



## AGRO-ECOLOGICAL DYNAMICS IN THE COASTAL AREAS OF THE VIETNAMESE MEKONG DELTA IN THE CONTEXT OF CLIMATE CHANGE: A CASE STUDY IN BAC LIEU PROVINCE

Pham Thanh Vu, Phan Hoang Vu, Van Pham Dang Tri and Nguyen Hieu Trung

College of Environment and Natural Resources, Can Tho University, Vietnam

### ARTICLE INFO

Received date: 03/08/2015

Accepted date: 26/11/2015

### KEYWORDS

*Agro-ecological zones, Bac Lieu, brackish and saline areas, climate change, sea level rise, upstream discharge*

### ABSTRACT

*Agro-ecological zoning is considered to be a suitable base for agricultural land use planning to especially meet local natural resources and socio-economic settings. The aims of this study were to evaluate historical trend (from 2000 to 2010) and predict changes in the agro-ecological zones of the bac lieu province in the context of sea level rise (+17cm) in combination with historical records of upstream discharge (since 1998). The Participatory Rural appraisal approach and household interviews were used to collect primary along with secondary data collected at different governmental departments and the numerical modelling results. The results showed that existing agro-ecological zones were well-reflected by the current farming systems in the study area. The defined agro-ecological zones of Bac Lieu in the future would include stable freshwater areas and changing brackish and saline-influenced areas according to the unsteady upstream discharge.*

Cited as: Vu, P.T., Vu, P.H., Tri, V.P.D. and Trung, N.H., 2015. Agro-ecological dynamics in the coastal areas of the Vietnamese Mekong Delta in the context of climate change (A case study in Bac Lieu province). Can Tho University Journal of Science. 1: 81-88.

### 1 INTRODUCTION

Agro-ecological zones reflect the interaction between physical properties (soil and water) and anthropological impacts (land use planning and socio-economic development), leading to a complex process of land use changes. The Vietnamese Mekong Delta (VMD) was previously characterized by six different agro-ecological zones, including: Ca Mau Peninsula, coastal areas, freshwater alluvial areas, Long Xuyen Quadrangle, Plain of Reid and trans-bassac depression (Xuan *et al.*, 1998). This classification did not present the actual agro-ecological characteristics of the areas especially after the 'doi moi' policy when the VMD was converted to be one of the most productive agricultural lands (Kakonen, 2008) due to the national policy of land reclamation. The area has been modified significantly with the development of the hydraulic

construction. In addition, the area has been even changed under significant impacts of climate change (Tri *et al.*, 2012; Tri *et al.*, 2013). In addition, at local scale, especially along the coastal areas, changes have progressed more intensively after the rise of conflicts between agriculture and aquaculture land use (Trung and Tri, 2014).

The VMD has been threatened by sea level rise (Nhan *et al.*, 2007; Tuan *et al.*, 2007; Tri *et al.*, 2013) especially along the coastal plain where saline intrusion was widely pronounced and projected to be more severe in the future (Dat *et al.*, 2011; Trung and Tri, 2014). Such changes in surface water resources might lead to great alteration of the existing agro-ecological zones resulting in negative impacts on livelihood of local residents, especially those who are living in the coastal plains (Adger, 1999; Trung and Tri, 2014). Therefore, the main aims of this paper were to study trends of historical

changes in the coastal plain of the VMD (Bac Lieu province) with great attention paid to surface water and land resources and agriculture land use. In addition, trends of changes in the future were also projected in order to provide an insight into the possibility of changes and to raise awareness of local residents on vulnerability of the area in the context of climate change.

## 2 METHODOLOGY

### 2.1 Data collection

Primary data was collected following the Participatory Rural Appraisal (PRA) approach and individual interviews:

- The PRA's were done with two different groups of stakeholder (including local governmental staffs and farmers). The data from governmental staffs were separately organized at the Department of Agriculture and Rural Development of all 7 districts of Bac Lieu while data from local farmers were collected with 12 groups of local farmers including well-being and poor group to depict all existing farming systems.

- Individual interviews were done randomly with local farmers who had sufficient farming experiences (living in the area for more than 10 years) in the area. Information to be asked during the individual interviews is presented in .

- Table 1: Information to be asked in the individual interview

- . In total, there were 300 households which had been interviewed in the study area.

**Table 1: Information to be asked in the individual interview**

Category	Available information
Physical	- Soil and water resources (2000 - 2010)
	- Farming systems (2000 - 2010)
	- Causes and effects of farming system changes
	- Crop calendar
Economic	- Governmental incentives for agriculture
	- Impacts of local and regional market on each farming system
Social	- SWOT (strengths, weaknesses, opportunities and threats) analysis at local community
	- Custom of agricultural practices, labor demand and supply for each farming system

Available maps of soil, land use, historical saline intrusion and canal network of the study area in 2000 and 2010 were collected at the Department of Natural Resources and Environment (DONRE) and the Department of Agriculture and Rural Development (DARD) of the Bac Lieu province. In addition, statistical data on land use (change) and relevant socio-economic data in 2000, 2005 and 2010 were collected according to the census data available at the Statistical Department of the province. Such data were the main base to evaluate the land use changes and driving factors.

### 2.2 Future scenarios for surface water resources

Scenarios for future seawater intrusion were developed according to the assumption of sea level rise of +17cm and three representative hydrological years based on flows from Kratie: (i) Scenario 1: Upstream discharge was low with data taken from the drought year in 1998; (ii) Scenario 2: Average upstream discharge with data taken from the year in 2004; and, (iii) Scenario 3: Abundant upstream discharge data taken from the flood year in 2000.

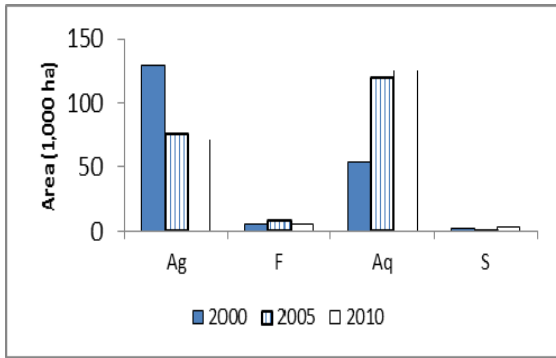
### 2.3 Hydrodynamics modelling

The hydraulic model VRSAP (Vietnam River Systems and Plains, developed by the Southern Institute for Water Resources Planning) was calibrated and used to simulate the surface water resources dynamics in the study area. This study inherited the results of Theme 5 from the project of Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems (CLUES).

## 3 Results and discussion

### 3.1 Land use change in the period of 2000-2010

In early 1990s, agricultural production (mainly rice) in the Bac Lieu province was rather extensive and unstable due to heavy dependence on the seasonal hydrological regimes. However, from 2000 to 2010, agriculture in the area changed both in terms of area and structure of farming systems. Due to high financial benefits from aquaculture (mainly shrimp cultivation), by the end of 1990s, a large proportion of rice farming areas was converted to shrimp farming. Fig. 1 presents the proportion of main land use types in the area in 2000, 2005 and 2010 and Fig. 2 presents the surface water resources in the study area in 2010. According to data recorded at the Department of Irrigation in the Bac Lieu province, the surface water resources in the study area were stable since 2005.

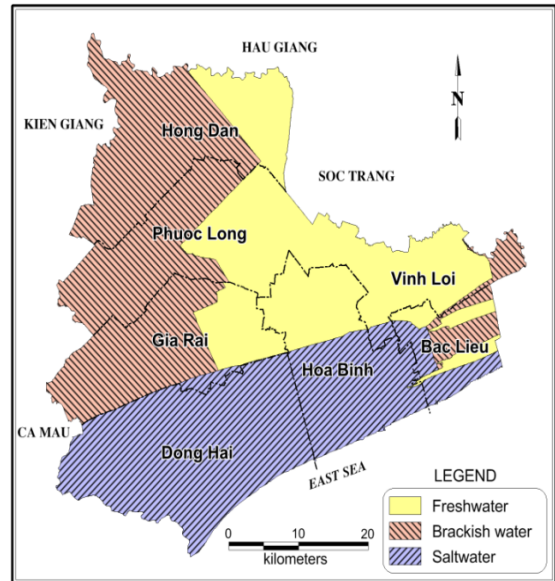


**Fig. 1: Area of main land use types in Bac Lieu in 2000, 2005 and 2010**

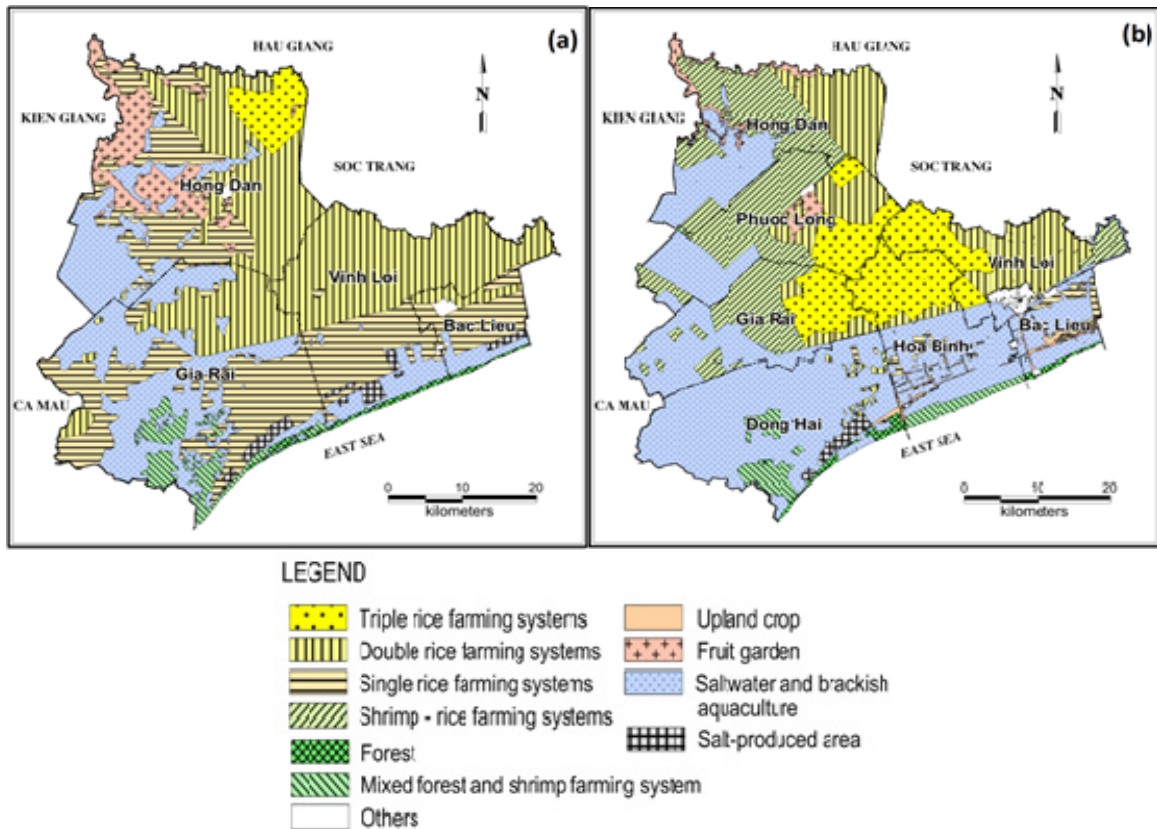
Ag: Agriculture, F: Forestry; Aq: Aquaculture; and, S: Salt-produced area

Fig. 3 presents land use map in the study area in 2000 and 2010. Land use changed remarkably during 2000 to 2010 to cope with physical changes of surface water resources. The brackish and salt water zones (Fig. 2) were converted from single rice crop system to either salt and brackish water shrimp or mixed rice and shrimp farming systems while the freshwater area was rather stable with

intensive double-rice farming systems. From 2005 to 2010, there were no significant changes in land use types in the study area; however, the mono rice or shrimp culture were set to be more intensive.



**Fig. 2: Surface water resources in Bac Lieu in 2010**



**Fig. 3: Land use in Bac Lieu in 2000 (a) and 2010 (b)**

### 3.2 Driving factors of land use changes

#### Saline intrusion

Under the effects of fresh water discharge of the Quan Lo-Phung Hiep canal and seawater intrusion by tidal regime of the East and West sea, the surface water resources in Bac Lieu were highly complex. Due to the food security issue, since early 1990s, hydraulic constructions were developed to provide sufficient freshwater for rice farming systems (Kam *et al.*, 2001).

Data collected from the PRA show that after 1998, the brackish and saline water caused less-favourable conditions for rice farming systems but creating suitable physical conditions for shrimp farming systems. In addition, market price for shrimp was good by that time leading to great fi-

nancial benefits for shrimp farmers. Local farmers adjusted farming systems by converting from rice to shrimp farming system causing saline intrusion further inland, the so-called autonomous adaptation (Trung and Tri, 2014).

Fig. 4 presents spatial distribution of saline intrusion in 2000 and 2010 (according to DONRE in Bac Lieu), which agrees to data obtained from the PRA. In general, the saline intrusion in Bac Lieu increased in both spatial and temporal scales. The freshwater area (Fig. 2) remained stable during the period due to construction of saline-controlled dyke system in 2000 while the rest was strongly influenced by different sources of water (i.e. seawater from both the East and West Sea and fresh water from the Quan Lo Phung Hiep canal).

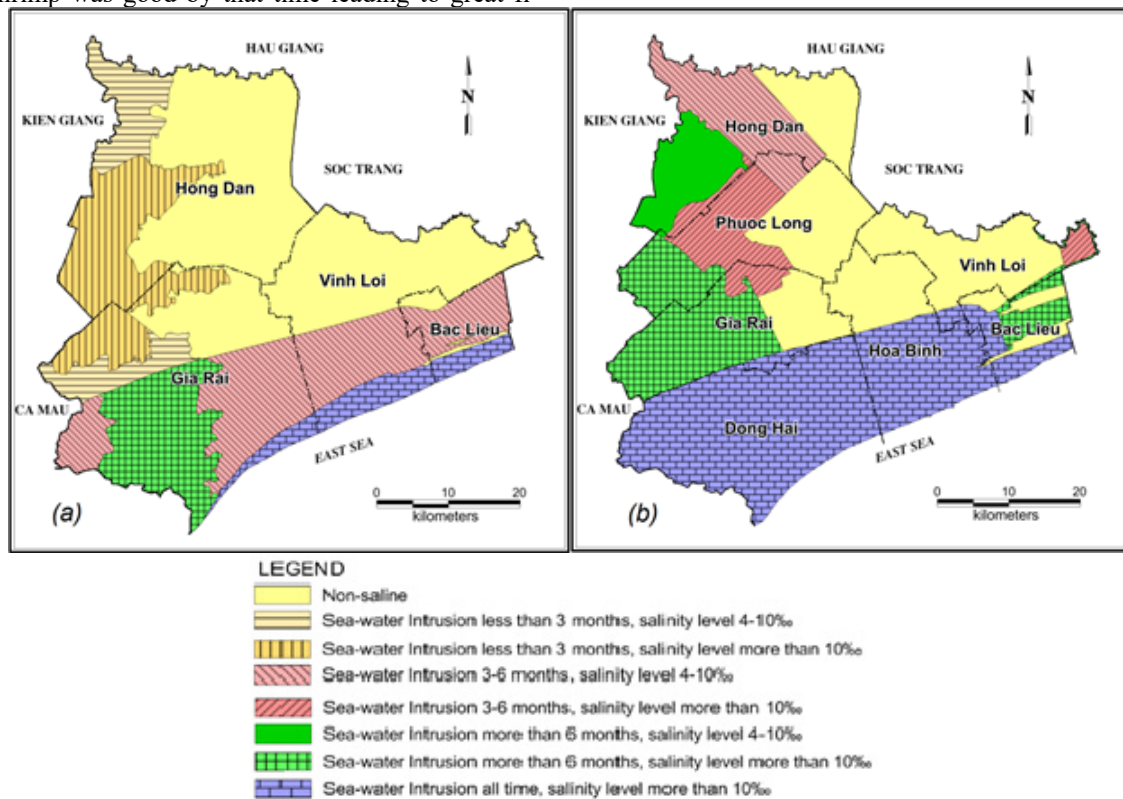


Fig. 4: Spatial distribution of saline intrusion in Bac Lieu in 2000 (a) and 2010 (b)

#### Socio-economic driving factors

Apart from the physical water resources, financial benefits and good market were amongst the most considered issues of local farmers (Fig. 5a). Financial benefits of shrimp farming system were greater than that of the rice farming system leading to the shift of double and triple rice farming systems to rice-shrimp integrated system in the area where

saline intrusion was found seasonally (during the dry season) and intensive shrimp farming system in the area where saline intrusion was found over the whole year round. In the freshwater area, the most favorable condition for rice culture, intensive (either double or triple) rice crop was rather stable due to reliable financial returns. Custom of agricultural practices was also important for farmers to decide what to be cultivated in their own farms



(Fig. 5b). Labour was not considered as an important criterion in the time being as the labour sources were rather abundant in the area. Apart

from that, due to improved farming technologies (i.e. mechanisation), pressure on labor was eased.

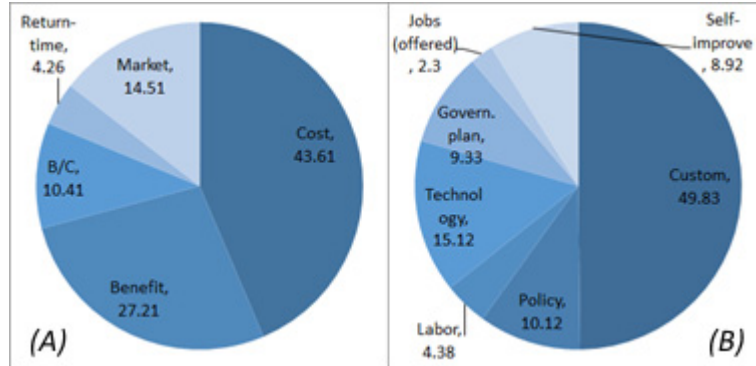


Fig. 5: Impacts of each socio-economic factor on the decision of local farmers

Source: PRA survey in 2012

### 3.3 Agro-ecological zones in 2000 and 2010

Fig. 6 presents agro-ecological maps in Bac Lieu in 2000 and 2010. There were seven sub-regions of

agro-ecological zones in 2000 and 2010. However, distribution of sub-regions was different by land properties changes (mainly domestic factors: salinity conditions).

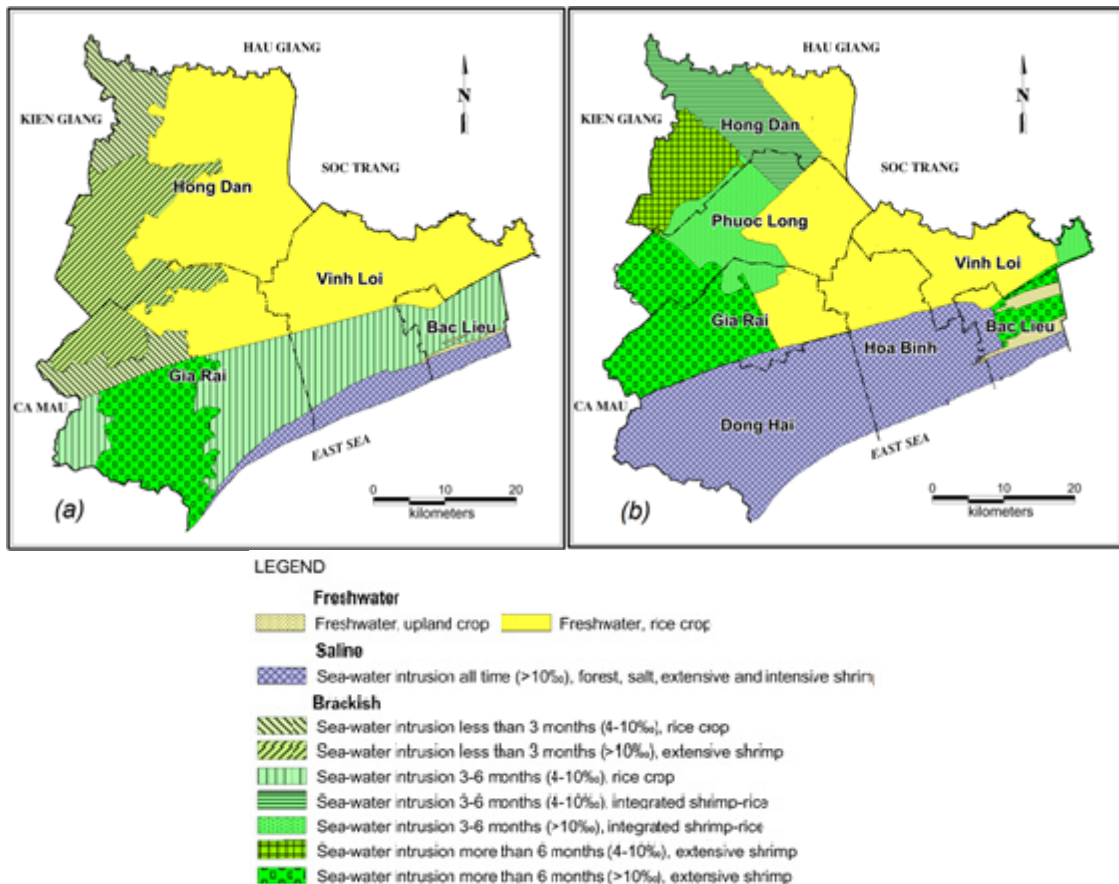
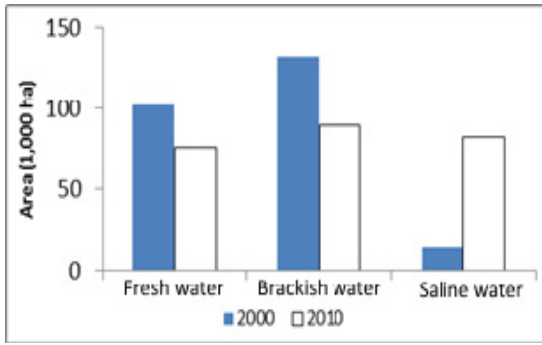


Fig. 6: Agro-ecological maps of Bac Lieu in 2000 (a) and 2010 (b)



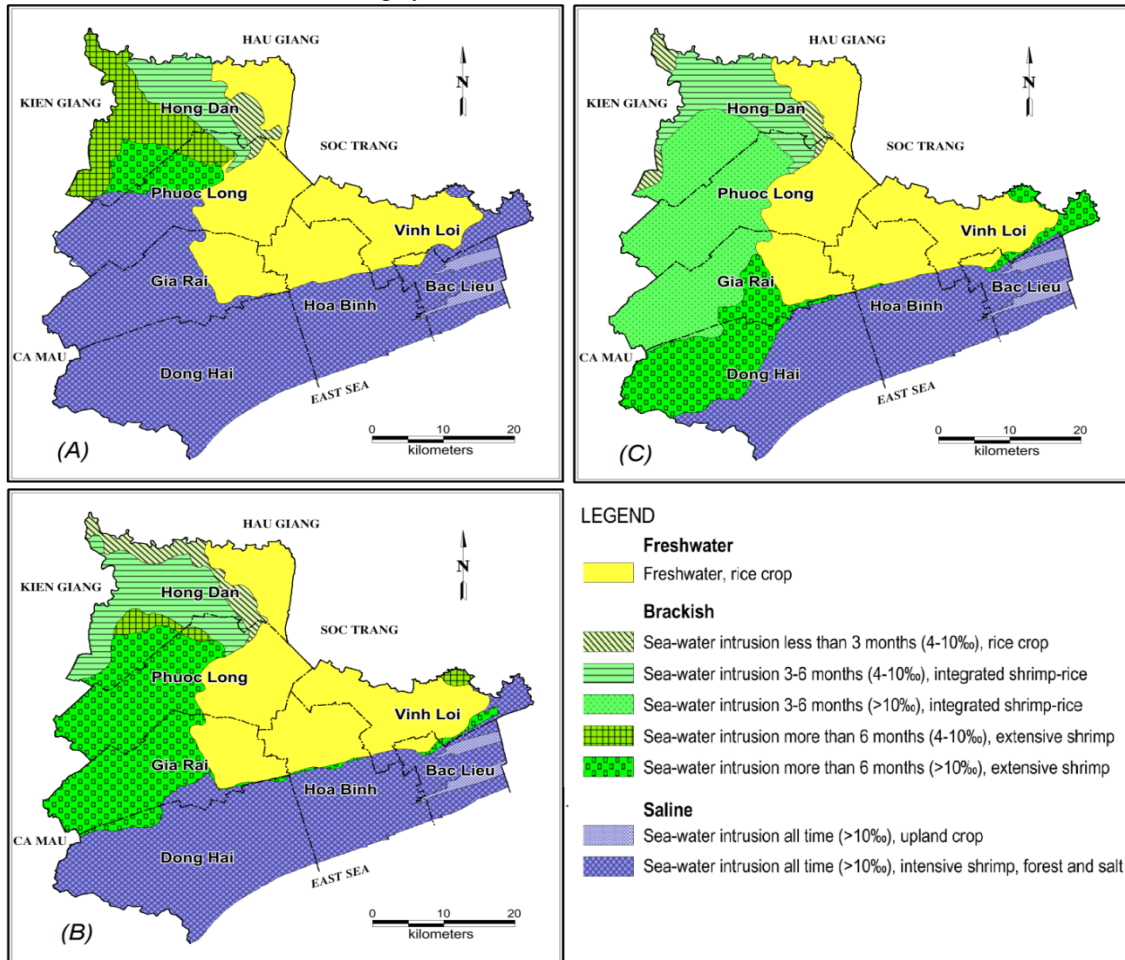
**Fig. 7: Areas of each agro-ecological zone in Bac Lieu in 2000 and 2010**

In 2000, when the saline control system was not well-developed, there was a mixed system of different natural conditions while in 2010 the study area was better divided into freshwater, brackish water and seawater based on farming systems. The

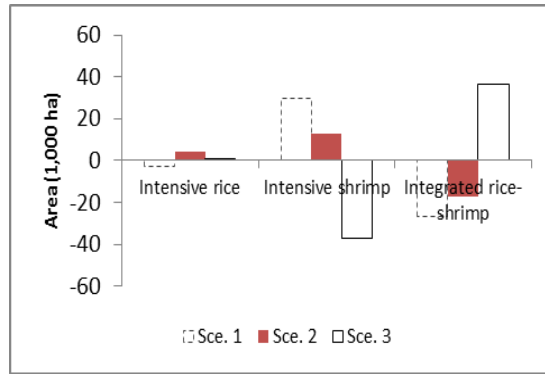
agro-ecological conditions in Bac Lieu in the period of 2000 - 2010 tended to change from fresh to brackish water and from brackish to seawater (Fig. 7).

### 3.4 Agro-ecological zones in the context of climate change

Fig. 8 presents the projection of agro-ecological zones of Bac Lieu in the future according to different scenarios (drought, normal and flood year) and areas of main land use types according to different scenarios are presented in Fig. 9. Each scenario included seven sub- agro-ecological zones. However, there were drastic changes of surface water resources as a consequence of saline intrusion leading to great changes of agro-ecological zoning in three different scenarios. Brackish water sub-region and seawater sub-region were of the greatest fluctuations in all three scenarios (Fig. 8).



**Fig. 8: Agro-ecological zones of Bac Lieu in the future scenarios of drought (A), normal (B) and flood (C)**



**Fig. 9: Area of main land use types according to different future scenarios**

Apart from the stable rice-cultivating areas due to well-established hard-measures, the rest would be changed depending on the salinity level of the surface water. Due to the changes of the hydrological conditions of the Mekong river and of tidal regime, the areas of favourable conditions for integrated rice-shrimp and intensive shrimp farming systems would change significantly. Given such changes in the brackish and saline water areas, the existing farming systems should be either adapted (in terms of cropping calendar) or changed (shifting to more suitable systems). The proposed changes could be found in Table 2.

**Table 2: Proposed farming systems for the areas in the context of (surface) water resources changes**

(Surface) Water re-sources conditions	Proposed farming systems
Salinity less than 4‰ and continuous saline-influenced period of less than 3 months	Intensive rice farming system Upland crops farming system
Salinity greater than 4‰ but less than 10‰ and continuous saline-influenced period ranging from 3 to 6 months	Integrated rice-shrimp farming system
Salinity greater than 4‰ but less than 10‰ and continuous saline-influenced period of more than 6 months	Extensive fish or shrimp farming system

#### 4 CONCLUSIONS

Land use changes were more pronounced in study area during 2000 to 2005 with the common trends of freshwater agriculture (extensive rice farming systems) to brackish and saline aquaculture (shrimp farming). From 2005 to 2010, agriculture

was shifted from extensive to intensive rice farming systems. The main causes of land use changed were accounted for hydrological changes (more saline intrusion could be found recently) and financial benefits (greater benefit from shrimp in comparison to that from rice even intensive systems).

The agro-ecological zones in the coastal areas of the VMD were mainly driven by the surface water resources. Such the hydrological factors were projected to be even more important in the context of future climate change and shrimp farming systems would be the main activities of the areas in the future.

#### ACKNOWLEDGMENTS

To complete this article, the team are thankful to Theme 5 (Integrated adaptation assessment of the Bac Lieu Province and development of adaptation master plan) of the CLUES project (Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems) for providing facilities to carry out the work. Funding for this study supported by ACIAR (Australian Centre for International Agricultural Research) is also acknowledged.

#### REFERENCES

- Adger, W.N., 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *Science Direct*. 27: 249-269.
- Dat, T.Q., Kanchit, L., Thares, S., Trung, N.H., 2011. Modeling the influence of river discharge and sea level rise on salinity intrusion in Mekong Delta. The 1st Environment Asia International Conference on "Environmental Supporting in Food and Energy Security: Crisis and Opportunity", 22-25 March 2011, Bangkok, Thailand. Pp. 685-701.
- Kakonen, M., 2008. Mekong Delta at the Crossroads: More Control or Adaptation? *Ambio*. 37:205-212.

- Kam, S.P., Hoanh, C.T., Tuong, T.P., Khiem, N.T., Dung, L.C., Phong, N.D., Barr, J., Ben, D.C., 2001. Managing water and land resources under conflicting demands of shrimp and rice production for sustainable livelihoods in the Mekong River Delta, Vietnam. INRM-2001 Workshop on Integrated Management for Sustainable Agriculture, Forestry and Fisheries. Centro Internacional de Agricultural Tropical, Cali, Colombia. Pp. 28-31.
- Nhan, D.K., Be, N.B., Trung, N.T., 2007. Water use and competition in the Mekong Delta, Vietnam. In: Be, T.T., Sinh, B.T., Miller, F. (Eds). Challenges to sustainable development in the Mekong Delta: regional and national policy issues and research needs: Literature analysis. Bangkok, Thailand: The Sustainable Mekong Research Network (Sumernet), pp. 143-88.
- Tri, V.P.D., Popescu, I., van Griensven, A., Solomatine, D.P., Trung, N.H., Green, A., 2012. A study of the climate change impacts on fluvial flood propagation in the Vietnamese Mekong Delta. *Hydrology and Earth System Sciences*. 16:4637-4649.
- Tri, V.P.D., Popescu, I., van Griensven, A., Solomatine, D.P., Trung, N.H., Green, A., 2013. A study of the climate change impacts on fluvial flood propagation in the Vietnamese Mekong Delta. *Hydrology and Earth System Sciences*. 9: 7227-7270.
- Tri, V.P.D., Trung, N.H., Thanh, V.Q., 2013. Vulnerability to flood in the Vietnamese Mekong Delta: mapping and uncertainty assessment. *Journal of Environmental Science and Engineering*. 2:229-237.
- Trung, N.H., Hoanh, C.T., Tuong, T.P., Hien, N.X., Tri, L.Q., Minh, V.Q., Nhan, D.K., Vu, P.T., Tri, V.P.D., 2015. Final report of Theme 5: Integrated adaptation assessment of Bac Lieu province and development of adaptation master plan. Climate change affecting land use in the Mekong Delta: Adaptation of rice-based cropping systems project (CLUES).
- Trung, N.H., Tri, V.P.D., 2014. Possible Impacts of Seawater Intrusion and Strategies for Water Management in Coastal Areas in the Vietnamese Mekong Delta in the Context of Climate Change. In: Thao, N.D., Hiroshi, T., Miguel, E. (Eds). Coastal disasters and climate change in Vietnam. Science Direct, pp. 219-232.
- Tuan, L.A., Hoanh, C.T., Miller, F., Sinh, B.T., 2007. Flood and salinity management in the Mekong Delta, Vietnam. In: Be, T.T., Sinh, B.T., Miller, F. (Eds). Challenges to sustainable development in the Mekong Delta: regional and national policy issues and research needs: Literature analysis. Bangkok, Thailand: The Sustainable Mekong Research Network (Sumernet), pp. 15-68.
- Xuan, V.T., Matsui, S., 1998. Development of farming systems in the Mekong Delta of Vietnam. Ho Chi Minh City Publishing House, Ho Chi Minh City, Vietnam.