ESTIMATION OF CHANGES IN MANGROVE CARBON STOCKS FROM REMOTELY SENSED DATA-BASED MODELS: CASE STUDY IN QUANG YEN TOWN, QUANG NINH PROVINCE DURING 2017 - 2019

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SUMMARY

Mangroves or tide-dominated mangroves are found along shallow shorelines with modest slope where they receive freshwater runoff and nutrients from rainfall. They have been globally recognised as their vital functions in preventing coastal erosion, mitigating effects of wave actions and protecting coastal habitats and adjacent shoreline land-uses from extreme coastal events. By using Sentinel 2A imageries, the study has constructed the spatial ditribution of mangrove forests in 2017 and 2019. The accuracy evaluation showed that the overall accuracy of the 2019 Sentinel classification was 89.0%, while accuracy assessments of 2017 Sentinel image also was 87.7% overall accuracy. There were 1822.9 ha of mangrove forests in March 2019, 2476.1 ha in December 2017. The AGB and C stocks of mangrove forests in Quang Yen has changed over time. There were small variations of AGB and C stocks of mangrove forests between field measurements and Sentinel-based estimation in 2019. Therefore, the study highly suggests that using Sentinel imageries to estimate AGB and C stocks of mangrove forests is reliable and applicable to Quang Ninh coast and it should be expanded in other similar coastal areas in Quang Ninh province.

Keywords: AGB (Above-ground biomass), C stocks, mangrove forests, NDVI, Sentinel 2.

1. INTRODUCTION

Mangroves or tide-dominated mangroves are found along shallow shorelines with modest slope where they receive freshwater runoff and nutrients from rainfall and have a high salinity concentration (Aschbacher et al., 1995; Giri et al., 2008; Lovelock et al., 2006; Liang et al., 2008; River-Monroy et al., 2008). They are also subject to wave actions and storm surges (Baldwin et al., 2001) and are flushed by regular tides (Lugo and Snedaker, 1974). Significantly, mangroves have been globally recognised as their vital functions in preventing coastal erosion, mitigating effects of wave actions, currents and storm surges, and protecting coastal habitats and adjacent shoreline land-uses from extreme coastal events (Lee et al., 2014; Mazda et al., 1997; Tamin et al., 2011). Although these significantly functional values of mangroves are well-recognised, they are still being destroyed and degraded for coastal settlement, aquaculture, resulting in a loss of ecosystem services and associated economic benefits (Thampanya et al., 2006). Consequently, a rapid reduction of mangrove extents together with the associated impacts of increased severity of storms has the potential to impact catastrophically on coastal communities.

In Vietnam, mangroves are recently recognised as a highly valuable resource (Hanh and Furukawa, 2007). These unique coastal forests provide multiple ecosystem services, including carbon storage, wood production for building, fish trap construction and firewood, habitat for aquatic food resources, and most importantly shoreline stability and erosion control (Lee et al., 2014; Spalding et al., 2014). However, the area of mangrove forests has rapidly declined over time; from an estimated 408,500 ha in 1943 to 290,000 ha in 1962, to 252,000 ha in 1982; and to 155,290 ha in 2000 (Government of Vietnam, 2005; Sam et al., 2005). Remarkably, recent evidence have shown that the area of mangrove forests increased to 210,00 ha in 2008 due to a National Action Plan for Mangrove Protection and Development; other international mangrove restoration and rehabilitation programs (Government of Vietnam, 2005; Sam et al., 2005; Hai-Hoa, 2014). Despite this national increase, some areas are still experiencing with decline of mangrove covers. In Quang Ninh province, increased fragmentation of mangroves has reduced their capacity to withstand coastal processes, such as coastal currents, wave actions, semi-exposed coastline locations (Gilman et al., 2008; Hai-Hoa, 2014; Hai-Hoa et al., 2013). In addition, underestimating the value of mangroves, weak management and protection have also led to severe degradation of mangroves over the years. This is resulting in the loss of key mangrove resources and associated ecosystem services, also threatening the local livelihoods by increased vulnerability of coastal communities to storm surges with large storms and typhoons. Therefore, an integrated approaches, including payments for carbon sequestration of mangrove forests should be adopted to restore and re-establish mangrove in Quang Ninh province.

Currently, climate change has been affecting negatively the world-wide environment and Vietnam is one of the most severely affected countries, including Quang Ninh province (Tri et al., 1998; Ward et al., 2016; Krauss, 2014). Therefore, to reduce carbon emissions from mangrove restoration and rehabilitation activities, monitoring mangrove forests emission is extremely essential due to main carbon storage sources in the world from mangrove forests (Dittmar et al., 2006; Tue et al., 2014).

In order to estimate mangrove ecosystem services, including carbon sequestration, it is necessary to first assess trends of mangrove dynamics associated with biomass and carbon stocks in Quang Ninh province. Various remote sensing technologies and techniques have extensively applied to monitor mangrove forests dynamics and estimate carbon stocks due to their large spatial- temporal coverage, cost effectiveness, ready availability and applicability (Aschbacher et al., 1995; Rozenstein and Karnieli, 2011; Stoms and Estes, 1993; Rajitha et al., 2008; Zhang et al., 2016; Zhu et al., 2012; Akumu et al., 2010; Tuxen et al., 2011). Despite the global extensive application of remote sensing and GIS technologies and techniques to monitor spatial-temporal dynamics of mangrove forests, such as extents, biomass and carbon stocks, accurate and reliable information regarding estimation of mangrove biomass and carbon stocks based on remote sensing data in Quang Ninh and Vietnam in general are very limited.

The aim of this paper was to quantify spatial-temporal dynamics of mangrove forests Quang Yent town, Quang Ninh province from 2017 to 2019 using Sentinel 2A imageries. It then estimated above-ground mangrove biomass and carbon stocks, and their changes. These findings were used to inform coastal management planning and policy development, particularly related to sustainable management of mangrove forests and likelihood improvements in the face of a changing climate in Vietnam.

2. STUDY SITE AND METHODS

2.1. Study site

Quang Yen is a coastal town of Quang Ninh province in the Red River Delta region of Vietnam that covers an area of 314.2 km². This district has population of 137,198. This study selected Quang Yen town as a study site due to mainly spatial distribution of mangrove forests with dominant species, known as Sonneratia caseolaris, Aegiceras corniculatum, Avicennia, Bruguiera gymnorrhiza. More importantly, this area is currently under great pressure from urbanization and shrimp farming activities (Fig. 1).

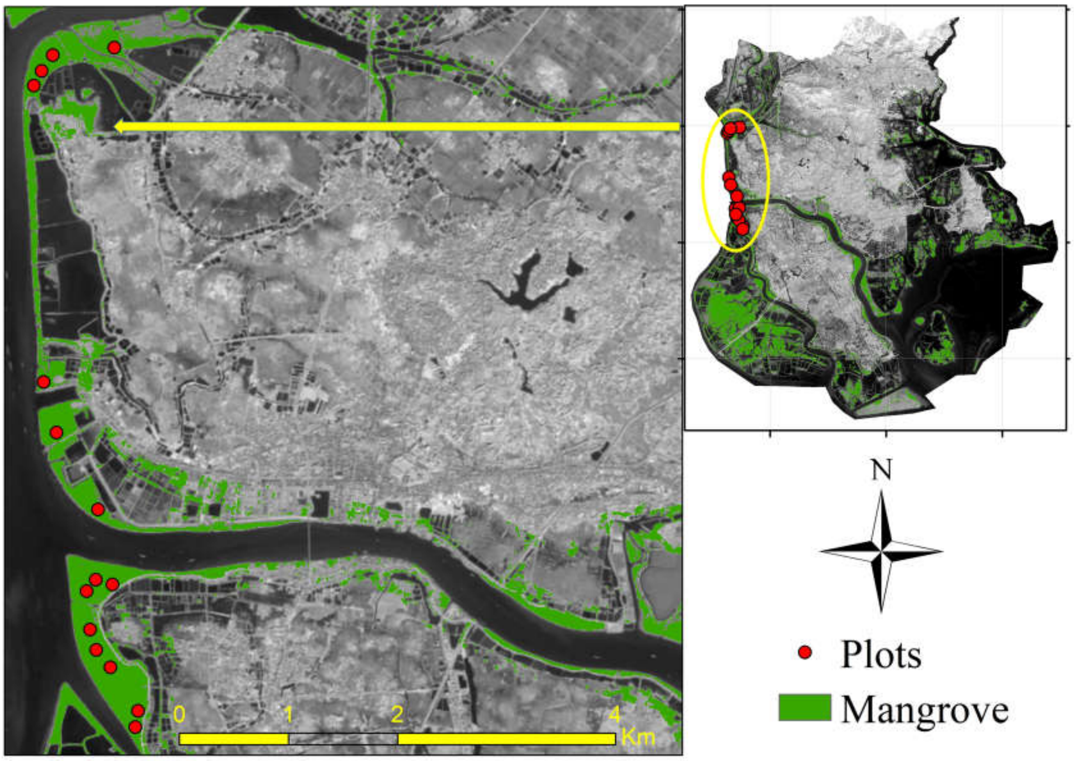


Figure 1. Study site in Quang Yen town, Quang Ninh province

2.2. Methods

2.2.1. Remote sensing data

In this study, the multi-temporal Sentinel imageries (2017- 2019) were used to detect mangrove covers; and then to calculate above-ground mangrove biomass and carbon stocks (table 1).

Table 1. Remote satellite imageries used in this study

ID	Image codes	Date	Resolution (m)	Remarks
1	L1C20190312T033026	12/03/2019	10x10	Sentinel
2	L1C20171217T033108	17/12/2019	10x10	Sentinel
3	20170529_023938_1027_3B_AnalyticMS	29/05/2017	3x3	PlanetScope
	20170605_062515_0c43_3B_AnalyticMS	05/06/2017	3x3	PlanetScope
	20170605_062516_0c43_3B_AnalyticMS	05/06/2017	3x3	PlanetScope
	20170529_023937_1027_3B_AnalyticMS	29/05/2017	3x3	PlanetScope
4	Forest status map in Quang Ninh	2015	1/50,000	

Source: http://earthexplorer.usgs.gov; https://www.planet.com/explorer

In addition, PlanetScope images in 2017 were used for accuracy assessments of 2017 Sentinel image in combination with the field survey conducted in 2019 because PlanetScope image offers higher spatial resolution (3 x 3 m) than Sentinel images (10 x 10 m).

2.2.2. Field data collection

Study gathered the ground reference data to guide the classification scheme, train the classification of the imagery and to analyse the accuracy of the final map. The field observations extended to over the Quang Yen coast where mangroves have been found. In this study, a total of 15 sampling plots were conducted to collect mangrove characteristics in 2019, such as species name, the diameter at the breast height and land-use information. The sampling plots were conducted along the shoreline with a dimension of 25 x 20 m (500 m^2). In addition, there were additional 155 GPS points in 2017 and 200 points in 2019 collected for three classes across over Quang Yen site for accuracy assessments.

2.2.3. Image analysis

Sentinel images were already geo-referenced. In order to obtain a pixel-to-pixel match between two images, Sentinel 2A in 2019 was used to register 2017 Sentinel to improve geometric accuracy. This geometric correction was required to improve the geo-location to a root mean square error of less than a pixel and accuracy of subsequent change analysis. All images were geo-referenced to UTM WGS 1984 Zone 48N projection and datum.

The mask was then used to define the mangrove area in the pre-processed Sentinel images (2017 and 2019), and PlanetScope images (2017). These images were clipped to extract only areas where mangroves were more likely to be present (e.g. low-lying areas and inter-tidal zones), and to exclude large coastal areas where mangroves did not occur (e.g. far inland, highlands and open ocean) before the image classification was undertaken (Long and Giri, 2011).

2.2.3.1. Image classification

In this study, Normalised Difference Vegetation Index (NDVI) was mainly used in combination with Unsupervised Classification approach for improvements of image classification (Rakotomavo, 2010; Thampanya et al., 2006). NDVI is defined as:

$$NDVI = (\rho 8 - \rho 4)/ (\rho 8 + \rho 4)$$

Where ρ4 and ρ8 are known as the reflectance values from Band 4 (RED) and Band 8 (NIR) of a Sentinel image, respectively. NDVI has been used extensively and intensively to estimate vegetation properties, despite being prone to noise from variation in atmospheric and soil conditions, and tending to saturate with increasing vegetation density (Gao, 1996). NDVI values range from -1.0 to 1.0, but are between 0 and 1 for vegetation because ρ8 is typically larger than ρ4 (Gao, 1996).

Raster Caculator in Spatial Analyst Tools in ArcGIS (Version 10.4.1) was used to calculate NDVI values and mangrove biomass and carbon stocks. In this study, images were classified using spectral signatures obtained from the ground truthing. These training samples were selected as points to represent distinct samples areas of various land cover types to be classified as mangroves, water and others (bare/wet soils, built-up areas…).

2.2.3.2. Post classification and accuracy assessments

In post-classification process, the filtering process was also applied to remove isolated pixels or noise from the classification output. The filtered classified image was then used as the final mangrove cover map for each year. The spectral classes were visually compared with reference data derived from the sampling plots, ground truthing, Google Earth, LULC map sheet (1/50,000) to verity land cover classification accuracy. The 2017 PlanetScope image (3 x 3 m) provided a higher spatial resolution reference data was suitable for assessing the classification accuracy of the Sentinel 2A in 2017. Therefore, the accuracy matrix was conducted based on comparison of the 2017 PlanetScope and 2017 Sentinel image, while the 2019 Sentinel image was assessed based on Google Earth and field survey.

2.2.3.3. Estimation of mangrove biomass, carbon stocks

In order to calculate the above-ground biomass (AGB), this study used the regression model developed from the independent variable Normalized Difference Vegetation Index (NDVI) by Myeong et al. (2006) shown as below:

$$\mathbf{AGB = 0.507 * e^{(NDVI*9.933)}}$$

Carbon stocks were then obtained by multiplying the total biomass with a conversion factor of 0.475 (47.5% of biomass).

Changes in mangrove biomass and carbon stocks were carried out by using the Spatial Analyst Tools in ArcGIS 10.4.1.

3. RESULTS AND DISCUSSION

3.1. Mangrove forest extents in Quang Yen

The accuracy evaluation showed that the overall accuracy of the 2019 Sentinel classification was 89.0% with user accuracy 88.7% and producer accuracy 88.0% for mangrove extents (table 2). The accuracy assessments of 2017 Sentinel image also showed more than 87.7% overall accuracy, while user accuracy was high for all classes (table 3). It was therefore assumed that using Sentinel images were adequate for mapping temporal changes in mangrove forests in Quang Yen.

Table 2. Accuracy assessments of Sentinel classification in 2019

Image classified	Ground truthing				
	M	**W**	**Oth**	**Total**	**User's accuracy (%)**
M	86	4	5	95	90.5
W	4	40	2	45	88.9
Oth	4	4	52	60	86.7
Total	93	48	59	200	
Producer's accuracy (%)	92.5	83.3	88.1		

M (Mangroves); W (Water); Oth (Others). Overal accuracy is 89.0%.

Table 3. Accuracy assessments of Sentinel classification in 2017

Image classified	Ground truthing				
	M	**W**	**Oth**	**Total**	**User's accuracy (%)**
M	**67**	3	5	75	89.3
W	2	**25**	3	30	83.3
Oth	3	3	**44**	50	88.0
Total	*73*	*30*	*49*	*155*	
Producer's accuracy (%)	93.1	80.6	84.6		

M (Mangroves); W (Water); Oth (Others). Overal accuracy is 87.7%.

Spatial mangrove forest extents in Quang Yen town

As a result of image classification shown that there were 2476.1 ha and 1822.9 ha of mangrove covers in 2017 and 2019, respectively (Fig. 2).

As can be seen from Fig. 2, there were 3 classes of land cover types classified in 2017 and 2019, including mangroves (NVDI > 0.38); water (NDVI < 0.05); and others (0.05 < NDVI < 0.38) including wet/bare soil, built-up areas, other plants... In this study, mangrove forests were a main theme. They were therefore separated from water and others for later estimation of mangrove biomass and carbon stocks.

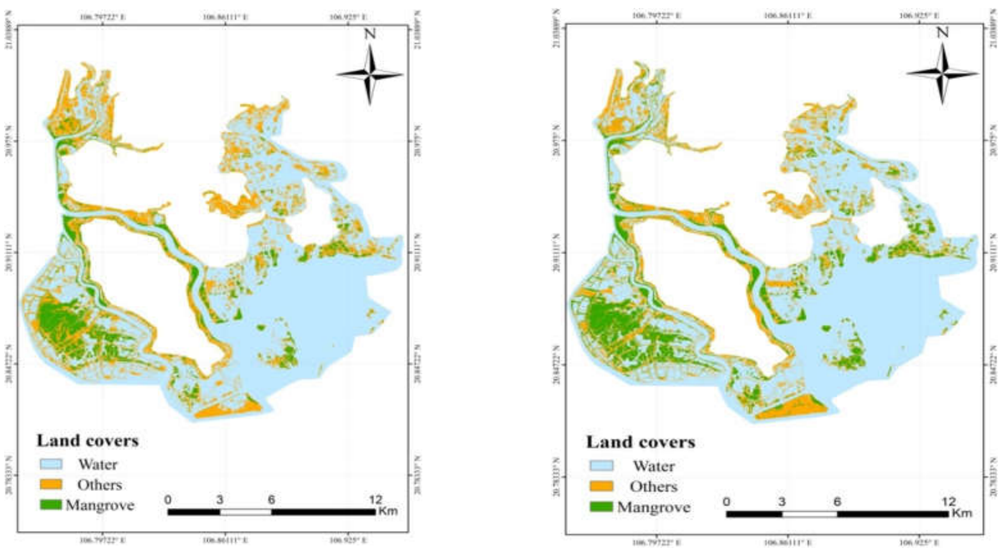


Figure 2. Spatial distribution of mangrove extents by Sentinel 2A 12/03/2019 (a); Sentinel 2A 17/12/2017 (b) in Quang Yen

3.2. Estimation of mangrove biomass and carbon stocks

3.2.1. Mangrove biomass and carbon stocks

In this study, the Myeong's model was adopted to estimate AGB of mangrove forests in 2017 and 2019 for Quang Yen (Myeong et al., 2006), then above-ground carbon stocks were estimated. The results shown as in fig. 3 and fig. 4.

Spatial distribution of AGB of mangrove forests in Quang Yen:

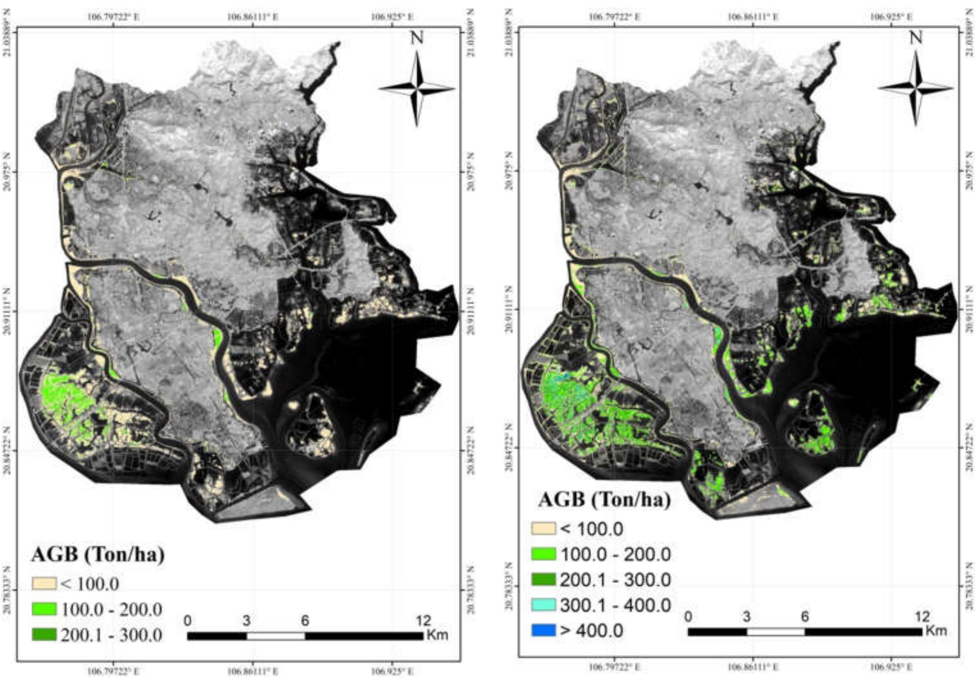


Figure 3. Spatial distribution of AGB of mangrove forests in 2019 (a) and 2017 (b)

As shown in fig. 3, AGB of mangrove forests in Quang Yen has changed over time. In 2017, the area of mangrove forests with AGB greater than 100.0 tons ha^{-1} was estimated at 1028.1 ha^{-1}, while the remaining areas were less than 100.0 tons ha^{-1} (about 1449.3 ha). In 2019, the area with AGB of mangrove forests less than 100.0 tons ha^{-1} increased to 75.9 ha, while there were 655.5 ha experienced with AGB decreased in comparison with 2017 (table 3). It is assumed that the loss of mangrove areas has contributed to an reduction of AGB of mangrove forests, nearly 654.5 ha lost during 2017 - 2019.

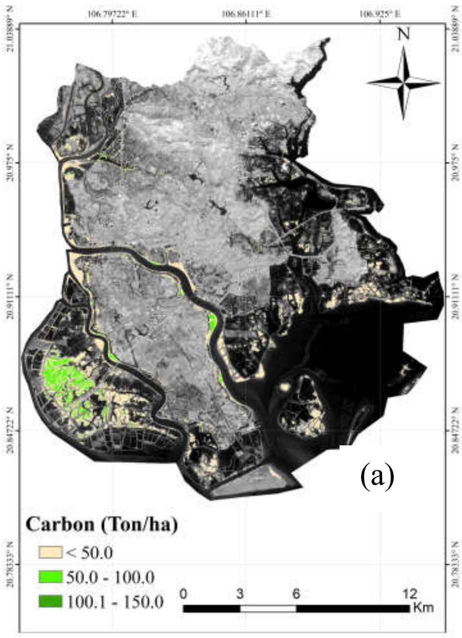
Table 4. Mangrove areas classified by classes of biomass and carbon stocks.

Classes of AGB	Dec 2017	Mar 2019	2017-2019	Classes of C	Dec 2017	Mar 2019	2017-2019
< 100.0	1449.3	1525.2	75.9	< 50.0	1496.6	1560.8	64.0
100.0 ÷ 200.0	664.7	295.2	-369.5	50.0 ÷ 100.0	667.9	261.2	-406.7
201.0 ÷ 300.0	281.1	2.5	-278.6	101.0 ÷ 200.0	249.7	0.9	-248.8
301.0 ÷ 400.0	69.8	-		15.1 ÷ 200.0	54.5	-	
> 400.0	12.5	-		> 200.0	8.6	-	
Area (ha)	**2477.4**	**1822.9**			**2476.2**	**1822.9**	

(+) refers to the areas of mangrove forest increased, (-) refers to the areas of mangrove forests decreased.

Spatial distribution of C stocks of mangrove forests in Quang Yen:

As results of C stocks of mangrove forests estimated shown in table 4 and fig. 4, there were large changes in C stocks of mangroves accumulated between two years. In particular, the most of mangrove areas (1349.7 ha) was found with classes of carbon stocks below 100.0 ha^{-1} and 100.0 ÷ 200.0 tons ha^{-1} in 2017, a large decrease of mangrove areas at the same classes in 2019, equivalent to 369.5 ha.



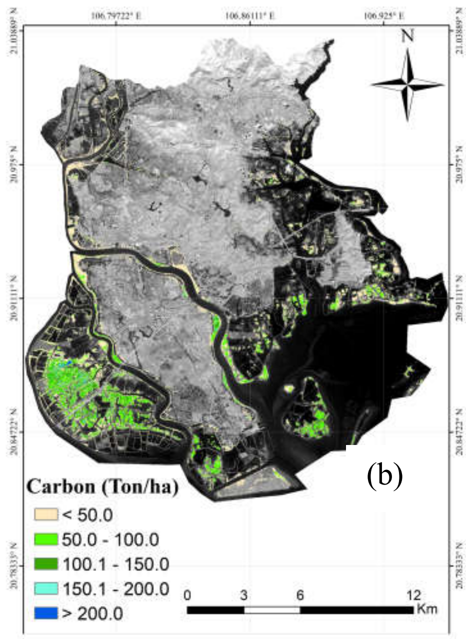


Figure 4. Spatial distribution of above-ground mangrove carbon stocks in 2019 (a); 2017 (b)

Table 5. Mangrove carbon stocks in 2 study years

Year	Dec 2017	Mar 2019	2017- 2019
C stocks (tons ha^{-1})	10.5 ÷ 284.9	10.7 ÷ 159.7	4.2 ÷ 58.5
∑ Accumulated C (tons)	126,099.7	53,775.5	134,606.5

Table 5 indicated that range of carbon stocks has reduced between 2017 and 2019. In particular, there was 126,099.7 tons over Quang Yen in 2015, but only 53,775.5 tons in 2019. Therefore, a total of carbon stocks in Quang Yen lost was 72,324.0 tons.

3.2.2. Variations of mangrove biomass and carbon stocks estimated from field survey and Sentinel imageries

To assess the variations of mangrove biomass and carbon stocks estimated between field measurement and Sentinel data, the study calculated mangrove biomass and carbon stocks from 15 sampling plots conducted in from March to May 2017, showing in Fig. 1 (Table 6). The study then compared the correlation between field-measured AGB and carbon stocks with Sentinel-calculated AGB and carbon stocks in 2017 according to Myeong's formula (2006). Results are shown in table 6.

As table 6 showed that there were small variations of mangrove biomass, carbon stocks between field measurements and Sentinel data-based estimation in 2017. More specifically, the variations of mangrove biomass and carbon stocks ranged at 0.1 ÷ 22.5 tons ha^{-1} and 1.3 ÷ 10.7 tons ha^{-1}, respectively. The results of mangrove biomass estimation and carbon stocks based on Myeong's model [2006] in comparison with plot-based measurement also showed that the percentage of carbon stocks difference ranged from 5.6% to 43.6%, with an average of 26.9% difference. In particular, a number of plots with difference in amount of carbon stocks estimated less than 20.0% were 4 plots, whereas there was only 6 plot with difference ranging from 20.0% to under 35.0%. There were 4 plots with variations of 37 ÷ 43.6%. Therefore, this finding illustrated the formula of Myeong [2006] applied to estimate mangrove biomass and carbon stocks from remote sensing data is suitable to Quang Yen town and this model should be applied to other similar study sites in Quang Ninh province.

Table 6. Field and Sentinel data- based C stocks estimation

Plot	**Field estimation*** (tons ha^{-1})		**Sentinel estimation** (tons ha^{-1})		**Variations between field and Sentinel C estimation**	
	Biomass	C stocks	Biomass	C stocks	C stocks (tons ha^{-1})	%
1	32.5	15.4	43.3	20.6	5.2	33.6
2	50.6	20.0	50.7	24.1	4.1	20.4
3	54.4	25.8	76.9	36.5	10.7	41.6
4	57.3	27.2	65.7	31.2	4.0	14.7
5	22.8	10.8	30.1	14.3	3.5	32.4
6	44.3	21.0	60.9	28.9	7.9	37.8
7	59.3	28.2	65.8	31.3	3.1	10.8
8	55.3	26.3	75.9	36.1	9.8	37.1
9	48.7	23.1	45.2	21.5	-1.6	-7.1
10	49.6	23.6	46.9	22.3	-1.3	-5.6
11	61.4	29.2	40.5	19.2	-10.0	-34.1
12	80.6	39.3	60.2	28.6	-10.7	-27.2
13	28.4	13.5	40.8	19.4	5.9	43.6
14	43.5	20.6	55.3	26.3	5.7	27.5
15	54.4	25.8	70.3	33.4	7.6	29.4

**Calculated from sampling plots with dimenssion 20 x 25 m (500 m^2).*

3.4. Changes in AGB and C stocks of mangrove forests

Changes in AGB of mangrove forests during period of 2017 - 2019 were summarised in table 7.

It can be seen in fig. 5 and table 4 and 7, there was a change in AGB of mangrove forests during 2017 - 2019. There was nearly 91.1% of the total area experienced with an decrease of AGB, while a small percentage of mangrove forest areas experienced with a slight increase. Similarly, there were huge changes in above-ground carbon stocks between 2017 and 2019, nearly 655.5 ha of mangrove lost with carbon stocks reduced at 50.0 ÷ 100.0 tons ha^{-1} and 201.0 ÷ 300.0 tons ha^{-1}. It is assumed that mangrove degradation and loss have contributed to carbon stocks lost in Quang Yen since 2017. It is argued that different tree age, mangrove structure, canopy, mangrove extents are factors that influence the carbon stocks in mangrove forests (Lehtonen et al., 2004).

Table 7. Changes in AGB and C stocks during 2017 - 2019

Changes	Ha	%
+	143.9	8.9
-	1480.5	91.1
Total	1624.4	100

(+) refers to the areas of mangrove forest increased, (-) refers to the areas of mangrove forests decreased.

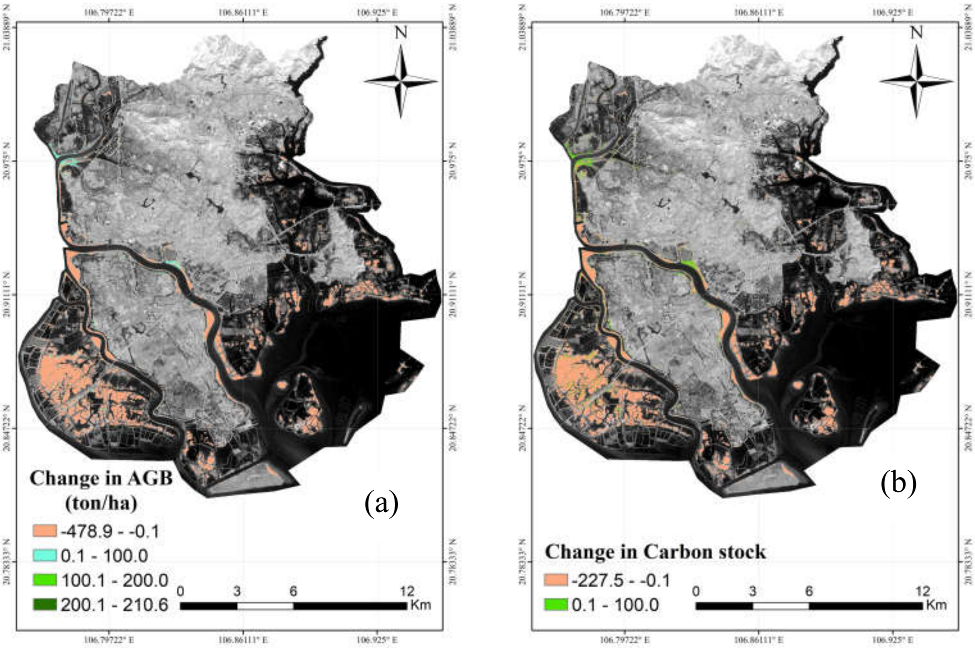


Figure 5. Changes in AGB (a) and C stocks (b) of mangrove forests in the period of 2017 - 2019

4. CONCLUTIONS

By using Sentinel 2A imageries, the study has constructed the spatial ditribution of mangrove forests in 2017 and 2019. The accuracy evaluation showed that the overall accuracy of the 2019 Sentinel classification was 89.0%, while the accuracy assessments of 2017 Sentinel image also was 87.7% overall accuracy. It was therefore assumed that using Sentinel images were adequate for mapping temporal changes in mangrove extents in Quang Yen. The study showed that there were 1822.9 ha of mangrove forests in 2019 and 2476.1 ha in 2017.

The AGB of mangrove forests in Quang Yen has changed over time. In 2017, the areas of mangrove forests with AGB greater higher than 100.0 tons ha^{-1} was 1028.1 ha, while the remaining areas were less than 100.0 tons ha^{-1}. In 2019, the area of mangrove with AGB less than 100.0 tons ha^{-1} increased to 75.9 ha, while about 655.15 ha of AGB decreased. It is assumed that the loss of mangrove areas has contributed to an reduction of AGB of mangrove forests, nearly 654.5 ha lost during 2017 - 2019. There were large changes in C stocks of mangroves accumulated between two years. In particular, the most of mangrove areas (1349.7 ha) was found with classes of carbon stocks below 100.0 ha^{-1} and 100.0 ÷ 200.0 tons ha^{-1} in 2017, while a large decrease of mangrove areas at the same classes was found in 2019, equivalent to 369.5 ha.

There were small variations of AGB and C stocks of mangrove forests between field measurements and Sentinel-based estimation in 2019. Therefore, the study highly suggests that using remote sensing imagery to estimate AGB and C stocks of mangrove forests is reliable and applicable to Quang Ninh coast and it should be expanded in other similar coastal areas in Quang Ninh province.

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ƯỚC TÍNH BIẾN ĐỘNG TRỮ LƯỢNG CÁC BON TRÊN MẶT ĐẤT RỪNG NGẬP MẶN DỰA VÀO DỮ LIỆU VIỄN THÁM: NGHIÊN CỨU ĐIỂM TẠI THỊ XÃ QUẢNG YÊN, TỈNH QUẢNG NINH GIAI ĐOẠN 2017 - 2019

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TÓM TẮT

Rừng ngập mặn phân bố dọc bờ biển với độ dốc trung bình, là nơi chúng tiếp nhận nguồn nước ngọt và chất dinh dưỡng từ trong đất liền. Chức năng của rừng ngập mặn đã được biết đến như ngăn chặn xói mòn bờ biển, giảm thiểu tác động của sóng, bảo vệ dân cư sống ven biển và khu vực đất liền kề bờ biển khỏi tác động của thiên tai. Nghiên cứu đã sử dụng ảnh Sentinel 2A để xây dựng bản đồ hiện trạng rừng ngập mặn năm 2017 và 2019. Kết quả đánh giá độ chính xác của bản đồ cho thấy độ chính xác tổng thể của giải đoán ảnh Sentinel năm 2019 là 89,0% và 2017 là 87,7%. Tổng diện tích rừng ngập mặn năm 2019 là 1822,9 ha và năm 2017 là 2476,1 ha. Sinh khối trên mặt đất và trữ lượng các bon rừng ngập mặn có sự thay đổi giữa năm 2017 và 2019 tại Quảng Yên. Kết quả so sánh giữa ước tính trữ lượng các bon trên mặt đất từ ảnh viễn thám Sentinel năm 2019 với kết quả tính toán tại ô tiêu chuẩn cho thấy sự khác biệt không lớn. Do vậy, việc sử dụng ảnh Sentinel để ước tính trữ lượng rừng ngập mặn đảm bảo độ tin cậy và có tính khả thi tại Quảng Yên. Việc sử dụng tư liệu ảnh Sentinel để ước tính trữ lượng các bon rừng ngập mặn nên được mở rộng cho các khu vực khác thuộc tỉnh Quảng Ninh.

Từ khóa: Ảnh Sentinel 2, chỉ số thực vật NDVI, rừng ngập mặn, sinh khối trên mặt đất, trữ lượng các bon.

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