MINISTRY OF EDUCATION AND TRAINING

HANOI UNIVERSITY OF MINING AND GEOLOGY

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MODELING LAND COVER CHANGES DUE TO FLOODING IN THE CUU LONG RIVER DELTA USING REMOTE SENSING DATA AND GIS

Department: Geodetic engineering
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SUMMARY OF TECHNICAL DOCTARAL THESIS

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The study was completed at: **Department of Photogrammetry and Remote Sensing, Faculty of Geomatics and Land Administration, HaNoi University of Mining and Geology.**

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The thesis will be defended in Thesis Assessment Council of University that meets at Hanoi University of Mining and Geology at …o'clock on … …, 2021

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INTRODUCTION

1. The urgency of the thesis topic

The Cuu Long River Delta is located downstream of the Mekong Basin, the regional terrain is fairly flat and vulnerable to annual flooding. The benefits of floods are to provide aquatic resources, accumulate alluvium for the delta, wash off saline-alkaline soil, and toxins accumulated in the lowlands. However, floods also cause serious damage to people and property that affected the lives of people in the delta. Considering the benefits and damage of floods, it is necessary to have studies on the rules of the effects of floods on land cover to serve the management and coordination in favor of socio-economic development activities and local sustainable livelihoods.

Researches in the world and Vietnam today have the same view that remote sensing data are useful in supervising the effects of flooding on the surface coating. The results of flooding effects on land cover monitored directly from remote sensing data will provide an accurate and up-to-date overview of the development of flooding.

For the above reasons, the author chose "**Modeling land cover changes due to flooding in the Cuu Long River Delta using remote sensing data and GIS**" as a thesis.

2. Mission of research

Constructing a model of land cover changes due to the effects of flooding by using remote sensing and GIS technology.

3. Objective of research

Land cover, land cover changes due to the effects of flooding.

4. Scope of research

Geographically: An Giang province and Dong Thap province.

The scope of research: radar remote sensing, optical remote sensing, effects of water level changes on the surface coating.

Chronologically: Between 2015 and 2019.

5. Research content

The thesis focuses on evaluating and modeling land cover changes due to the effects of flooding in the Cuu Long River Delta by using remote sensing data and GIS and evaluating the accuracy of the obtained model results.

Thesis results:

- Land cover maps at the time of the experiment
- The model of land cover changes due to the effects of flooding

6. Research method

The thesis is based on theoretical research method, inheritance method, Remote sensing material integration method, and GIS combined with field inspection, synthetic analysis comparison method, modeling method, and expert methods.

7. The scientific and practical significance of the thesis

Scientifically, the thesis presents a method of constructing a model of land cover changes due to the effects of flooding in the Cuu Long River Delta by using remote sensing data and GIS.

Practically, the result of the thesis provides a model and data on the transforming area of land cover due to flooding in the period from 2015 - 2019. The result of the model can be used to forecast land cover changes due to the effects of flooding.

8. Defending thesis

The first thesis: The object-oriented classification method combined with multi-temporal remote sensing images and DEM are effective in classifying land cover in seasonal flooding areas.

The second thesis: The solution combines optical remote sensing data, radar remote sensing, DEM, and hydrometric monitoring to allow creating a model of land cover changes due to the effects of flooding to suitable for the Cuu Long River Delta.

9. New contribution

The method using multi-temporal remote sensing images, multi-resolution remote sensing images, and GIS technology with other complementary data such as DEM, water level to model the effects of flooding on land cover will provide a new result that directly reflects the effects of floods at the monitoring time.

The model is built based on the results classified from optical remote sensing images and radar continuously monitoring directly in the field even when it is cloudy or rainy. It gives the results that determine the flooded areas for better types of land cover. The result of the model can predict land cover changes due to the effects of flooding at any time when the water level is indicated and consistent with the practical situation conditions in the Cuu Long River Delta.

10. Structure of the thesis

The thesis consists of the introduction, 4 chapters, the conclusion presented in 168 pages with 41 figures, 15 tables, references, and an appendix.

Chapter 1 - OVERVIEW OF RESEARCH ISSUES

1.1. The concept of surface coating

Land cover (ground) is a material cover that consists of vegetation cover, human constructions covering the surface of the earth. Water, ice, exposed rocks or sand strips, vacant land ... are also considered as the surface coating.

1.2. The concept and general characteristics of flooding in some areas of Vietnam

Flooding is the level of water and the rate of flow on rivers and streams that exceeds the normal level. Flooding is the phenomenon of inundation of an area caused by floods. Flooding can be caused by large floods, floodwater overflowing river banks (dikes), or breaking buildings that prevent flooding into the lowlands, or maybe by sea-level rise as the storm overflowing coastal waters.

In the Red River Delta, the typhoon season usually lasts from June to October. In the Cuu Long River Delta, the flood season usually lasts from the end of June to the end of December and is divided into three phases. The first phase is from July to August. The peak of flooding occurs in the second phase when the water level of the Tien River in Tan Chau is higher than 4.2 m and the Hau river level in Chau Doc is higher than 3.5 m. The third phase is from October to the end of December.

1.3. The situation of studying land cover changes due to the effects of flooding

In the world, many scientific works are using optical remote sensing data to study flooding, wetland ecosystems, hydrology, and geomorphology. In which, there are several tasks such as: Classifying the surface coatings, distinguishing between upland vegetation, wetland plants, and seasonal wetland; assessing land-use change; analyzing principal components (PCA) in wetland change detection...

Besides, radar remote sensing technology has been applied in many fields including monitoring natural disasters such as floods, landslides, forest fires, monitoring pollution (oil spills), exploring geology, measuring map, monitoring the situation of the land cover, monitoring current land-use status, inventorying forest land and monitoring crops...

The outstanding achievement of radar remote sensing systems to study the wetlands is to provide land cover information that can not be observed from the optical remote sensing system due to weather conditions. The radar remote sensing system can also detect changes in surface conditions under the canopy.

Sub-conclusion of chapter 1: In general, previous studies both at home and abroad often use a model of calculating flooding area based on the Digital Elevation Model and water level. These models do not provide the land covers affected by floodwater. A model to assess the effects of flooding on land cover in Tonle Sap, Cambodia built on multi-time satellite images, Digital Elevation Model and the water level has been applied to areas with steep terrain and water level changes from 1m to 10m. Meanwhile, the Cuu Long River Delta research area has little change in terrain and the water level in the river basin varies from 1m to 4m. The types of land cover in this area are also much different from the research area in Tonle Sap. Therefore, it is practical to create a model of land cover changes due to the effects of flooding in Cuu Long River Delta.

Chapter 2 - THE SCIENTIFIC BASIS OF DETERMINING LAND COVER CHANGES DUE TO THE EFFECTS OF FLOODING FROM SATELLITE IMAGES

2.1. Determining land cover changes due to the effects of flooding from optical remote sensing data

The main energy source used in optical remote sensing consists mainly of the spectral region of the visible spectrum and infrared light. The intensity of the wave energy reflected on a satellite depends on the type, the properties, and the surface structures of the object with which it interacts. The interactive characteristics of the objects on the ground are generalized as shown in Figure 2-1

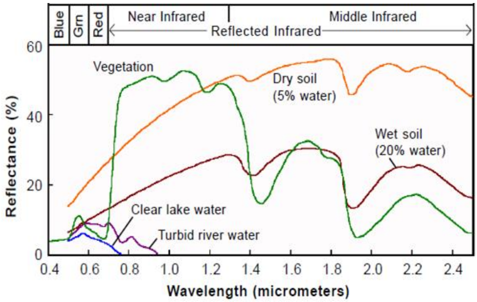


Figure 2-1: Spectral reflection curves of natural objects.

- *Several methods of determining land cover changes:*

The general method of determining land cover changes is to compare land cover status at the timelines that need to be assessed. There are some basic methods such as comparing after classifying method, classifying directly the multi-time images method, adding colors on an image channel method, analyzing the vector caused by a change in the spectrum method, and combination method.

- *After using normalized difference vegetation index (NDVI) to classify vegetation cover:*

When classifying the vegetation cover for the group of objects identified on the image there must be other additional data and additional investigations in the field. In this case, the object-oriented classification method is usually applied.

Additional information for classification such as the normalized difference vegetation index is calculated from spectral channels of satellite images by formula (2-1).

$$NDVI = \frac{NIR - \operatorname{Re} d}{NIR + \operatorname{Re} d} \qquad (2\text{-}1)$$

2.2. Determining land cover change objects due to the effects of flooding from radar remote sensing data

On the land surface, the radar signal interacts with the plants and the subsurface layer of soil. The backscattering properties of plants depend on the geometrical structure, the dielectric properties of the plants, and on the moisture content contained in the leaves. Radar signals penetrate through the leaf layer and scatter back from the water surface and the lower foliage of the vegetation (branches and trunks). Compared to normal scattering conditions of the water surface, the presence of inverse scattering in the lower foliage of the vegetation leads to an increase in the radar signal returning to the sensor.

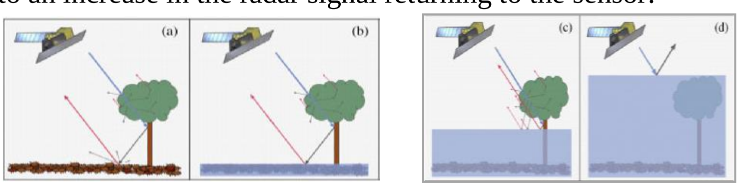


Figure 2-6: Scattering mechanism in flooding and non-flooding areas that hace vegetation.

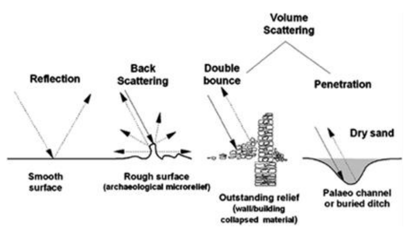


Figure 2-7: Double bounce that occurs at the construction area makes

inverse scattering in the construction area stronger than other areas.

2.3. Applicability of GIS in studying land cover changes due to the effects of flooding

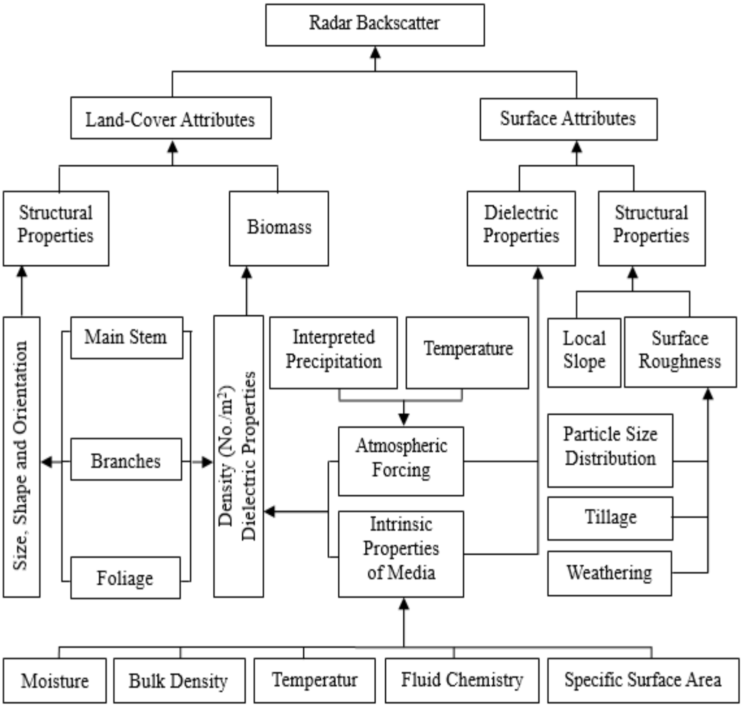
The general principle of assessing the fluctuation is that after stacking two information layers of the map, the software will automatically display the fluctuating areas of the data field registered between the two layers, then calculate the area of fluctuations of those regions on the map.

When using remote sensing data and GIS to study the change of the land cover, land cover maps are edited and statistically calculated by using GIS tools. The statistical process at different points during the annual flood cycle will provide the rule of the area of land cover changes area and the change in the spatial distribution of each layer with the impact of water level.

2.4. Modeling and applying the model to land cover research

A model is a structure that describes a minimized image according to the characteristics or the fluctuation of an object, a phenomenon, a concept or a system.

Two main factors that affect the inverse scattering from the terrain are shown in Figure 2-8: (1) The geometrical factors are related to the structural properties of the surface and vegetation cover (2) The electrical factors are determined by the relative dielectric constants of soil and plants at a particular wavelength.



Hình 2-8: The main factor affects the inverse scattering from the terrain.

The inverse scattering model of Santa Barbara was applied to simulate the inverse scattering SAR of ERS-1 from vegetation. Under dry soil conditions, inverse scattering increases by about 2-3 dB as the biomass increases from 0.05 kg / m^2 to about 0.5–1.5 kg / m^2, and inverse scattering can be saturated near the biomass level at 0.5–1.5 kg / m^2. As soil surface moisture increases, the major contributor to total inverse scattering is changed from volume scattering to surface scattering and from 0.4 kg / m^2 to about 1 kg / m^2.

According to the model of Kasischke and Bourgeau-Chavez, for wetlands containing shrubs, there are three different layers to consider Figure 2-9 (a): (1) The canopy layer consists of small branches and foliage, (2) The trunk layer consists of large branches and trunk (3) The surface layer, which may or may not be covered by water.

For wetlands without trees, a simple two-layer model can be used as shown in Figure 2-9 (b): (1) a canopy consisting of herbaceous vegetation and (2) a surface layer, which may or may not be covered by water.

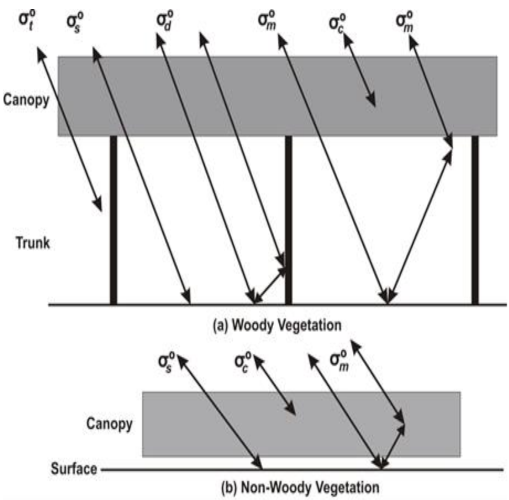


Figure 2-9: Schematic representation of the sources scattered from wetlands.

Sub-conclusion of chapter 2:

The mechanism of interaction between the electromagnetic waves and land cover shown on optical satellite images depends closely on the characteristics of natural objects through spectral channels in the visible and near-infrared waves.

The inverse scattering characteristics of the radar satellite image depend heavily on the reflective surface. The types of cover have different reflective surfaces. The inverse scatterings reflecting on the satellite images are different.

From the scattering characteristics of land cover objects, it is possible to model land cover changes due to the effects of flooding.

Chapter 3 - CONSTRUCTING A MODEL OF LAND COVER CHANGES UNDER THE CHANGE IN THE WATER LEVEL CAUSED BY FLOODING IN THE CUU LONG RIVER DELTA

3.1. Studying land cover changes due to the effects of flooding through the change in the covers according to the function of the water level

Land cover changes depend on the change of the water level in an annual cycle and has a certain rule.

To model land cover changes, it is necessary to model the change of water level in an annual cycle.

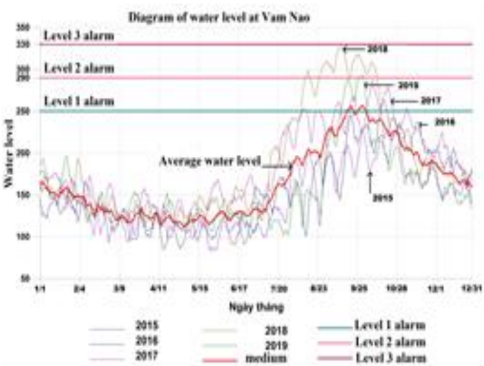


Figure 3-1: The water level of flooding annually from 2015 to 2019.

The overall process diagram for constructing a model of land cover changes due to the change of water level shown in Figure 3-2:

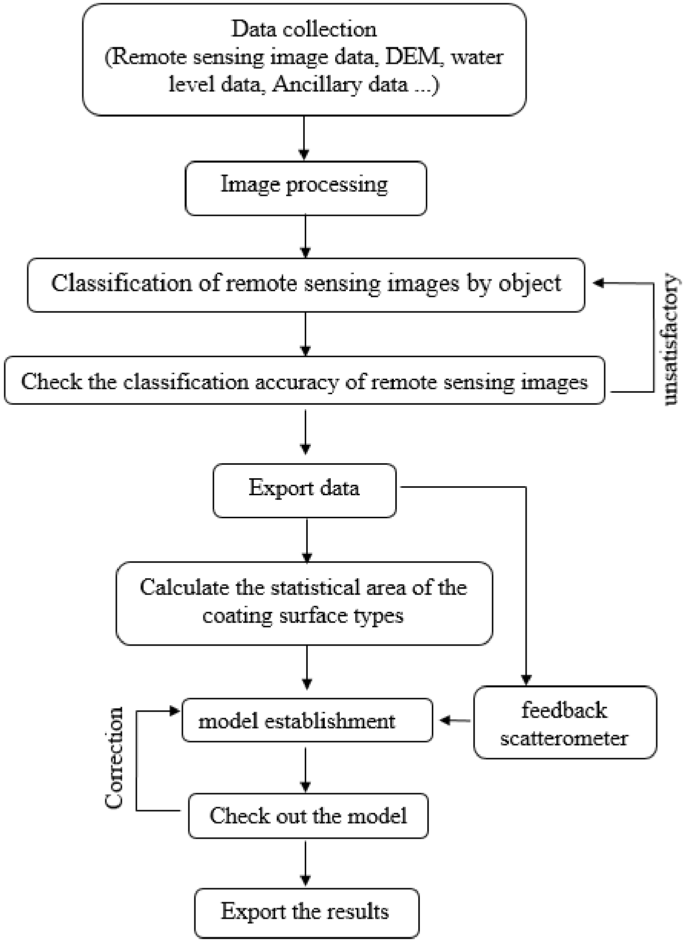


Figure 3-2: The overall process diagram for constructing a model of land cover changes due to the effects of water level

The process of constructing a model of land cover changes according to the water level function is carried out as the following steps:

Step 1: Model the water level monitored over many consecutive year cycles. the water level is represented by the average water level line as shown in Figure 3-6.

Step 2: From the intersection point A, we can determine the line e passing through point A and being parallel t the area value axis.

Step 3: Determine line d, which is parallel to the time axis and intersects with the area value axis at the time the water level corresponds to the shooting time.

Step 4: From the defined intersection point of line e and line d, we can determine an intersection point of the model (Point C).

Step 5: Perform the same thing with the water levels that correspond to the other shooting times. We can determine n intersection points. (Note that using the water levels that distributed evenly on the model and focusing on the rainy season months to improve the accuracy of the model)

Step 6: Determine the lines that represent land cover changes due to the changes in water level.

Draw the regression lines from the points identified in step 6 (Filter out interference points before drawing the regression lines)

Step 7: Determine the errors bars

The presented error bars on the model are based on the results of evaluating the accuracy of each type of land cover.

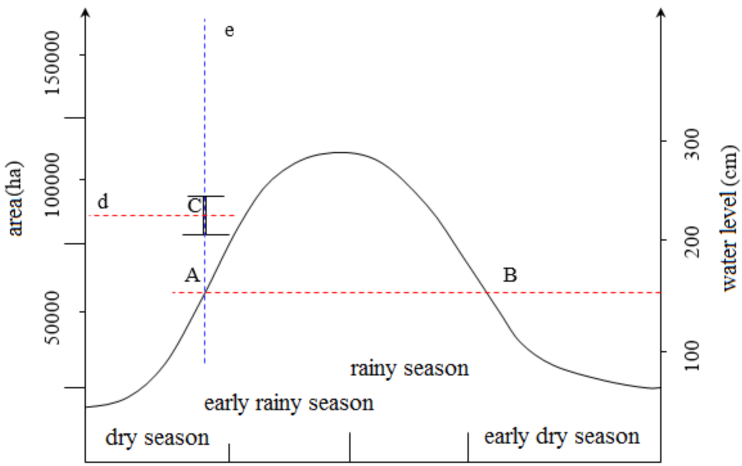


Figure 3-6: Represent the area of land c according to the change of water level Biểu diễn diện tích của lớp phủ bề mặt theo sự thay đổi của mực nước

3.2. Model testing method

Based on the model, we can calculate the area of land cover corresponding to the data of water level at the testing time and the area obtained from the results of the satellite image classification at the testing time. Then, comparing the results to evaluate the accuracy of the model.

Sub-conclusion of chapter 3:

Land cover changes depending on the change of water level according to the annual flooding cycle has a certain rule.

Predicting the effects of flooding on land cover by the model is based on the function of water level in the annual flooding cycle and the land cover map at the monitoring times.

Chapter 4 EXPERIMENT AND EVALUATE THE RESULTS

4.1. Research area and experimental process

4.1.1. Usage data

The usage data includes 50 images from Sentinel-1 (taken from March 2015 to November 2019) and 06 images from Sentinel-2 (taken from September 2015 to November 2016); Digital Elevation Model data; Water level data (collected at 4 monitoring stations from January 1st, 2015 to December 31st, 2019: Vam Nam, Chau Doc, and Long Xuyen and Tan Chau); and some other supporting data.

4.1.2. Object oriented classification experiment of land cover from Sentinel-2 satellite data

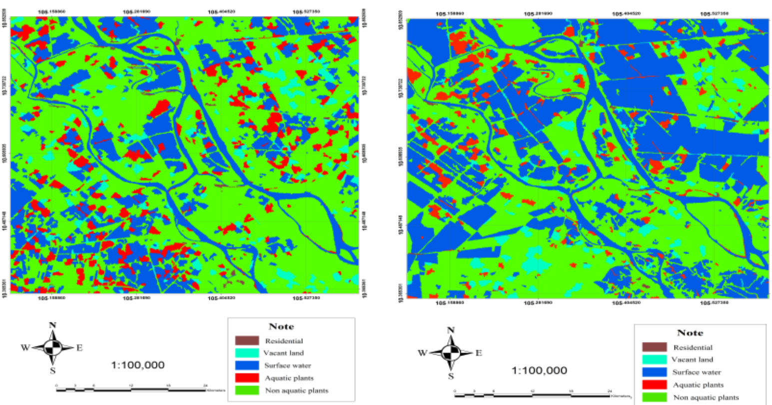
The object-oriented classification process includes: (1) Multi-resolution segment; (2) Constructing class hierarchy; (3) Classification by decision tree (classification rules); (4) Evaluate the classification results.

Table 4-4: Land Cover Classification Rule.

Land cover	Classification rules		
	NDVI	DEM(m)	Water level (m)
Surface water	< 0	-	-
Vacant land	$0 \leq$ and < 0.1	-	-

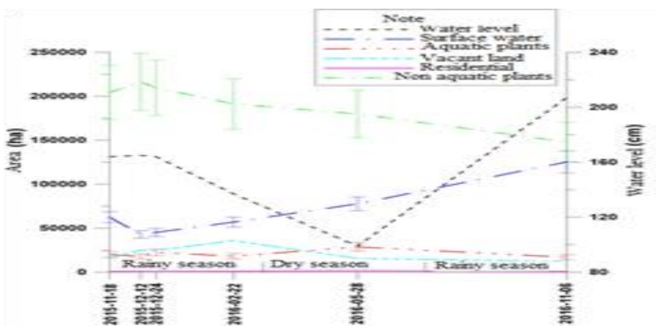
Residential	0.1 ≤ and< 0.3	-	-
Aquatic plants	0.3 ≤ and< 0.7	< 1	≥ 1
Non aquatic plants	0.7 ≤	≥ 1	< 1

Among the classified satellite images, the total accuracy ranged from 0.78 to 0.84 and the Kappa number ranged from 0.75 to 0.8.



(e) (f)

Figure 4-6: Land cover map at the moment (e) May 28th, 2016; and the moment (f) November 6th, 2016.



Hình 4-7: Water level and land cover changes

4.1.3. Object oriented classification experiment of land cover from Sentinel-1 satellite data

Land cover types in the research area include Surface water; Plants of group 1 (fruit trees, planted forests, ...); Plants of group 2 (rice, grass, shrub...); Aquatic plants(lotus, water lily ...); Vacant land; Residential (Residential areas, industrial zones, transportation ...).

The classification rule is set up as Figure 4-8.

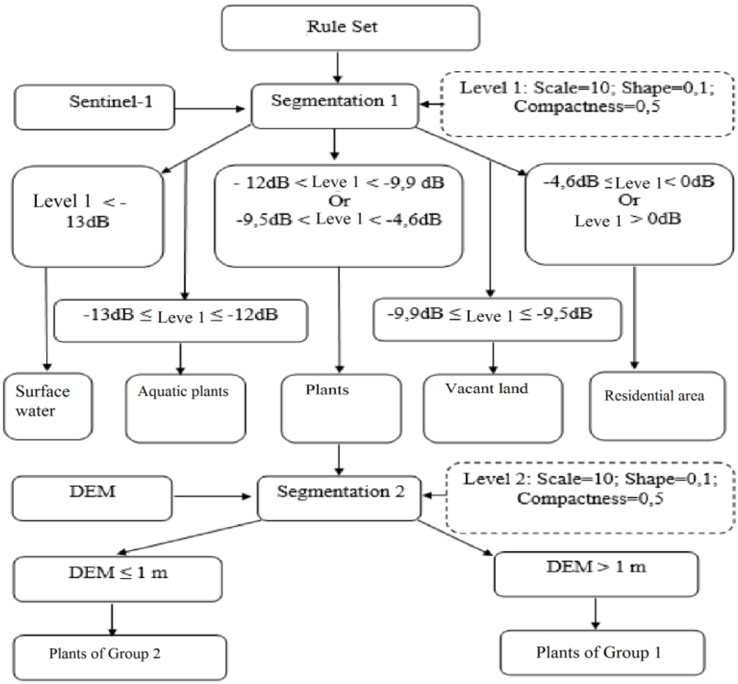


Figure 4-8: Classification Rule For Sentinel-1 Data

Among the classified satellite images, the total accuracy ranged from 0.77 to 0.89 and the Kappa number ranged from 0.72 to 0.87.

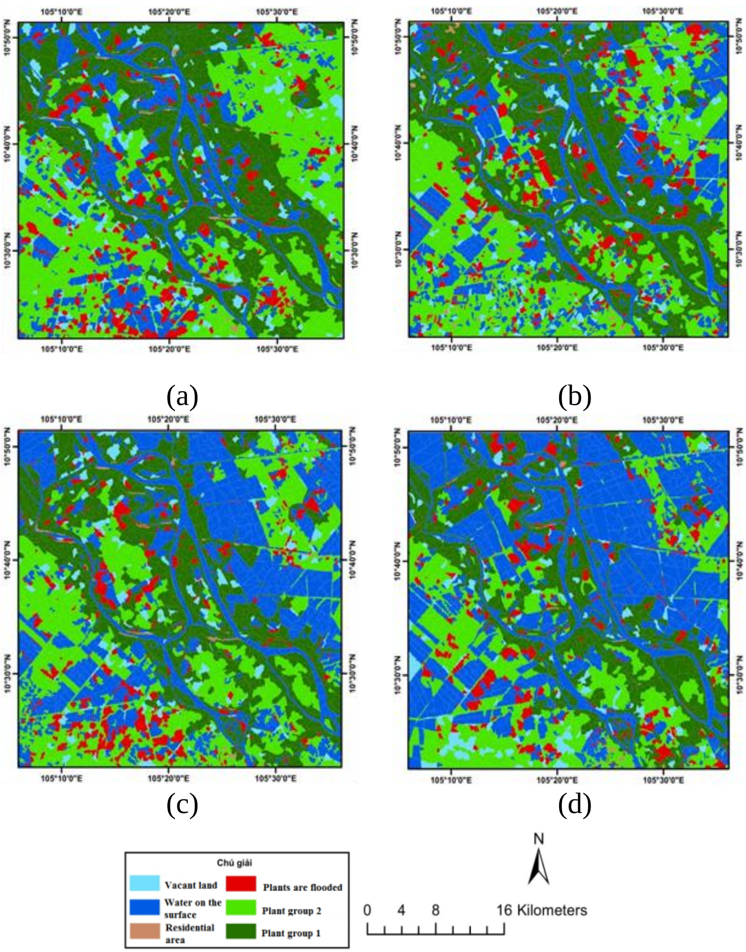
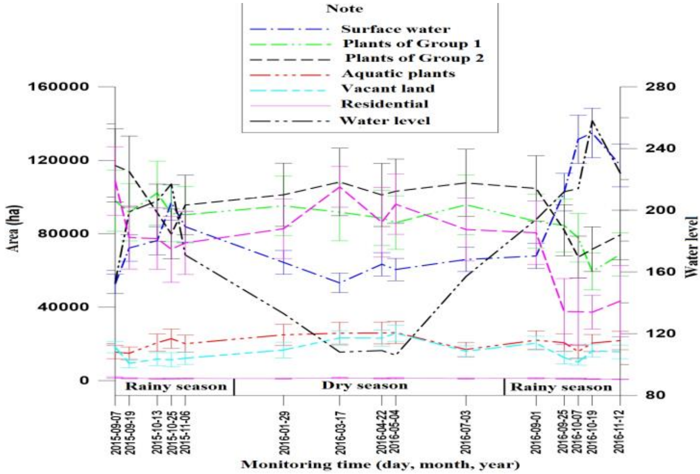


Figure 4-17*: Land cover map at water level times(a) 133 cm, (b) 187 cm, (c) 212 cm, (d) 250 cm.*

Table 4-8: The area of each land cover monitored in the period from 2015 to 2019

(unit: Hectare and percent)

ST	Date taken	Surface water		Plants of Group 1		Plants of Group 2		Aquatic plants		Vacant land		Residential	
		(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)	%
1	2015-03-11	65829,0	21,7	90256,2	29,8	96277,5	31,8	27138,8	9,0	22670,8	7,5	1076,6	0,4
2	2015-04-04	36523,8	12,0	97079,4	32,0	118200,7	39,0	23565,3	7,8	26286,1	8,7	1593,7	0,5
3	2015-05-10	35793.7	11,8	106070,2	35,0	126371,2	41,7	16017,2	5,3	17101,0	5,6	1896,6	0,6
…	…	…	…	…	…	…	…	…	…	…	…	…	…
48	2019-09-28	130451,0	43,0	75965,1	25,0	71339,1	23,5	13751,1	4,5	10944,2	3,6	798,9	0,3
49	2019-10-17	129832,9	42,8	78084,8	25,8	55671,0	18,4	28532,2	9,4	10322,2	3,4	806,1	0,3
50	2019-11-10	87553,4	28,9	80745,3	26,6	78349,1	25,8	43082,4	14,2	12680,9	4,2	838,4	0,3



Figue 4-14: The water level and the area corresponding to the types of land cover in the period from 2015 to 2016

4.2. Constructing the model of land cover changes due to the effects of water lever

The result of constructing the model of land cover changes according to the change in water level is shown in Figure 4-20 and Figure 4-21.

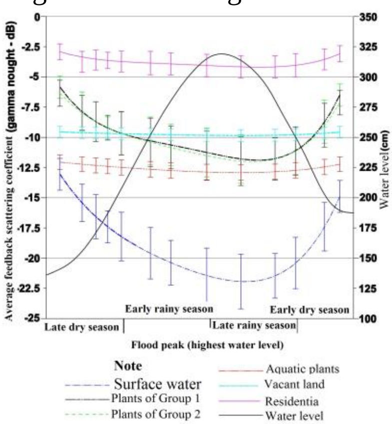


Figure 4. 20: Scattering coefficient feedback model with water level for 6 types of surface coatings

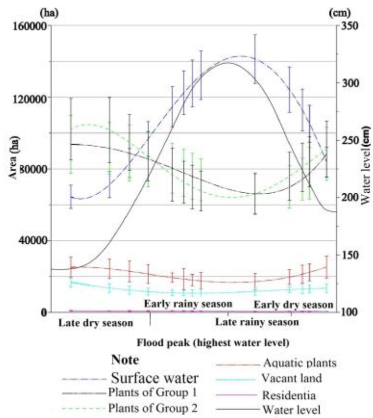


Figure 4 21: Area change pattern with water level of 6 types of surface coatings

4.3. Testing the model

Table 4-9: Compare the results of the model and the test results when the water level is 260cm (Photo collected date: 09/09/2017)

	Land cover	Results from model (Ha)	Test results (Ha)	Difference (Ha)	Ratio %
1	Water surface	113973,9	115673,6	-1699,7	1%
2	Plants of group 1	80688,0	78775,9	1912,1	2%
3	Plants of group 2	77246,3	75697,8	1548,5	2%
4	Aquatic plants	19530,1	20393,0	-862,9	4%
5	Vacant land	10970,9	11925,9	-955,0	9%
6	Residential	840,4	783,3	57,1	7%

Sub-conclusion of chapter 4: Selecting both Sentinel-1 and Sentinel-2 data is suitable for the study of land cover changes due to the effects of annual flooding to take the advantage of them. Besides, the ability to monitor in any weather condition including during the rainy season (Sentinel-1 data) and the free data open up the opportunity to apply new data in this study. Using the object-oriented classification method brings scientific and theoretical efficiency for classification problems with lots of input data**.**

CONCLUSIONS AND RECOMMENDATIONS

Conclusions: The object-oriented classification method combining using multi-time remote sensing images and the Digital Elevation Model is effective in classifying land cover in seasonal flooding areas.

The solution of combining optical remote sensing, radar remote sensing, DEM, and hydro-meteorological observation allows constructing a model of land cover changes due to the effects of flooding in the Cuu Long River Delta. The model can predict land cover changes at any time. It also can help to manage, plan and develop the socio-economic of the Cuu Long River Delta.

Recommendations: Requiring a high-resolution image source to improve the accuracy of the model.

There should be more research on the rules on the effects of flooding on land in favor of socio-economic development activities and local sustainable livelihoods in areas at high risk of flooding.

LIST OF PUBLICATION

Vietnamese:

[1] Nguyen Van Trung, Pham Vong Thanh, Nguyen Van Khanh (2014), "Using ALOS PALSAR data for constructing a backscattering coefficient variation model for the lood plain Tonle Sap, Campuchia", *Journal: Journal of Mining and Earth Sciences*, (48) issue, page 78-84.

[2] Nguyen Van Trung, Pham Vong Thanh, Nguyen Van Khanh (2014), "Eveluate the LandSat 8 OLI image mixture methods",

Collection of 21st Science Conference reports, *University of Mining and Geology*, 14/11/2014, page 150-156.

[3] Nguyen Van Trung, Nguyen Van Khanh (2016), "Monitoring coastline using landsat multi-temporal data in the Cua Dai estuary, Thu Bon rvier, Quang Nam", *Journal: Journal of Mining and Earth Sciences*, (57) issue.

[4] Nguyen Van Khanh, Nguyen Van Trung, Le Thi Thu Ha, Tran Xuan Truong (2019), "Detection of innundation extent of Tien, Haurivers delta and establishment of flood frequency mappings using multi - temporal Sentinel - 2 data", *Journal: Journal of Mining and Earth Sciences*, 60 (02) issue, page 88-97.

[5] Nguyen Van Khanh (2019), "Application of optical remote sensing in rapid assessment of water resource changes in the Cuu Long River Delta: Case studies in Tra Vinh and Vinh Long", *Natural Eesources And Environment Magazine*, 13 - (315) issue, page 31-33.

English:

[1] Nguyen Van Khanh, Tran Xuan Truong, Vu Xuan Cuong, Hoa Thi Luong, Van Tung Pham, Tran Thi Ha Phuong, Nguyen Thi Vinh, Nguyen Thi Tham (2017), "Inundation extent and flooded maps of vegetation in Cuu Long River delta using multi-temporal sentinel-1 data", *Published by: Publishing House for Science and Technology*, Vietnam ISBN: 978-604-913-618-4 Printed in Viet Nam.