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Above-ground Biomass Estimation for Evergreen Broadleaf Forests in Xuan Lien Nature Reserve, Thanh Hoa, Viet Nam

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Introduction

The estimation of above-ground biomass (AGB) and carbon sequestration in forests plays as a key role to modeling carbon cycle and has a significant concern in addressing the potential areas for carbon credits under Reducing Emissions from Deforestation and Forest Degradation-Plus (REDD+). This study was conducted to estimate the living AGB for evergreen broadleaf forests in Xuan Lien Nature Reserve, Viet Nam with the purpose of providing data for sustainable forest management and baseline data for carbon monitoring.

Study Site

This study was conducted at Xuan Lien Nature Reserve, Thanh Hoa, Viet Nam (19°52'-20°02'N, 104°58'-105°15'E). The nature reserve covers 61,797 ha of two forest types, located 65 km south-west of Thanh Hoa city (Fig. 01). Mean annual temperature is about 23-24°C. Average annual rainfall at this area is approximately 1700-1900 mm.

The vegetation in the study area is mainly closed evergreen broadleaf (EB) forest, which was classified into two main types: Subtropical Evergreen Broadleaf Forest (STEB, distributed between elevation of 800 m and 1605 m) and Tropical Moist Evergreen Broadleaf Forests (TMEB, distributed under 800 m).

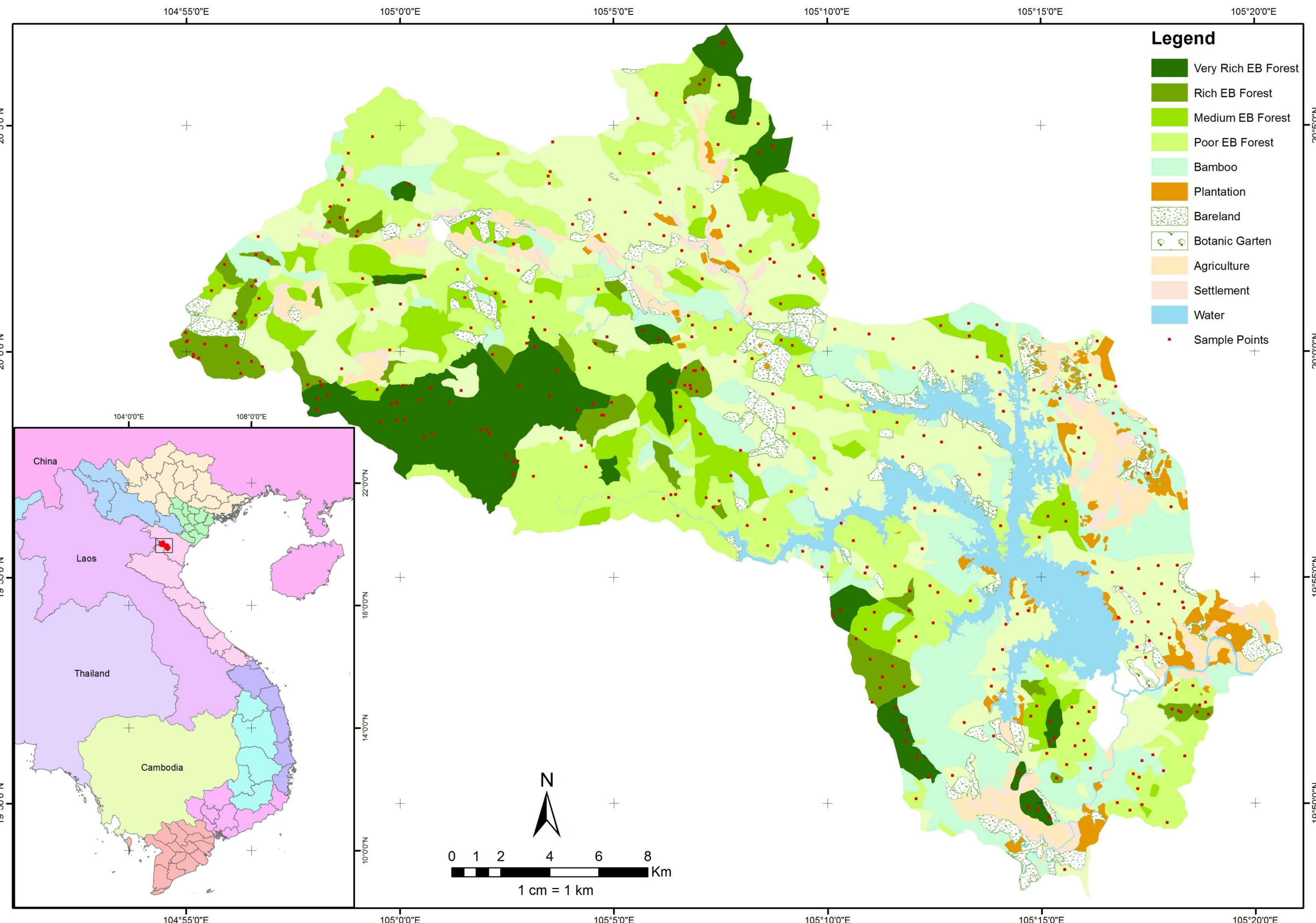

Fig. 1 Location of sample plots in Xuan Lien Nature Reserve

Methods

The dataset used for this research was collected from three main sources (Table 1):

- The Annual Investigation Program of the Xuan Lien Nature Reserve (XLNR), conducted from 2008 to 2014;
- The Pilot National Forest Inventory Program (Thanh Hoa is the pilot province) implemented by Institute for Forest Ecology and Environment (IFEE), Vietnam National University of Forestry (VNUF) in 2014; and
- The field measurement conducted by authors in 2015.

The forest stands were classified to four categories by governmental standard basing on standing volume (V), including poor forest (V ≤ 100 m^3 ha^{-1}), medium forest (100 < V ≤ 200 m^3 ha^{-1}), rich forest (200 < V ≤ 300 m^3 ha^{-1}), and very rich forest (V > 300 m^3 ha^{-1}). A total of 380 sampling plots were randomly sampled and all trees with diameter at breast height (DBH) ≥ 5.0cm were included for biomass estimation. In each plot, their diameters at breast height (DBH) and total height (H) were measured.

Table 1 Sources of dataset

Source of dataset	Implementation year	No. of plots	Plot size and shape
XLNR	2008, 2010, 2012-2014	79	500 m^2, 1000 m^2, 2000 m^2; rectangle
IFFE (VNUF)	2014	121	1000 m^2, rectangle; Bitterlich sample points
Authors	2015	180	500 m^2, rectangle
Total		**380**	

The above-ground biomass (AGB) of live trees was estimated by using the following allometric equation (developed by Vu Tien Hung et al (2014)):

$$AGB_t = 0.05196 \times DBH^{1.8075} \times H^{0.9940} \qquad R^2 = 0.9555 \qquad \text{(Eq. 1)}$$

With sample plots which applied Bitterlich method (implemented by IFEE-VNFU), we used Biomass Expansion Factor (BEF) to estimate AGB (Brown, 1997).

$$AGB = BEF \times V \times WD \qquad \text{(Eq. 2)}$$

where, $BEF = Exp(3.213 - 0.506 \times ln(BV))$ for BV < 190 Mg ha^{-1}
$BEF = 1.74$ for BV ≥ 190 Mg ha^{-1}

with BV is biomass of inventoried volume (V, m^3 ha^{-1}) in Mg ha^{-1}, $BV = V \times WD$; and WD is wood density (Mg m^{-3}). In this study we opted WD = 0.57 (Brown, 1997).

Results

Both individual trees and height of the forest canopy in STEB grew higher compared to TMEB; however, there is no significant difference of stem density between two types of forest (Table 2).

The distribution of stem density and live AGB by diameter size class showed a contrasting pattern across the elevational gradient (Fig. 2). In general, the smaller diameter class (<30 cm) held most of the stems and a small fraction of the live AGB.

Table 2 Above-ground stand structural characteristics of two forest types in XLNR

Forest Types	Stand Types	Nr. of Plots	Basal area (m^2 ha^{-1})	Stem density (ha^{-1})	DBH (cm)	Height (m)	Estimated AGB (Mg ha^{-1})
Tropical Moist Evergreen Broadleaf Forests (TMEB) distributed below 800 m							
	Poor	86	7.7 (0.2)	487 (19)	14.5 (0.3)	13.1 (0.2)	49.9 (1.9)
	Medium	65	13.0 (0.4)	583 (21)	17.3 (0.4)	13.7 (0.3)	92.2 (3.2)
	Rich	26	19.2 (2.5)	643 (107)	20.3 (2.5)	14.2 (0.6)	167.3 (9.2)
	Very Rich	36	25.9 (1.2)	524 (31)	25.4 (0.8)	16.7 (0.6)	299.3 (20.7)
Total/Mean		213	11.8 (0.5)	545 (16)	16.7 (0.3)	13.7 (0.2)	95.0 (6.0)
Subtropical Evergreen Broadleaf Forests (STEB) distributed above 800 m							
	Poor	29	7.9 (0.4)	568 (97)	14.3 (0.9)	13.1 (0.3)	49.3 (2.0)
	Medium	32	13.2 (0.5)	616 (55)	17.5 (0.9)	14.1 (0.5)	94.8 (3.9)
	Rich	54	18.2 (0.5)	530 (30)	21.5 (0.8)	15.5 (0.4)	168.1 (4.3)
	Very Rich	52	25.7 (1.1)	521 (28)	26.0 (0.9)	16.8 (0.9)	304.4 (12.9)
Total/Mean		167	19.9 (0.8)	547 (21)	22.2 (0.6)	15.6 (0.2)	208.3 (11.5)

Notes: Two forest types were classified into four stand categories: Poor (V ≤ 100 m^3 ha^{-1}), Medium (100 < V ≤ 200 m^3 ha^{-1}), Rich (200 < V ≤ 300 m^3 ha^{-1}), and Very Rich (V > 300 m^3 ha^{-1}). The number in parentheses is Standard Error.

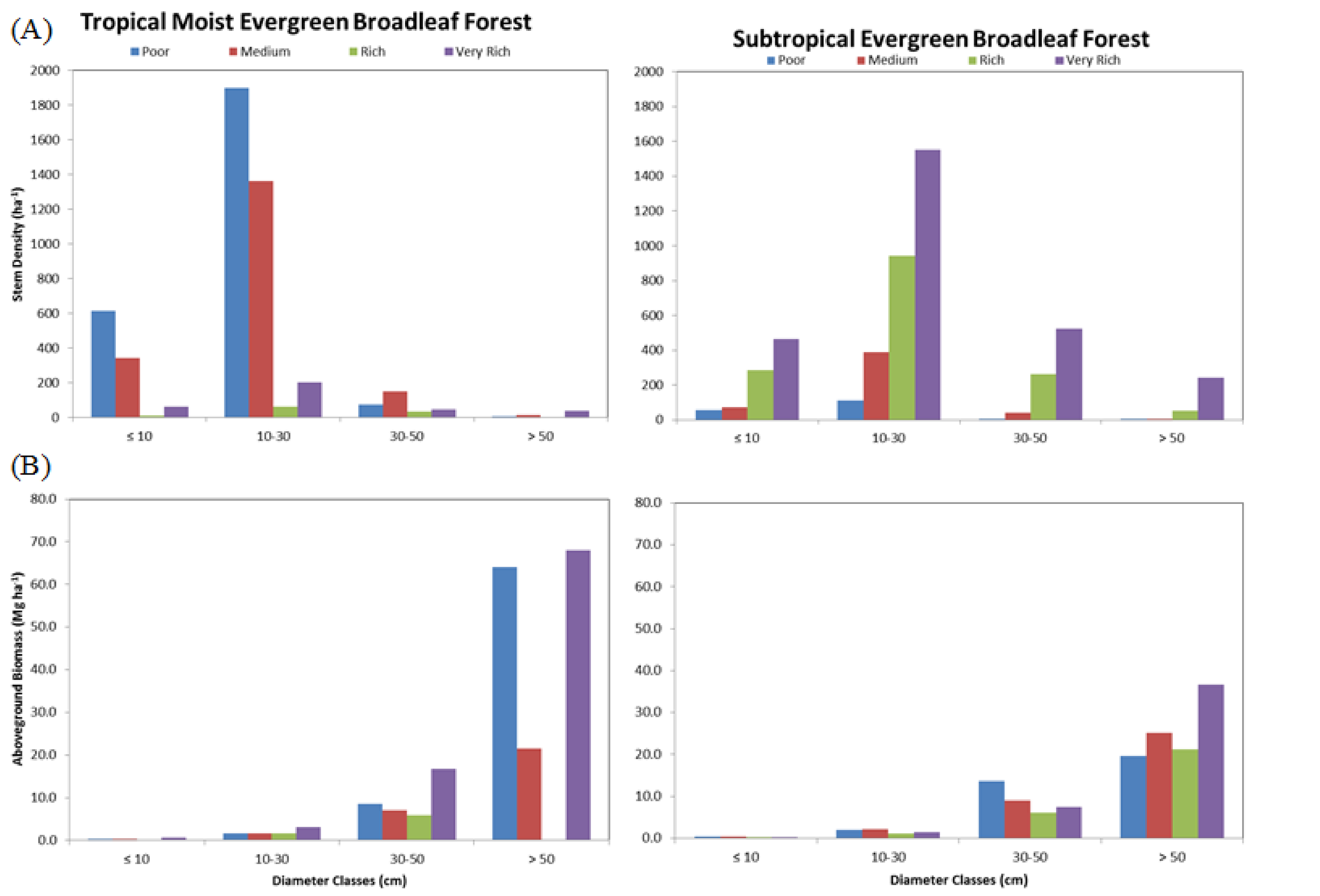

Fig. 2 Distribution of (a) stem density (n ha^{-1}) and (b) aboveground biomass (Mg ha^{-1}) by size class (DBH cm) on different forest types along the elevational grandient of evergreen broadleaf forest.

Conclusions

It is concluded that tropical evergreen broadleaf forest in XLNR has significant amount of aboveground carbon stock. The spatial variation of AGB for EB forest is related to land-use types, the degree of human disturbance and the gradients of elevation.

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