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USING LANDSAT 8 TO ESTIMATE ABOVEGROUND BIOMASS AND CARBON STOCKS IN XUAN THUY NATIONAL PARK, NAM DINH PROVINCE

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Từ khóa: Aboveground biomass (AGB), carbon stocks, Landsat 8, Xuan Thuy National Park

TÓM TẮT

Mangroves is considered as one of the most important carbon sinks in the tropic and their roles are wellknown as preventing coastal shoreline erosion and mitigating impacts of storms and wave actions. The productivity of mangroves could be evaluated by estimating their biomass and carbon stocks. Nowadays, a various number of methods are used to estimate mangrove biomass and carbon stocks and one of them is commonly used as the remotely-sensed satellite data approach. In this study, Landsat 8 is used to identify the spatial distribution of mangroves using NDVI values, then to calculate total of aboveground biomass and carbon stocks of mangroves in the Xuan Thuy National Park. As a result, the average of mangrove diameter and height values are measured at 2.80 ± 0.23cm and 3.82 ± 0.52m, respectively. The NDVI values are used for mangrove classification with the accuracy of 88.3%. In general, the biomass of mangrove forests in Xuan Thuy National Park is relatively high, calculated at 62,692.8 ± 192.16 tons and carbon stocks are calculated as 29,465.6 ± 90.32 tons.

Keywords: Sinh khối bề mặt, trữ lượng cácbon, ảnh Landsat 8, VQG Xuân Thủy

Sử dụng ảnh Landsat 8 để ước tính sinh khối và trữ lượng carbon bề mặt rừng ngập mặn tại Vườn quốc gia Xuân Thủy, tỉnh Nam Định

Hệ sinh thái rừng ngập mặn được coi như bể chứa các bon quan trọng nhất trong vùng nhiệt đới. Năng suất của các hệ sinh thái rừng có thể được đánh giá bằng cách ước lượng sinh khối của nó. Việc đánh giá sinh khối rừng ngập mặn giúp chúng ta hiểu các quá trình và những thay đổi trong hệ thống rừng ngập mặn. Ngày nay có rất nhiều phương pháp để ước tính sinh khối trên mặt đất và trữ lượng các bon của rừng ngập mặn, một trong các phương pháp sử dụng đó là dùng tư liệu viễn thám. Nghiên cứu dựa vào việc sử dụng giá trị NDVI để xác định sự phân bố của rừng ngập mặn, tính toán tổng sinh khối trên mặt đất và trữ lượng cácbon của rừng ngập mặn tại Vườn quốc gia Xuân Thủy. Kết quả điều tra và tính toán cho thấy giá trị đường kính của rừng ngập mặn là 2,80 ± 0,23cm và chiều cao trung bình là 3,82 ± 0,52m. Chỉ số NDVI được sử dụng để xây dựng bản đồ phân bố rừng ngập mặn với độ chính xác là 88,3%. Nhìn chung, sinh khối và trữ lượng cácbon bề mặt đất tại vườn quốc gia Xuân Thủy ở mức tương đối cao. Giá trị sinh khối bề mặt đất của rừng ngập mặn là 62.692,8 ± 192,16 tấn và trữ lượng cácbon là 29.465,6 ± 90,32 tấn. Kết quả cho thấy trữ lượng cácbon và sinh khối bề mặt tại đây là tương đối cao. Qua đó, cần có các chính sách bảo tồn cácbon và quản lý rừng ngập mặn hiệu quả hơn theo cơ chế REDD+.

I. INTRODUCTION

Vietnam has more than 3200km of coastline and a lot of estuaries. In a developing country as Vietnam, the existence of the mangroves plays a very important roles in terms of not only fighting against natural disasters, inundation, environmental protection and climate regulators in coastal areas but also contributing to economic and social development of the country. Mangrove ecosystem productivity can be evaluated by estimating its biomass and carbon stocks. Biomass estimation is very important for evaluating forest ecosystem productivity and controlling carbon budgets (Zianis and Mencuccini, 2004, Hall *et al.,* 2006). Accurate prediction of biomass is crutial to better understand the carbon cycles in mangrove ecosystems, which act as a major pool of carbon (Houghton, 2005). Various techniques, such as ground measurements (Schroeder *et al*., 1997, Houghton *et al*., 2001) and remotely-sensed data (Foody *et al*., 2003, Lu, 2005), have been used to estimate the amount of biomass and its carbon stocks. Nowadays, one of the most common methods to determine mangrove AGB and carbon stocks is based on using remotely-sensed data. In Vietnam, remote sensing and GIS technologies have been paid much attention to calculate biomass and carbon stocks. Multi-spectral imagery in various resolution allows to quickly gather synchronized and objective information of many factors affecting mangroves in Xuan Thuy National Park, including temperature and humidity. This technical approach is still not well-recognized for people in Vietnam. This study intends to determine the spatial distribution of coastal mangroves at Xuan Thuy National Park, then estimate biomass and carbon stocks of mangroves using Landsat images and field-based data. Finally, possible solutions are given to better manage coastal mangroves in studied areas.

II. MATERIALS AND METHODS

2.1. Study materials

Table 1. Remotely sensing data used in the study

ID	Landsat and Sentinel codes	Date	Resolution (m)	Path/Row
1	LC81260462016191LGN00	17/07/2016	30	126/46

Source: http://glovis.usgs.com.

2.2. Study site

Xuan Thuy National Park is located in Giao Thuy District, Nam Dinh Province, 150km away on South-East from Hanoi. It is well-known as one of the largest coastal ecosystems in the North of Vietnam and placed in the South of the Red River mouth. The core zone has a total area of 7,100ha of which has 4,000ha of low tidal wetlands and 3,100ha of land. It covers the islets of Con Ngan, Con Lu and Con Xanh. Con Ngan is known as the largest islet, which is covered by the aquaculture farming and mangroves, while Con Lu islet is ocupied by sandy and aquaculture farming. Giao Thuy district is situated in tropical monsoon region, which has two distinct seasons. Hot and rainy seasons last from April to October, whereas cold and dry seasons start from November untill the next March. The annual average temperature is around 24°C. The highest temperature in summer is about 40.3°C, while the coldest temperature in winter is around 6.8°C. The average humidity is around 84%, while the annual average rainfall is between 1,700 and 1,800mm with 133 rainy days year^{-1}.

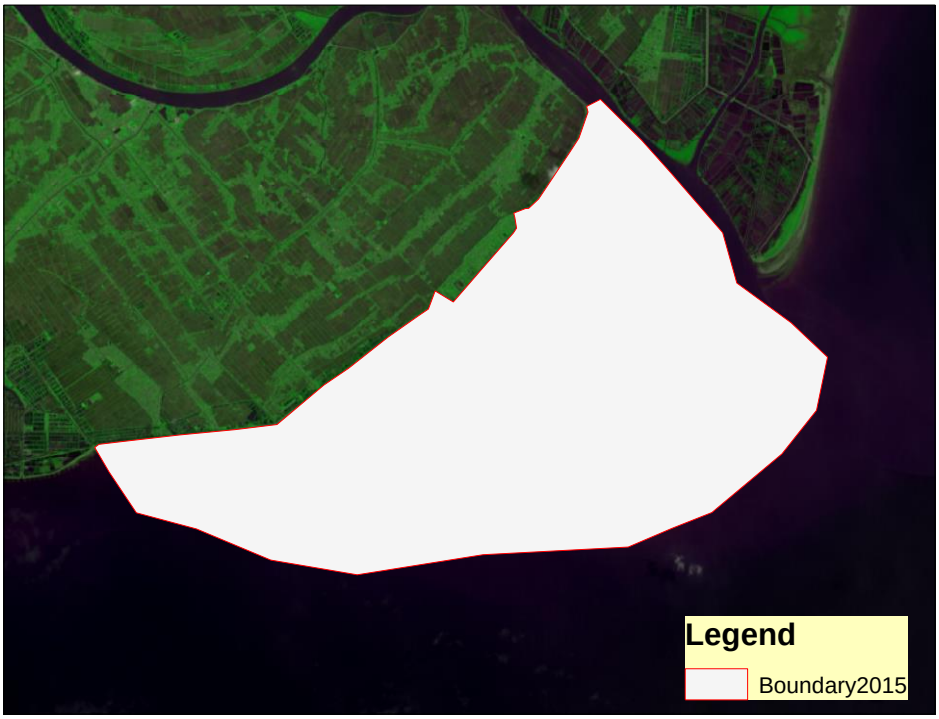

Fig. 1. Location of the study area (Landsat 8 2016, Composite bands: 453)

Plot layouts and field data collection:

There were 8 plots with dimension of 20m × 20m (equivalent to 400m^2) set up to investigate mangrove structures, namely canopy height, diameter, species and density. Each plot has five sub-plots indicated as Fig. 2 as below.

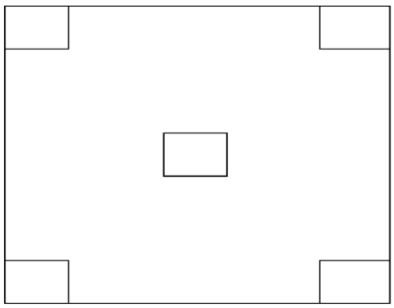

Fig. 02. Spatial layout of sampling plots and subplots this study

After setting up plots and sub-plots, the key information of species names, number of species, canopy height, crown diameter and healthy condition of mangroves was collected to determine the quality and situation of mangroves and then calculate its biomass, carbon stocks. The study also used the GPS 650 Garmin to mark key points for accuracy assessment and classification purposes. The coordinates were recorded and imported into ArcMap 10.2. In this study, estimating canopy cover each plot was conducted using 100 point-based counting approach.

Mapping status of mangroves and their spatial distribution in 2016

The process of interpretation of 2016 Landsat 8 satellite images and mangrove distribution map is explained as following diagram:

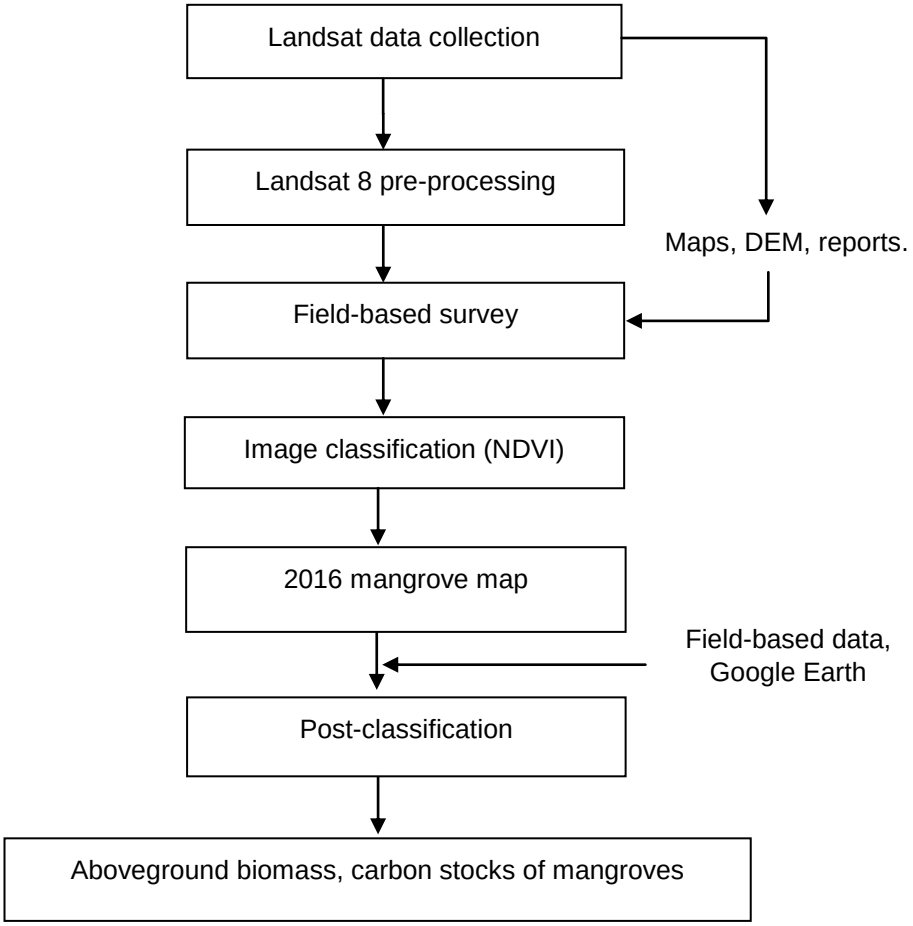

Diagram 1. Flow chart of estimating biomass and carbon stocks

As shown in Diagram 1, estimating biomass and carbon stocks could be explained as the following steps:

Step 1: Collecting data: Primary data collection is conducting by fieldwork and retrieving data about National Park collection, namely collecting Landsat 8 data and processing data to GIS.

Step 2: Landsat image pre-processing: This process includes downloading images from satellite map, setting boundaries, cutting, processing images and compositing bands for the best display.

Step 3: Constructing mangrove distribution maps using Normalised Differences Vegetation Index (NDVI).

$$NDVI = (Band_{NIR} - Band_{Red})/(Band_{NIR}+Band_{Red}) \quad (1)$$

Where $Band_{NIR}$ = Band 5, $Band_{Red}$ = Band 4 for Landsat 8.

Step 4: Assessing the accuracy of classification method: The quality of mangrove maps is only valid as its accuracy is assessed and recognised. Therefore, it is necessary to assess the accuract of the information by using the ground truthing-based approach (Table 4).

Step 5: Post classification: The quality of the remote sensing images can be improved by combining bands. Landsat images classified is categorised into two big groups, mangrove and non- mangrove group, including residential, water, agriculture, industrial areas.

Mangrove aboveground biomass and carbon stocks estimation

To calculate mangrove biomass: due to the research area's domination with *Kandelia obovata species*, so this study uses the formula, which is developed by Khan (2009) as below.

Biomass of *Kandelia obovata* = $3.203 \times 10^{-2} (D^2_{0.1} \times H)^{1.058}$ (2)

Where $D_{0.1}$ is the distance from *Kandelia obovata's* stump to position measured.

To calculate mangrove carbon stocks: This study uses the equation developed by IPCC (2016).

Carbon stock = Biomass × 0.47 (3)

III. RESULTS AND DISCUSSION

3.1. Mangrove species, structures and its spatial distribution

Mangrove species:

The findings show that coastal mangroves extend along the Southeast of Nam Dinh, but are mainly found in the coastal communes of Giao Thuy district. Environmental conditions for the growth of mangroves are characterised as muddy, with high water and low oxygen levels, low salinity concentration and slow drainage.

As a result shown, there are three main mangrove species identified in this study site, namely *Kandelia obovate*, *Aegiceras corniculatum and Sonneratia caseolaris species*. In particular, mangroves were planted in Con Lu with *Aegiceras corniculatum*, *Caseolaris sonneratia*, *Avicennia marina*, *Acanthus ilicifolius* species, which have formed the mixed mangrove areas adjacent to the buffer zone; and separate monoculture areas of *Kandelia obovata*, *Aegiceras corniculatum*, *Sonneratia caseolaris* species. Further field survey and interviews of 30 households Giao Thuy in the core and buffer zones have also evidenced that coastal mangroves were planted during the period of 1995 - 1998 and showed that mangrove plantation was mainly carried out with the national funds of 327 Program.

Table 2. Plots information and mangrove characteristics in study site

Plot	Location	Coordinates		Dominant species
		Latitude	Longitude	
1	Con Lu	20.24414	106.571678	*Kandelia obovata, Aegiceras corniculata*
2	Con Lu	20.22038	106.54900	*Kandelia obovata*
3	Con Lu	20.24396	106.57148	*Kandelia obovata, Aegiceras corniculata*
4	Con Lu	20.25371	106.57028	*Kandelia obovata, Sonneratia caseolaris*; *Rhizophora stylosa, Kandelia candel*, *Aegiceras corniculata*
5	Con Lu	20.23942	106.57504	*Kandelia obovata*
6	Con Lu	20.23521	106.56779	*Kandelia obovata*
7	Con Lu	20.22426	106.55946	*Kandelia obovata*
8	Con Lu	20.215450	106.552673	*Kandelia obovata*

As Table 2 shows that mangrove species were recorded in both core and buffer zones of Xuan Thuy National Park. Species identified include *Sonneratia caseolaris*; *Rhizophora stylosa*, *Kandelia candel* and *Aegiceras corniculata*.

Key mangrove structures: The standard plots were established to investigate and monitor the growth of specific species in study areas as presented in Table 3.

Table 3. Averaged diameters and heights of mangroves.

Plot	Location	Coordinates		Average D_{01} (cm)	Average canopy height (m)
		Latitude	Longitude		
1	Con Lu	20.24414	106.57168	2.80 ± 0.30	3.80 ± 0.5
2	Con Lu	20.22038	106.54900	2.90 ± 0.20	3.78 ± 0.6
3	Con Lu	20.24396	106.57148	2.70 ± 0.15	3.85 ± 0.6
4	Con Lu	20.25371	106.57028	2.85 ± 0.25	3.47 ± 0.5
5	Con Lu	20.23942	106.57504	2.80 ± 0.15	3.89 ± 0.30
6	Con Lu	20.23521	106.56779	2.90 ± 0.30	3.89 ± 0.55
7	Con Lu	20.22426	106.55946	2.80 ± 0.30	3.98 ± 0.60
8	Con Lu	20.21545	106.55267	2.80 ± 0.20	3.85 ± 0.50
Average				2.82 ±0.23	3.82 ±0.52

Where D_{01} is a distance from stump to position measured at 10cm.

As Table 3 shows that there is not much variation of averaged diameter and canopy height values among plots, but there is much difference between the minimun and maximum values of diameters and heights within each plots and among plots.

Spatial distribution of mangroves:

In this study, Normalized Difference Vegetation Index known as NDVI was used to identify spatial distribution of mangroves in Xuan Thuy National Park as indicated in Fig. 3.

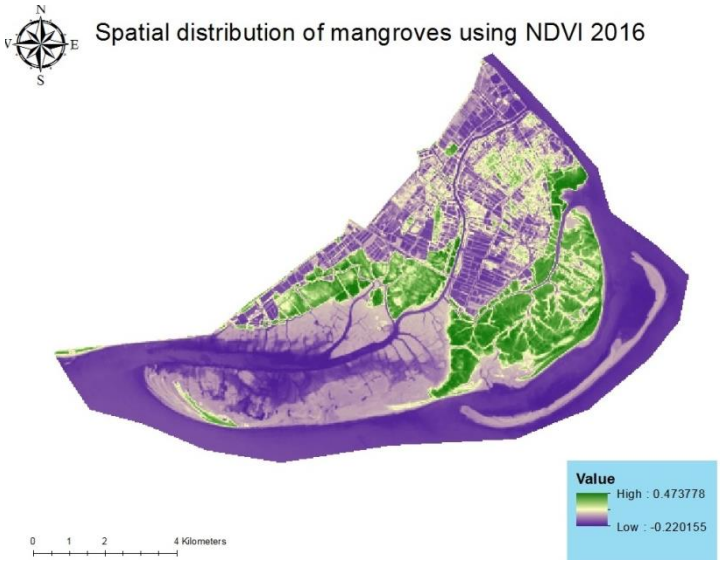

Fig. 3. Spatial distribution of mangroves using NDVI (Landsat 8 2016)

As shown in Fig. 3, the range of NDVI values is from -0.22 to 0.47. The highest values are, then the most densely populated are mangroves, while values below zero identified are wetlands, wet soils and bare ground. As result indicated that NDVI values that range from 0.19 to 0.47 and from -0.22 to 0.19 are mangroves; and other plants, agriculture, bare

soils and others respectively. Similarly, calculation of SAVI (Soil Adjusted Vegetation Index) values are also relatively high, ranging from -0.25 to 0.66. This range is broader than that of NDVI values, but mangroves have a similar threshold of values as 0.19. These findings are same as previous studies and also reconfirmed by Khairul (2011) in Tumpat, Kelantan Delta, East Coast of Peninsular Malaysia.

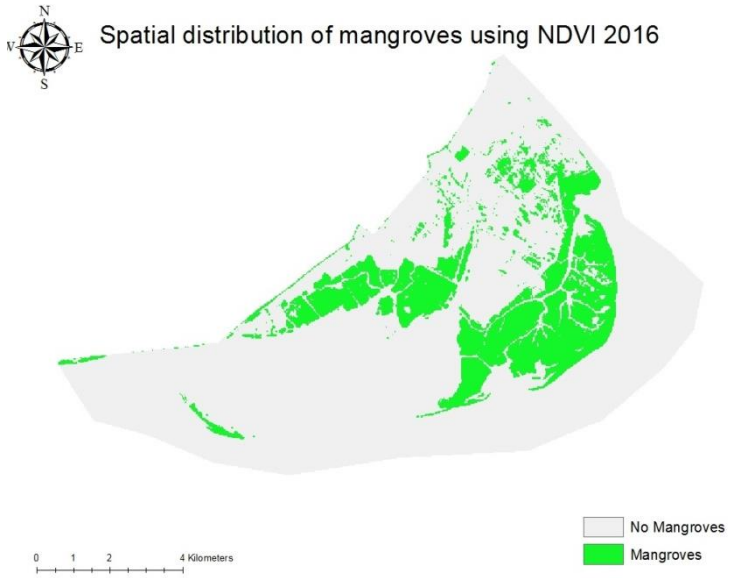

Fig. 4. Spatial distribution of mangrove extents in 2016 (Landsat 8, 2016)

Accuracy assessment of classified mangrove map

To assess the accuracy of the training samples for classifying coastal mangroves, the study used the same set of test data points in the field for the different samples and objects collected by GPS 650. Comparison of ground truthing and classified image helps to assess the accuracy of classified image.

Table 4. Accuracy assessment of classified map by Landsat 8 (ha).

Samples by GPS / Map classifed by GPS	Mangroves	Bare, Wet Soil	Water	Total	Accuracy (%)
Mangroves	33	3	4	40	82.5
Bare, Wet Soil	5	35	0	40	87.5
Water	2	0	38	40	95.0
Total	**40**	**38**	**42**	**120**	**88.3**

Results shows that overall accuracy of classified map in 2016 is 88.3%. In general, the accuracy of classified map is relatively high. However, training samples for classifying coastal mangroves can be used in the analysis and image interpretation of these areas and could be applied to other similar coastal researches connected with mangroves in Vietnam.

3.2. Quantification of mangrove extents, biomass and carbon stocks of mangroves

Results of field survey has shown that there are three main mangrove species identified,

including *Kandelia obovata, Aegiceras corniculatum and Sonneratia caseolaris,* in particular among three species, *Kandelia obovata* is the most dominant mangrove species. Therefore, this study has selected *Kandelia obovata* as representative of mangroves species for calculating biomass and carbon stocks.

Calculation of mangrove extents

In this study, mangrove and its extents are classified and defined by using NDVI values as shown in Table 5.

Table 5. Mangrove extents classified by Normalised Difference Vegetation Index (ha).

Classified objects	Area
Mangroves	1909.6
Non- mangroves	7758.8

Where non- mangroves include other plants, agriculture, water bodies, bare and wet soil.

As Table 5 shown that extents of mangroves and non-mangroves are 1909.6 and 7758.8ha respectively. In particular, the total areas of non-mangroves is three times largger than that of mangroves, showing that there is a great potential opportunities for mangrove plantation expansion in Xuan Thuy National Park.

Calculation of mangrove biomass and carbon stocks:

Based on the result of averaged plot investigation, mangrove structures were measured in all eight plots, then they are taken as an average below:

D_{01} = 2.80 ± 0.23 (cm) equivalent to 0.028 ± 0.0023 (m), while the averaged values of height (H) = 3.82 ± 0.52 (m).

Based on the formula of *Kandelia obovata* developed by Khan (2009), the study has a formula as below:

Biomass of *Kandelia obovata* = $3.203 \times 10^{-2} \times (D^2_{0.1} \times H)^{1.058}$

Where $D^2_{0.1}$ is distance from the stump to position measured (10cm) and H is height of the mangrove species.

AGB *Kadelia obovata* = $3.203 \times 10^{-2} \times (0.028^2 \times 3.82)^{1.058} = 0.684 \times 10^{-5} \pm 4.19 \times 10^{-8}$ (kg/tree)

The result of surveyed plot showed that there are an average of 240 *Kandelia obovata* tree plot^{-1}. Therefore, the average of AGB in surveyed plot = 0.684 x10^{-5} × 240 tree/plot × 10000 = 32.83 ± 0.10 tons ha^{-1}

So, the total of AGB in Xuan Thuy National Park = 32.83 × 1909.62 = 62,692.8 ± 192.16 tons

This study has used the formula for calculation of carbon stocks, which is developed by IPCC (2016): Carbon = Biomass × 0.47

As a result of total carbon of *Kandelia obovata* forests in Xuan Thuy, Nam Dinh is

62,692.8 × 0.47 = 29,465.6 ± 90.32 tons

3.3. Enhancing measures for better mangrove management

Mangroves are well-known as a valuable natural wealth and they have received the attention from both local and national government levels. It is important to propose solutions for better management of coastal mangroves sustainably based on the findings.

Implementation of REDD+ program to coastal mangroves

Payments for environmental services (PES) or mechanisms of REDD+ should be studied and applied in Xuan Thuy National Park, which is more likely to significantly contribute to sustainable mangrove management. One of options is known as REDD+ mechanisms, which act as forest carbon sequestration

services. These mechanism are tied in with reducing emissions from deforestation, forest degradation and enhancing forest carbon stocks (REDD+). Vietnam has approved a National Action Plan with special emphasis on mangroves which has played as the basis for reducing greenhouse gas emissions from forestry sector.

The basic idea of payments for environmental services (PES) is to encourage local people to protect environment by compensating them all costs incurred during sustainable management. In 2004, the government of Vietnam have created a base for a nationwide program of Payments for Forest Environmental Services (PFES), specified in revised Forest Protection and Development Law.

Enhancement of communication channels

The means of mass media, including newspapers, radio and television are also needed to strengthen propaganda for information on climate change, mitigate impacts of climate change, enhance the functions of mangroves in terms of coastal protection and mitigating coastal erosion and other damages caused by extreme natural disasters. Organizing field training courses and sustain models of coastal livelihoods to increase people's incomes may contribute to better management of mangroves.

Improvement of socio-economic benefits

There is a need to establish more transparent regulations about illegal exploitation leading to mangrove degradation and deforestation or and excessive activities connected with aquaculture farming. As study shown that mangroves have been replaced by aquaculture activities in some areas, so the state government regulations also should be tougher in forest land allocation in combination with economic development. The results from the study in Giao Thuy, Nam Dinh showed that local people are heavily dependent on accessing mangrove resources for their daily livelihoods, such as fisheries activities with an average of 20 ± 30 times month^{1}, bringing yearly income around 35 ± 40 million per household year^{-1}. Therefore, the government should have a clear policy on stabilising local livelihoods on fisheries, which could encourage people to protect mangroves.

IV. CONCLUSSION

Application of remotely sensed data for mangrove biomass and carbon stocks mapping is a very effective method. The average of mangrove diameter and height values are measured at 2.80± 0.23 cm and 3.82 ± 0.52 m, respectively. The NDVI values are used for mangrove classification with the accucary of 88.3%. In general, the biomass of mangrove forests in Xuan Thuy National Park is relatively high, calculated at 62,692.8 ± 192.16 tons and carbon stocks are calculated as 29,465.6 ± 90.32 tons. However, this study found that some places have lower biomass values due to on the smaller size of the trees (Saenger 2002; Komiyama *et al*., 2008; Alongi 2008). These findings also have proved that using Landsat 8 in combination with field-based data for estimating biomass and carbon stocks is reliable and applicable to study mangroves.

Acknowledgments

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