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Extracting Land-Cover Information from Landsat Satellite Images by the Decision-Tree Model to Generate a Land-Use Map in Ba Tri District, Ben Tre Province

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Abstract: Monitoring the distribution of land-cover change plays a very important role in making decisions about land-use activities of the environmental management. Ben Tre is a new developing city in the Mekong Delta, an average topographical elevation of which is less than five meters across the province. This is one of the areas that is quite sensitive to fluctuations in mean sea level rise. In the current context, the effects of global climate change on the natural environment have become more and more obvious, especially for coastal plain areas with relatively low terrain elevation. Therefore, it is necessary to generate and update constantly land-cover or land-use maps for coastal plain areas such as Ben Tre province. Based on the land-cover or land-use maps produced over many stages, environmental managers could monitor the changing directions of the distribution of land-cover and then make sound and rational decisions about land-use activities. The main purpose of this topic is to study and build a decision tree model which can extract the real land-cover information from Landsat images in the most effective way to generate a land-cover or land-use map. Thereby, it is possible to reduce the costs of field trips during the mapping process. Research results show that the accuracy of modelling interpretation on different objects ranges from 73% to 97%. The average accuracy of the prediction results across the region reached 86.7%.

Keywords: Land-Cover, Land-Use, Landsat Images, Ba Tri, Decision Tree

1. Introduction

Effective and reasonable land-use planning is an important task of the government and environmental resource managers. In Vietnam, the land-use map is usually updated every 5 years showing the distribution of land-use units at a specified time, and made according to each administrative unit, such as district, city, province, etc. [1]. The population explosion now has brought a number of problems related to human such as: the expansion of urban areas, the socio-economic growth, and the exploitation of natural resources etc. has had a great impact on land-use. In the face of such influences, land-use ways and land-cover areas change constantly according to the development and demand of society. Therefore, monitoring and updating changes in land-use is very important to be able to deal with negative incidents in the land-use process. These land-use maps can help environmental planners and managers have an overview of the environment in the area, from which to make the good decisions and quickly handle environmental problems. Based on this data, managers can also plan how to use land resources in the most rational and effective way.

The diversified development of remote sensing technology with many different resolutions (low, medium, and high) besides the processing software technology has also developed more and more brilliantly in the past decades. Therefore, remote sensing images have been used a lot in the work of mapping all kinds of thematic maps over the world [2, 6, 13, 26, 34, 35]. Depending on research objects and the economic capacity of each country, researchers have the choice of the category of remote sensing data suitable for their works. Vietnam is one of the developing countries with limited economic capacity, however, in the period 1995-2000 following the development trend of the world, many environmental agencies of provinces and cities in this country also started to apply the remote sensing technology (mainly based on SPOT satellite images) to map land use [9, 19, 30]. Most of this SPOT satellite image data is managed by the government (Vietnam Ministry of Natural Resources and Environment), to use this data source for research works, agencies have to pay with the fee is about 15 million VND per scene (according to Circular 70/2012/TTBTC issued by the Ministry of Finance on 3rd May 2012) [7]. However, the US Department of the Interior, or DOI for short, since 2008 has announced that the US government has approved a decision ready to provide all data of Landsat satellite images free of charge to worldwide organizations or individuals [31]. This has given researchers in developing countries like Vietnam the opportunity to access and use easily remote sensing data in their studies at free. Although it is a medium-resolution remote sensing data (MS: 30m and PAN: 15m), Landsat satellite images are very suitable for studying surface objects such as land-use, land-cover, or other thematic map units (geomorphological and geological maps) has a medium scale (from 1: 50000 to 1: 30000).

1.1. Literature Review

Research topics on land-use changes in order to analyse, evaluate and forecast development trend (positive or negative) have been widely applied in the world such as generating urban maps to monitor development of urban land [6], or producing abandoned land maps to monitor land-use efficiency in the area [2], or extracting information from satellite images to map wetland maps [35]. Researches on land-cover or land-use and urban soil changes have also been carried out in Vietnam from the 2000s up to now [3, 5, 9, 14-17, 20-22, 24, 25, 27, 30, 32, 33], in which, to examine the changes in shrimp farming areas in the province of Ca Mau, Binh et al. used aerial photographs, SPOT4 and Landsat imageries [3]. Some low spatial resolution such as MODIS products were used to analyze the land use and rice cropping patterns change in the whole Mekong Delta [25, 27, 32]. Besides, Nguyen *et* al. (2012-2016) processed and analyzed many categories of remote sensing data to study about rice cropping in MRD (Mekong River Delta) such as SPOT [17], Envisat ASAR WSM (Advanced Synthetic Aperture Radar Wide Swath Mode) data [15], or Sentinel 1-A [16]. Phung et al. [22] and Phan et al. [21] also used Sentinel-1 to monitor rice growth in An Giang. Moreover, many researchers also use various types of remote sensing data to monitor land use changes in many parts of the MRD over a long period of time [18, 20]. Most of these topics use the Maximum Likelihood classification method [9, 13, 26] combined with fieldwork [29] or the analysis of ratio images to extract information of interests (water coverage, bare-land, or wetlands etc.) [14, 17, 35]. All studies are done with the support of software such as ERDAS, ENVI etc.

In general, the above studies applied commonly classification methods such as Maximum Likelihood but inevitably some weaknesses reduce the accuracy of the predicting objects. The accuracy of the interpretation depends on the quality of the satellite image, on the other hand, the accuracy is also degraded in the case of the reflectance values of different objects are similar. Therefore, researchers are always finding to develop ways to distinguish these confusing situations in order to increase the accuracy of the interpretation process.

Decision tree is one of the models with high interpretability and can perform the task of classification. Build decision trees by asking a series of questions to the data to lead a decision. The advantage of this method is that it is easy to understand and simple in the process of designing thresholds for dividing objects. Therefore, in this study, authors want to develop this method as a new approach in analysing and processing remote sensing data to extract useful information of the earth surfaces such as land-cover, surface structures etc. To cross-evaluate the predicting accuracy of the decision tree model, we use a land-use map that is mapped based on SPOT satellite data and field measurements published in 2014 and managed by the Department of Natural Resources and Environment of Ben Tre Province. During this period (2014) only Landsat-8 satellite imagery was the free data source, so this data was used in the research.

1.2. Study Area

Ba Tri is one of three coastal districts of Ben Tre province with an area of about 358.37km^2, located in the east of Bao islet. This place is about 36km from Ben Tre city centre along Provincial Road 885 (Figure 1). This area is surrounded on three sides by rivers and the sea, the land here is mainly deposited by alluvium of two rivers Ba Lai and Ham Luong [4]. In general, Ba Tri district has a relatively flat terrain and the average altitude is about 1.2m above sea level. The elevation gradually decreases and tends to lean towards the district center along the arc-shaped sand dunes. Because Ba Tri district is in the coastal estuary area under the influence of tides, wind, waves, etc., this place is very susceptible to saline intrusion, especially in the dry season. The salinity of sea water varies from month to month due to the combined influence of tides and tidal inflows [4]. From the above characteristics of topography and natural geographical conditions, this area is very sensitive to the effects of global climate changes in the present. It also shows that the monitoring and management of land use in this locality is very important. Landsat satellite images with a repeat cycle of 16 days/set of images and spatial resolution (PAN-15m & MS-30m) are very suitable for monitoring changes in land cover and mapping thematic maps of land use with scales from 1: 50000 to 1: 30000.

The purpose of this research is to build a model to extract land-cover information from Landsat images by decision tree method. From the obtained results, it is possible to reduce and save a lot of costs incurred for field trips in the process of mapping land use maps. The evaluation of the research results showed some objects whose interpretation accuracy can reach 97%, and the average accuracy in whole study area is 86.7%.

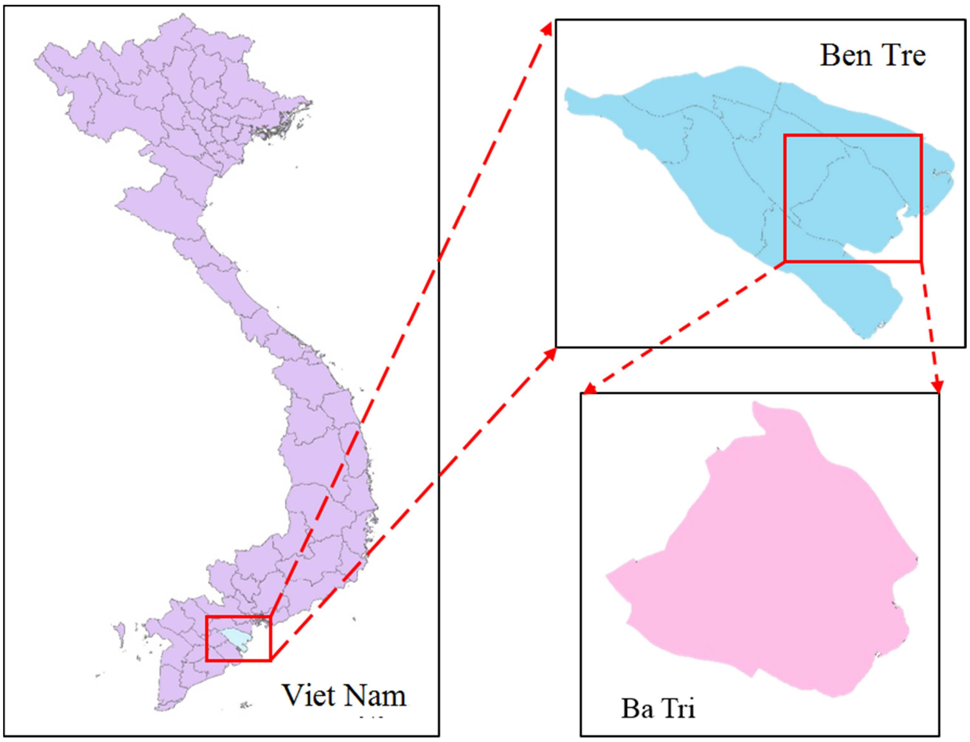

Figure 1. *Study area (Ba Tri District, Ben Tre Province).*

2. Definitions of Land-Use Units

Table 1 showed the categories of land-use units in Ba Tri district Ben Tre province which defined according to regulations promulgated by the National Assembly of Vietnam in: Law of the land-use" [1], including the following:

1. Urban: is the area for house construction or construction of works in service of life including gardens and ponds in the same parcel of land which has been recognized as the residential land.
2. Paddy field: is the fields or swidden fields which grow rice from one crop or more, or here people combined rice cultivation with some other purpose permitted by law, but rice cultivation is still mainly.
3. Perennial crops: is the place where plants grow over a year from planting to harvesting. Here are mainly woody plants (fruit trees) such as pomelo, durian, etc. However, based on the above definition, some plants are not woody or vines such as dragon fruit, banana, pineapple, grape etc. has a growth period of more than one year is also classified in this group.
4. Forestry: is the land with natural or planted forests, or wasteland zoned for reforestation (this place that was once forested but has been exploited, deforested, or forest fired, but now invested in forest restoration). Forestry also includes land with newly planted forest trees.
5. Aquaculture: is the land used for aquaculture purposes such as shrimp, fish etc. Aquaculture here includes land for aquaculture in brackish water, salt water, and fresh water.
6. Salt field: is the land used for producing salt.

Table 1. *Descriptions of Land-use units.*

N_0	Unit	Description
1	Urban land	is the area for house construction or construction of works in service of life including gardens and ponds in the same parcel of land which has been recognized as the residential land.
2	Paddy field	is the fields or swidden fields which grow rice from one crop or more.
3	Perennial crops	Perennial crops: is the place where plants grow over a year from planting to harvesting.
4	Forestry	Forest is the land with natural or planted forests, or wasteland zoned for reforestation.
5	Aquaculture	is land used for aquaculture purposes.
6	Salt field	is land used for producing salt.

3. Materials

3.1. Landsat Satellite Image

Landsat-8 satellite was launched into orbit in 2013 carrying two sensors including the "Operational Land Imager" (OLI) and the Thermal Infrared Sensor (TIRS). These sensors are designed for improved performance and greater reliability over previous generation Landsat sensors. Landsat-8 acquired data with a total of 11 bands, including nine shortwaves and two thermal infrared. These two sensors will provide detailed seasonal Earth surface information with 30m spatial resolution in the visible, near-infrared, and short-wave infrared, whereas thermal infrared data has a smaller resolution of 100 meters. Similar to Landsat-7 satellite, the panchromatic image of Landsat-8 also has the largest spatial resolution of 15m [11]. The OLI sensor provides two new bands including the "Coastal aerosol" band for monitoring coastal water quality fluctuations and the "Cirrus" band for detecting the thick and thin densities of the cirrus (meaningful for meteorology). While the TIRS sensor will record data in two regions of thermal infrared (long wave) wavelengths, respectively, band 10 and band 11. The data of these two bands are used to measure the evaporation rate of water and surface temperature. The OLI and TIRS sensors have been improved to minimize atmospheric noise while allowing radiation resolution of the data set to be increased above 12 bits, resulting in increased image quality in a comparison to previous versions. Criteria for selecting images in here is that are not covered by clouds or although covered by clouds, the percentage of being covered by clouds is low, so the scene taken on February 22nd, 2014 with assessed image quality at level 9 has chosen [10].

3.2. Land-Use Map

This study uses a land-use map in Ba Tri district, Ben Tre province generated in 2014 as the base data to evaluate the accuracy of predicting by decision tree model. This map was produced by the Department of Natural Resources and Environment of Ben Tre province based on documents such as topographic map, administrative boundary file, basic administrative map, previous land-use maps, extract of changes, high resolution aerial photos or SPOT satellite imagery, and field trips. The map shows units such as: "rice filed", "perennial crops", "aquaculture", "salt filed", "forestry", "industrial land" (Figure 2).

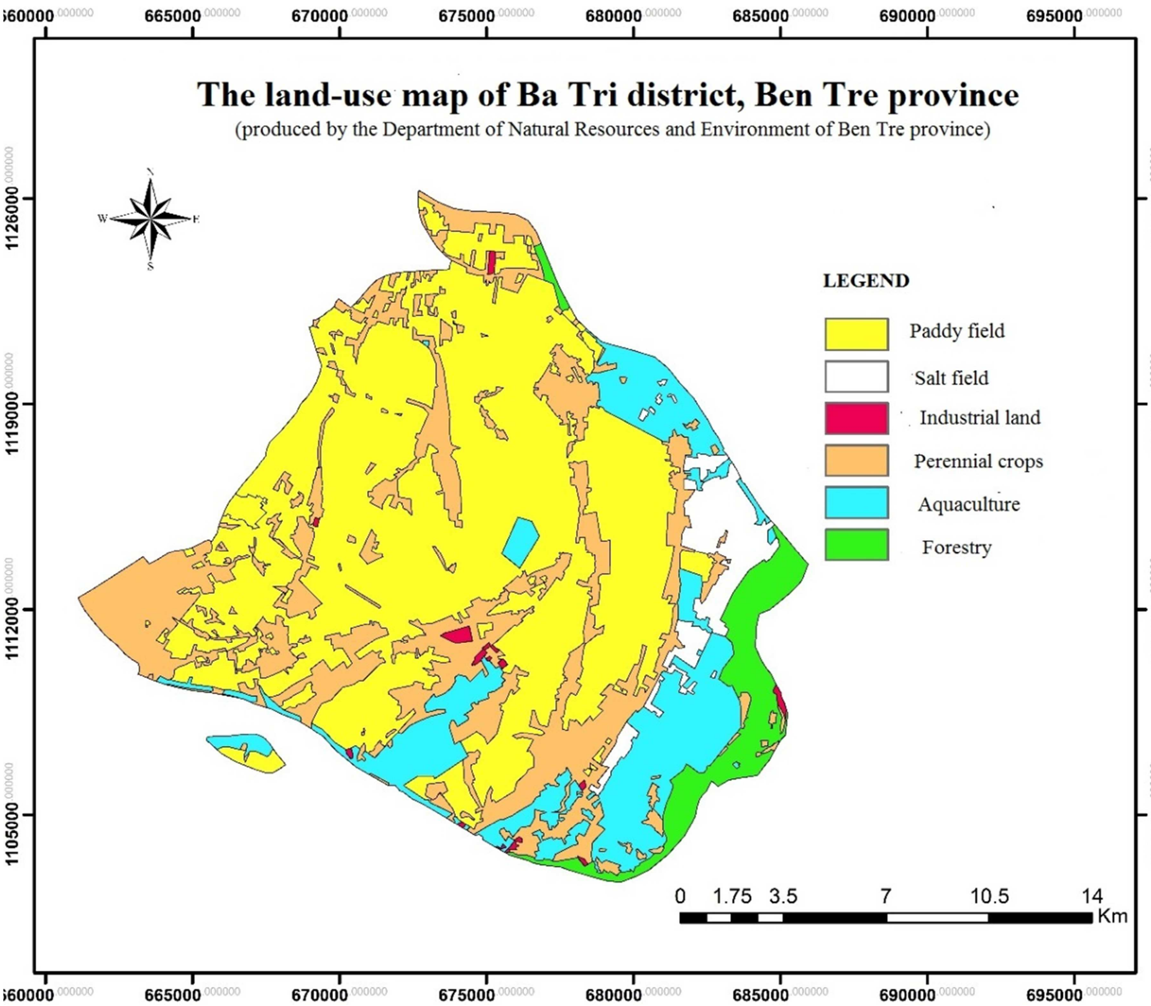

Figure 2. *The land-use map of Ba Tri district, Ben Tre province (produced by the Department of Natural Resources and Environment of Ben Tre province).*

4. Methodology

Figure 3 describes the steps to carry out the research, including:

* *Collecting Landsat-8 satellite image*

Landsat imagery data (Level 1A) was downloaded from the USGS Explorer website. Based on the image collection criteria mentioned above, the image data set taken on April 22nd, 2014 was collected for use in this study.

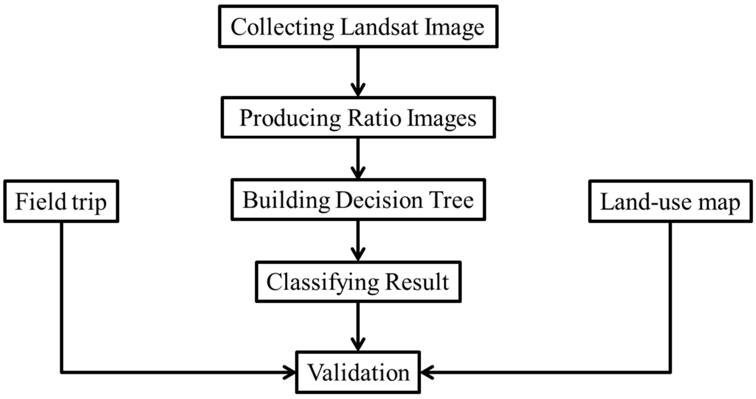

Figure 3. *Flowchart of study.*

* *Producing ratio images*:

Ratio images including UI, NDVI and NDWI (Figure 4) are respectively produced from raw Landsat-8 (Level 1A) image data, in which:

Urban Index or UI in short is determined by the ratio between two bands of the visible (BLUE) and mid-infrared (SWIR 2) (1). This index is used to identify residential or other civil construction areas.

$$\mathrm{UI} = \frac{\mathrm{BLUE}}{\mathrm{SWIR\ 2}} \quad (1)$$

NDVI: Formula 2 describes the Normalized Difference Vegetation Index, also known as NDVI, which is the ratio between the difference and sum of the near infrared (NIR) and the visible (RED). This index shows the difference in the concentration of vegetation or biomass on the surface [12]. The value of NDVI ranges from [-1÷1]. The higher the NDVI value, the better the vegetation coverage in the area, and vice versa.

$$\mathrm{NDVI} = \frac{\mathrm{NIR-RED}}{\mathrm{NIR+RED}} \quad (2)$$

NDWI: The Normalized Difference Water Index, known as NDWI, is described in (3). This is the ratio between the difference and the sum of the visible (RED) and mid-infrared (SWIR). The NDWI index is based on the different reflections of vegetation in the visible (RED) and mid-infrared (SWIR) to filter out wet vegetation coverages and water areas. One can also rely on this index to distinguish green vegetation from dry vegetation [8].

$$\mathrm{NDWI} = \frac{\mathrm{RED-SWIR}}{\mathrm{RED+SWIR}} \quad (3)$$

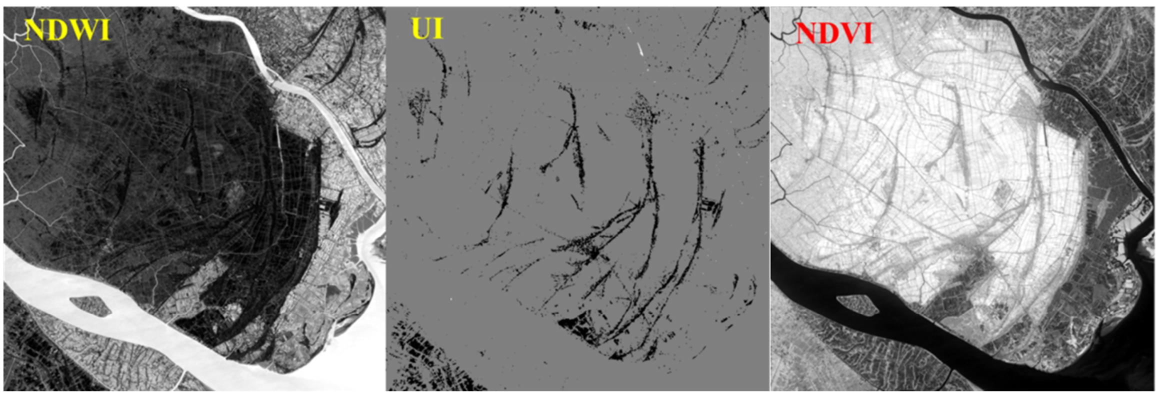

Figure 4. *Ratio images of UI, NDVI, and NDWI in Ba Tri Dist., BenTre Province.*

* *Building the decision tree model:*

The decision tree method is one of the multi-layer classification methods, each layer can be applied to one or more data types. These data are related to each other by conditional algorithms. Specifically, the condition here is by combining the ratio images (UI, NDVI, and NDWI) with appropriate separation thresholds. Based on these thresholds of division to make a decision of “consensus” (Yes) or “disagreement” (No) to classify and filter the researching objects (land-use units) from Landsat-8 satellite image, and then to generate a land-use map for the study area [23] (Figure 5).

Figure 5 depicts the process of separating and filtering the land-use classes from the Landsat 8 dataset. First node, setting up threshold value of NDWI index is 0 to divide into two groups including the land and the water (Wa & Wet). The land group includes urban, paddy field, perennial crops, and forestry NDVI values of which are less than 0, whereas the water group consist of water coverage, aquaculture, salt field, and mangrove forest. And then mixed objects of these two groups will be further classified as follows:

The second node, a threshold of NDVI in the water group (Wa & Wet) was set to larger than 0 to extract the water body (Water) from the remaining objects (salt field, aquaculture, mangrove forest) where water zones correspond to NDVI values less than or equal to 0 and vice versa pixels with NDVI value greater than 0 will correspond to the mixing group (salt field, aquaculture, mangrove forest). And then, a threshold of NDWI values was set to greater than 0.1 (the third node) to separate the salt field from aquaculture and forestry (mangrove forest). Finally, using a threshold of NDVI values was set to equal and greater than 0.2 (the fourth node) to distinguish mangrove forest from aquaculture (Figure 5).

In the land group (Figure 5), based on the urban index (UI), it is possible to separate the urban (Urban) from the mixed group with the condition of UI=0. Areas with UI values unequal 0 include paddy fields, perennials crops, and forests. The forest in this group can be filtered out from other objects by applying a threshold of NDWI values greater than (-0.03). Areas with NDWI values less than or equal to (-0.03) correspond to the mixed zones including paddy fields and perennial crops. Finally, NDVI values can be used again to separate paddy fields and perennial crops, in which the areas with NDVI values less than 0.4 correspond to perennial crops (Crop) and the remaining ones are paddy fields (Figure 5).

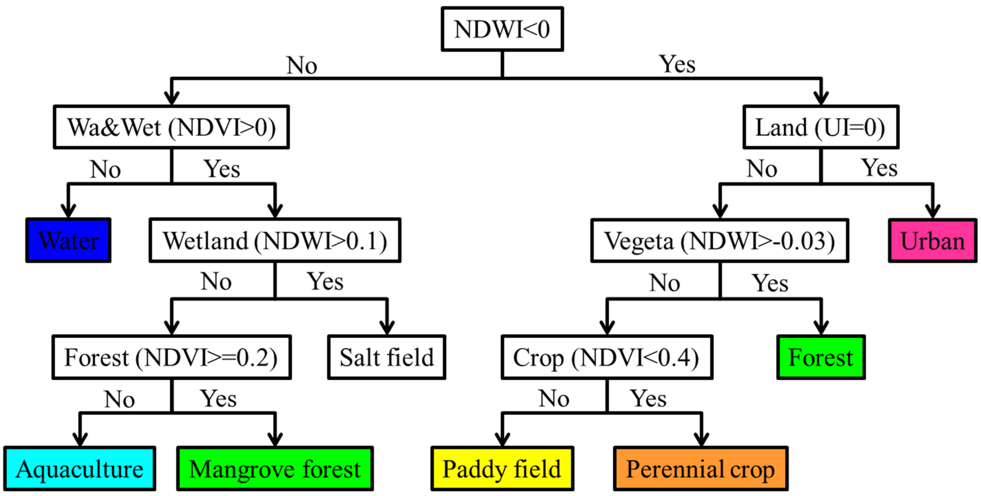

Figure 5. *Decision tree model for mapping the land-cover map.*

* *Predicting evaluation by the binary classification method*

The "binary classification" method is a method of evaluating the accuracy of the predictive models, this method is quite commonly used in research topics related to statistics of economics, medicine or GIS [28]. In this research, the evaluation of the interpreting results will be detailed as follows:

1. Accuracy: TP + TN.
2. Error: FP
3. Missing: FN

and: TP+FN+FP+TN=100%, where TP: interpreting result "Yes" corresponds to "Yes" on the basic data and is called correct prediction; TN: the interpreting result "No" corresponds to the "No" of the base data and is also called correct prediction; FP: the interpreting result "Yes" corresponding to "No" of the base data is called incorrect prediction; FN: interpreting results "No" corresponds to "Yes" on the basic data and is called missing prediction (Table 2).

Table 2. *Validating the accuracy of interpreting results by the binary classification method.*

		Interpreting result	
		Yes	**No**
Basic data	Yes	TP	FN
	No	FP	TN

5. Results and Discussion

5.1. Interpreting Results of the Land-Use in 2014

The results of interpreting land use units based on Landsat 8 images shows that areas of "urban" (corresponding to UI=0 and NDWI<0) are shown in pink colour covers an area of approximately 23km^2, whereas the unit occupying the largest area on the interpreting results is not "paddy field" coloured in yellow (corresponding to NDWI<-0.03 and NDVI>=0.4) but "perennial crop" coloured in brown-yellow (corresponding to NDWI<-0.03 and NDVI<0.4) (Figure 6). The area of "salt field" (coloured in white) which corresponded to NDVI>0 and NDWI>0.1 is 9.10 km^2, and the "aquaculture" (coloured in light blue) correspond to 0<NDVI<0.2 and 0<NDWI<=0.1 which has an area of 40.73 km^2 (Figure 6).

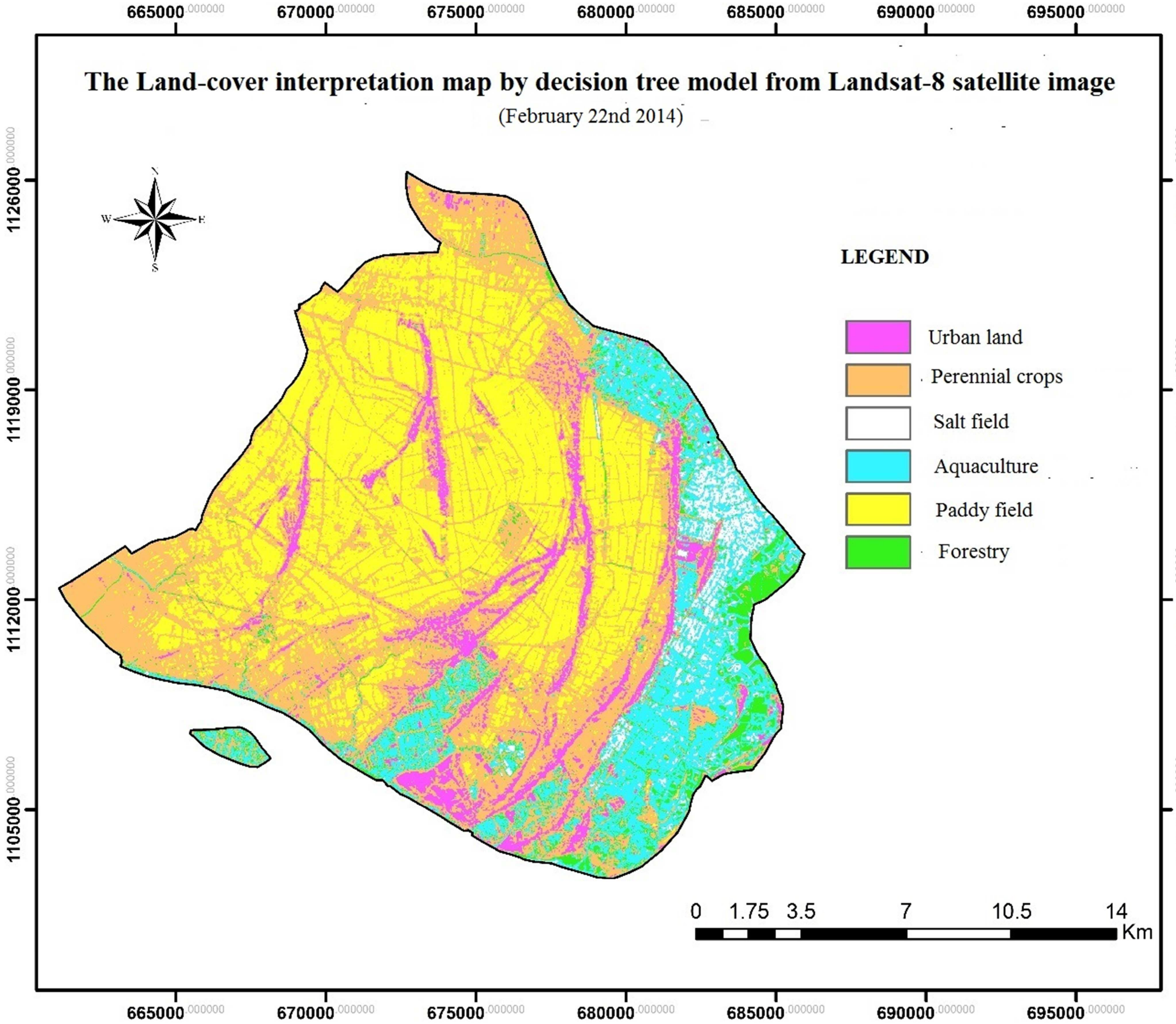

Figure 6. *Interpretation map of land-use units by the decision tree method in Ba Tri district, Ben Tre province.*

5.2. Validating Results

Comparing "interpreting results" and "basic data" (The land-use map in Ba Tri district, Ben Tre province produced by the Department of Natural Resources and Environment of Ben Tre province in 2014) to evaluate the accuracy of the "decision tree" model by the "binary classification" method. However, due to the land use map published by the Department of Natural Resources and Environment of Ben Tre province included two objects "urban" and "perennial crops" into a unit and collectively referred to as "perennial crops", therefore these units also combined during assessment process and referred to as "perennial crops".

Table 3 shows the results of accuracy evaluation, in which "perennial crop" coloured in yellow-brown and "urban" coloured in pink (Figure 6) combined together referred as "perennial crop" with an area of 143,89km^2, accounting for 45.3% of the whole study area. Comparing with the "perennial crop" unit of the "base data", the evaluation results presented FP (false interpretation: 25%), FN (missing interpretation: 3%), TP and TN (correct interpretation: 72%). For "aquaculture" (coloured in light blue) with a distribution area of 40.73km^2 (accounting for about 12.8% of the study area) showed the high accuracy of the predictive model in a comparison with "base data", in which the "correct interpretation" reached nearly 90% (TP+TN: 89.3%), while "false and missing interpretation" (FP+FN) is 10.7%. Comparing with the successful interpretation results of the remaining land-use units, the "salt field" (coloured in white) has the highest accuracy with "correct interpretation" (TP+TN) can reach more than 96% while "false and missing interpretation" is less than 4%. In contrast, "paddy field" (coloured in yellow) occupies a large area (108.27km^2) only less than "perennial crop", accounting for about 34.1% of the study area, but accurate results (TP+TN) can only reach 78%. Finally, the "forestry" unit distributed mainly in coastal areas with an area of 15.67km^2 also has a high accuracy (TP+TN=93.9%).

Table 3. *Evaluating the accuracy of predictive results by the binary classification method.*

Land-use unit	(%)					
	TP	TN	FN	FP	TP+ TN	FP+FN
Paddy field	32.0	46.0	20.0	2.0	78.0	22.0
Perennial crop	21.0	51.0	3.0	25.0	72.0	28.0
Aquaculture	7.2	81.2	6.7	4.5	89.3	10.7
Forestry	1.9	91.5	3.2	3.2	93.9	6.1
Salt field	1.9	93.0	2.2	2.2	96.5	3.5
Mean					85.9	14.1
Accuracy: 85.9 %; Error 14.1%						

5.3. Discussion

The results of the accuracy assessment of the "paddy field" unit showed that FN (missing interpretation) is quite high (20%) and these mistaken positions often correspond to the "perennial crops" and "aquaculture". Besides, the FP (false interpretation or error) of "paddy field" is only 2% that is the lowest in a comparison to other units (Table 3), where the model mainly misinterprets between "paddy field" and "aquaculture" (specifically at the of Dat Islet), at the period that the satellite swept across the place, "paddy field" in this area was harvested thus causing these misinterpretations. Similar to the above explanation, the error result for "perennial crop" is 28.0%, the highest among the classes (Table 3) which can be explained by the fact that at the time of satellite scanning, both of "paddy land" and "aquaculture" do not have vegetation (because farmers have harvested, or prepared a new crop, or discharged the pond), therefore the predictive model is mistaken when separating the above objects. In addition, when classifying "perennial crop" and "forestry", because the vegetation types in these two land-use units sometimes have similar reflectance intensity, it can lead to misinterpretations, confusion, and reducing accuracy.

6. Conclusions

In the current global climate change, the density of natural disasters is increasing (the more and more, the shorter the cycle), especially the rising mean sea level cause seriously affecting on countries with border areas adjacent to the sea, including Vietnam. Land-use planning should be given more attention and attention. Monitoring and evaluating changes or changing land-use purposes appropriately will contribute to improving the environment in a positive direction. This can help us to extend this global "time of upheaval" so that we can find enough time to find a way to overcome the problem in the most peaceful and safest way.

In general, this research has successfully built the "Decision tree" model to extract useful information related to the land-cover units from Landsat-8 satellite images with high accuracy. This is clearly shown through the evaluation results of the interpretation accuracy by the "binary classification" method, in which the average accuracy of the whole study area reached 86%. To further confirm the usefulness and correctness of this model, we will continue to test the application of the model in the division of land-use units in other places of Ben Tre province, as well as apply this model to Landsat data types at different times in the future.

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