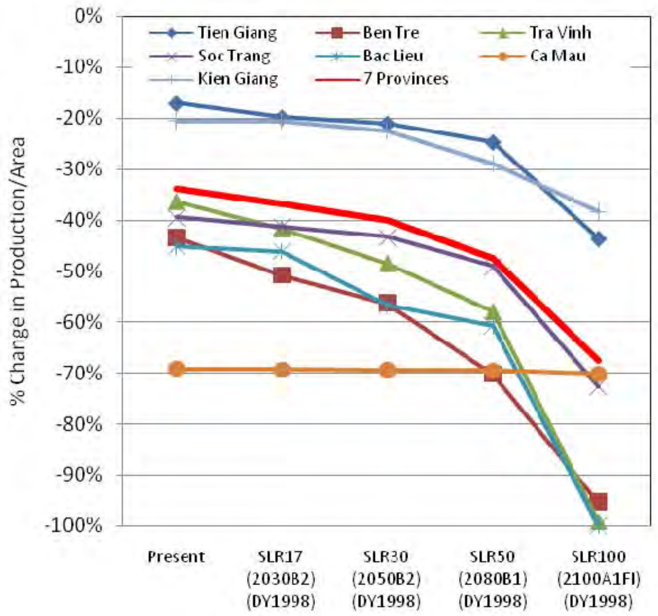


**Figure 3.3.83 Production Loss(%) by Province**
(DY1998 MR Discharge with Different SLR)

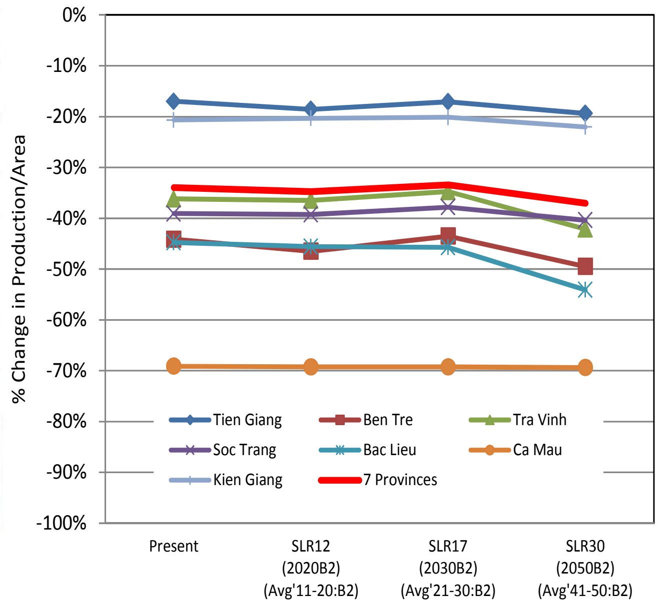


**Figure 3.3.84 Production Loss(%) by Province**
(Scenario B2 MR Discharge with Different SLR)

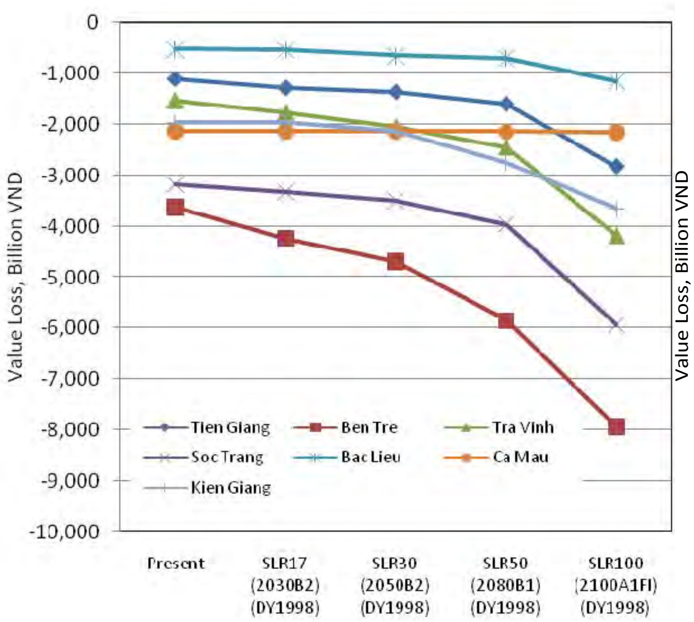


**Figure 3.3.85 Production Loss(VND) by Province**
(DY1998 MR Discharge with Different SLR)

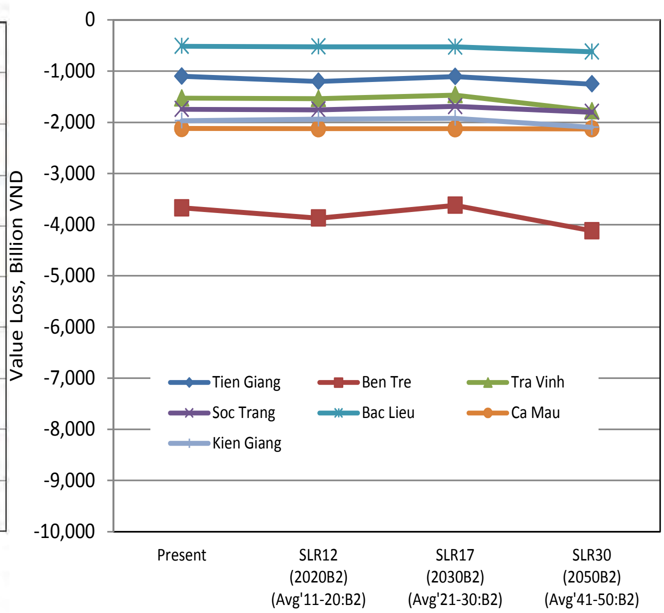


**Figure 3.3.86 Production Loss(VND) by Province**
(Scenario B2 MR Discharge with Different SLR)