COMPARISON OF VARIOUS SPECTRAL INDICES FOR ESTIMATING MANGROVE COVERS USING PLANETSCOPE DATA: A CASE STUDY IN XUAN THUY NATIONAL PARK, NAM DINH PROVINCE

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SUMMARY

Using remote sensing and GIS technology to quantify the extents of land covers and detect their changes, in particular mangrove covers, is very important to identify drivers of change, thus providing a good scientific foundation for better management of mangroves in Xuan Thuy National Park, Nam Dinh province. In this study, eight vegetation indices were used, namely SR, NDVI, GNDVI, BNDVI, TV, SAVI, OSAVI and EVI, to quantify the extents of mangrove covers is adopted. As a result, all vegetation indices are reliable for classifying and mapping land covers, greater than 80% of accuracies, in particular OSAVI is the most accurate in comparison with other indices, more than 90% of mapping accuracy as using Planet Scope (3 m x 3 m). Regarding changes in mangrove covers, using 2016 and 2017 PlanetScope data for detecting the change, it has been evidenced with a slight increase of mangroves with 75 ha established. The main drivers of increase of mangrove extents are due to effective mangrove rehabilitation and restoration programs. These findings imply thatmangrove mangement in Xuan Thuy National Park is in a good place.

Keywords: GIS, Land covers, mangroves, Nam Dinh, remote sensing, vegetation indices, Xuan Thuy.

I. INTRODUCTION

In Vietnam, there are 30 provinces and cities that have directly associated with coastal mangroves and coastal wetland areas. Coastal mangrove regions are divided into 4 main zones, namely North-Eastern coast from Ngoc cape to Do Son, defined as Zone I; Northern delta from Do Son to Lach Truong river, known as Zone II; Central coast from Lach Truong to Vung Tau as Zone III; and Southern delta from Vung Tau to Ha Tien as Zone IV (Phan Nguyen Hong, 1999). Total mangrove extents in Vietnam have reduced dramatically from 1943 to 2000 due to natural disasters, wars and shrimp farming, unsustainable management and other human activities (Phan Nguyen Hong, 1999).

Coastal mangroves are well-known as highly productive ecosystems that typically dominate the intertidal zone with low energy tropical and subtropical coastlines (Hai-Hoa, 2014). In addition, mangroves serve some key important functions, namely the maintenance of coastal water quality, reduction in severity of storm, wave attenuation, flood prevention and mitigation, and nursery and feeding areas for commercial fishery species. Remote sensing is an impressive management tool to quantify mangrove extents because of allowance of quantitative and qualitative assessments of ground conditions over large and inaccessible areas (Haboudane et al., 2004). Multispectral sensors on satellite platforms, including synthetic aperture radar (SAR), Landsat, and SPOT, Sentinels, PlanetScope and Rapid-eyes, are the most popular for mangrove monitoring and analysis due to their cost-effectiveness (Jiang et al., 2008). Planet Scope is the optimal satellite that provides data in multispectral mode (3 m resolution). The reflectance of vegetation is low in both the blue and red regions of the spectrum because of absorption by chlorophyll for photosynthesis. The highest peak in visible region is the green region which is the green color of vegetation. Vegetation indices (VIs) are combination of surface reflectance at two or more wavelengths designed to highlight a particular property of vegetation (Wang et al., 2007; Jiang et al., 2008). It is notable that spectral indices have become very popular in the remotely sensed vegetation features recently. However, reflections of soil and rocks are often much more than reflections of sparse vegetation that lead to the separation of plant signals more difficult. This study tends to classify and quantify land covers, in particular extents of mangrove covers using eight vegetation indices in Nam Dinh province during 2016 to 2017, namely SR, NDVI, GNDVI, BNDVI, TVI, SAVI, OSAVI and EVI. The most suitable index is then selected to quantify the extents of coastal land covers for Xuan Thuy National Park, and detect the change during the period of 2016 - 2017.

II. RESEARCH METHODOLOGY

2.1. Study site

Xuan Thuy National Park is geographically located in the Hong River, Biosphere Reserves in Nam Dinh Province, Vietnam that covers an area of 12000 ha. This Park was established according the Decision number 01/203/QD-TTg, dated 2nd January 2003. It is well-known by a variety of mangrove species and other coastal creatures. This study has selected Xuan Thuy National Park with emphasis on the spatial distribution of mangrove covers and other land covers (Fig. 01).

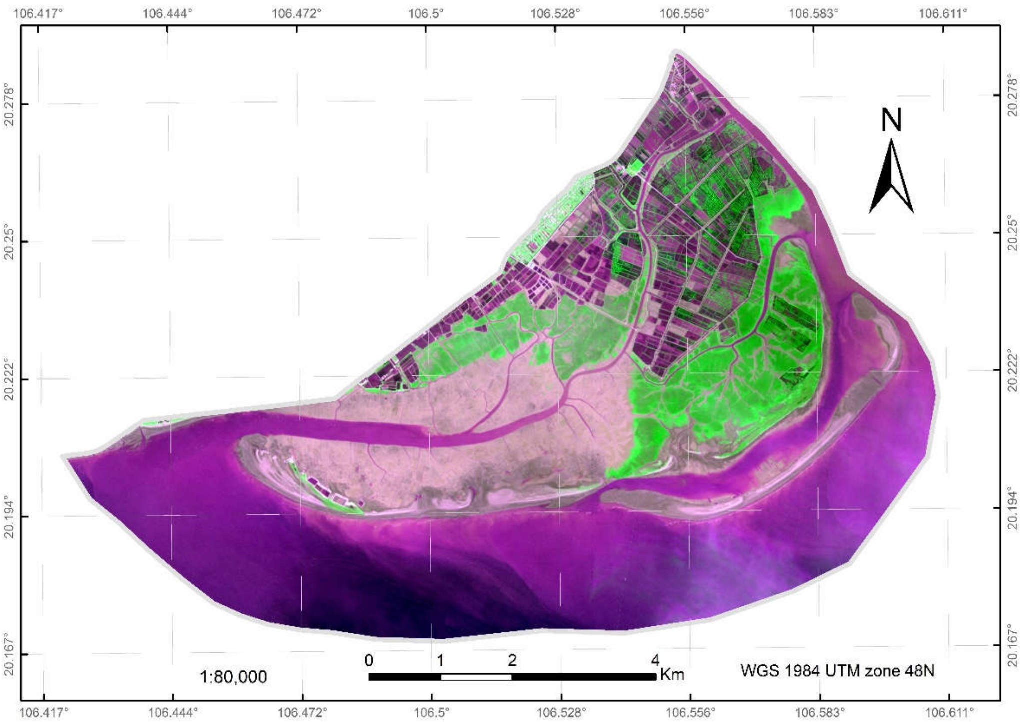

Figure 01. The satellite image of study site (PlanetScope 8th August 2016, 3 m x 3 m)

2.2. Materials

This study aimed to use Planetscope data with spatial resolution 3 m x 3 m in August 2016 and June 2017 (Table 01) to classify mangrove and Non-mangrove covers in the Xuan Thuy National Park, Nam Dinh province, Vietnam. Eight vegetation indices, including Simple Ratio (SR), Normalized Different

Vegetation Index (NDVI), Green Normalized Different Vegetation Index (GNDVI); Blue Normalized Different Vegetation Index (BNDVI); Transformed Vegetation Index (TVI); Soil Adjusted Vegetation Index (SAVI), Optimised Soil Adjusted Vegetation Index (OSAVI) and Enhanced Vegetation Index (EVI) are tested to find out the best classification accuracy for the study area (Table 02).

Table 01. Remotely- sensed data used for estimating mangrove covers

ID	Image codes	Date	Resolution (m)	Note
1	20160808_023705_0e0f_3B_AnalyticMS	08/08/2016	3	Provided by CLS
2	20160808_023706_0e0f_3B_AnalyticMS	08/08/2016	3	Provided by CLS
3	20170603_023949_1006_3B_AnalyticMS	03/06/2017	3	Provided by CLS
4	20170603_023948_1006_3B_AnalyticMS	03/06/2017	3	Provided by CLS

Source: https://www.planet.com/explorer

2.3. Methods

In order to classify and quantify mangrove covers based on different vegetation indices, there are a number of methods used as shown in Fig. 01.

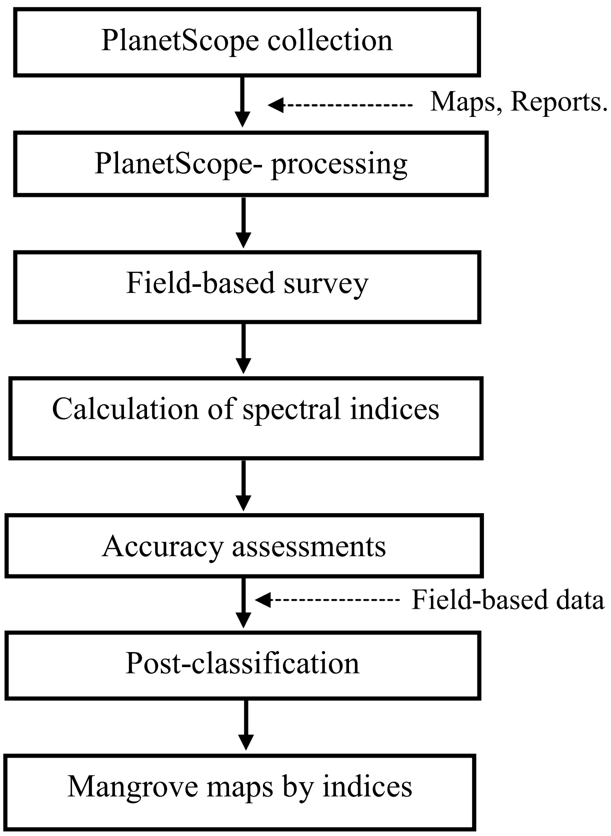

Fig. 01. Flow chart of quantifying mangrove covers using different vegetation indices.

Field survey and secondary data collection:

To gain additional information in relation to the spatial distribution of mangroves in Xuan Thuy National Park, study has reviewed all the relevant documents of vegetation indices, previous mangrove studies and projects in Xuan Thuy National Park. In addition, the field survey has been required to collect information of mangroves and non-mangroves (including water, cloud, agricultures, other plants and other land use types) with support of GPS Garmin 650. In particular, there were 500 GPS points collected from the field, including 300 points for mangroves and 200 points for non-mangroves in which 150 points of mangroves and 100 points of non-mangroves has been used for accuracy assessments.

Image pre-processing:

PlanetScope images are processed at level 3B, which are orthorectified and scaled Top of Atmosphere Radiance image product, and they are suitable for analytic and visual applications(Planet Imagery Product Specification, 2017). Geometric and radiometric corrections are all applied to images this study. In particular, sensor-related effects are corrected using sensor telemetry and a sensor model. Spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Conversion to absolute radiometric values is based on calibration coefficients.

PlantnetScope has 4 bands, namely Band 1 is Blue, Band 2 is Green, Band 3 is Red and Band 4 is Near infrared. Mosaicking two PlanetScope images is required, and then clipping mosaicked image is carried out based on the study boundary as shown in Fig. 01.

To calculate mangrove covers by using various equations of spectral indices, study has used the vegetation indices as shown in Table 02.

Table 02. Equation of vegetation indices used for estimating mangrove cover

ID	Indices	Equations
1	SR (Simple Ratio)[1]	NIR/RED
2	NDVI (Normalised Difference Vegetation Index)[2]	$\frac{NIR - RED}{NIR + RED}$
3	GNDVI (Green Normalised Difference Vegetation Index)[3]	(NIR-GREEN)/(NIR+GREEN)
4	BNDVI (Blue Normalised Difference Vegetation Index)[4]	(NIR-BLUE)/(NIR+BLUE)
5	TVI_1 (Transformed Vegetation Index)[5,6]	$\sqrt{NDVI + 0.5}$
6	SAVI (Soil Adjusted Vegetation Index)[7]	$\frac{(NIR-RED)}{(NIR+RED+L)}$*(1+L), L = 0.5
7	OSAVI (Optimised Soil Adjusted vegetation Index)[8]	(1+0.16)*[(NIR-RED)/(NIR+RED+0.16]
8	EVI2 (Enhanced Vegetation Index)[9,10]	2.5*[(NIR-RED)/(NIR+2.4*RED +1)]

Sources: [1]*Jordan (1969);* [2]*Rouse et al., (1973);* [3]*Gitelson et al., (1996);* [4]*Wang et al., 2007;* [5]*Deering et al., (1975);* [6]*Broge and Leblanc (2000);* [7]*Huete (1988);* [8]*Rondeaux et al., (1996);* [9]*Jiang et al., (2008);* [10]*Haboudane et al., (2004).*

Calculation of spectral indices:

The spectral index calculation is conducted based on the Equations given in Table 02. To be more specific:

Simple Ratio Index (SR) offers a high value for vegetation, whereas the low value represents for soil, ice or water. This index indicates amount of vegetation, which is able to reduce the effects of atmosphere and topography (Jordan, 1969). Simple Ratio values for bare soils are generally close to 1. As the amount of green vegetation increases in a pixel, Simple Ratio value increases and its values can increase far beyond 1. Generally, very high Simple Ratio values are on the order of 30.

Normalised Difference Vegetation Index (NDVI) has values ranging from -1 to 1, indicating vegetation and non-vegetation, which is able to distinguish between vegetation and soil, minimize the topographic effects, but not eliminate atmospheric effects (Rouse et al., 1973).

Green Normalised Difference Vegetation Index (GNDVI) is an index of plant and one of the most commonly used indices to assess canopy variation in biomass (Gitelson et al., 1996), whereas Blue Normalised Difference Vegetation Index (BNDVI) is used to analyse the leaf area index (Wang et al., 2007).

Transformed Vegetation Index (TVI) is used to eliminate negative values and transform NDVI histograms into a normal distribution (Deering et al., 1975; Mroz and Sobieraj, 2004). Similarly, Soil Adjusted Vegetation Index (SAVI) is used to minimise the soil influence on vegetation quantification by giving the soil adjustment factor as L. L is equal to 0.0 or 0.25 used for high vegetation cover, whereas the low vegetation cover is with L of 1.0. The intermediate vegetation cover is with L of 0.5 (Huete 1988; Mroz and Sobieraj, 2004). In contrast, Optimised Soil Adjusted vegetation Index (OSAVI) is a simplified index of SAVI to minimize the influence of soil brightness. This index is recommended to analyze vegetation in early to mid growth stages, where there is relatively sparse vegetation and soil is visible through the canopy (Rondeaux et al., 1996).

Enhanced Vegetation Index (EVI) is subject to be more sensitive to plant canopy differences such as leaf area index, canopy structure and plant phenology, so it is commonly used to monitor variations in vegetation (Huete et al., 1994; Jiang et al., 2008).

III. RESULT AND DISCUSSIONS

3.1. Mangrove covers by difference vegetation indices

Values of vegetation indices driven by PlanetScope data

Findings of eight spectral indices are presented in Table 03 and Fig. 02.

Table 03. Values of vegetation indices calculated by PlanetScope in 2016

ID	Vegetation indices	Minimum	Maximum	Mean
1	SR	0	3	0.169
2	NDVI	-0.537	0.578	-0.225
3	GNDVI	-0.625	0.430	-0.318
4	BNDVI	-0.631	0.424	-0.335
5	TVI	0	1.038	0.483
6	SAVI	-0.805	0.867	-0.337
7	OSAVI	-0.623	0.670	-0.261
8	EVI	-0.647	1.115	-0.279

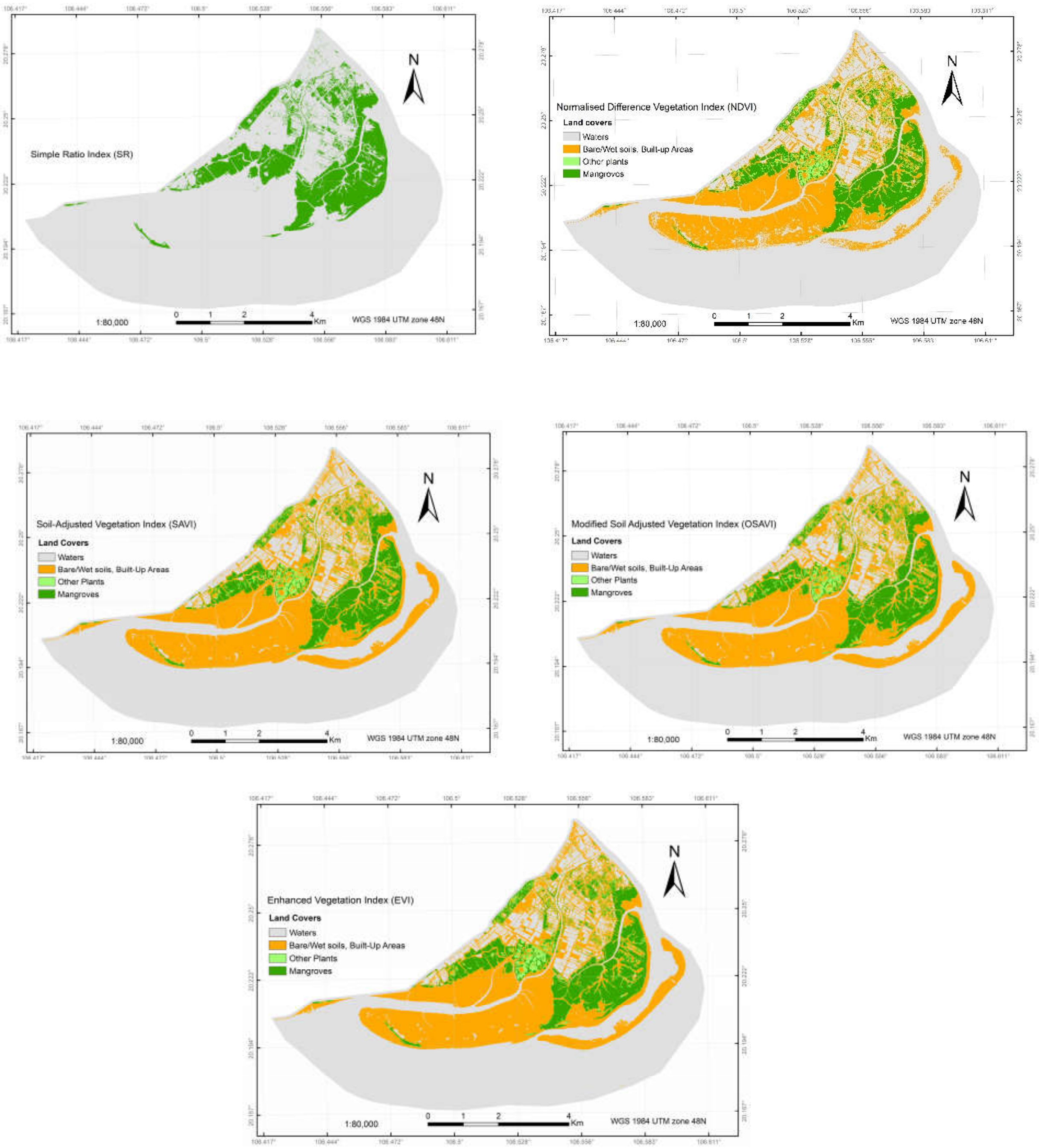

Figure 02. Coastal land covers in Xuan Thuy National Park (PlanetScope 8 August 2016)

As can be seen in Table 03, regarding NDVIs, there are slight differences in vegetation values cross three indices, including NDVI, GNDVI and BNDVI. In particular, NDVI has the largest range of values in comparison with BNDVI and GNDVI, from -0.537 ÷ 0.578, followed by GNDVI and BNDVI. For these indices, positive values represent the vegetation, the higher NDVIs values are, the more dense vegetation are (Wang et al., 2007; Jiang et al., 2008). Similarly, SAVI and OSAVI values range from -0.805 to 0.867 and -0.623 to 0.670, respectively, indicating that the higher values of SAVIs tend to be more density of vegetation. On the contrary, TVI has a value of 0.0 to 1.038, which the values are greater than 0.5 representing vegetation.

Index of SR has values less than 1 or close to 1, which represent to the soil or water, whereas the values of SR are greater than 1, showing the vegetation. Values of EVI range from -0.647 to 1.115, showing there is a variation of land cover types in this study, where positive values represent vegetation compared to negative values for water or bare/wet soils.

Land use types in association with different vegetation indices

To classify different land use types according to various vegetation indices, each vegetation index was classified into 30 classes and then 100 points of mangroves and 100 points of non-mangroves (50 points of other plants, 30 bare/wet soils and built-up areas, 20 points of water bodies) were used to identify and classify different land use types. The result indicated that there were four different types of land use and land covers presented in Table 04.

Table 04. Values of vegetation indices for different land use types

ID	Indices	Mangroves	Non- mangroves		
			Other plants	Bare/wet soils, built-up	Water bodies
1	SR	> 1.0	values are less than 1.0		
2	NDVI	0.132 ÷ 0.578	0.058 ÷ 0.131	-0.196 ÷ 0.057	-0.537 ÷ -0.195
3	GNDVI	0.002 ÷ 0.424	-0.076 ÷ 0.002	-0.312 ÷ -0.075	-0.631 ÷ -0.311
4	BNDVI	0.013 ÷ 0.046	-0.065 ÷ 0.012	-0.306 ÷ -0.066	-0.625 ÷ -0.306
5	TVI_1	0.794 ÷ 1.038	0.725 ÷ 0.793	0.525 ÷ 0.724	0.077 ÷ 0.525
6	SAVI	0.198 ÷ 0.867	0.086 ÷ 0.178	-0.294 ÷ 0.086	-0.805 ÷ -0.294
7	OSAVI	0.112 ÷ 0.670	0.021 ÷ 0.111	-0.227 ÷ 0.020	-0.623 ÷ 0.227
8	EVI	0.238 ÷ 1.115	0.051 ÷0.238	0.050 ÷ -0.294	-0.647 ÷ -0.294

Extents of mangrove covers and accuracy assessments

Table 05. Accuracy assessments, mangrove covers by different vegetation indices in 2016

ID	Index	Mangrove (ha)	Non-mangrove (ha)				Total of Areas	Accuracy (%)
			Other plants	BWS, BU	Water bodies	Total		
1	SR	2169.9	11400.3				13570.2	90.4
2	NDVI	1442.2	426.4	3453.4	8248.2	12128.0	13570.2	89.2
3	GNDVI	1358.8	550.9	4114.3	7546.2	12211.4	13570.2	82.4
4	BNDVI	1358.8	550.9	4400.9	7259.6	12211.4	13750.2	82.8
5	TVI_1	1452.3	587.7	4081.7	7442.5	12111.9	13570.2	85.2
6	SAVI	1442.1	426.4	4058.9	7642.8	12128.1	13570.2	89.6
7	OSAVI	1442.2	426.4	4058.9	7642.7	12128.0	13570.2	91.6
8	EVI	1550.5	443.1	4089.1	7487.4	12020.0	13570.2	81.6

BWS: Bare/wet soils; BU: Built-up; Water bodies: Shrimp farms, sea waters, ponds.

As shown in Table 04 and Table 05, there are relationships between values of vegetation indices and different land cover types, in particular mangrove covers across eight indices. These findings are similar to other studies, such as Haboudane et al. (2004), Montandon and Small (2008). As indicated in Table 05, accuracy assessments of all vegetation indices are greater than 80.0%, in particular coastal land covers classified by OSAVI is the most accurate among vegetation indices, around 91.6%, followed by the SR, SAVI and NDVI at 90.4%, 89.6% and 89.2% respectively. However, SR cannot be used to classify various kinds of vegetation covers due to its difficulty in separating different vegetation covers, but between vegetation cover and water and bare/wet soil (Mroz et al., 2004). Therefore, in this study, the OSAVI is selected to classify mangrove covers of Xuan Thuy National Park in 2017 due to its highest accuracies.

3.2. Changes of mangrove covers during the period of 2016 - 2017

This study has used OSAVI to classify different land covers in 2017 as shown in Table 06 and Figure 03.

Table 06. Land covers in Xuan Thuy National Park by PlanetScope in 2017

Land covers in 2017	Mangrove (ha)	Non-mangrove (ha)			Total of studied areas
		Other plants	BWS, BU	Water bodies	
	1517.2	284.6	4372.1	7396.3	13570.2
Total	1517.2		12053.0		

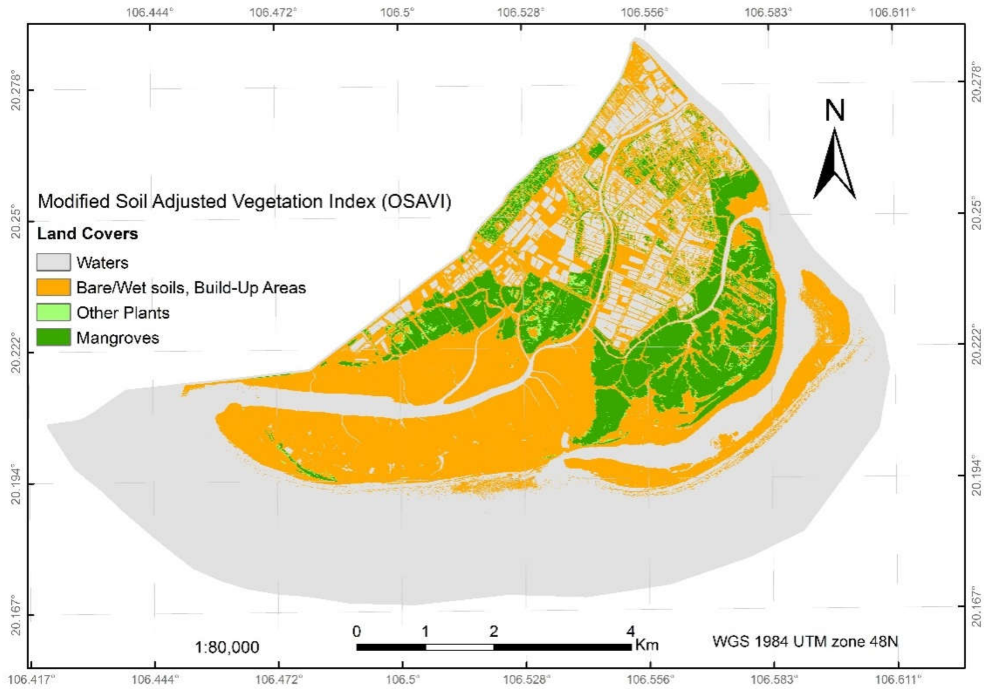

Figure 03. Mangrove covers using PlanetScope in 3 June 2017 (ha)

As shown in Table 05 and Figure 03, the extents of mangrove cover in 2017 by PlanetScope is 1517.5 ha, whereas non-mangroves are 12053.0 ha. In comparison with mangrove covers in 2016, there is a relative difference in extents of mangrove covers as shown in Table 06.

Table 06. Changes in extents of mangrove extents between 2016 and 2017 using PlanetScope

Classes	2016	2017	2016 – 2017	
			Ha	%
Mangroves	1442.2	1517.2	75.0	0.05
Non-mangroves	12128.0	12053.0	-75.0	-0.05

Non-mangroves include Waters, Bare/Wet soils; other plants

As indicated in Table 06, mangroves have been experienced with an increase of mangrove extents, approximately 75 ha between 8th August 2016 and 3rd June 2017, equivalent to 0.05%. This increase is due to the strengthened management activities and local people's rising awareness from government, such as mangrove restoration and development projects. Recently, rehabilitation and sustainable development of mangrove ecosystems project in Xuan Thuy National Park.

IV. CONCLUSIONS

Based on using different vegetation indices, this study has quantified the extents of land covers, in particular mangrove covers using PlanetScope data with 3 m spatial resolution and GIS in Xuan Thuy National Park, Nam Dinh province during 2016 - 2017, the study has come up with the following conclusions. Firstly, using spectral indices to classify land covers have shown that all indices are reliable for mapping coastal land covers with 3 m x 3 m PlantScope data and accuracy assessments of land covers are all greater than 80%, but the OSAVI is the most accurate index. Secondly, there is a change in coastal land covers between 2016 and 2017, in particular mangrove cover has been evidenced with an increase of 75 ha as a result of good mangrove restoration and rehabilitation in Xuan Thuy National Parks.

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SO SÁNH SỰ KHÁC BIỆT CHỈ SỐ THỰC VẬT TRONG ƯỚC TÍNH DIỆN TÍCH RỪNG NGẬP MẶN QUA VIỆC SỬ DỤNG ẢNH PLANETSCOPE: NGHIÊN CỨU ĐIỂM TẠI VQG XUÂN THỦY, TỈNH NAM ĐỊNH

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TÓM TẮT

Việc sử dụng công nghệ viễn thám và GIS trong ước tính diện tích bao phủ đất và phát hiện sự thay đổi của chúng, đặc biệt là rừng ngập mặn ven biển, có ý nghĩa rất quan trọng để xác định được nguyên nhân, yếu tố thay đổi, cung cấp cơ sở khoa học cho việc đưa ra các giải pháp quản lý rừng ngập mặn tốt hơn tại Vườn Quốc gia Xuân Thuỷ, tỉnh Nam Định. Trong nghiên cứu này, 8 chỉ số thực vật, bao gồm SR, NDVI, GNDVI, BNDVI, TV, SAVI, OSAVI và EVI được sử dụng để ước tính diện tích che phủ bởi rừng ngập mặn và các trạng thải phủ khác. Kết quả cho thấy tất cả các chỉ số thực vật đều có độ tin cậy trên 80% và có thể sử dụng để phân loại và lập bản đồ bao phủ đất khu vực nghiên cứu, đặc biệt là chỉ số OSAVI có độ chính xác cao nhất so với các chỉ số khác, trên 90% độ chính xác khi sử dụng PlanetScope với độ phân giải 3 m x 3 m. Đánh giá sự thay đổi diện tích rừng ngập mặn giai đoạn 2016 - 2017 cho thấy có sự tăng nhẹ về diện tích rừng ngập mặn, khoảng 75 ha rừng ngập mặn là kết quả của hoạt động trồng mới và phục hồi rừng ngập mặn tại khu vực nghiên cứu. Kết quả này cũng chỉ rõ công tác quản lý rừng ngập mặn tại Vườn Quốc gia Xuân Thủy và các trạng thái thảm phủ khác là hiệu quả.

Từ khoá: Chỉ số thực vật, GIS, lớp phủ mặt đất, Nam Định, rừng ngập mặn, viễn thám, Xuân Thuỷ.

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