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Estimation of biomass for calculating carbon storage and CO_2 sequestration using remote sensing technology in Yok Don National Park, Central Highlands of Vietnam

Ước lượng sinh khối cho tính toán lượng tích trữ các bon và hấp thụ CO_2 ở Vườn Quốc gia Yok Đôn, Tây Nguyên Việt Nam, bằng cách sử dụng công nghệ viễn thám

Event report

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Global warming and climate change are closely related to the amount of CO_2 in the air. Forest ecosystem plays very important role in the global carbon cycle; CO_2 from the atmosphere is taken up by vegetation and stored as plant biomass. Therefore, quantifying biomass and carbon sequestration in tropical forests has a significant concern within the United Nations Framework Convention on Climate Change (UNFCC), Kyoto Protocol and Reducing Emission from Deforestation and Forest Degradation (REDD) program for the purpose of the improvement of national carbon accounting as well as for addressing the potential areas for carbon credits, basis for payment for environmental services. The aim of research is to estimate biomass and carbon stocks in tropical forests using remote sensing data for dry forest of central highlands of Vietnam. This result showed that from satellite images of the SPOT, satellites could build the land cover map, carbon map and biomass map of Yok Don National Park, Central Highlands of Vietnam. Through which also the biomass (above ground biomass and below ground biomass) of each type of forest can be calculated. For instance the biomass of the dry forest (Dry Dipterocarp Forest) is 153.49 tones x ha^{-1}, biomass of rich forest is 343.35 tones x ha^{-1}, biomass of medium forest is 210.34 tones x ha^{-1} and biomass of poor forest & scrub are 33.56 tones x ha^{-1}.

Sự ấm lên toàn cầu và biến đổi khí hậu có liên quan chặt chẽ với tổng lượng CO_2 trong không khí. Hệ sinh thái rừng có vai trò rất quan trọng trong chu trình các bon toàn cầu; khí CO_2 trong khí quyển được hấp thụ bởi thảm thực vật dưới dạng sinh khối. Vì vậy, việc xác định sinh khối và carbon tích trữ trong rừng nhiệt đới đã có được sự quan tâm đáng kể trong Công ước của Liên hiệp quốc về biến đổi khí hậu (UNFCC), Nghị định thư Kyoto và Chương trình giảm phát thải từ phá rừng và suy thoái rừng (REDD) gần đây, nhằm cho mục đích cải thiện việc tính toán lượng các bon tích trữ cũng như giải quyết các vấn đề tiềm năng cho tín dụng các bon, làm cơ sở cho việc thanh toán cho các dịch vụ môi trường. Mục đích của nghiên cứu này là ước lượng sinh khối và các bon lưu trữ trong các khu rừng nhiệt đới bằng cách sử dụng dữ liệu viễn thám, mà ở nghiên cứu này là cho rừng khộp Tây Nguyên của Việt Nam. Kết quả cho thấy rằng, từ ảnh vệ tinh SPOT có thể xây dựng bản đồ lớp phủ thực vật, bản đồ các bon và bản độ sinh khối của Vườn quốc gia Yok Đôn, Tây Nguyên Việt Nam. Qua đó đã tính toán được sinh khối (bao gồm cả trên mặt đất và dưới mặt đất) như: đối với sinh khối của rừng khô cây họ dầu (Dry Dipterocarp Forest) là 153,59 tấn/ha, sinh khối rừng giàu là 343,35 tấn/ha, sinh khối rừng trung bình là 210,34 tấn/ha và sinh khối rừng nghèo&cây bụi là 33,56 tấn/ha.

Keywords: tropical forest biomass; carbon storage; CO_2 sequestration; remote sensing

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1. Introduction

The rise of Earth's temperature has led to heavy losses to human beings such as droughts, floods, sea level rise etc., being nowadays a global concern. Vietnam is one of the five countries most affected by the climate change (World Bank, 2009). Climate change and sequestration of CO_2 of plant are closely related. Scientists fear that the increase of greenhouse gas, especially CO_2, is the main factor causing unusual and unforeseen climate change. According to calculations of scientists, the concentration of CO_2 in the atmosphere is doubled; the Earth's temperature has increased by about 3°C. The rise of CO_2 concentration is mainly attributed to human activities. Over the last 20 years, burning fossil fuel formed the majority of emission, while 10-30% was attributed to land use change, forest destruction and deforestation. Scientists have estimated that up to 2030, carbon dioxide content of Earth's atmosphere will be 600 ppm (0.06%), twice the content of the 19th century.

Forest ecosystem plays very important role in the global carbon cycle. It stores about 80% of all aboveground and 40% of all belowground terrestrial organic carbon (IPCC, 2001). During productive season, CO_2 from the atmosphere is taken up by vegetation (Losi et al., 2003; Phat et al., 2004) and stored as plant biomass.

Forest in central highlands of Vietnam has not only great significance on the direct economic value to humans, but also a very important role in the environment, including the sequestration of CO_2, contributing to reduction of greenhouse effect through the photosynthesis process. The question is how to achieve the accurate data from calculating the amount of CO_2 sequestration by forests with reduction of costs, time, labour for application in large-scale, and participation in the joint programs of the world: Clean Development Mechanism (CDM), Reducing Emissions from Deforestation and degradation (REDD) or REDD+.

Currently, many scientists worldwide have conducted studies of forest biomass, including in Vietnam. However, studies done in Vietnam tend to focus on individual species, planted vegetation or scrub, grass, and usually they are done on a small area; for larger areas, the authors make use of remote sensing data.

The present paper introduces the results of applying remote sensing technology for the estimation of biomass for carbon storage and CO_2 sequestration in Yok Don National Park, an ecosystem containing unique natural dry dipterocarp forest in Central Highlands of Vietnam.

2. Research objectives

- Calculating the index of the structure of forest cover (diameter, height, density, timber volume and quality of trees) and biomass of each state forest of the study area
- Building of land cover map, biomass map and carbon/CO_2 map of the study area from satellite images
- Estimation of the CO_2 sequestration capacity of forest ecosystems in the study area as the basis for the Payment for Environment Services – PES.

3. Study area

The Yok Don National Park is located in Kron Na commune, Buon Don district, 40km west of Buon Ma Thuot city, and is the largest national park in Vietnam. Yok Don National Park is proud of its bio-diversity, which attracts both tourists and scientists. Its jungles bear the characteristics of tropical forest in Southeast Asia. The study area lies in geographic co-ordinate between; 12°45'N - 13°10'N Latitude and 107°29'E - 107°48'E Longitude.

Yok Don National Park borders four communes in Dak Lak province: Ea Bung and Chu M'Lanh communes- Ea Sup district, Krong Na commune- Buon Don district, and Ea Po commune - Cu Jut district. The park covers a flat plain that extends from eastern Cambodia to northern Dak Lak province and southern Gia Lai province in Vietnam.

The topography of the site is at an elevation of 200m with lowland landscape dominated by dry forest studded with seasonal pools. Semi-evergreen forest can also be found along watercourses. There are, however, several ranges of low hills within the national park; the highest is the eponymous Mount Yok Don at 482 m in the southeastern range.

Figure 1. Location of the study area

In terms of biodiversity, the vegetation at Yok Don National Park is dominated by dry deciduous forest and semi-evergreen (mixed deciduous) forest, with smaller

areas of moist evergreen forest, particularly on hills and along watercourses. The dry deciduous forest contains members of the *Dipterocarpaceae* family, including *Dipterocarpus tuberculatus, D. obtusifolius* and *Shorea obtusa*. However, the *Anacardiaceae, Combretaceae, Fabaceae* and *Myrtaceae* families are also well represented. According to Nguyen and Ngo (2001), the flora has 854 vascular plant species belonging to 129 families, have been recorded at the national park, of which 28 are listed in the Red Data Book of Vietnam. Yok Don National Park is considered to be one of seven internationally important Centres of Plant Diversity in Vietnam (Figure1).

4. Materials and Methods

4.1 The data and documents

- Literature review, data and results of previous studies in the study area.
- Using remote sensing images of SPOT satellite in 2010 with resolution of 15m x 15m of study area (Figure 2):

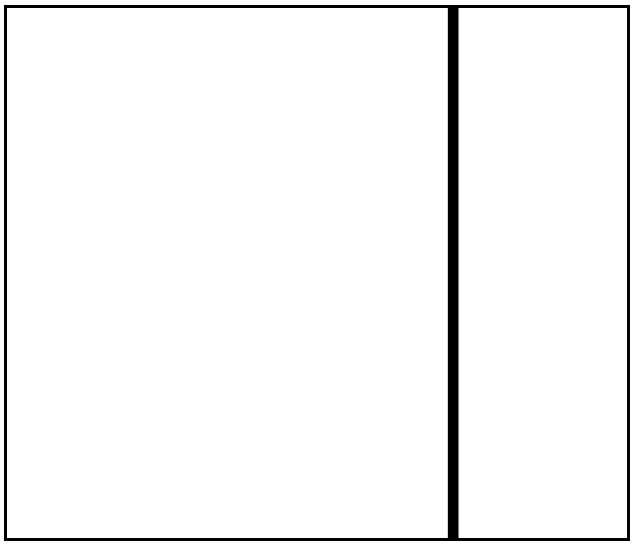

Figure 2. False-color combinations (FCC) study area in 2010

4.2 Method for determining forest biomass

4.2.1 Formula for calculating biomass (above ground and below ground)

This study applied the allometric equations for estimating biomass (correlation model) that were given by Chaiyo et al. (2010) based on two main parameters: diameter at breast height ($D_{1.3m}$) and height of tree stand (H_m). The equations were developed based on the equations of Ogawa and Yoda; Ogino and Kira "Comparative ecological studies on three main type of forest vegetation in Thailand, II, Plant Biomass" and follow the guideline of IPCC reports (2001, 2003 and 2006). After considering the natural conditions, field work methods, especially the characteristics of the vegetation of the two study area, we believe that these are entirely possible equations applied in our study in Vietnam, especially in current conditions. The followings are the allometric equations that have been applied for biomass in this study area (Eq.1; Eq.2 and Eq.3).

$$AGB = 0{,}0396 \times D^2 \times H^{0.932} \quad (1)$$

$$BGB = 20\% \times AGB \quad (2)$$

$$TAB = AGB + BGB \quad (3)$$

Where: AGB - above-ground tree biomass (kg); BG - below-ground tree biomass (kg); TAB - amount of biomass (tons); D - diameter at breast height (cm); H - height of tree stand (m).

4.2.2 Formula for calculating the amount of carbon storage and CO2 sequestration by plants

The amount of carbon storage of vegetation is calculated with the equation (3) based on guideline in the IPCC report (2006) and with the equation (4), (5) by S.V. Belop (1976, 1980):

$$CBS = 0.5 \times TAB \quad (4)$$

$$CO_2 = 3.67C \quad (5)$$

Where: CBS - amount of carbon (tons/ha); TAB - amount of biomass (tons/ha); 0.5 - default conversion factor

4.3 Surveys in the study area

The first survey served for establishing the sample plot network. The sample plot size for woody forest is 25 m x 20 m (500 m^2). Total of $D_{1.3}$ and height were recoded for all trees with $D_{1.3} > 5$ cm.

The second survey implied that the total number of ground control points taken are 40 as a part of ground check, and used for accuracy check analysis.

4.4 Method of satellite image classification

The supervision classification method used is based on the likelihood classification algorithm. From the remote sensing image of SPOT with the resolution is 15 m x 15 m, we can identify and classify the land cover of the study area into six classes as follows: Dry dipterocarp forest (Dry forest), Rich forest, Medium forest, Poor forest and shrub, Water body and Other land (including: building land, barren land, farmland).

5. Results

5.1 Structure of land cover

This study focuses on the current state of vegetation that has a large biomass. The results were calculated from 20 sample plots at Yok Don National Park. The current state of land cover such as Dry forest, Rich forest, Medium forest and Poor forest and shrubs. The results are shown in the Table 1 and Figure 3.

Table 1. Parameters of the structure of land cover

State of land cover	Area (ha)	$D_{1.3}$ (cm)	H (m)	N/ha (trees)	M (m^2)
Dry forest	72,596	18.32	10.85	888	126.92
Rich forest	15,932	23.66	14.84	860	280.42
Medium forest	7190	18.88	14.26	540	107.74
Poor forest & scrub	6559	10.44	7.1	733	22.26

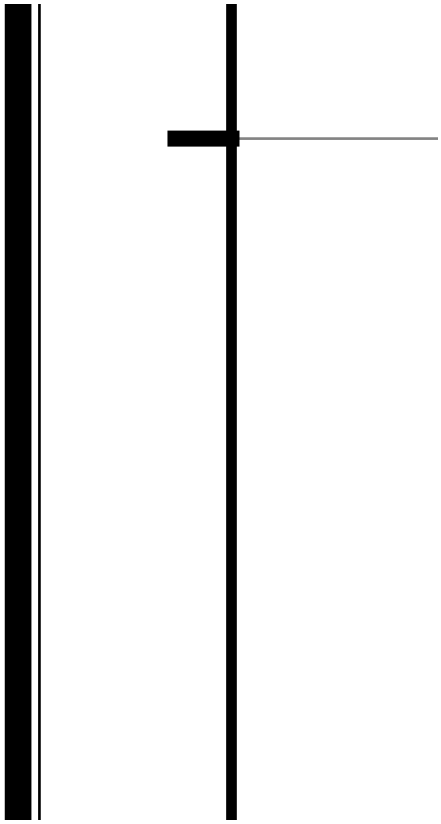

Figure 3. Land cover map in the study area

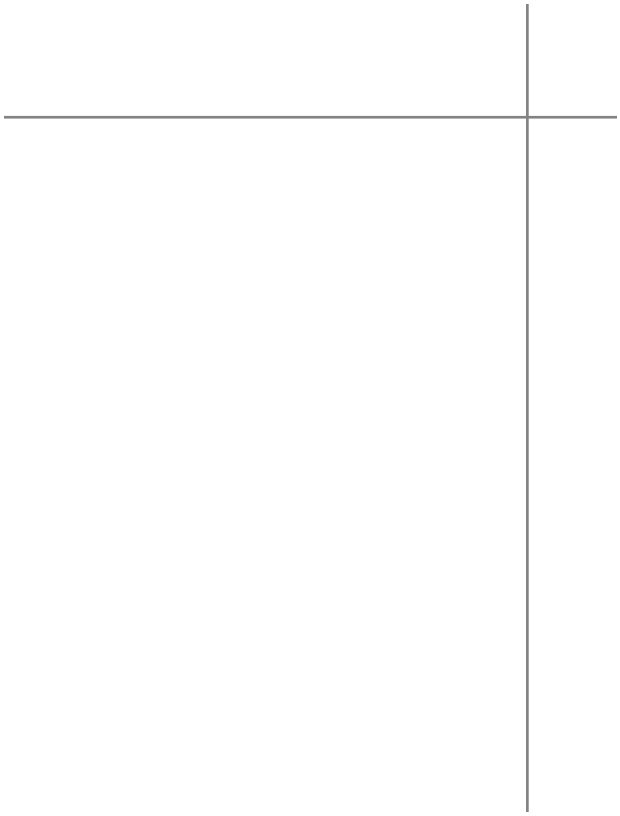

Figure 4. Biomass map in the study area

The assessment results in classification accuracy in mapping forest cover from the SPOT in 2010 with the overall accuracy are 85.89% and average accuracy is 83.95%. Kappa statistics (K^) is 0.8094.

5.2. Estimated biomass of forest cover

From the data such as area, diameter and height in Table 1, the application of formula (1) and (2) above, the result of data on biomass of Yok Don National Park is given in Table 2 and Figure 4.

The quantity of biomass (including: aboveground biomass and belowground biomass) of Yok Don National Park is thus 18,345,249 tons.

Table 2. Biomass of study area

State of land cover	Area (ha)	Biomass (tons)			Total (tons)
		AGB	BGB	Total	
Dry forest	72,596	122.7	30.70	153.49	11,142,526
Rich forest	15,932	274.67	68.67	343.35	5,470,190
Medium forest	7,190	168.27	42.07	210.34	1,512,394
Poor forest & scrub	6,559	26.85	6.71	33.56	220,139
Water body	11,486				
Other land	18,256				
Total	115,589	592.59	148.15	740.74	18,345,249

5.3. Carbon storage and CO_2 sequestration

Based on the relationship of carbon storage and CO_2 sequestration with the biomass, the amount of carbon storage is calculated by the formula (4) and CO_2 sequestration by the formula (5). The results are shown as followings and in Figure 5 below:

+ The amount of Carbon = 0.5 x 18,345,249 (tons)
= 9,172,625 tons
+ The amount of CO2 = 3.67 x 9,172,625 (tons)
= 33,663,533 tons

Thus, at the time of this study, total plant biomass of Yok Don National Park was 18,3 million tons, from this data infer that the total amount of carbon storage is 9,1 million tons or total amount of CO_2 sequestration is 33,7 million tons.

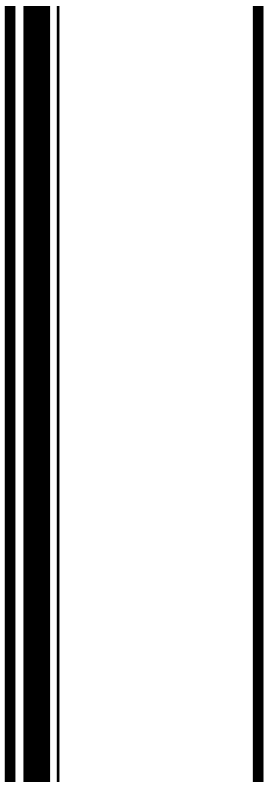

Figure 5. Carbon map of study area

6. Recommendation

- Using data from satellite images with high resolution or Lidar data for making land cover map, biomass map, carbon/CO_2 maps and change maps of Yok Don National Park annually (preferably one or two years).
- Building the sample plots network (in accordance with standards, sufficient in number) in all of the current statuses of forest, conducting measurement and statistics annually.
- Developing the allometric equations for estimating biomass of the study area.
- Building capacity of staffs that directly manage and protect forests here in the using the RS & GIS technology for the forest management, forest monitoring through short-term training.
- Should quickly build mechanisms and policies for payment for environmental services on the basis of scientifically calculated to capacity of CO_2 sequestration of natural forests.

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