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To cite this article: Nguyen Thi Hong Diep *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **964** 012019

IOP Conf. Series: Earth and Environmental Science **964** (2022) 012019 doi:10.1088/1755-1315/964/1/012019

Adaptation to saline intrusion for agriculture farming transformation in the coastal Ben Tre province, Vietnam

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Abstract. This study aimed to evaluate the adaptive capacity (AC) of agriculture farming transformation to improve for the adaptability by saline intrusion of those culture systems in the coastal Ben Tre province. The primary data was collected by questionnaires in three coastal districts of Ba Tri, Thanh Phu and Binh Dai with 178 households to distribute on agriculture land use transformations. An Object-Based Image Analysis (OBIA) and multi-temporal image analysis approach was developed to detect how LULC changes during 2010-2020 in the coastal Ben Tre province using Landsat TM and OLI data. The MODIS (MOD09 8-day reflectance) data was processed into monthly NDVI maps with the Time Series Product Tool software package and then used to classify regionally common rice crops LULC types using unsupervised classification by ISODATA algorithm. Based on primary data collection, evaluating adaptation measures was assessed the compilation of modification options based on a detailed description and criteria including human, society, infrastructure and natural conditions by standardized a weight ranges of adaptive indicators in the agriculture land use changes. The results detected five agriculture land use transformation including rice-shrimp crop rotation to aquaculture, single rice crop to aquaculture, double rice crop to perennial plant/orchards, double rice crop to rice-shrimp crop rotation, and triple rice crop to double rice crop. The adaptability of these transformations conducted the shrimp-rice crop rotation to aquaculture in Binh Dai of strongly high adaptability. Next is followed by double rice crops to orchards and double rice crops to rice-shrimp crop rotation with high adaptability while the rice-shrimp crop rotation to aquaculture is only moderate in Thanh Phu. The low adaptability levels were identified on single rice crop to aquaculture and triple rice crop to double rice crop transformations due to tolerant condition of saltwater for rice crop cultivation. The studies results can further contribute to support adaptation planning in these sectors by using, developing and streamlining this framework to additional and different socio-ecological contexts.

1. Introduction

The Vietnamese Mekong Delta (MKD) is located at the end of the Mekong River, one of the 10th largest rivers in the world and flows through six countries (China, Myanmar, Thailand, Laos, Cambodia and Vietnam) [1]. The Mekong Delta is a key agricultural and aquaculture production area of the country. The Mekong Delta contributes three major export products, which are rice, fruit and seafood. Annually, the Mekong Delta provides more than 50% of the national rice production, 90% of export rice production, 70% fruit, 40% of caught fish and 74% of the country's aquaculture [2]. However, agricultural production and people's lives here also face many difficulties, especially in coastal areas. Every year, in the dry season, the upstream water flows less and the rainfall decreases, so saline water intrusion the field, making more than 2 million hectares of saline soil, affecting crops, livestock and community activities, especially the poor [3,4]. In the Mekong Delta, the problem of saltwater intrusion and water scarcity in dry season has been complicated and tend to become more serious, especially in the context of global climate change and over-exploitation Mekong River's water source in the upstream of the country and seriously affects the production as well as the daily life of people in the Mekong Delta provinces.

Faced with the situation like the ones from above, Ben Tre province is the most affected locality, especially in coastal rural areas where the quality of water for crop irrigation is vital to the economy. Currently, in Ben Tre province, saline water continues to penetrate deep into major rivers: Co Chien, Ham Luong, and Cua Dai rivers, affecting agricultural production and people's daily life on a large scale [5]. Three coastal districts of Ben Tre province, in which Ba Tri district has more than 26,000 hectares of agricultural production on land, accounting for 2/3 of the natural land area. Every year, saltwater intrusion goes deep into the field in the dry seasons, when the Mekong River's water flow decreases [6]. According to the report of the Provincial People's Committee, during the last salt season of 2016, Ben Tre province suffered heavy damage due to the early appearance of saline water. The damaged rice area is about 20,356 ha, about 458.31 ha of crops, 5,240.48 ha of orchards, 151,357 seedlings. The rate of damage was about 60 - 70%, in addition, the area of industrial crops also lost 1,302.51 ha, and 1,380,115 flowers and ornamental plants died due to salt water.

According to the National Climate Change Scenario, Ben Tre province with sea level rise of 12 cm in 2020, Binh Dai district will be affected the most, having the highest percentage of flooded area; next is Thanh Phu district, whose boundary line is adjacent to Ham Luong, Co Chien rivers and has a long coastline, thus the flooding rate is quite high; Ba Tri and Giong Trom districts also have relatively high salinity areas. At a sea level rise of 30cm by 2050, Binh Dai and Ba Tri will be most affected.

Adaptability to salinity intrusion is the capacity of human, natural, infrastructural and social systems to resist adverse conditions caused by salinity intrusion, which is the opposite of vulnerability, adaptability is an activity aimed at reducing adverse effects, reducing harm or taking advantage of opportunities. Adaptation to salinity intrusion is the adjustment of natural, social, human systems to changing circumstances or environments to reduce vulnerability to existing or potential saltwater intrusion and to utilize and take advantage of the opportunities it presents. Assessing the current adaptive capacity is an important scientific basis for building effective adaptation strategies to salinity intrusion. Assessment of adaptability to salinity intrusion aims to review current development activities, plans and adaptation options to the risks posed by salinity intrusion.

The study "Assessment of adaptability of transformative farming models in coastal areas of Ben Tre province in the period 2010-2020" was carried out to assess the adaptability of transformative farming models to intrusive salinity intrusion, as a basic premise in land use planning, thereby improving the adaptability of farming models.

2. Study area and methods

2.1. Study area

Ben Tre is located in the Vietnamese Mekong Delta (VMD), which is about 85 km Southwest of Ho Chi Minh City. The province lies between two tributaries of the Mekong branch (normally known as Tien River), one of two main branches of the Mekong River at the VMD. Smaller inland rivers and canals created complex waterway networks, leading the province to be major agricultural production for the region, especially rice farming systems. Ben Tre province consisted of three islands including An Hoa, Bao and Minh among Mekong branch in the North, Co Chien River in the South and Ham Luong River straight down from Ben Tre city center. The discharge flows through those channels before eventually running off to the sea via three estuaries (Figure 1).

Ben Tre was considered as one of the most provinces seriously affected by climate change impacts in the VMD. According to the provincial Department of Agriculture and Rural Development, serious saline water intrusion had periodically occurred further not only in inland rice farming systems but also affected households in terms of water storage and purification, hygiene promotion, nutritional support and livelihood recovery in each four to five years before 2000. However, the frequency of serious saline water intrusion has intended to be more regular since 2000, in two-year or even annually period. In the years of 2000, 2002, 2004, 2005, 2007, 2009, 2010, the water salinity were reported at 4‰ at some times during dry seasons, in which the monitoring in 2004, 2005, 2010 indicated the furthest inland saline water intrusion ever recorded in Vam Mon, being about 60 km from Ham Luong estuary. In those years, salinity increased by 1‰ to cover almost entirely Ben Tre province. Moreover, salinity variability was reported as one of the main factors of climate change dramatically impacting the coastal provinces based on sea-level rise underflow discharge degradation from the upstream part of the VMD. These changes have accumulatively led to serious consequences in agricultural production. In 1995 - 2008, drought and saline water intrusion caused damage of VND 672,305 billion. Additionally, the drought-induced by freshwater scarcity damaged and reduced the yield of 1,575 hectares of rice, 4,500 hectares unproductive, damaged and reduced the yield of 10,162 hectares of orchards in 2010, which total damage is estimated at 198 billion VND.

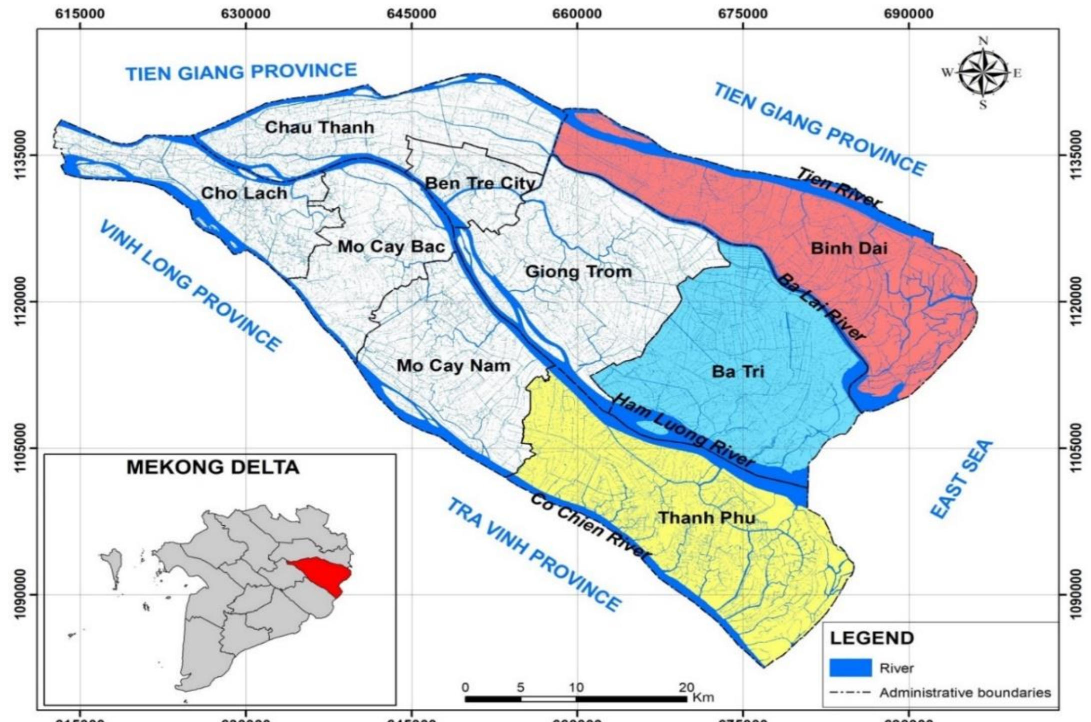


Figure 1. Study area location map.

2.2. *Method*

2.2.1. *Data collection*

LANDSAT data: the images including Landsat 4-5 TM in 2010 and Landsat 8 OLI in 2020 at 30-meter spatial resolution and 16 days of temporal resolution were collected through downloading from http://earthexplorer.usgs.gov/ of the United States Geological Survey (USGS). Images were orthorectified and georeferenced to UTM projection, zone 48 to provide users with standard Level-1 product.

MODIS data: MODIS/Terra data (MOD09Q1) acquired from the U.S. National Aeronautics and Space Administration for two years of 2005 and 2020 from January to December each year. This data product has two spectral bands (red and near infrared) and a spatial resolution of 250 m. Each pixel of the data product contains the best possible L2G observation during an 8-day period, selected based on high observation coverage, low viewing angle, absence of clouds, and aerosol loading. The data have been geometrically and radiometrically corrected for these two spectral bands [7].

Secondary data: Three types of primary data including spatial maps, annual reports and related research in the study area were collected to provide the general information and baseline for the research. Detail of collected primary data was illustrated in Table 1.

Table 1. List of primary data collection.

No.	Data content	Periods	Data sources
1	Land-use map in Ben Tre province	2010 - 2020	Ben Tre Provincial Department of Natural Resources and Environment
2	- Water-based risk annual report - Water infrastructure system	2020	Ben Tre Provincial Agency of Irrigation
3	Relevant studies on saltwater intrusion in the Vietnamese Mekong Delta	2010 - 2020	- International Journals (ISI, Scopus, SCI) - Recognized Vietnamese Journals

Primary data:

- 178 household surveys were conducted in three coastal districts in Ben Tre province, consisting of Thanh Phu, Ba Tri and Binh Dai through directive interview approach to understand possible impacts of saltwater intrusion on local livelihoods and the relationship between land use practices and saltwater intrusion-induced vulnerability.

- The sample size of 178 was chosen according [8], where the size from 30 and above being possibly used for multiple research criteria and the size from 100 and above can work for most of social survey-based research at the local scale. This research then implemented 30 household surveys per each changing land use type based on the random sampling technique. Indicators for structuring the survey were framed aiming at identifying possible impacts-induced vulnerability of water hazards on local agricultural land use types, which this study paid attention to on saltwater intrusion in 2010 – 2020 [9]. The questionnaire was developed depending on four baselines (Table 2) regarding human-being (1); society (2); infrastructure (3); and natural system (4).

Table 2. Criteria for building the questionnaire.

Serial	Criteria	Description
1	People	Household demography, perception, community communication, social learning and behavior change.
2	Society	Technical training and governmental financial loan provision.
3	Infrastructure	Water irrigation, water infrastructure improvement and natural disaster protection.
4	Natural system	Cultivation areas affected by saltwater intrusion and areas potentially switched to another land use practice type.

2.2.2. LANDSAT data processing.

Atmospheric Correction: the products were then atmospherically corrected using Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) tool based on MODTRAN radiative transfer model in ENVI software to obtain surface Reflectance images [10].

Defining class features: Five main classes were defined for this study: Agriculture, Orchards, Forest, Build-up area, Aquaculture and River. These classes and their subsequent inheritance relationships were established in the class hierarchical window of eCognition. The GeoTIFF file was modified a study area of Tra Vinh province and reduce the processing time. All of the necessary classes defined in the sample selection were present in the study area. Class features were defined by image indices and brightness images in Table 3.

Table 3. The class features used in this study.

No.	Image Indices	Equation	Author
1	Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{NIR - Red}{NIR + Red}$ (1)	Khan et al (2010) [11]
2	Normalized Difference Water Index (NDWI)	$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$ (2)	McFeeters (1996) [12]
3	Normalized Difference Index (NDBI)	$NDBI = \frac{MIR - NIR}{MIR + NIR}$ (3)	Zha et al (2005) [13]
4	Brightness value	μ =(Red+Green+Blue)/3 (4)	

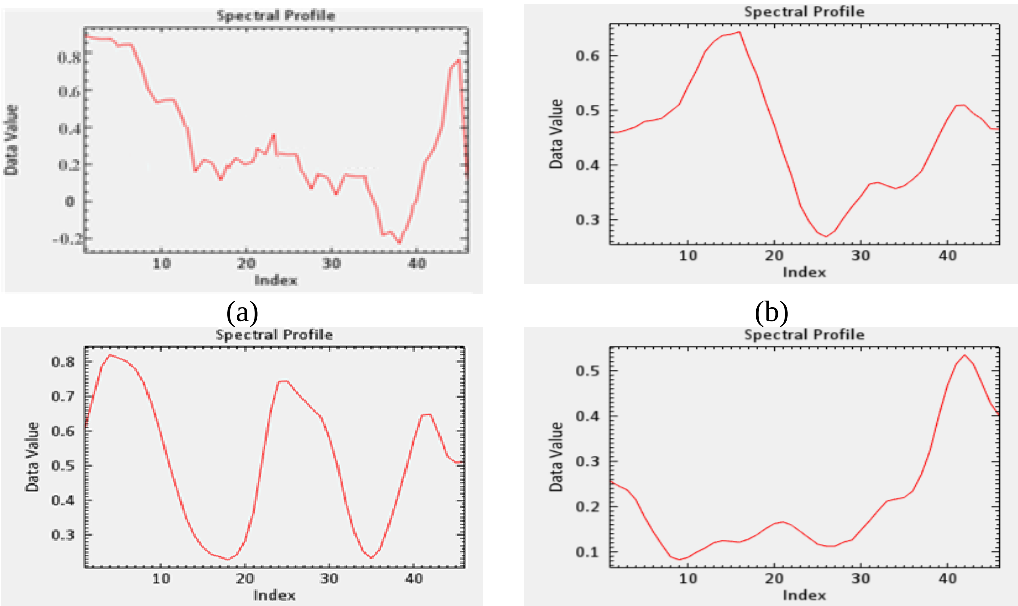
Segmentation: Image segmentation was carried out on the pan-sharpened imagery. Multi-resolution segmentation (MRS), as implemented in Trimble eCognition software, was used for generating the image objects. MRS is a region-merging pair-wise algorithm in which each data point is associated with another data point, where the delineation algorithm will predict which of the two is "more" relevant according to the input parameters. It segments on pixel or object level based on user-defined scale, shape, and compactness parameters [14]. The multi-resolution function was applied for the extraction of image objects using modifiable scale parameters, single layer weights, and homogeneity concerning color and shape [15]. Within the shape setting, smoothness and compactness can also be weighted from 0 to 1. In our study, segmentation parameter used for analysis applying with shape, compactness and scale at 15, 0.5, 0.5, respectively.

Rule-Based Classification: we applied the Membership Function to obtain the suitable feature values from Sample Editor for each class. We selected the features which have less overlap from one another. Range of the feature's value were selected and also changed based on the features statistical value displayed in Sample Editor window. The suitable values to specify each class based on the statistical analysis were selected for the development of Membership functions. For the main classes, we use the Classification process in Process tree with the Active Class which needed to classify for five main classes in Tra Vinh province.

2.2.3. MODIS data processing

MODIS NDVI Time-Series Data: these data have an effective measurement of vegetation with high temporal resolution from MODIS, NDVI data facilitate meaningful comparisons of seasonal and inter-annual changes in vegetation growth and activity. The strength of NDVI lies in its rationing concept, which reduces many forms of noise (illumination differences, cloud shadows, atmospheric attenuation, and certain topographic variations) present in multiple bands. In addition, a comparison of sensitivity to the dynamics of vegetative cover shows that NDVI data are more sensitive because they enable more accurate change detection as a result of NDVI data presenting higher variability and abrupt changes in the growing season [16,17]. Reflectance values in band 1 and band 2 in the MOD09A1 product are used to calculate NDVI, as shown in Equation 1 above [12].

Rice crop phenology detection: We estimated sowing and harvesting dates from phonological events of rice plant computed from MODIS NDVI time-series data (Fig. 2). Rice fields were often irrigated before sowing; NDVI responses from rice fields were relatively low during this period. The rice plants grow quickly after sowing, quickly increasing NDVI values; thus, the sowing date can be estimated using the greenup onset or inflection point (i.e., the point at which the concavity changes from negative to positive). The point earlier than this inflection point was determined as the sowing date. Likewise, NDVI values begin leveling off after harvesting, the harvesting date can thus be estimated from the inflection point (i.e., the point at which the concavity changes from positive to negative). The point after this inflection point was determined as harvesting date. In this research, we detected rice crop phenology due to the fluctuation of NDVI in year (Figure 2).



(c) (d)

Figure 2. NDVI value to determine phenological events of rice plant during a cropping cycle (a) single rice crop, (b) double rice crop, (c) triple rice crop, (d) rice-shirmp rotation.

Rice crop classification: Rice crop classification was subsequently performed using information for sowing, heading, and harvesting dates. We defined the heading date as the date at which the rice plant is completely emerged, leading to the maximum NDVI value. This date can be identified from the smooth NDVI profile using the local maximum algorithm, and it must be between the maturity onset (i.e., the date when plant green leaf area reaches the maximum NDVI value) and the senescence onset (i.e., the date when photosynthetic activity and green leaf area begin to decrease). Similarly, the greenup and senescence dates can also be estimated by the transition dates corresponding to the times when the rate change in the curvature in the NDVI data exhibit local minima or maximums. In this study, a threshold of 0.6 was set based on the analysis of NDVI rice profiles to remove unrealistic cropping patterns. Moreover, the duration from sowing to harvesting should not be longer than 120 days, given the length of rice cycle in the study region is approximately 90-100 days [18].

2.2.4. Accuracy assessment

Overall accuracy (OA) is easily interpreted as it represents the percentage of classified pixels or objects that corresponds to errors of commission and omission [14,19-24]. While Kappa index (K) can be used to assess statistical differences between classifications. The estimate of K is based on the difference between the actual agreement (the major diagonal) and the chance agreement indicated by the row and column totals. This value is computed for each error matrix and is a measure of how well the produced classification agrees with the reference data, values range from -1 to +1 [14]. The higher the value of kappa, the better the classification performance. As values in the off-diagonal increase, the value of kappa decreases.

2.2.5. GIS technique
The advantage of GIS techniques it's not only linked to exploitation of database capabilities, but also to the ability to manage different LULC maps by means of typical vector format like "intersect" and "union", in order to easily evaluate the amount of change [25].

2.2.6. Adaptive Capacity (AC) indicators
The adaptability index was selected according to four main indicators which are also the criteria for developing [26] to the questionnaire illustrated in Table 2. Each indicator was defined and calculated via a set of predictor variables to be divided into four main aspects which are further downscaled to a group level and finally to an item level (Table 4).

Table 4. The Indicator s and Predictor variables for adaptability index of agriculture land use changes.

Serial	Indicators	Predictor variables	Unit
1	Human-being (AC1)	- Individual perceptions about saltwater intrusion impacts;	Level
		- Training participatory ratio of study communities;	Level
		- Social learning towards saltwater intrusion knowledge sharing;	Level
		- Formal saltwater intrusion information accessibility;	Level
		- Areas of changing agricultural-based land use types towards saltwater intrusion adaptation;	Hectare (ha)
2	Society (AC2)	- Quantity of saltwater intrusion impacts and solution annual training;	Number
		- Agricultural production-based loan;	Amount of money
3	Infrastructure (AC3)	- Frequency of agricultural irrigation system improvement;	Level
		- Agricultural farming sufficiently irrigated;	Level
		- Quantity of water infrastructure for natural disaster prevention and protection;	Level
4	Natural condition (AC4)	- Agricultural farming areas affected by saltwater intrusion;	ha
		- Areas of changing agricultural-based land use types possibly adapting with future saltwater intrusion;	ha

2.2.7. Estimating Adaptive Criteria
The predictor variables were estimated on average by the 30 interviewed households in each predictor variable of each indicator (AC) for agricultural land use changes. Then, the adaptability was estimated by the average of each indicator (AC). Qualitative predictor variables were coded into number values ranging from 1 to 5 according to their levels before normalization. Those predictor variables were either binary or continuous variables that ranges and units were diverse and the normalization was utilized to put all variables to an optimal range towards preventing potential bias. The normalization values due to the variable components and sub-variables are used to evaluate the variable structures in each transformation of land use types. The highest values indicate either those variables presenting or adaptive capacity levels (Table 5).

Table 5. Normalization data for each component variable.

Indicators	Predictor variables	Average values	
		Predictor variables	Indicators
People (AC1)	- Individual perceptions about saltwater intrusion impacts (AC11),	0.814	0.53
	- Training participatory ratio of study communities (AC12),	0.0	
	- Social learning towards saltwater intrusion knowledge sharing (AC13),	0.627	
	- Formal saltwater intrusion information accessibility (AC14),	1.000	
	- Areas of changing agricultural based on land use types towards saltwater intrusion adaptation (AC15).	0.229	
Society (AC2)	- Quantity of saltwater intrusion impacts and solution annual training (AC21),	1.000	0.5
	- Agricultural production based on loan (AC22).	0.000	
Infrastructure (AC3)	- Frequency of agricultural irrigation system improvement (AC31),	1.000	0.46
	- Agricultural farming sufficiently irrigated (AC32),	0.000	
	- Quantity of water infrastructure for natural disaster prevention and protection (AC33).	0.372	
Natural condition (AC4)	- Agricultural farming areas affected by saltwater intrusion (AC41),	1.000	0.5
	- Areas of changing agricultural based on land use types possibly adapting with future saltwater intrusion (AC42).	0.0	

2.2.8. Standardization Adaptive Capacity levels

The Standardization Adaptive Capacity levels was estimated the range [0,1] to normalize predictor variables following the formula (5) according [27].

$$x_{ij} = \frac{x_{ij}(t) - Min\{x_{ij}(t)\}}{Max\{x_{ij}(t)\} - Min\{x_{ij}(t)\}} \quad (5)$$

Where: xij, yij were normalized values of variable i in the study district/commune j; xij(t) were raw values of variable i in the study district/commune j; Max and Min respectively were maximum and minimum values of each predictor variable;

Table 6. Standardization Adaptive Capacity levels on the agriculture land use changes.

Adaptive Capacity (AC) levels	Land use changes					
	Double rice crop - Orchards	Single rice crop - Rice-shrimp	Double rice crop - Rice shrimp	Triple rice crop - Double rice crop	Rice shrimp - Aquaculture	
					Thanh Phu	Binh Dai
AC1	2.38	1.50	2.26	1.29	2.01	2.47
AC2	0.38	0.38	0.18	0.28	0.24	0.32
AC3	1.41	1.36	1.24	1.57	1.19	1.47
AC4	0	0.08	0.43	0	0.33	0.41
AC	**0.67**	**0.12**	**0.63**	**0**	**0.40**	**1.00**

The adaptation levels will be divided into 4 levels: low level (0<AC≤0.25), moderate level (0.25<AC≤ 0.5), high level (0.5< AC≤0.75) and the highest level (0.75<AC≤1.0) [28]. The adaptability in five types of agricultural land use changes including single-rice crop to rice-shrimp, rice-shrimp to aquaculture, double-rice crop to orchards, double-rice crop to rice-shrimp and triple-rice crop to double rice crop were assessed the adaptive capacity levels in each district location in the coastal area of Thanh Phu, Ba Tri, Binh Dai in Ben Tre province.

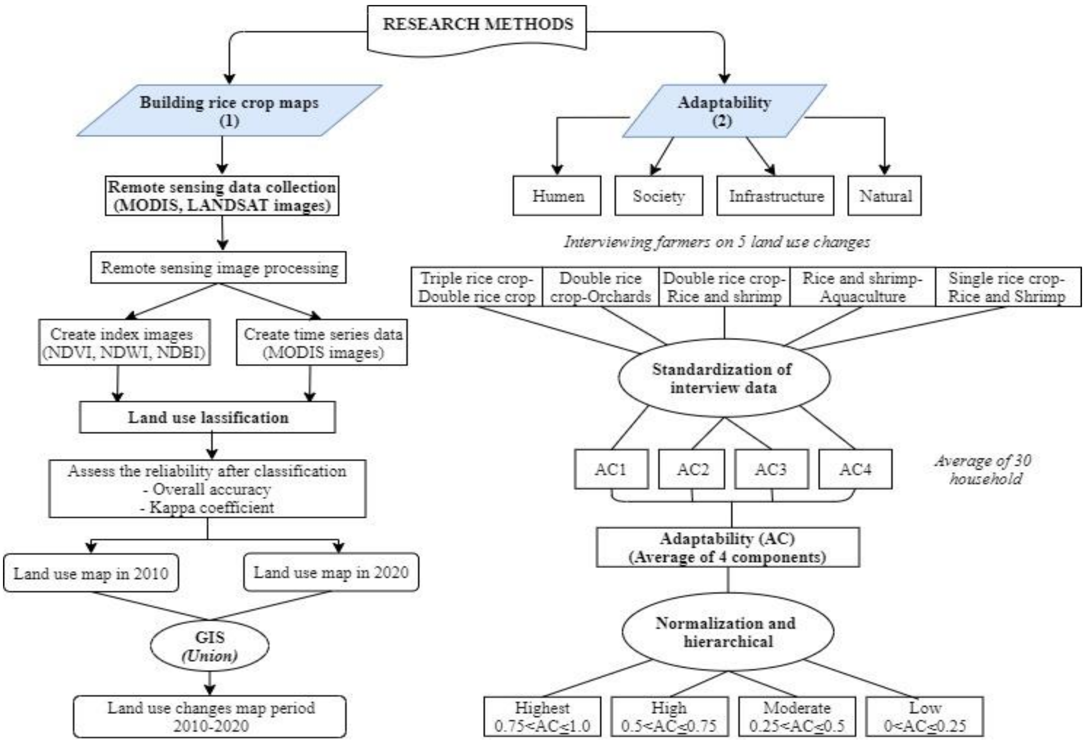


Figure 3. The flowchart of the methods.

3. Results and discussion

3.1. Accuracy assessment

To assessment the accuracy of image interpretation results conduct sampling and scoring surveys by Google Earth platform. Based on the formula for estimating the survey points of Corchan (1977) [29], the research has sampled a total of 385 sampling, the survey points were distributed in different land use types depends on the percentage of the area to be analyzed in each land use on the map (Table 7).

Table 7. Survey points to accuracy assessment after classification.

Land use types	Survey samlings	
	2010	2020
Perennial plant /Orchard	207	151
Rive	71	67
Rice crop	60	38
Aquaculture	22	61
Forest-shrimp	16	19
Urban area	5	41
Forest	4	5
Rice-shrimp	-	5
Total	**385**	**385**

The results overall accuracy of the classification results as 88.7% and the Kappa coefficient = 0.77 (in 2010); and overall accuracy 86.7% and the Kappa coefficient = 0.73 (in 2020). From this result, it is shown that the accuracy of classification results has statistical significant (no less than 75%) and the classification ability indecates a good reliability (Kappa ≥ 0.70) (Table 8).

Table 8. Accuracy assessment results after classification.

Parameters	2010	2020
Overall accuracy	88.7%	86.7%
Kappa	0.77	0.73

3.2. Land use/Land cover in 2010 and 2020 in the coastal area in Ben Tre province

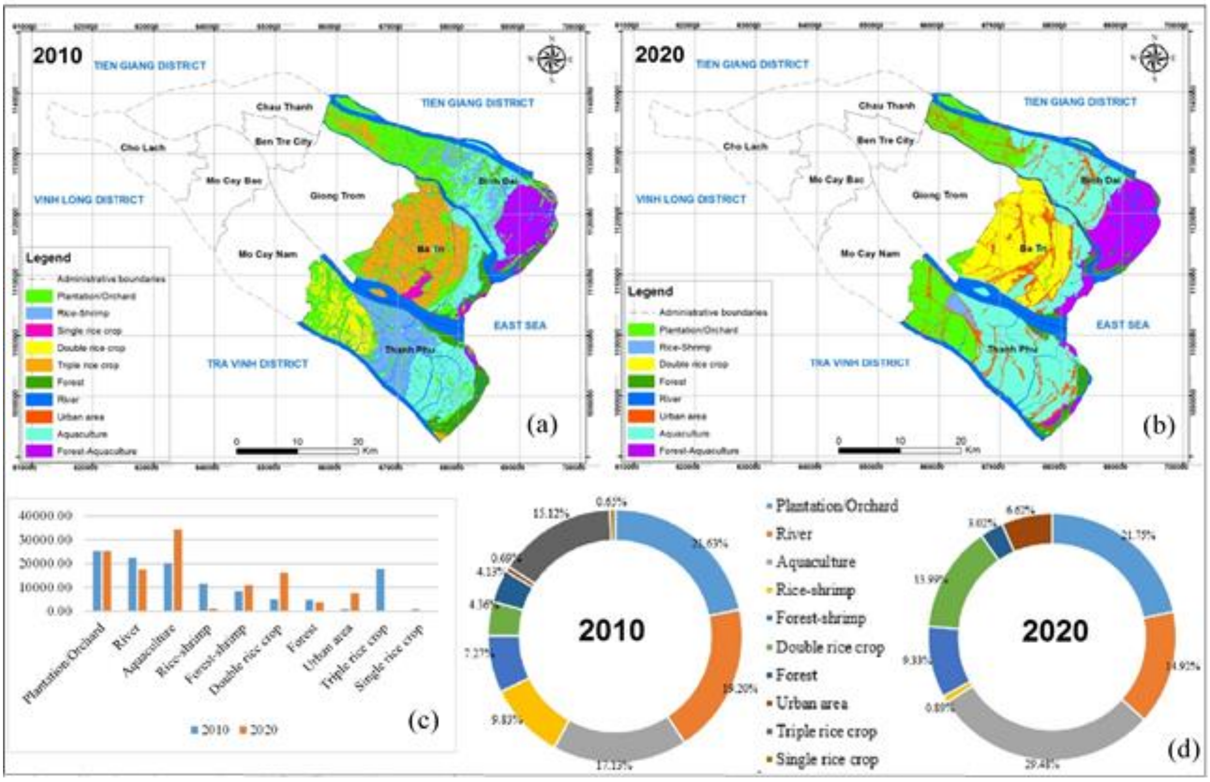


Figure 4. Land use/Land cover in 2010 and 2020 in the coastal area in Ben Tre province, (a) Land use area distribution in 2010, (b) Land use area distribution in 2020 (c) Land use area in 2010 and 2020, (d) Land use percentage in 2010 and 2020.

In 2010, there are ten land use types to be identified in the coastal area in three districts of Thanh Phu, Ba Tri and Binh Dai in Ben Tre province (Figure 4a). The perennial plants/orchards cover with the highest area at 21.63 % of total area. The next land use types of river, aquaculture and triple-rice crop are high distribution at 19.20%, 17.13% and 15.12%, respectively. The rest land use types (rice-shrimp rotation, double rice crop, forest and forest-shrimp) were distributed lower than 10% of total area. The last land use types are single rice crop and urban area with the distribution area at 0.65% and 0.69%, respectively. In 2020, there are eight land use types covering in the study area which were disappeared two land use types including single-rice crop and triple-rice crop (Figure 4b). The increasing of aquaculture, build-up area and double-rice crop were transformed by single and triple-rice crops (Figure 4c). The highest areas increasing identified on aquaculture (17.13 to 29.48%), double-rice crop (4.36 to 13.99%) and urban area (0.69 to 6.52%) and the decreasing areas on rice-shrimp rotation (9.83 to 0.89). The triple -rice crop and single-rice crop are dramatically decreasing areas at 15.12% and 0.65%, respectively (Figure 4d).

The areas of three districts of Thanh Phu, Binh Dai and Ba Tri distributed with 35.31%, 34.37% and 30.31% of total area, respectively (Tab. 9) in which Ba Tri district has the lowest than the remaining provinces. In Binh Dai district, perennial plant /orchard has the highest distribution area at 31.17% with two times higher than the others land use types. In Ba Tri district, triple rice crop has the highest area at 40.46% with the nearest 3 times higher than the others land use types distribution. Lastly, in Thanh Phu district, there are four land use types of rice-shrimp, aquaculture, river and orchards having the highest area from 23.26% to 16.2% approximately 0.5 time area distribution comparing to the others land use types (Table 9). There have no rice-shrimp and double rice crop that could be culture in Ba Tri district, single and double rice crops in Binh Dai district and single rice crop in Thanh Phu district in 2010. In 2020, double rice crop covers the highest area in Ba Tri at 46.17%, both districts of Binh Dai and Thanh Phu have the highest are of aquaculture at 27.83% and 42.48%, respectively. Next to perennial plant/orchards is distribution a similar area in both Binh Dai and Thanh Phu at 25.16% and 26.35%, respectively. There have no double rice crop distribution in Binh Dai and Thanh Phu districts and rice-shirmp in Ba Tri and Binh Dai districts. The lowest of land use type is forest in Ba Tri and Binh Dai districts with only at 1.73% and 2.23%, respectively; forest-shrimp culture system is a land use types with the lowest area to distribute in Thanh Phu district at 2.07% (Table 9).

Table 9. Land use area distribution in the coastal area in 2010 and 2020 in Ben Tre province.

Unit: ha

Land use types	2010			2020			Total		Percentage (%)	
	Ba Tri	Binh Dai	Thanh Phu	Ba Tri	Binh Dai	Thanh Phu	2010	2020	2010	2020
Perennial plant	6,047.1	12,476.2	6,664.7	4,420.8	10,072.8	10,837.1	25,188.0	25,330.7	21.6	21.8
Double rice crop	-	-	5,076.9	16,296.9	-	-	5,076.9	16,296.9	4.4	14.0
Forest	987.0	817.0	3,008.9	611.3	891.9	2,016.9	4,812.9	3,520.1	4.1	3.0
River	6,220.8	8,183.2	7,952.0	3,741.6	7,217.2	6,420.0	22,355.9	17,378.8	19.2	14.9
Urban area	428.4	213.2	157.4	3,013.1	2,195.0	2,501.0	798.9	7,709.1	0.7	6.6
Aquaculture	4,192.6	6,192.2	9,568.7	5,715.3	11,140.2	17,472.3	19,953.5	34,327.9	17.1	29.5
Rice-shrimp	-	3,252.1	8,196.9	-	-	1,032.1	11,449.0	1,032.1	9.8	0.9
Forest-shrimp	474.4	7,673.4	315.1	1,499.5	8,512.4	852.1	8,462.9	10,864.0	7.3	9.3
Total	**35,298.60**	**40,029.43**	**41,131.48**	**35,298.6**	**40,029.4**	**41,131.5**	**116,459.5**	**116,459.5**	100.0	100.0
%	30.31	34.37	35.31	30.31	34.37	35.31	**100**	**100**		

A disappearance of land use types in 2020 comparison in 2010 were identified in single rice crop and triple rice crop that farmer could not culture those cultivation system because of the impact of saline water intrusion, people are not proactive about water sources, causing damage to crops especially for rice that is not adapted to current conditions. From there, changing the farming model suitable for saline water intrusion conditions is shown in the change of land use status.

3.3. Land use changes in the coastal area in Ben Tre province

From 2010 to 2020, there are five types of agriculture systems transformation in the coastal area of Ben Tre province. In Thanh Phu district, there are three land use types transformation including shrimp-rice crop rotation to aquaculture, double-rice crop to perennial crops/orchards and double-rice crop to shrimp-rice crop rotation. In Ba Tri district, there are two types of agriculture transformation which is single-rice crop to aquaculture and triple-rice crop to double-rice crop. In Binh Dai district, it has only one farming model transformation from shrimp-rice crop rotation into aquaculture (Figure 5).

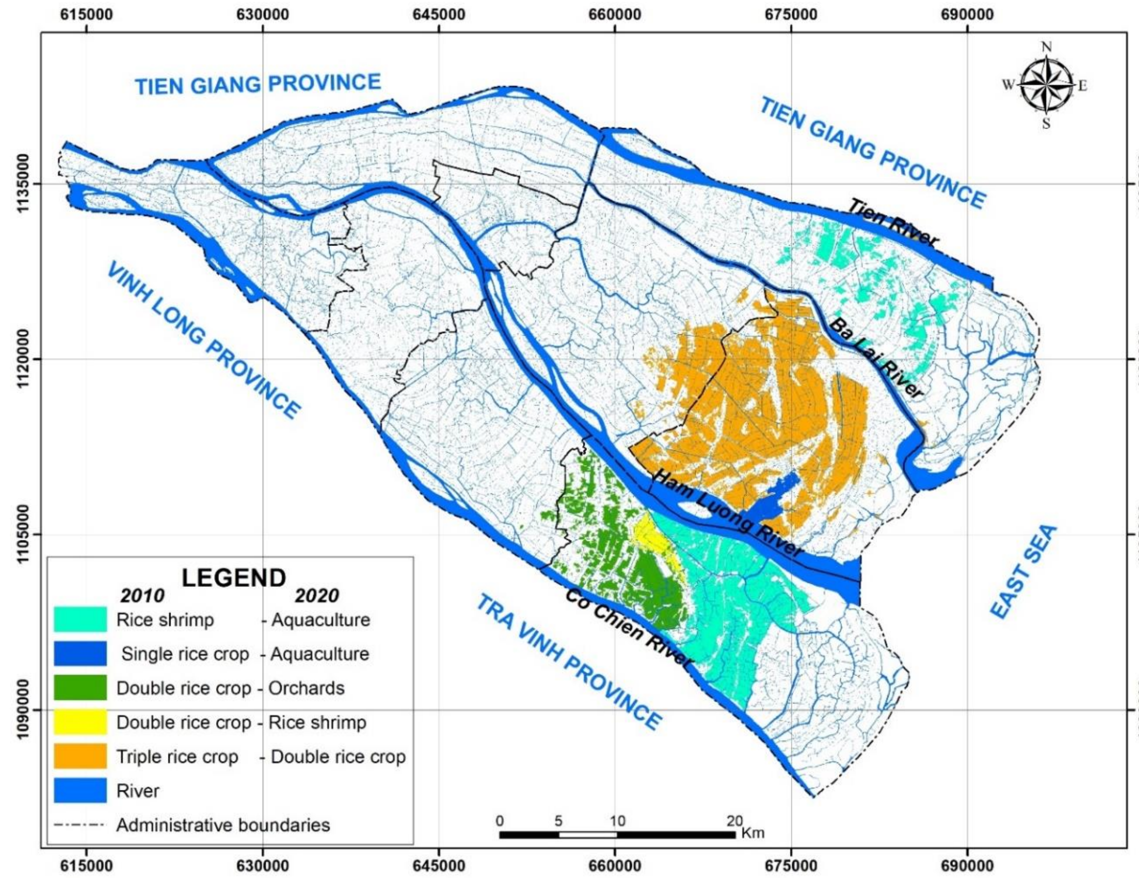


Figure 5. Land use changes map in the coastal area in Ben Tre province in the period of 2010 to 2020.

The five types of agriculture land use has a total area of 30,315 ha in the period from 2010 to 2020 in which Thanh Phu district has three agriculture types changes on shrimp-rice crop rotation to aquaculture which has an area of 7,646 ha (15.13%); double-rice crop to perennial plants/orchards which has an area of 3,971 ha (13.10%), and double-rice crop to shrimp rice crop which has an area of 705 ha (2.33%). In Ba Tri district, there are two types of land use change consists of triple-rice crop to double-rice crop with an area of 14,588 ha (48.12%), single-rice crop to shrimp-rice crop of 658 ha (2.17%), and the rest changing from shrimp-rice crop to aquaculture in Binh Dai district with an area of 2,744 ha (9.05%). The largest change of agriculture land use was detected on triple-rice crop to double-rice crop and the lowest changes were focused on single-rice crop to shrimp-rice crop in this area (Table 10).

Table 10. Area of land use changes in the coast area in Ben Tre province.

No.	Land use changes		Districts	Area (ha)	Percentage (%)
	From	To			
1	Triple-rice crop	Double-rice crop	Ba Tri	14,588	48.12
2	Rice-shrimp	Aquaculture	Thanh phu	7,646	15.13
3	Double-rice crop	Orchards	Thanh Phu	3,972	13.10
4	Rice-shrimp	Aquaculture	Binh Dai	2,744	9.05
5	Double-rice crop	Rice-shrimp	Thanh Phu	705	2.33
6	Single rice crop	Rice-shrimp	Ba Tri	658	2.17
		Total		**30,315**	**100**

3.4. Household interviews

The sampling interviewed 178 households distributed on five types of agriculture land use changes in which the triple-rice crop to double-rice crop at 35 samples, double-rice crop to perennial plants/orchards at 34 samples, shrimp-rice crop to aquaculture at 30 samples. In addition, there are some areas with small scale transformation of agricultural land use with spontaneous transformation scattered distributed in single-rice crop to aquaculture at 26 samples, double-rice crop to shrimp-rice crop rotation at 26 samples and shrimp-rice crop to aquaculture at 27 samples (Figure 6). The adaptability indicators were selected the developing criteria by the questionnaire illustrated according to four main criteria in Table 2 and the indicators and predictor variables in Table 4. For computing the strength of the adaptive capacity, the score must be given according to its properties based on the agriculture land unit is used as an analysis unit which integrated all input data involved indices. Each indicator has specific measurements, causing difficulties in integration and computation. The sequential method is applied for measuring the score by using a relative level for each indicator, denoting that the score of each item represents the relative level of adaptability.

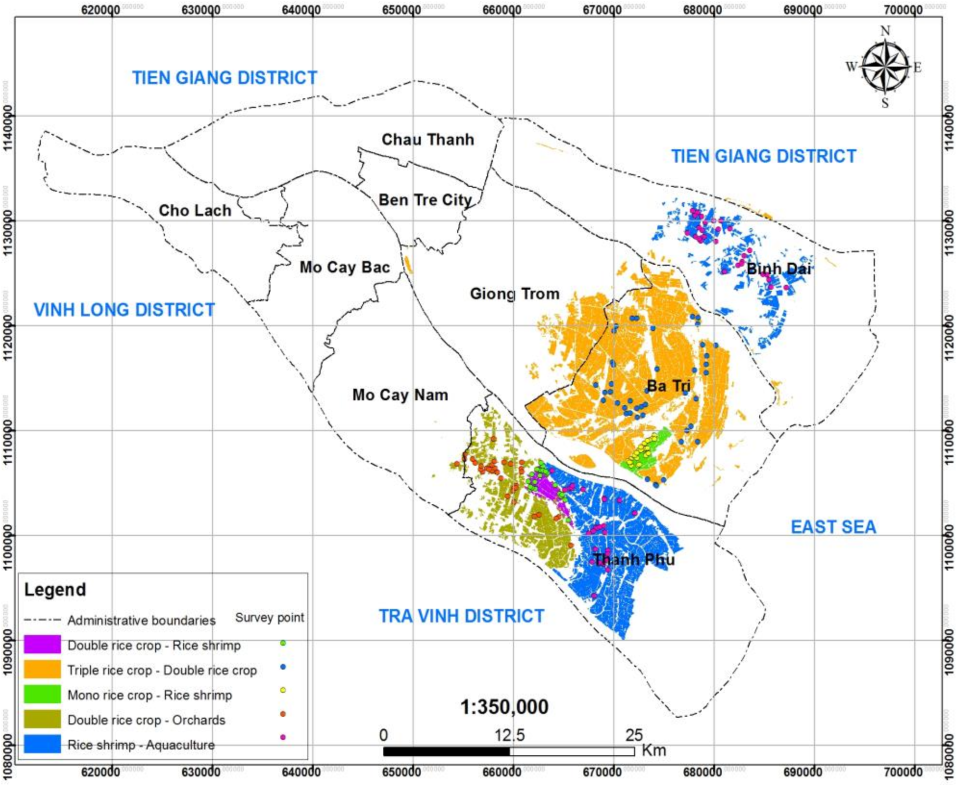


Figure 6. Location of household survey samplings in the coastal area of Ben Tre province.

3.5. Adaptive Capacity Assessment for the transformation of land use area

3.5.1. The Normalization adaptive capacity variables

There are four adaptable component parameters selecting for the changing of land use types: people, infrastructure, society and natural condition in which people are the highest variable effects on the land use changes at the average value of 0.53; next to the natural condition and society at 0.5 and the lowest variables effect of infrastructure at 0.46. It shows that people are one of four the most important adapting factors due to saline water intrusion in coastal area (Figure 7). The people indicator (AC1) shows the highest adaptability identifies on predictor variables of saltwater intrusion information accessibility (AC14) with the maximum value at 1.0. Moreover, the social variable (AC2) found that the predictor variable of quantity of saltwater intrusion impacts and solution annual training (AC21), the natural variable (AC4) with agricultural farming areas affected by saltwater intrusion (AC41) contribute the highest of adaptability at 1.0. In contract, the remaining of data set shows low adaptability contribution because of variable values nearly 0.0.

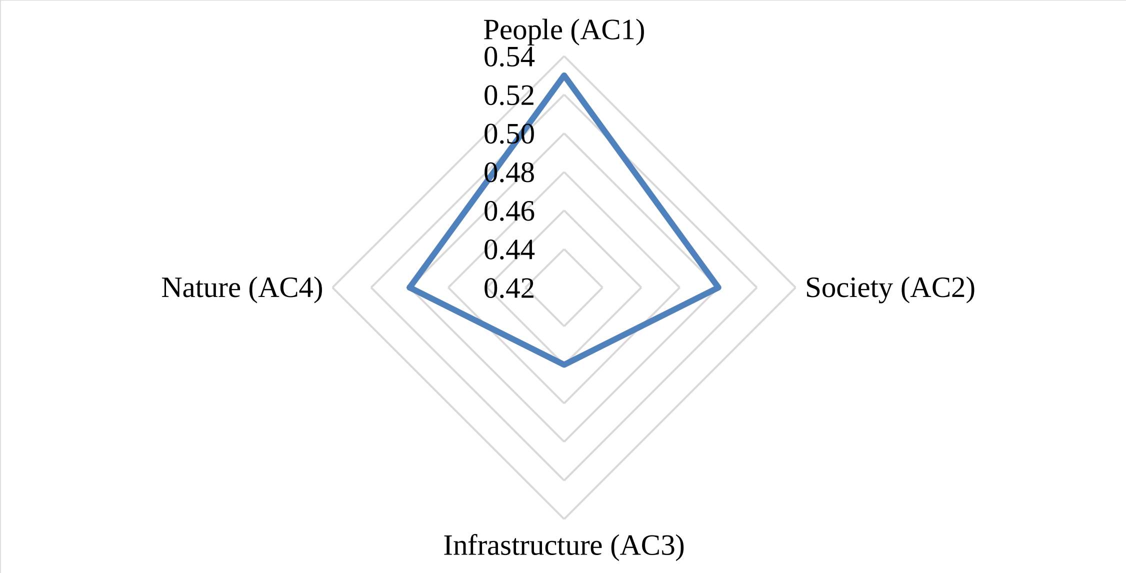


Figure 7. Normalization data for each component indicator.

In Figure 8 identifies the adaptability parameters on each land use type transformation. Society factors highly adapted due to the transformation of single-rice crop to aquaculture and triple-rice crop to double-rice crop in Ba Tri; double-rice crop to perennial plants/orchards in Thanh Phu. Natural factors greatly contributed on the double-rice crop to shrimp-rice crop in Thanh Phu. Also, infrastructure factors have a high influence on the transformation of shrimp-rice crop to aquaculture in Thanh Phu area. The lastly, people indicator have a mainly adaptable on the transformation on shrimp-rice crop to aquaculture in Binh Dai district.

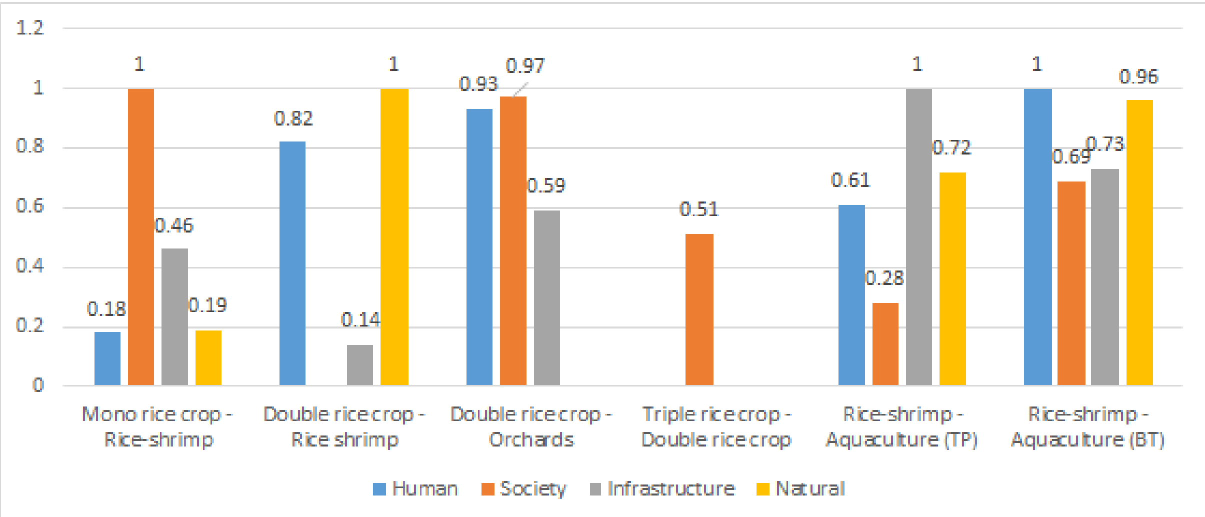


Figure 8. The impact levels in each indicator for whole the land use changes.

3.5.2. Standardization Adaptive Capacity (AC) levels

The adaptability of the agriculture with the transformation from shrimp-rice crop to aquaculture in Binh Dai district has a higher adaptability than other land use transformation, while the converting of triple-rice crop to double-rice crop has lowest adaptability compared with the remaining agriculture land use transformation (Figure 9). People indicator shows the highest impact in each land use changes in three coastal provinces, infrastructure is next to impact and the lowest effects on Adaptive Capacity are society and natural condition for land use changes in coastal area in Ben Tre province.

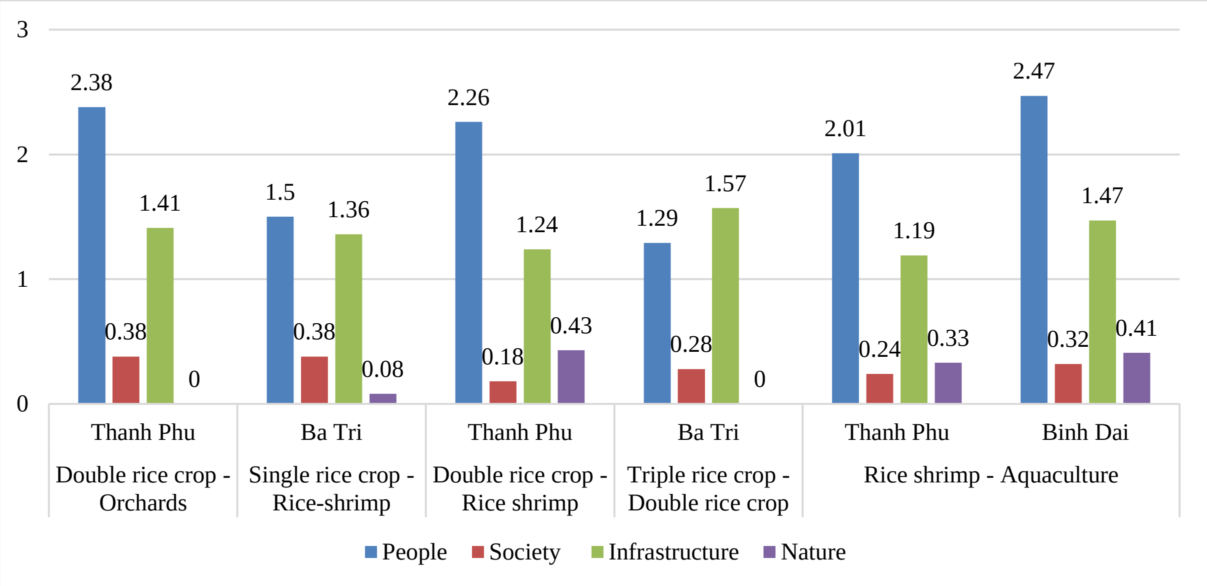


Figure 9. Average Adaptive Capacity (AC) levels for the land use changes.

3.5.3. The adaptability for the changing of land use transformation

The indicator values were converted into a ratio ranges from 0 to 1 and divided into 4 group levels: low, medium, high and very high for adaptability areas. From the collected data and analysis results, it shows that the adaptability of the land use transformation from shrimp-rice crop rotation to aquaculture in Binh Dai area is the highest adaptability to saline water intrusion because the aquaculture cultivation (the industrial aquaculture) is suitable for irrigation and ecological conditions in the saline water intrusion conditions. Moreover, there are two types of land use transformation which have high adaptability to saline water intrusion identifying on double-rice crop to perennial plants/orchards and double-rice crop to shrimp-rice crop in Thanh Phu. Also, the land use transformation from shrimp-rice crop rotation to aquaculture in Thanh Phu district has medium adaptability to saltwater ecosystem. Finally, the triple-rice crop to double-rice crop transformation is a culture system with low adaptability to coastal area due to rice is a poor salt-tolerant crop (Table 11).

Table 11. The value of adaptability index to salinity intrusion in the coastal area in Ben Tre province.

STT	Land use changes	Ecological zone	District	AC (0-1)	Level
1	Rice shrimp - Aquaculture	Saline	Binh Dai	1.00	Strongly high
2	Double rice crop - Orchards	Fresh brackish	Thanh Phu	0.67	High
3	Double rice crop - Rice shrimp	Saline brackish	Thanh Phu	0.63	High
4	Rice shrimp - Aquaculture	Saline	Thanh Phu	0.40	Moderate
5	Mono rice crop - Aquaculture	Saline brackish	Ba Tri	0.12	Low
6	Triple rice crop - Double rice crop	Fresh brackish	Ba Tri	0.00	Low

The adaptable levels for each agriculture land use transformation as well as each district are not similar due to different location. Binh Dai is a district with very high adaptability; high and medium adaptability in Thanh Phu district and the lowest adaptation level is in Ba Tri district (Figure 10).

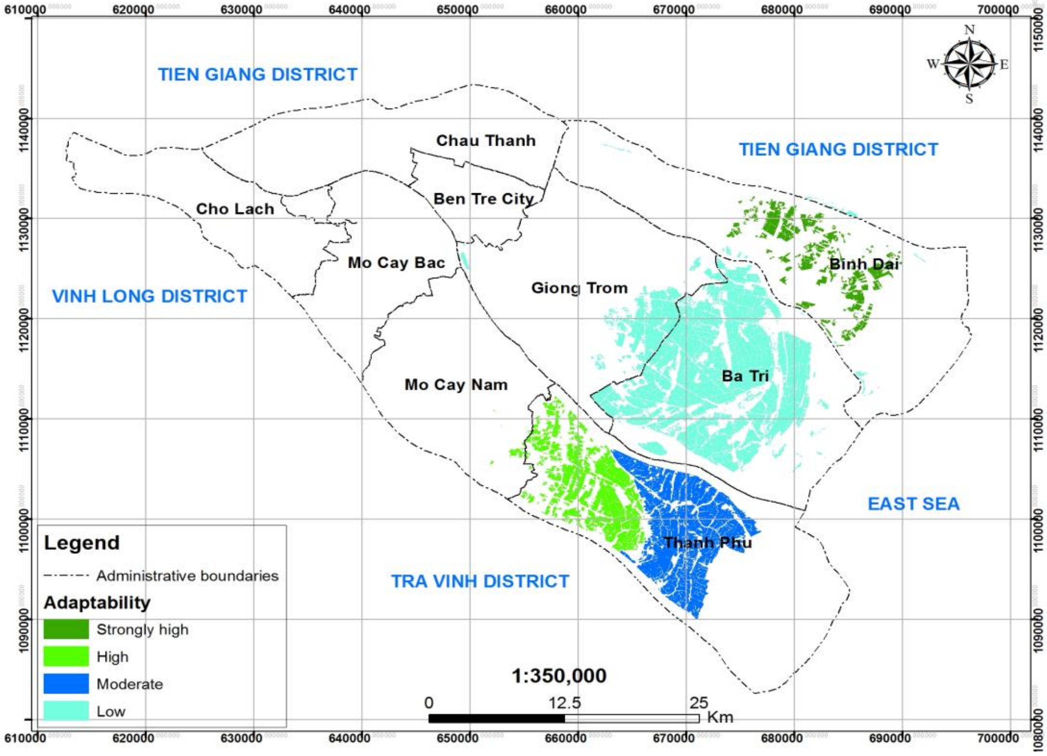


Figure 10. Adaptation map on transition status in the area coastal in Ben Tre province.

4. Discussion

The adaptation options showed the expectation of agriculture farming households which provided useful information for policy makers. Based on the research findings, there were many factors affecting household's decisions responding to different levels of adaptive capacity to saline intrusion. In order to develop adaptation policies and strategy options, agriculture farming households should be involved in balance of economic, social and environmental aspects, especially household's adaptive capacity and government policy supports. The adaptation options at regional/national level should consider regional links and transfer of adaptation experience of saline intrusion between each land use changes models in study area to supervise the implementations of saline intrusion prevention and mitigation in the context of future saline intrusion. According to the results of the adaptive capacity assessment of agricultural land, the entire study region can be selected three land use change types including Rice shrimp – Aquaculture in Binh Dai; Double rice crop – orchards and double rice crop - rice shrimp rotation in Thanh Phu that are low effect in coastal saline intrusion of the adaptation aspect.

In terms of the adaptive capacity assessment framework, this study involved many approaches to moderate data and integrate computation results. For instance, the assessment matrices were employed to establish rules for combining consequences from different sectors including four indicators of people, society, infrastructure and natural conditions. These procedures were limited by the data format, uncertainties in the relationships between criteria, and a lack of information; however, despite these limitations, through the conceptual integration mechanism, the matrices could still effectively simulate the relative locations of adaptive capacity agricultural land, and subsequently develop follow-up strategies.

Agricultural land is one of the essential elements of agriculture. Emphasizing the multiple values of the nature of agricultural land will help to enhance the possibility and application of policy inputs. The main purpose of the application of adaptive capacity assessment is not to explicitly describe the status of agricultural land to climate change, but to help local government and farmers to identify the critical area and to discussing the appropriated adaptive policies and agriculture future. The consequence of adaptive capacity is a relative score and it simplifies the complex values for local people. Local people can feel a real difference between individuals and neighbours. That creates the possibility to connect local government and local farmer and to generate consequences. In addition, by the characteristics of agriculture land location, adaptive policies would have new opportunities to integrate, to efficiently benefit, and to create a new development direction.

Agriculture farming households had the opportunity to continue their production activities under the interest of government investment into the planning stage of agriculture production, especially irrigation, dyke and sluice gate systems which mitigated the impacts of saline intrusion on production activities. Provinces had supported many policies and projections in order to deal with saline intrusion. Nevertheless, according to surveyed households, the government policies and projections had two-sided effects on rice and fish farming households. The policies and projections focused on the efficiency of production activities, including stability of productivity and sustainable livelihood, but less on adaptive capacity. Leaders of provinces confirmed that saline intrusion adaptation must ensure provincial development goals focusing on the strength and adaptability. The adaptation options recommended by provinces were as (1) in the areas facing with severe freshwater shortage, provinces should adjust production activities to adapt to saltwater ecosystems. Shrimp and brackish fish species should be encouraged as main cropping systems in these regions; (2) in the areas facing with salinity-effected freshwater in dry season, provinces should apply integrated production models or modify seasonal calendar to one rice or fish crop in freshwater months-one brackish fish or shrimp crop in saline intrusion duration; (3) in the areas where freshwater was slightly affected by saline intrusion, provinces should encourage households to continue their production activities normally. However, the improvement of farming practices and the development of salt-tolerant rice varieties and fish species should be developed as adaptation options under future saline intrusion impacts.

5. Conclusions

The study identified five agricultural land use transformation in the coastal district of Ben Tre province including shrimp-rice crop rotation to aquaculture in Thanh Phu and Binh Dai, single-rice crop to aquaculture in Ba Tri, double-rice crop to orchards in Ba Tri, double rice crop to rice-shrimp in Thanh Phu and triple- rice crop to double-rice crop in Ba Tri. A set of indicators of Adaptive Capacity (AC) was created due to the effect of salinity intrusion on the land use changes consists of four main variables of people, society, infrastructure, nature conditions and twelve sub-variable components. The results show that the assessment of adaptability levels in saltwater ecosystem on agricultural in the coastal area of Ben Tre province in the transformation on rice-shrimp crop rotation to aquaculture in Binh Dai district has the highest level adaptation and the lowest adaptation on triple-rice crop to double-rice crop transformation. Assessing adaptability is important for defining the risks posed and provides information for identifying measures to adapt to climate change especially in saline intrusion impacts. It enables practitioners and decision-makers to identify the most adaptable areas, sectors and social groups. In turn, this means climate change adaptation options targeted at specified contexts can be developed and implemented for agriculture land use changes in saltwater ecosystem area.

Acknowledgements

The authors thank the survey participants from three districts of Ba Tri, Binh Dai and Thanh Phu provinces, Ben Tre province. We are also in great debt to the Department of Science and Technology and Department of Environment and Natural Resources in Ben Tre province which have been very helpful in providing valuable materials and supporting us during the survey. We highly appreciate a practical project funded in part by the Technological Cooperation Project "Building capacity for Can Tho University to be an excellent institution of education, scientific research and technology transfer" of JICA. Our gratitude extends to the Can Tho University Improvement Project VN14-P6, which was

IOP Conf. Series: Earth and Environmental Science **964** (2022) 012019 doi:10.1088/1755-1315/964/1/012019

funded by a Japanese ODA loan. Lastly, but of equal importance, we owe an outstanding debt to the project management board and the colleagues at the College of Environment and Natural Resources to support us during this project accomplishment.

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