USING LANDSAT IMAGERY AND VEGETATION INDICES DIFFERENCING TO DETECT MANGROVE CHANGE: A CASE IN THAI THUY DISTRICT, THAI BINH PROVINCE

Nguyen Hai Hoa[1], Tran Duy Binh[2]
[1,2]*Vietnam National University of Forestry*

SUMMARY

Using multi-temporal Landsat data and GIS technology to quantify changes in coastal mangroves is very important in terms of identifying drivers and providing scientific foundation for better mangrove management in Thai Thuy district, Thai Binh province. Vegetation indices, such as NDVI, SAVI, IPVI, DVI, SR, RVI is adopted as a suitable method to quantify and monitor the extents of mangrove this study. As a result, NDVI is the most accurate in comparison with other indices. Regarding historical changes in mangrove extents, overall mangrove extents during 2001- 2016 have increased by 538.5 ha. In particular, the period of 2001 - 2006 has evidenced with a slight increase of mangroves and continued to a considerable increase during 2006 to 2011, 454 ha of new mangrove extents created, while the period of 2011 - 2016 has experienced with an increase of mangrove extents with 80.3 ha. The main drivers of increase of mangrove extents are due to the effective mangrove rehabilitation and restoration programs. These findings imply that mangrove mangement is in a good place in Thai Thuy district and local people are better aware of the importance of mangroves. Based on the findings, the study has given a number of solutions for better manage mangroves extents in the study site.

Keywords: Change detection, Landsat, NDVI, remote sensing, vegetation cover, vegetation indices.

I. INTRODUCTION

Vietnam has a coastline of 3260 km that creates an favorable environment for mangroves development. Mangroves play an important role for maintaining the environment goods and services and providing endless subsistence to the local people, such as carbon storage, sediments trapping, shoreline stability and erosion prevention, wood for construction, firewoods, fisheries, shelters for fishes and other marine species. In Vietnam, there are 30 provinces and cities that have been 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 is defined as Zone I; Northern delta from Do Son to Lach Truong river as Zone II; Central coast from Lach Truong to Vung Tau as Zone III; and Southern delta from Vung Tau to Ha Tien is known as Zone IV (Pham Van Ngot, 2012).

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). Therefore, protecting and restoring mangroves in coastal regions have becoming an extremely important task of the central Government, local authorities, organizations and individuals. The coastal mangroves extents of Thai Thuy district, Thai Binh province is not out of this trend. For many years, they have been protected successfully. This achievement is due to a good organization of the Thuy Truong commune in that they have set up a specialized forest protection task force with 6 members. Mangroves in Thai Binh have a high biodiversity level with many terrestrial and marine species. They not only help create a formidable forest that withstand typhoons and waves, but also help form a marine ecosystem where is the main source of incomes for local people. The commune has about 3.7 km of sea dike in length and before 1994, it was often threatened by high sea waves. However, nowadays, with around 1,300 ha of mangroves distributing along this dike system with the widest area up to 1.8 km, it has become very safe after many typhoon seasons. Especially, the 2nd and 8th typhoons in 2005 that destroyed the concrete dike systems in Hai Phong and many nearby provinces, but the one in Thuy Truong survived. Apart from protecting the sea dikes, Thai Binh's mangroves also ensure the safety of more than 3,000 ha of nearby aquaculture ponds.

Realising the role of mitigating the impact of tides and storms, Thai Binh has launched hundreds of mangroves plantation campaign to counter typhoons and climate change, and has planted tens of thousands of hectares of trees. In particular, Thai Thuy district has the largest mangrove area, with about 4.700 ha stretches over 27 km along the coastline. To promote afforestation, coastal communities have sought to allocate forest land to household management and afforestation. Accordingly, the growers enjoy the planting and care funding from the district and commune, and they would enjoy all the marine resources brought from the forest, so people are actively involved in this project.

Remote sensing is well known as an important source of information to quantify forest extents in large areas. In particular, 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 difficult. This study tends to quantify changes in mangrove extents based on the vegetation indices in Thai Binh province during 2001 to 2016, namely NDVI, SAVI, IPVI, DVI, RVI and SR. Study then identifies drivers of changes in mangrove extents and suggests feasible solutions for enhancing mangrove management activities.

II. MATERIALS AND METHODS

2.1. Study site

Thai Thuy is a coastal district of Thai Binh Province in the Red River Delta region of Vietnam that covers an area of 257 km². This district has population of 267,012 in 2003. The centre of district lies at Diem Dien. This study selects 3 communes of Thai Thuy district as study sites due to mainly spatial distribution of mangroves.

Figure 01. Study area with three communes of Thai Thuy district, Thai Binh province

2.2. Materials

In this study, the multi-temporal Landsat images (2001 - 2016) and Sentinel image (2016) are used to detect mangrove cover and changes. Sentinel image in 2016 is only used for accuracy assessment of Landsat image in combination with the field survey because Sentinel image offers higher spatial resolution (10 m x 10 m) than Landsat data, but it is only available since 2014.

Table 01. Remoted sensed data used for detecting changes in coastal mangroves

ID	Image codes	Date	Resolution (m)	Path/Row
1	LE71260462001272SGS00	29/09/2001	30	126/46
2	LT51260462006310BJC00	06/11/2006	30	126/45
3	LT51260462011148BKT00	28/05/2011	30	126/46
4	LC81260462016114LGN00	23/04/2016	30	126/46
5	S2A_20160117T083907_A002975_T48QXH	17/01/2016	10	

Sources: earthexplorer.usgs.gov, https://scihub.copernicus.eu/dhus

2.3. Methodology

To calculate the mangrove covers by using vegetation index, study has used the vegetation indices as shown in table 02.

Table 02. Equation of Vegetation Indices used for mangrove mapping

Name	Equation	References
SR/ RVI	$SR = \frac{NIR}{RED}$	Jordan (1969)
DVI	$DVI = R_{NIR} - R_{RED}$	Tucker (1980)
NDVI	$NDVI = \frac{NIR - RED}{NIR + RED}$	Rouse et al., (1973), Claudio Parente (2013)
IPVI	$IPVI = \frac{NIR}{NIR + RED}$	Crippen (1990)
SAVI	$SAVI = \frac{(1 + L)(NIR - RED)}{(L + NIR + RED)}$	Huete (1988)

Social survey and secondary data collection:

To gain additional information regarding mangrove management, study reviews all the documents from the previous research, legal documents and the documents in relation to mangrove management and development in study site.

To assess the status of coastal mangrove management and mangrove structures, the study conducts the interview with People's Committee at district and village levels, local people who have been living nearby mangroves for a long time. In addition, mangrove rangers, forestry officials and local guards also targets to be interviewed to obtain the additional information of coastal mangroves, such as mangrove species names, historical spatial distribution.

Image pre-processing:

Landsat Images: Atmospheric correction is applied to remove errors and to increase accuracies using Spatial Analyst Tools in ArcGIS 10.2 indicated as below.

DN values to TOA reflectance = **Band-specific reflectance_Mult_Band x DN values + Reflectance_Add_Band**

Correct for Sun Angle = TOA Reflectance/sin(Sun Elevation).

ArcToolbox => Spatial Analyst Tools => Map Algebra => Raster Calculator

NDVI caculation:

Change detection in mangrove cover and

land use during the period of 2001 - 2016 is conduted using the NDVI differencing technique followed by Singh (Singh, 1989) as shown in Eq. 1.

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where: Band TM4 is Near infrared - NIR, Band TM3 is Visible red - RED.

The resulting images are subtracted to assess the ΔNDVI image with positive values and negative values (Eq. 2):

$$\Delta NDVI = NDVI_{2016} - NDVI_{2001} \quad (2)$$

Difference Vegetation Index (DVI): Probably the simplest vegetation index

$$DVI = NIR - RED \quad (3)$$

This DVI is sensitive to the amount of vegetation, so it is able to distinguish between soil and vegetation.

Ratio-based vegetation index: Simplest ratio-based index is called the Simple Ratio (SR) or Ratio Vegetation Index (RVI)

$$SR = \frac{NIR}{RED} \quad (4)$$

This SR is suitable to detect vegetation and soil. The high value is for vegetation and low values are more likely to be soil, ice, water. Using this index not only indicates amount of vegetation and but also reduces the effects of atmosphere and topography.

IPVI (Infrared Percentage Vegetation Index): Crippen (1990) recognized that the red radiance subtraction in the numerator of NDVI is irrelevant and he formulated the infrared percentage vegetation index (IPVI):

$$IPVI = \frac{NIR}{NIR + RED} \quad (5)$$

IPVI is functionally equivalent to NDVI and RVI, but it only ranges in value from 0.0-1.0. It also eliminates one mathematical operation per image pixel which is important for the rapid processing of large amounts of data.

SAVI (Soil Adjusted Vegetation Index):

$$SAVI = (NIR – RED)/(NIR + RED+L)]*(1+L) \quad (6)$$

Where: L is soil brightness correction factor, varies by cover of green vegetation.

High vegetation area (L=0), the area have no green vegetation (L=1), generally L = 0.5 in most causes and it works well. As L = 0 then NDVI = SAVI.

III. RESULTS AND DISCUSSION

3.1. Historical changes in coastal mangrove extents

Vegetation indices: As a result shown that five mangrove indices are relatively various from 2001- 2016. In particular, NDVI and SAVI is better indices than others as quantifying mangrove extent due to their higher accuracies.

Table 03. Values of Vegetation indices calculated from 2001 to 2016

ID	Vegetation indices	2001	2006	2011	2016
1	NDVI	-0.48 ÷ 0.43	-0.39 ÷ 0.27	-0.41 ÷ 0.42	-0.24 ÷ 0.64
2	DVI	-0.48 ÷ 0.57	-0.41 ÷ 0.38	-0.39 ÷ 0.56	0.05 ÷ 0.31
3	SR	0.35 ÷ 2.54	0.43 ÷ 1.7	0.41 ÷ 2.5	0.6 ÷ 4.6
4	SAVI	-0.31 ÷ 0.29	-0.26 ÷ 0.18	-0.27 ÷ 0.28	0.049 ÷ 0.21
5	IPVI	0.74 ÷ 1.45	0.89 ÷ 1.41	0.65 ÷ 1.60	0.16 ÷ 0.62

As can be seen in table 03, there are slight differences in values of vegetation indices cross different years. In particular, NDVI values range from -0.24 to 0.64, indicating that the higher NDVI values is, the more dense mangroves are. Similarly, SAVI values range from -0.31 to 0.28. Higher values of SAVI tends to be more density of mangroves.

Table 04. Accuracy assessments, mangrove extents in different vegetation indices in 2016

ID	Vegetation index	Mangrove (ha)	Non-mangrove (ha)	Accuracy (%)
1	NDVI	1138.8	769.2	97
2	DVI	852.9	1055.1	80
3	IR	851.6	1056.4	85
4	SAVI	957.7	950.3	94
5	IPVI	1131.1	776.9	95

As a result findings show that there are relationships between vegetation indices and mangrove extents across five indices. These findings are similar to other studies, such as Carlson and Riziley (1997), Haboudane et al., (2004), Montandon and Small (2008). Elmore et al., (2000) have reported that there is correlation between the vegetation cover area and NDVI values in semi-arid regions. As shown in Table 6, the mangrove classification by NDVI is the most accurate among vegetation indices, around 97.0%. Therefore, this study uses NDVI to quantify changes in coastal mangroves in Thai Thuy district.

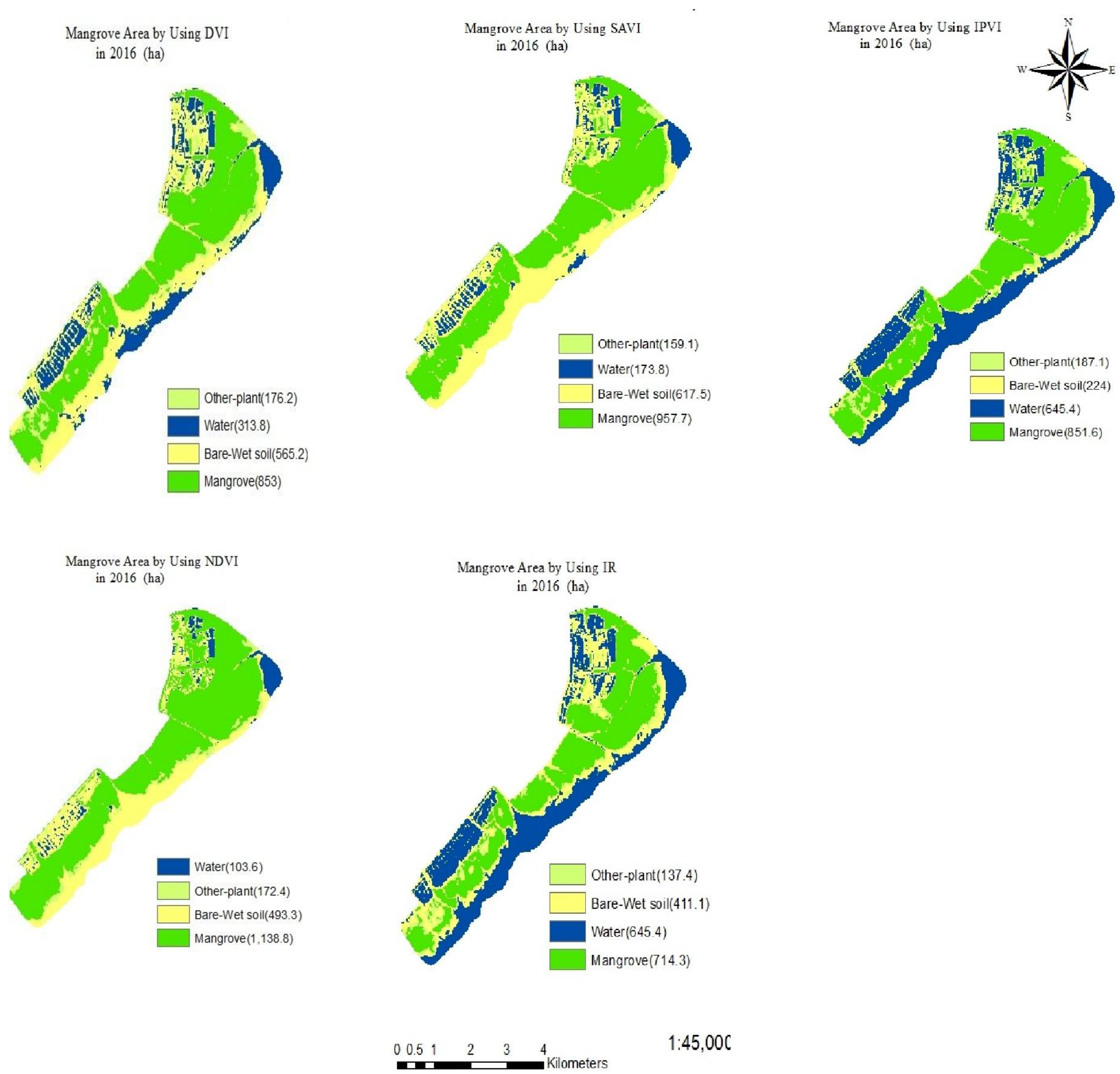
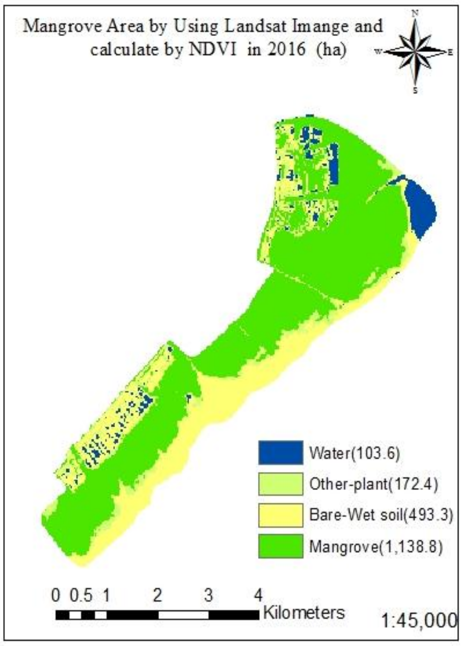


Figure 02. Mangrove extents by different vegetation indices in 2016 (ha)

To assess the reliability of mangrove extents using Landsat 8, the study use Sentinel data with spatial resolution (10 m x 10 m).



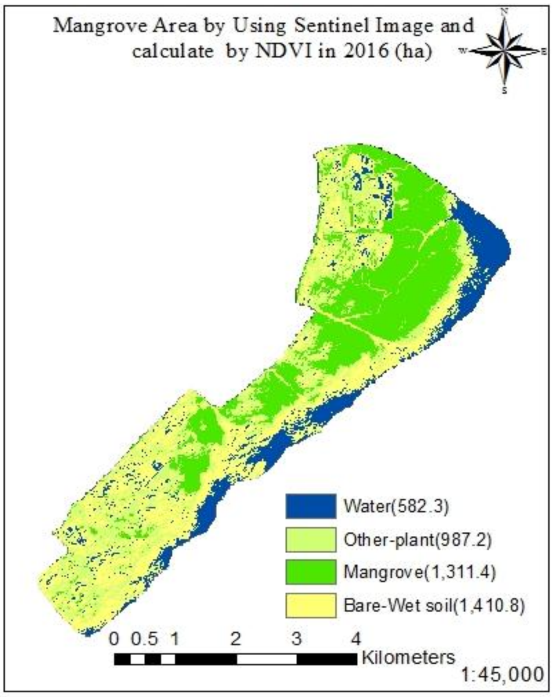


Figure 03. Mangrove extents using Landsat 8 and Sentinel in 2016 (ha)

As shown in figure 03, there is a difference in mangrove extents between Landsat 8 and Sentinel data. Mangrove extents quantified by Sentinel image are larger than by Landsat 8, around 172.6 ha. This is because Sentinel image offers higher spatial resolution than Landsat, thus providing more accuracy. Similarly, the extents of other classified items, including waters and other plants by Landsat 8 are smaller than those by Sentinel, except for bare and wet soils. Therefore, it is concluded that using Sentinel data for mapping mangrove extents is ideal.

3.2. Mangrove change detection and drivers

This study uses NDVI to quantify coastal mangrove extents (table 03) and calculate the changes in different periods as shown in table 04.

Table 04. Changes in mangrove extents in different periods: 2001– 2006; 2016 – 2011 and 2011 – 2016 using Landat data

Classes	2001	2006	2001 – 2006		2011	2006 – 2011		2016	2011 - 2016	
			Ha	%		Ha	%		Ha	%
Man	600.4	604.6	4.2	0.6	1058.6	454	43	1138.9	80.3	7
Non-man	1307.6	1303.4	-4.2	-0.3	849.4	-454	-53	769.1	-80.3	-10

Non-man is Non-mangroves, including waters, bare and wet soils, and other plants); while Man is Mangroves.

Period of 2001 - 2006: This period evidences mangroves extents have increased slightly with 3.5 ha (equivalent to 0.6 %). This is a result of national mangrove restoration and rehabilitation plans. There are some well-known programs, such as 5 million ha of forest plantation including mangroves from 1999 to 2010. The mangrove extents increased about 3.8 ha.

Period of 2006- 2011: The mangrove extents in this period have increased rapidly with 454 ha (43%). This period is characterized by the government programs when there is financial investment for mangrove restoration and plantation. In this period, the program 661 was ended and new project started. Mangrove restoration and development were set up for period 2011 – 2015.

Period of 2011 - 2016: The mangrove extents again have evidenced with an increase of mangrove extent, approximately 80ha (equivalent to 7%). This increase is due to the strengthened management activities and local people's rising awareness from government, such as mangrove restoration and development projects during period of 2011 - 2015. Recently, rehabilitation and sustainable development of mangrove ecosystems project in Thai Binh Province, Vietnam has been launched by the South Korean Government and approved by the Ministry of Agriculture and rural Development for a 10 -year implementation period.

3.3. Solutions for enhancing mangrove management

Strengthening forest allocation: For better management and protection of mangroves in the study area, quick process of allocation of mangroves to local residents and villages should be implemented at different levels so that all mangrove extents have true owners. In addition, local people also need to have reasonable mechanisms and policies on mangrove management, clear responsibilities and rights from management and protection activities.

Allocation priority should be given to local people according to the project and the plan approved by the competent authorities associated with certificates of land use rights for forest owners. No allocation of forest to households should be implemented near river mouths, estuaries or in front of the dike area and along the coast near residential areas where are easily being eroded and often attacked by storms, these areas should be handed over to local communities.

Decentralising forest management responsibility to local levels, including districts, communes and villages should be carried out under Decision 07/2012/QĐ-TTg dated 08/02/2012 of the Prime Minister in order to strengthen forest protection and enhance responsibility of party committee and government at all levels in forest protection.

Raising public awareness: Propaganda campaigns through various forms of newspaper, radio and television, training conferences, meeting and banners should be carried out to convey the roles of mangroves to coastal communes; and propagate guidelines, policies and laws in relation to natural resources management and marine protection.

IV. CONCLUSIONS

Based on quantifying changes in coastal mangroves using Landsat data and GIS in Thai Thuy district, Thai Bình province during 2001 – 2016, the study concludes as below:

Using vegetation indices to quantify and monitor the extents of mangrove is suitable. As a result, NDVI is the most accurate in comparison with other indices. Landsat and Sentinel data are both otpimal sources of data for mapping mangroves due to their free access. However, Sentinel data offers better accuracy than Landsat due to its higher spatial resolution. Therefore, using Sentinel data should be encouraged to monitor changes in mangrove extents.

Regarding historical changes in mangrove extents, overall mangrove extents during 2001-2016 have increased by 538.5 ha. The period of 2001 – 2006 evidences an increase of mangroves and it continues to a significant increase during 2006 to 2011, while the period of 2011- 2016 experiences with an increase of mangrove extents. These findings imply that mangrove management is in good place and local people are aware of the roles of mangroves. Based on the findings, the study has given a number of solutions to better manage mangroves extents in the study site.

Acknowledgments

This research was conducted via the thesis project named "Using Landsat vegetation indices in quantifying coastal mangrove cover in Thai Thuy district, Thai Binh province" in 2016. The anonymous reviewers are thanked for their comments and suggestions for improving this paper.

REFERENCES

1. Baugh, W.M., Groeneveld, D.P. (2006) *Broadband vegetation index performance evaluated for a low-cover environment.* International Journal of Remote Sensing, 27 :4715–4730.

2. Crippen, R.E (1990). *Calculating the vegetation index faster*. Remote Sensing of Environment. 34:71–73.

3. C. Elachi, J. VanZyl (2006). *Introduction to the Physics and Techniques of Remote Sensing*. John Wiley & Sons, Hoboken, New Jersey.

4. Susan Barati, Behzad Rayegani, Mehdi Saati. *Comparison the accuracies of different spectral indices for estimation of vegetation cover fraction in sparse vegetated areas*. 49–56.

5. Z. Jiang, A.R. Huete, K. Didan, T. Miura (2008). *Development of a two-band enhanced vegetation index without a blue band*. Remote Sensing of Environment. 112:3833–3845.

6. A. Kallel, S. Le-Hégarat-Mascle, C. Ottlé, L. Hubert-Moy (2007). *Determination of vegetation cover fraction by inversion of a four-parameter model based on isoline parametrization*. Remote Sensing of Environment. 111:553–566.

7. L.M. Montandon, E.E. Small (2008). *The impact of soil reflectance on the quantification of the green vegetation fraction from NDVI*. Remote Sensing of Environment, 112 (2008): 1835–1845

8. A.J. Xiao, A. Moody (2005) *A comparison of methods for estimating fractional green vegetation cover within a desert-to-upland transition zone in central New Mexico, USA*. Remote Sensing of Environment, 98: 237–250.

SỬ DỤNG DỮ LIỆU ẢNH LANDSAT VÀ KHÁC BIỆT CHỈ SỐ THỰC VẬT ĐỂ PHÁT HIỆN BIẾN ĐỘNG RỪNG NGẬP MẶN: NGHIÊN CỨU ĐIỂM HUYỆN THÁI THỤY, TỈNH THÁI BÌNH

Nguyễn Hải Hòa, Trần Duy Bình

Trường Đại học Lâm nghiệp

TÓM TẮT

Sử dụng dữ liệu ảnh viễn thám Landsat đa thời gian và công nghệ GIS xác định sự biến động về diện tích rừng ngập mặn ven biển có ý nghĩa rất quan trọng trong xác định các nguyên nhân biến động và cung cấp cơ sở khoa học nâng cao hiệu quả quản lý rừng ngập mặn tại huyện Thái Thụy, tỉnh Thái Bình. Nghiên cứu đã sử dụng các chỉ số thực vật gồm NDVI, SAVI, IPVI, DVI, SR và RVI để lượng hóa và theo dõi biến động diện tích rừng ngập mặn, các chỉ số này được coi là một phương pháp phù hợp. Kết quả nghiên cứu cho thấy NDVI có độ chính xác cao nhất so với các chỉ số khác. Đối với sự biến động diện tích rừng ngập mặn, nhìn chung cả giai đoạn 2001- 2016, diện tích rừng ngập mặn tăng lên đáng kể với tổng diện tích là 538.5 ha. Giai đoạn 2001-2006 chứng kiến sự gia tăng diện tích với 454 ha được trồng và tiếp tục tăng với diện tích đáng kể vào giai đoạn 2006- 2011, trong khi diện tích rừng chỉ tăng lên không nhiều so với giai đoạn 2011 - 2016 với 80.3 ha. Nguyên nhân chính của sự gia tăng này là do các dự án trồng rừng và phục hồi rừng ngập mặn có hiệu quả. Kết quả nghiên cứu trên cho thấy hoạt động quản lý rừng ngập mặn tại khu vực nghiên cứu là tốt, người dân địa phương có nhận thức cao về tầm quan trọng của rừng ngập mặn. Trên cơ sở kết quả nghiên cứu, đề tài đã đưa ra một số đề xuất nhằm nâng cao hiệu quả quản lý rừng ngập mặn khu vực nghiên cứu.

Từ khóa: Che phủ bởi thực vật, chỉ số thực vật, chỉ số thực vật NDVI, Landsat, phát hiện sự thay đổi, viễn thám.

Reviewer	**: Assoc. Prof. Dr. Tran Quang Bao**
Received	**: 15/8/2016**
Revised	**: 30/9/2016**
Accepted	**: 10/10/2016**