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# ASSESSMENT OF CHANGES IN THE LAND USE STRUCTURE IN TRA VINH PROVINCE UNDER THE SCENARIOS OF CLIMATE CHANGE AND SEA LEVEL RISE

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**Abstract.** Currently, in the context of climate change, droughts, salinity intrusion, sea level rise etc. and through the reality, it can be seen that the structure of land use in Tra Vinh Province, Viet Nam has been impacted quite strongly. The salinity intrusion, flooding and drought have increased in recent years, requiring appropriately comprehensive and proactive solutions. First and foremost, it's a solution to change the structure of land use in combination with the change of seed structure and crop production structure to ensure efficient and sustainable development. For an overview of these changes as well as predictions for later years, the assessment of the impact of sea level rise on the average scenario (2030) affects the structure of land use by 2030 compared to the land use data in Tra Vinh in 2016, the results show that the areas flooded under the scenario of climate change and sea level rise RCP6.0 in 2030 are at risk of land use change. The land area has the risk of land use change in the whole province is nearly 24,235 ha, in which the most affected land area is specializing in rice land (occupies 71 %), area aquaculture (11 %), and paddy land remaining (8 %). Especially 4 % of residential land in rural areas will be affected, that will directly affect the lives of people in the shallow village.

*Keywords:* climate change, sea level rise, structure of land use in Tra Vinh Province.

*Classification numbers:* 3.5.1, 3.5.2, 3.8.3.

## 1. INTRODUCTION

Tra Vinh is one of the provinces of the Mekong River Delta (Viet Nam) with low terrain, especially in the eastern coastal area. Therefore, the rise of sea level, resulting in saline water intrusion into the field will have a bad impact on crops and people's livelihoods, especially in the absence of fresh water. Rising sea levels are leading to a series of coastal hazards [1], especially coastal areas, which are most affected by climate change, including flooding and frequent flooding, storm surges, loss of wetlands, coastal erosion, salt water and groundwater intrusion, etc.

The negative impacts of climate change, in recent decades, under the forms of drought, salinization, and sea level rise have been directly damaged on the pattern of variations in land use proportion around coastal areas [2-7]. With mainly flat terrain at an altitude of 1 m above sea level, Tra Vinh is vulnerable to sea level rise, following the medium range emission scenario in years 2030 when the sea level rises by 13 cm [1].

Global sea level rise (SLR) ranging from 0.5 m to 2 m has been predicted over the next century and it would disrupt the physical processes, economic activities and social systems in the coastal zones [5, 8, 9]. Besides the destruction through increased rates of erosion, sea level rise situations increase the risk of inundation [10].

Therefore, it is necessary to map the land use change and zone as area during the period of 2016-2030 at a level scale of 1: 100.000 under the sea level rise scenarios. The study aims at (i) Mapping of changes in the land use structure in the period 2016-2030; (ii) Analysis and assessment of changes in the land use structure in the period 2016-2030.

## 2. MATERIALS AND METHODS

### 2.1. Study area

Tra Vinh geographical location ranges from 9°31'46" to 10°04'05" latitude and from 105°57'16" to 106°36'04" longitude. Its northern boundary is bordered by the Ben Tre Province, in the south the Soc Trang Province, in the west the Vinh Long Province, and in the east the East Sea. Note that an islet is located between the Tien and Hau Rivers. The total natural area of Tra Vinh Province is about 2,341.2 $km^2$, with nine subordinate administrative units, including Tra Vinh City, Duyen Hai town and seven districts: Cang Long, Chau Thanh, Cau Ke, Tieu Can, Cau Ngang, Tra Cu and Duyen Hai (Figure 1).

Tra Vinh is characterized by the lower delta terrain, belonging to the last point of downstream of the Mekong River. Its soil is attributed by high sediments mainly deposited due to annual flooding. Its sedimentations were from the river and sea to form alluvial plains, lowland, swamp and sand dunes. The terrain is significantly low and severely separated by rivers, natural canals, and irrigation canals with average elevation ranging from 0.6 meter to 1.0 meter (occupying 66 % of the area of the province). The sand dunes have an average height of 1.0 m to 3.0. For example, high altitude terrains in the Tra Vinh Province can be seen in Figure 1. Located in the tropical monsoon climate, Tra Vinh's climate is divided into two distinct seasons, namely rainy and dry seasons. The rainy season is from May to October with prevailing wind of southwest monsoon and causes heavy rain. The dry season is from November to April. In a year, rainfall is unevenly distributed, forming two distinct seasons corresponding to the monsoon regime in the area. The rainy season associated with the southwest monsoon starts in May and ends in October. At Cang Long weather station, the average rainfall in the rainy season is 1,617 mm with less annual fluctuation. The dry season is associated with less damping northeast winds, starting in November and ending in April of the next year. The average dry

season rainfall is 198 mm and fluctuates significantly through the season. The temperatures in the area are relatively high (26 – 27.6 $^{o}$C), while their difference is not much during the season. The lowest temperature in a year falls in January and the highest temperature is in April. The average humidity in a year is 83 – 85 %. The driest months are in February and March. Average evapotranspiration varies from 48 mm in July to 111 mm in March. The highest evapotranspiration occurs in the dry season from December to April, during which timeframe rainfall is negligible. The Tra Vinh Province is directly affected by the semi-tide regime of the East Sea through the Co Chien River and Hau River. The tidal effect gradually decreases from the sea to the inland, mainly in coastal areas.

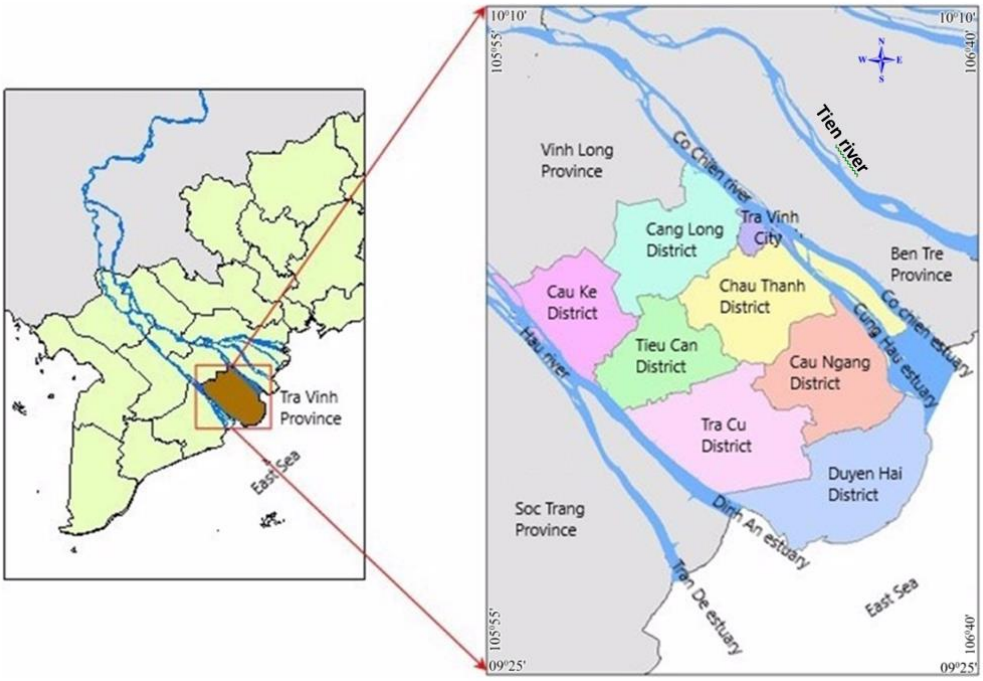


*Figure 1.* Geographical location of Tra Vinh Province in the Mekong Delta, Viet Nam.

**2.2. Data**

To assess changes in the land use structure of Tra Vinh Province in the context of climate change and sea level rise scenarios, the Geographic Information System (GIS) approach was used: using GIS tools for spatial analysis, standardization and integration of digital documents, maps, etc. into the database and statistical analysis methods at the same time. For the analysis and evaluation of GIS data, statistical space analysis tools in GIS software or statistical analysis in Excel were used.

Specifically: The study collected land use map data in Tra Vinh province in 2016 at the scale of 1:100,000. The coordinate system of the map data is the national coordinate system VN2000. Digital Elevation Map (DEM) data is provided by the Shuttle Radar Topography Mission (SRTM), which combines two agencies NASA and NGA to draw three-dimensional topographic features for the Earth with a detailed level of a large area (SRTM 90m data download for Viet Nam). The research team used topographic DEM data with a resolution of 3 arc-second with WGS84 geographic coordinates and altitude calculated from average sea level (geoid surface). This terrain elevation will be adjusted in terms of standard elevation of Viet

Nam through the elevation of the land use map. The topographic map results are shown in Figure 2.

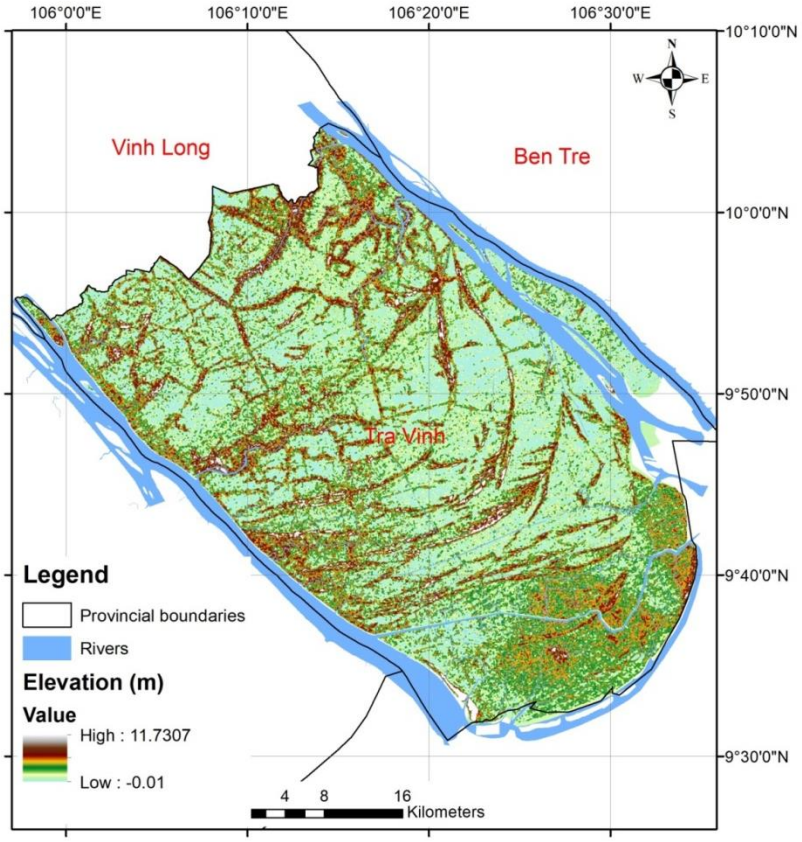


*Figure 2*. Terrain model of Tra Vinh Province.

### 2.3. Method

The research method in this paper is presented as shown in Figure 3. The establishment of flooded maps in 2030 and the analysis of its impacts requires data on land surface elevation and sea level elevation also forecasting for 2030. SRTM provides global topographical data with a resolution of 90 mm and relying on that terrain elevation data in the study area of Tra Vinh Province was extracted. SRTM digital elevation model is one of the free DEMs available for the globe. A 90 m resolution DEM is prepared for the study area. The predicted average sea level elevation is estimated from the Representative Concentration Pathways (RCP) model according to the high average emission scenario (RCP6.0) for 2030 in Tra Vinh Province [1].

The flooded forecast maps for the period of 2016 - 2030 and land use map established in 2030 were used for establishing the risk map of land use change and the analysis of the ability to change land use. Quantification of affected areas or the risk of potential land use changes by flood is estimated by overlaying land use maps, digital elevation models and sea level elevation [11]. The land use map established in Tra Vinh Province, in which the land use classes present in the study area consist of waters, vegetation, urban land, etc.

The land use classes with elevation lower than sea level are forecasted according to RCP6.0 scenario and DEM model, and the layers in these areas are extracted. This area is mainly

covered by growing rice or aquaculture. All classes of land use affected by flooding are important for social aspects, and their impacts may increase the risk of changing land use purposes. Different land use zoning in flooded areas due to sea level rise and various water level increase scenarios have been analyzed in this study.

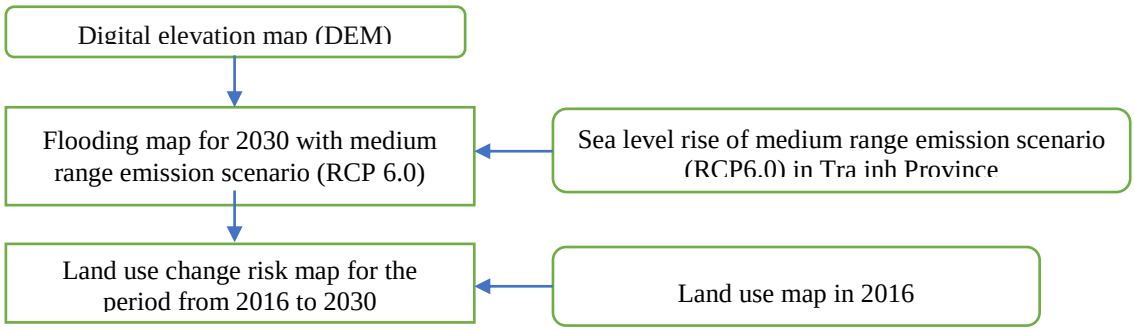


*Figure 3.* Flow chart for research method.

In addition, in this study the forecasted results from the Ministry of Natural Resources and Environment (MoNRE)'s the medium range emission scenario (RCP6.0) for sea level rise in Viet Nam was used Ministry of Natural Resources and Environment, climate change, sea level rise for Viet Nam, 2009, 2011, 2016 [1, 12, 13]. According to the climate change scenario, the medium range emission scenario (RCP6.0) until 2030, the sea level rise is projected of about 0.5 cm per year. This report used the average sea level for Tra Vinh Province based on tide data at Dinh An - Tran De - My Thanh estuaries (geographic coordinates: the latitude of $9^{o}25'29.2$ N and the longitude of $106^{o}10'15.3$ 'E) is 6 cm above the standard elevation (Hon Dau) by 2015. Thus, we have a sea level rise under the medium range emission scenario (RCP6.0) in 2030 of 13 cm (compared to the average sea level in the period 1980 - 1999 for Viet Nam), corresponding to the sea level at My Thanh Station in Scenario RCP6.0 in 2030 is 13.5 cm (compared to the national standard height - Hon Dau), which will be used to calculate floodplains on topographic maps. In this study, the sea level rise in the medium range emission scenario (RCP6.0) is 13 cm (2030), which means that the sea level rise in Tra Vinh Province compared to the national standard height is 13.5 cm (2030).

In 2013, IPCC published an updated scenario, Representative Concentration Pathways (RCP) used to replace SRES scenarios [14]. RCPs are selected so that they are representative of emitted scenario groups, and ensure that the range of future greenhouse gas concentrations is reasonably included. RCPs also ensure similarity with SRES scenarios [15]. Four RCP scenarios (RCP8.5, RCP6.0, RCP4.5, RCP2.6) have been built. The names of the scenarios were matched by RCP and the magnitude of the total radiation impact of atmospheric greenhouse gases by the time of 2100. High average greenhouse gas concentration scenarios (RCP6.0) were developed by AIM modeling team at the Institute of Environmental Research (NIES), Japan.

RCP6.0 is one of two medium scenarios with stable impact radiation. The impact radiation in RCP6.0 increased to about 6.0 W/m2 in 2100 and stabilized later on the assumption of applying technologies and strategies to reduce greenhouse gas emissions. The RCP6.0 scenario is equivalent to the SRES B2 scenario [16, 17].

## 3. RESULTS AND DISCUSSION

### 3.1. Risk map for changing land use structure for 2016-2030

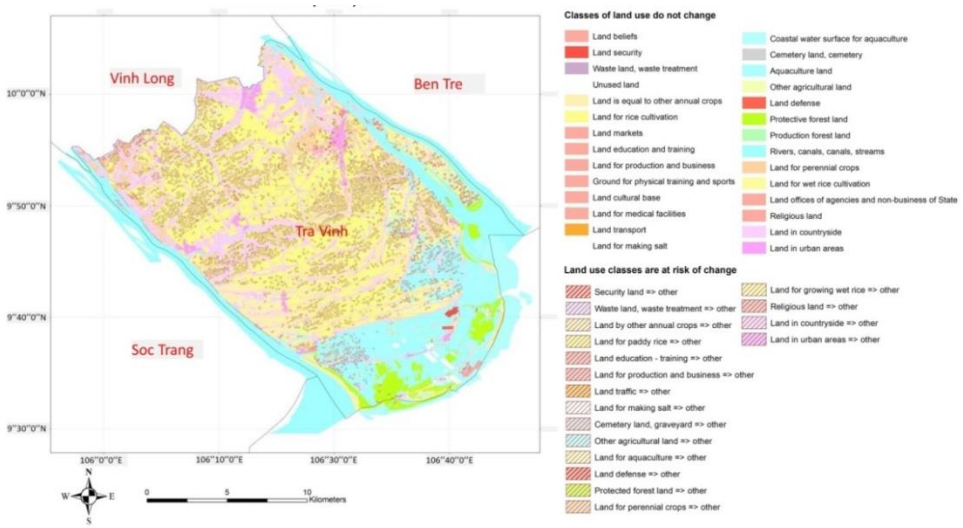


*Figure 4.* The risk map of the land use change for the period from 2016 to 2030 following the medium range emission scenario.

*Table 1.* Land use groups for the risk map of land use change for the period 2016 – 2030.

| No | Group | Type of land use | Code | Acreage (ha) |
|---|---|---|---|---|
| 1 | Group of land use unchanged | Land for security | CAN | 225.1 |
| 2 | | Waste land, waste treatment | DRA | 73.5 |
| 3 | | Unused land | BCS | 736.4 |
| 4 | | Flat land for other annual crops | BHK | 9,598.9 |
| 5 | | Land for markets | DCH | 8.7 |
| 6 | | Land for rice cultivation | LUC | 68,979.8 |
| 7 | | Land for education and training establishments | DGD | 1,177.5 |
| 8 | | Land for production and business establishments | SKC | 459.7 |
| 9 | | Land for physical training and sports | DTT | 8.2 |
| 10 | | Land for cultural organizations | DVH | 3.5 |
| 11 | | Land for medical facilities | DYT | 22.3 |
| 12 | | Land for transportation system | DGT | 27.1 |
| 13 | | Land for making salt | LMU | 205.4 |
| 14 | | Coastal water surface for aquaculture | MVT | 8,625.3 |
| 15 | | Cemetery land, cemetery | NTD | 116.1 |

| | | | | |
|---|---|---|---|---|
| 16 | | Other agricultural land | NKH | 53.0 |
| 17 | | Land for aquaculture | NTS | 31,032.4 |
| 18 | | Land in urban areas | ODT | 3,337.0 |
| 19 | | Land in countryside | ONT | 39,736.2 |
| 20 | | Land for national defense | CQP | 206.2 |
| 21 | | Protective forest land | RPH | 7,855.2 |
| 22 | | Production forest land | RSX | 35.5 |
| 23 | | Rivers, canals, canals, streams | SON | 40,445.1 |
| 24 | | Land for beliefs | TIN | 8.9 |
| 25 | | Land for religions | TON | 358.7 |
| 26 | | Land for perennial crops | CLN | 11,063.2 |
| 27 | | Land for wet rice cultivation | LUK | 10,174.2 |
| 28 | | Land offices of agencies and non-business of State | TSC | 19.6 |
| 29 | Land use groups are at risk of change | Land for security => other | | 18.1 |
| 30 | | Waste land, waste treatment => other | | 7.7 |
| 31 | | Land for other annual crops => other | | 551.2 |
| 32 | | Land for paddy rice => other | | 17,145.8 |
| 33 | | Land for education - training => other | | 45.6 |
| 34 | | Land for production and business establishments => Other | | 56.4 |
| 35 | | Land for transportation system => other | | 0.1 |
| 36 | | Land for making salt => other | | 25.5 |
| 37 | | Cemetery land, graveyard => other | | 2.4 |
| 38 | | Other agricultural land => other | | 10.9 |
| 39 | | Land for aquaculture => other | | 2,594.4 |
| 40 | | Residential land in urban areas => other | | 30.0 |
| 41 | | Residential land in the countryside => other | | 940.8 |
| 42 | | Land for national defense => other | | 3.7 |
| 43 | | Protective forest land => other | | 52.0 |
| 44 | | Land for religions => other | | 2.2 |
| 45 | | Land for perennial crops => other | | 858.9 |
| 46 | | Land for growing wet rice => other | | 1,889.3 |

According to the Ministry of Natural Resources and Environment's Circular No. 37/2011/TT-BTNMT dated October 14, 2011 on "Regulations on Economic- technical issues of 1:25,000, 1:50,000, 1:100,000 and 1:250,000 thematic maps", the detailed map "Map of risk of land use change for 2016-2030 at 1:100,000 scale" has been created and presented in Figure 4. The specific content of the land use groups figured out in the map is presented in Table 1.

### 3.2. The changes in proportion of land use during the period of 2016-2030

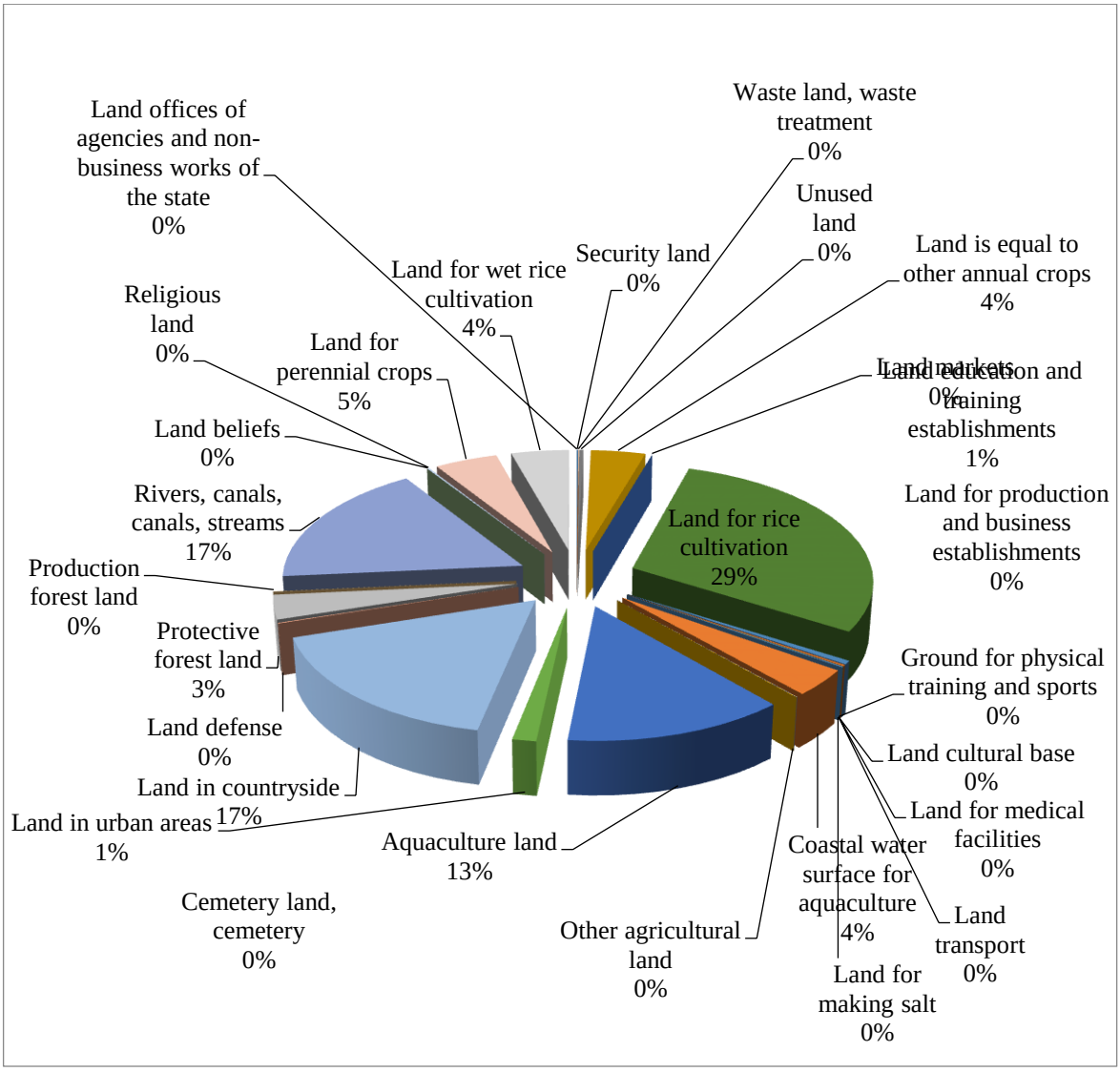


*Figure 5.* Structure of land use in 2016 in Tra Vinh Province.

The results of land use statistics in Tra Vinh Province in 2016 (Figure 5) showed that the areas of paddy fields and aquaculture accounted for 33 % and 13 % of the total land area, respectively. The low lands are mainly in paddy land and aquaculture land (Figure 6).

Tra Vinh Province has a relatively low topography of about below 1 m above sea level and there are many low-lying areas, so there is a flooded area gathering on these lowland areas.

Based on terrain data and land use data, it is possible to identify areas at risk of land use change in the model of sea level rise scenarios. By using GIS technique, we overlap the data layers of the flood map on land use types to estimate areas affected by sea level rise in the medium range emission scenario. The results of the flood plains in Tra Vinh Province, according to the medium range emission scenario RCP6.0, are shown in Figure 6.

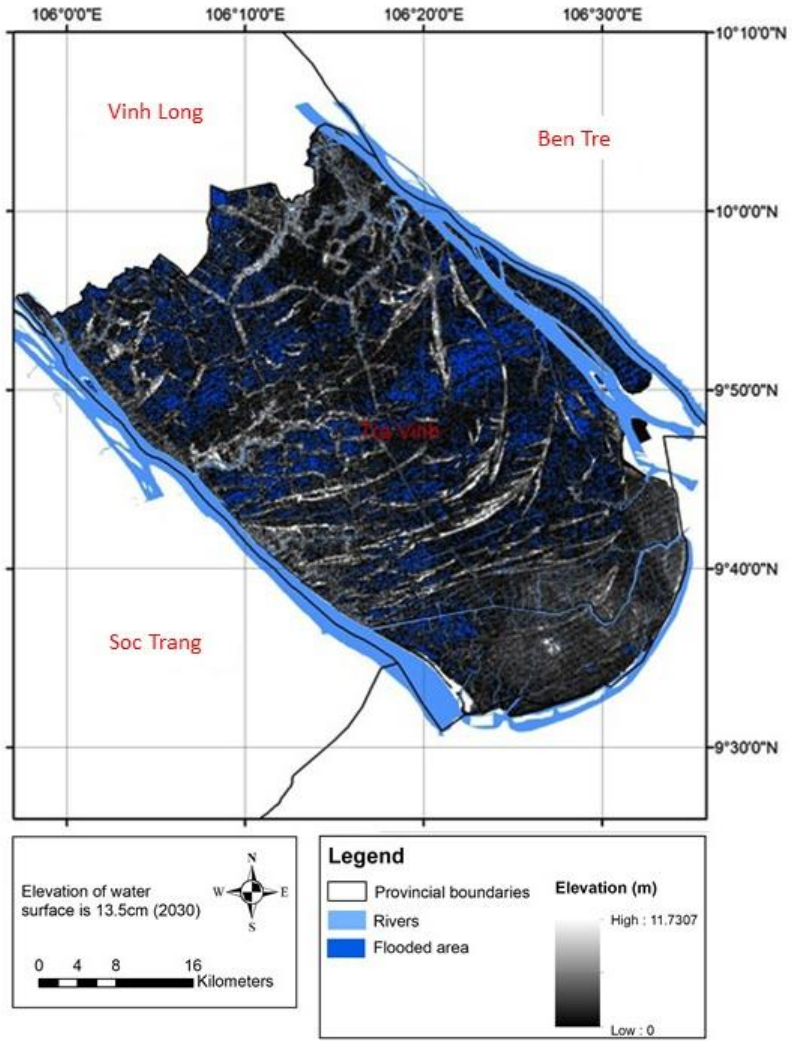


*Figure 6.* Prediction of flood map in 2030 with climate change scenarios according to the medium range emission scenario RCP6.0.

Flood area statistics are shown in Table 2: The total area of each land use type and the area of each flooded area. From the statistical results, it can be seen that the impact of climate change and sea level rise to land use accounts for about 10.3 % of the Tra Vinh land area, in which the most affected areas are rice cultivation and aquaculture.

*Table 2.* The total area of each land use type and the area of each flooded area.

| No. | Code | Type of land use | Acreage (ha) | Flooded area (ha) | Flood rate (%) |
|---|---|---|---|---|---|
| 1 | CAN | Land for security | 225.1 | 18.1 | 8.0 |
| 2 | DRA | Waste land, waste treatment | 73.5 | 7.7 | 10.5 |
| 3 | BCS | Unused land | 736.4 | 0 | 0 |
| 4 | BHK | Flat land for other annual crops | 9,598.9 | 551.2 | 5.7 |
| 5 | DCH | Land for markets | 8.7 | 0 | 0 |
| 6 | LUC | Land for rice cultivation | 68,979.8 | 17,145.8 | 24.9 |
| 7 | DGD | Land for education and training establishments | 1,177.5 | 45.6 | 3.9 |
| 8 | SKC | Land for production and business establishments | 459.7 | 56.4 | 12.3 |
| 9 | DTT | Land for physical training and sports | 8.2 | 0 | 0 |
| 10 | DVH | Land for cultural organizations | 3.5 | 0 | 0 |
| 11 | DYT | Land for medical facilities | 22.3 | 0 | 0 |
| 12 | DGT | Land for transportation system | 27.1 | 0.1 | 0.3 |
| 13 | LMU | Land for making salt | 205.4 | 25.5 | 12.4 |
| 14 | MVT | Coastal water surface for aquaculture | 8,627.3 | 0 | 0 |
| 15 | NTD | Cemetery land, cemetery | 116.1 | 2.4 | 2.0 |
| 16 | NKH | Other agricultural land | 53.0 | 10.9 | 20.6 |
| 17 | NTS | Land for aquaculture | 31,032.4 | 2,594.4 | 8.4 |
| 18 | ODT | Land in urban areas | 3,337.0 | 30.0 | 0.9 |
| 19 | ONT | Land in countryside | 39,736.2 | 940.8 | 2.4 |
| 20 | CQP | Land for national defense | 206.2 | 3.7 | 1.8 |
| 21 | RPH | Protective forest land | 7,855.2 | 52.0 | 0.7 |
| 22 | RSX | Production forest land | 35.5 | 0 | 0 |
| 23 | SON | Rivers, canals, canals, streams | 40,445.1 | 0 | 0 |
| 24 | TIN | Land for beliefs | 8.9 | 0 | 0 |
| 25 | TON | Land for religions | 358.7 | 2.2 | 0.6 |
| 26 | CLN | Land for perennial crops | 11,063.2 | 858.9 | 7.8 |
| 27 | LUK | Land for wet rice cultivation | 10,174.2 | 1,889.3 | 18.6 |
| 28 | TSC | Land for offices of agencies and non-business works of the state | 19.6 | 0 | 0 |
| | | **Total** | **234,594.8** | **24,234.9** | **10.3** |

In this section the results of the assessment of changes in land use structure 2016-2030 are presented. More particularly, it is the evaluation of the impact of sea level rise on the average scenario (2030) affecting the structure of land use in 2030 compared to the land use data in Tra Vinh in 2016. In this study, the flooded areas according to climate change scenarios and sea level rise by 2030 are areas with land use change.

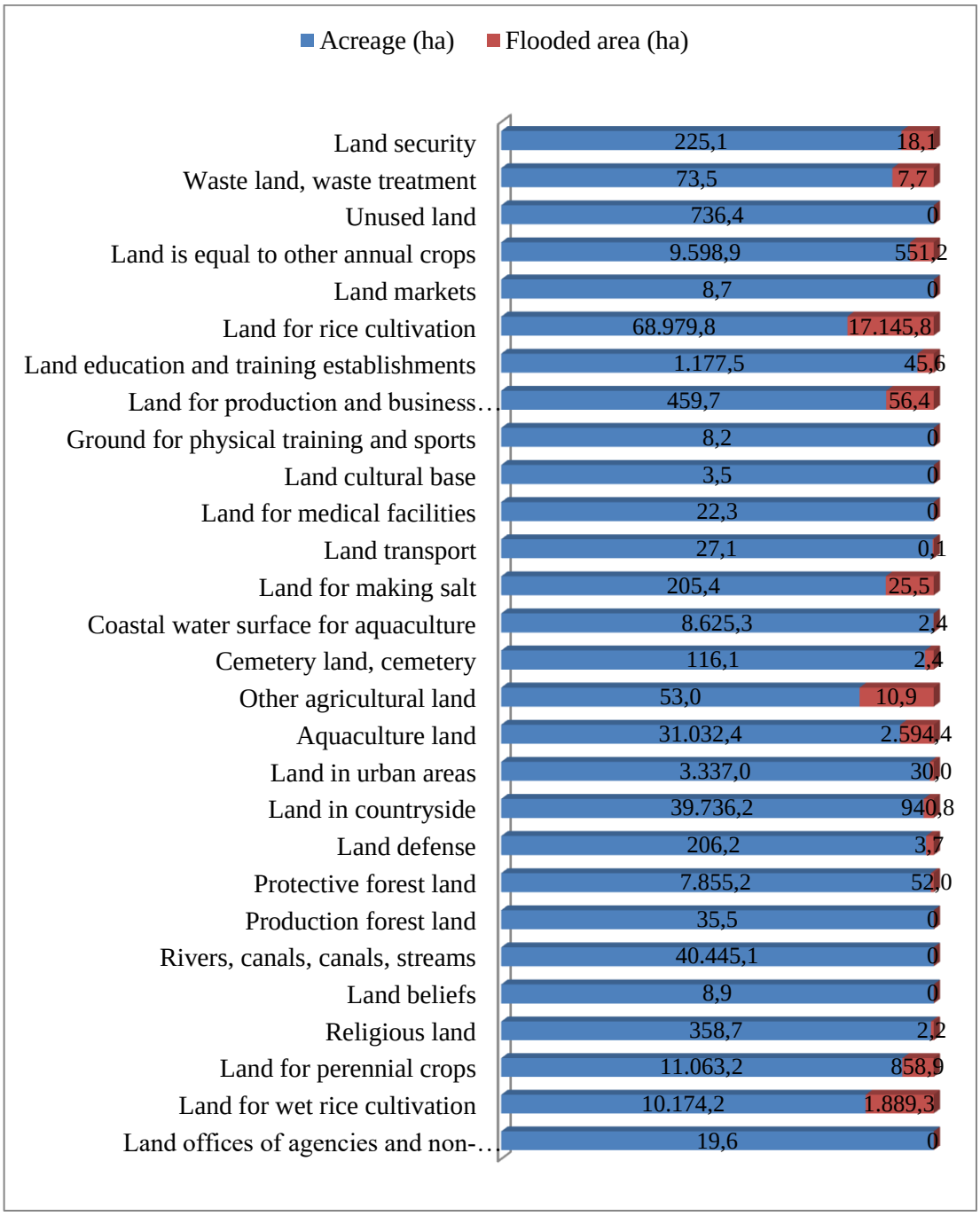


*Figure 7.* Comparison of flooded area with land use categories in 2016, Medium range emissions scenarios in Tra Vinh.

From statistical results, the impact of climate change and sea level rise to land use accounts for about 10.3 % of total land area in Tra Vinh Province and 2030 (Table 1). In addition, land use area in 2016 of the medium range emission scenario in 2030 (Figure 7) shows that the most affected areas are rice cultivation (17,145.8 ha), the remaining paddy land (1,889.3 ha), land for aquaculture (2,594.4 ha), rural land (940.8 ha) and other annual trees land (551.2 ha). There is a risk of land use change in the whole province of 24,235 hectares, under the influence of Scenario RCP6.0.

Under the impact of climate change and the sea level rise according to the medium range emission scenario, the structure of land use area is at risk of change. The most affected land areas are rice cultivation, accounting for 71 %, aquaculture (11 %), paddy land (8 %); In particular, 4 % of residential land in rural areas will be affected, which will directly affect the lives of local people (Figure 8).

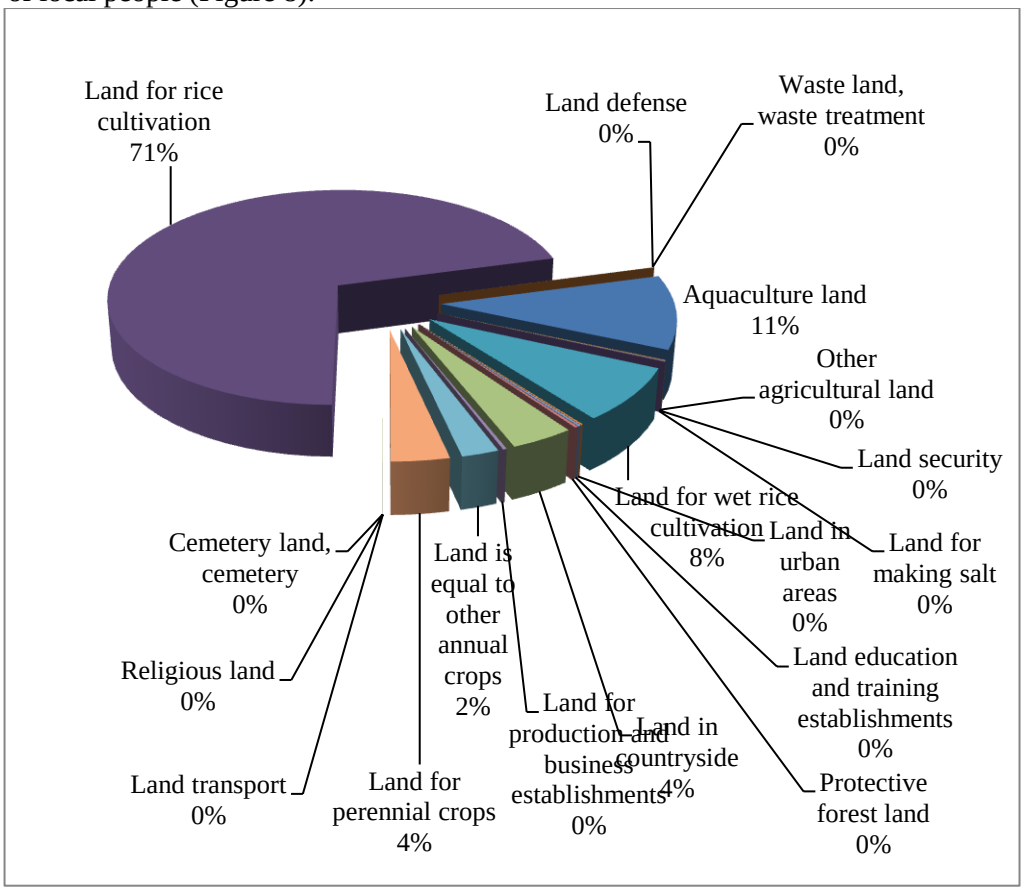


*Figure 8.* Structure of area at risk of land use change by 2030 under the impact of climate change, sea level rise according to the medium range emission scenario.

## 4. CONCLUSION

From the initial research results, the low terrain in Tra Vinh is highly affected by climate change and sea level rise according to the medium range emission scenario by 2030. A risk map of land use change has been established for the period from 2016 to 2030 according to the Scenario model. The land area which has the risk of land use change in the whole province is nearly 24,235 ha. In which the most affected land areas are rice cultivation land (71 %), land for

aquaculture (11 %), the remaining paddy land (8 %). Especially, there is 4 % of residential land in rural areas affected, this will directly affect the lives of people in the rural areas.

Based on spatial statistical analysis techniques, the research results show that, under the average emission scenario, sea level will rise in Tra Vinh Province area by 15 cm in 2030. This will lead to saltwater intrusion into the field, which will adversely affect land use types. There are 06 most impacted land use types under sea level rise, which will run the risk of conversion to other types of production: land for rice cultivation, land for aquaculture, land for wet rice cultivation, land in countryside, land for perennial crops, flat land for other annual crops.

This result will help local authorities and people to prepare and gradually replace the plants and living conditions, in accordance with rising sea levels.

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