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RELATIONSHIP BETWEEN CLIMATIC CONDITION AND MANGROVE FOREST STRUCTURE ON NORTHERN COAST OF VIETNAM

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ABSTRACT

The differences in mangrove forest structure, climate, and the linear relationship between climate and mangrove forest structure on the northern coast of Vietnam were analyzed using mangrove forest data measured in 28 sample plots (Dong Rui-8, Xuan Thuy National Park-12 and Lach Sung-8) and climate data collected at the meteorological stations near the study sites (Dong Rui-Tien Yen station, Xuan Thuy National Park-Van Ly station and Lach Sung-Thanh Hoa station) in the period of 1994 - 2012. Results showed that the differences in mangrove forest structure (stem diameter, biomass and basal area) and climate (temperature and rainfall) among study sites were significant ($p < 0.05$). Stem diameter, tree height, basal area and biomass had positive linear relationship with annual average temperature and January average temperature, and negative linear relationship with annual rainfall. A consistently low regression coefficient of less than 0.66 was found among the variables. However, all the regression models were statistically significant ($p < 0.05$). The results could be used to develop multiple linear regression models to predict the change of mangrove ecosystems.

Keywords: climate, mangroves, northern coast of Vietnam.

1. INTRODUCTION

Northern coast of Vietnam stretches across the provinces of Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh and Thanh Hoa, and is divided, according to the distribution and characteristics of mangrove ecosystems, into two zones: I) North-east coast from Ngoc cape to Do Son cape; II) Northern delta from Do Son cape to Lach Truong estuary. Due to the differences in topography, climate and hydrology, ecological characteristics of mangrove ecosystem in these zones are also different [1, 2].

Mangrove ecosystem on the northern coast of Vietnam plays important roles in economic development and environmental protection. Mangrove ecosystem supports a veriety of economic activities, such as firewood, charcoal, shrimp, crabs, etc. collection. Mangrove ecosystem stabilizes coastlines, promote coastal accretion and provide a natural barrier against storms and tidal bores. In addition, mangrove forest is a carbon sink accumulating atmospheric CO_2, contributing to reduction of greenhouse gas emission [1, 2, 3, 4, 5, 6].

According to Ministry of Natural Resources and Environment (2012) [7], Vietnam will be one of the countries most affected by climate change. The change in temperature, rainfall will impact directly to the structure, growth and development of coastal ecosystems, including mangrove forests [2, 5]. Therefore, studying and modeling the relationship between mangrove structure, growth of mangrove forest and climate are essential and could be used to predict the variation of mangrove ecosystems in the context of climate change.

In this paper, we present the initial results of study on the relationship between climate and mangrove forest structure (tree height, stem diameter at 0.3 m height, basal area and biomass) conditions (temperature and rainfall) on northern coast of Vietnam.

2. MATERIALS AND METHODS

2.1. Study site

Three study sites, which have specific mangrove ecosystems, high biodiversity and the least affected by human, were selected to establish sample plots for measuring the structural characteristics of the vegetation and climate. The selected sites are: 1) Dong Rui (Tien Yen, Quang Ninh), 2) Xuan Thuy national park (Giao Thuy, Nam Dinh) and 3) Lach Sung esturary (Thanh Hoa) (Figure 1).

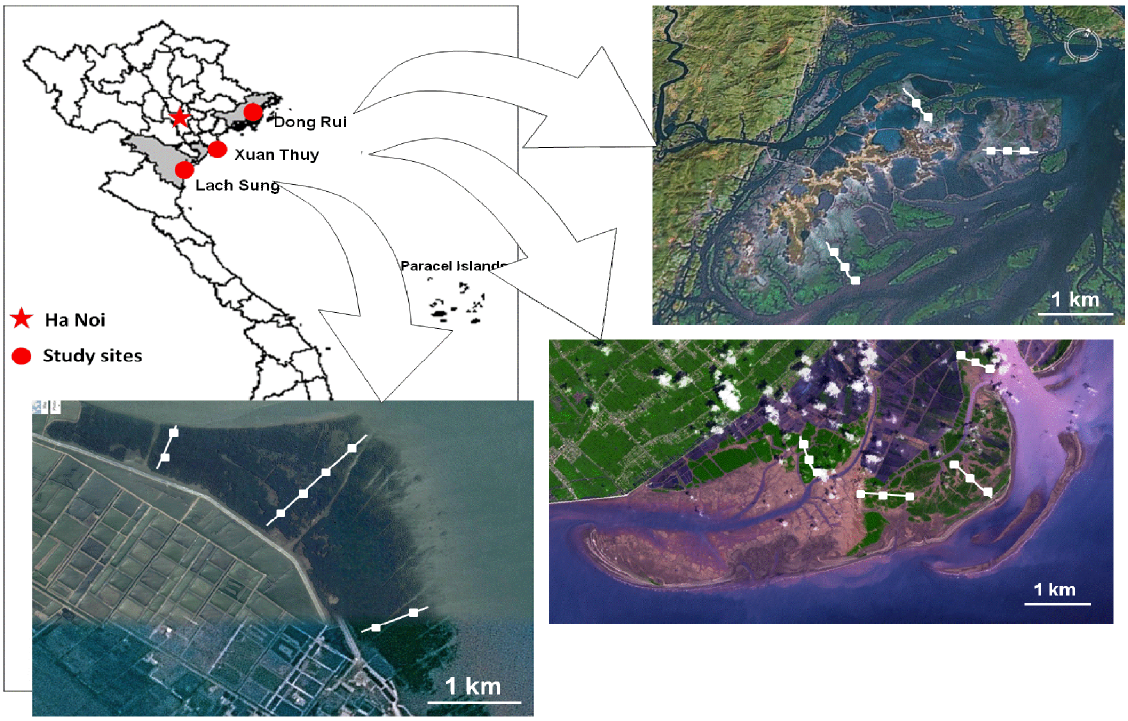

Figure 1. Location of study sites.

2.2. Data collection

2.2.1. Mangrove forest structure

Mangrove forest structure (tree height, diameter at 0.3 m height, basal area, and biomass) were measured in the 10 × 10 m sample plots established in the study sites. In 3 study sites, we established 28 sample plots (8 in Dong Rui, 12 in Xuan Thuy national park and 8 in Lach Sung estuary). In each sample plot, species name, tree height, diameter at 0.3 m height of all trees were measured and recorded. We measured the data on mangrove forest structure in Dong Rui on 5-8 April 2014, in Xuan Thuy on 1-4 May 2014 and in Hau Loc on 5-7 May 2014. The sample plots were established by the method of Nguyen Nghia Thin (2008) [8].

Tree height was measured directly by a pole (0.1 m scale). Stem circumference at 0.3 m height was measured by measuring tape and then converted into stem diameter. Tree height and stem diameter for each sample plot were calculated by total tree height, stem diameter of all trees dividing the total number of trees in the sample plot. The tree height and stem diameter for a study site were average tree height and stem diameter of all sample plots measured in that study site.

Basal area (m^2/ha) for each sample plot was calculated by the total cross section area of all trees in the sample plot dividing the area of the sample plot. Basal area for a study site was average basal area of all sample plots measured in that study site.

The common biomass equation $B = 0.251\rho D^{2,46}$ [9] was used to calculate the biomass of each tree in the sample plots, in which B is biomass (kg), D is stem diameter (cm) and $\rho = 0.752$ (g/cm^3) is the wood density [3]. Biomass (tons/ha) of each sample plot was calculated by the total biomass of all trees in the sample plot dividing sample plot area. Biomass of a study site was average biomass of all sample plots measured in that study site.

2.2.2. Climate condition

Phan Nguyen Hong (1991), Nguyen Hoang Tri (1999) and Blasco (1996) [1, 5, 10] documented that the changes in temperature and rainfall are factors limiting the growth and development of mangroves. Therefore this study was conducted to specify the relationship between those climate conditions and mangrove forest structure. Climate data, including annual average temperature, annual average rainfall and average temperature of the coldest month (January), of each study site were calculated from monthly temperature, rainfall collected from Hydrometeorological Data Center (Ministry of Natural Resources and Environment). The climate data was recorded at the meteorological station near the study site in the period of 1994 - 2012 (Dong Rui - Tien Yen station; Xuan Thuy national park - Van Ly station and Lach Sung - Thanh Hoa). The average temperature of the coldest month was also considered because low temperature is a limiting factor affecting growth and development of mangroves thus affecting their structure, species composition and distribution [2, 5, 10].

2.3. Statistical analysis

Climate data and mangrove forest data were described by using statistical software SPSS 11.5 and Microsoft Excel 2007. The description of the basic features of the data is presented in Table 1. One-way analysis of variance (one-way ANOVA) was used to assess differences in mangrove forest structure and climate at different study sites. The ordinary least square method was used to construct the regression models, i.e. to determine the parameters *a, b* for the equation $y = ax + b$, when x is independent variable (annual average temperature, January average temperature or annual average rainfall) and y is dependent variable (tree height, biomass, basal area or diameter at 0.3 m height). The corellation coefficient (R^2) and Fisher test (F-test) were used to evaluate the goodness of fit on data [11, 12].

Table 1. Descriptive statistics: variables measured at different study sites.

Variables	Study sites	N	Mean	Std. Dev.	Std. Err.	95% confidence intervals	
						Lower limit	Upper limit
Annual average temperature (^oC)	Dong Rui	19	22.9	0.5	0.1	22.7	23.1
	Xuan Thuy	19	23.7	0.6	0.1	23.4	24.0
	Lach Sung	12	24.4	0.5	0.1	24.0	24.7
January average temperature (^oC)	Dong Rui	19	15.3	1.3	0.3	14.7	15.9
	Xuan Thuy	19	16.4	1.4	0.3	15.8	17.1
	Lach Sung	12	16.8	1.3	0.4	16.0	17.7
Annual average rainfall (mm)	Dong Rui	19	2351	404	93	2156	2546
	Xuan Thuy	18	1612	249	59	1489	1736
	Lach Sung	12	1751	259	75	1586	1915
Diameter at 0,3 m height (cm)	Dong Rui	8	2.9	1.0	0.4	2.1	3.8
	Xuan Thuy	12	3.1	0.9	0.3	2.6	3.7
	Lach Sung	8	4.3	1.2	0.4	3.4	5.3
Tree height (m)	Dong Rui	8	2.5	0.7	0.2	1.9	3.1
	Xuan Thuy	12	3.6	1.7	0.5	2.5	4.7
	Lach Sung	8	3.0	0.4	0.1	2.7	3.3
Biomass (ton/ha)	Dong Rui	8	31.4	10.6	3.7	22.6	40.2
	Xuan Thuy	12	44.9	12.6	3.6	36.9	52.9
	Lach Sung	8	107.2	54.7	19.3	61.5	152.9
Basal area (m^2/ha)	Dong Rui	8	7.0	1.8	0.6	5.4	8.5
	Xuan Thuy	12	13.0	7.8	2.3	8.0	17.9
	Lach Sung	8	21.3	10.1	3.6	12.9	29.8

3. RESULTS AND DISCUSSIONS

3.1. Climatical differences among study sites

Climatical differences among study sites were assessed by using one-way ANOVA. The results showed a significant difference in the annual average temperature, January average temperature and annual average rainfall among the study sites ($p < 0.01$). However, the pair comparisons (Table 2) showed that January average temperatures and annual average rainfall in Xuan Thuy national park were not significantly different from January average temperatures and annual average rainfall in Lach Sung estuary ($p > 0.05$). That may be due to the distance between Xuan Thuy national park and Lach Sung estuary (about 50 km in north-south direction) is much shorter than distance between Dong Rui and Xuan Thuy national park (about 100 km in north-south direction) (Figure 1), and Dong Rui is located in Tien Yen Gulf and surrounded by several small islands.

Table 2. Climatical differences among study sites.

Variables	Study sites	Differences	Significant level (*p*)
Annual average temperature (^{o}C)	Đong Rui- Xuan Thuy	-0.9	< 0.01
	Xuan Thuy-Lach Sung	-0.6	< 0.01
	Lach Sung-Đong Rui	1.5	< 0.01
January average temperature (^{o}C)	Đong Rui- Xuan Thuy	-1.1	< 0.05
	Xuan Thuy-Lach Sung	-0.4	0.404
	Lach Sung-Đong Rui	1.5	< 0.01
Annual average rainfall (mm)	Đong Rui- Xuan Thuy	738	< 0.01
	Xuan Thuy-Lach Sung	-138	0.396
	Lach Sung-Đong Rui	-600	< 0.01

3.2. Forest structural differences among study sites

Table 3. Forest structural differences among study sites.

Variables	Study sites	Differences	Significant level (*p*)
Diameter at 0.3 m height (cm)	Đong Rui- Xuan Thuy	-0.2	0.660
	Xuan Thuy-Lach Sung	-1.2	< 0.05
	Lach Sung-Đong Rui	1.4	< 0.05
Tree height (m)	Đong Rui- Xuan Thuy	-1.1	0.171
	Xuan Thuy-Lach Sung	0.6	0.588
	Lach Sung-Đong Rui	0.5	0.232
Biomass (ton/ha)	Đong Rui- Xuan Thuy	-13.5	< 0.05
	Xuan Thuy-Lach Sung	-62.4	< 0.05

Variables	Study sites	Differences	Significant level (*p*)
	Lach Sung-Đong Rui	75.8	< 0.05
Basal area (m^2/ha)	Đong Rui- Xuan Thuy	-6.0	0.092
	Xuan Thuy-Lach Sung	-8.4	< 0.05
	Lach Sung-Đong Rui	14.4	< 0.01

Statistical analysis (one-way ANOVA) showed that the differences in stem diameter, biomass and basal area among study sites were significant ($p < 0.05$). Only the difference in tree height was not significant ($p > 0.05$). The differences in mangrove forest structure may be due to differences in climate, topography and geomorphology, etc. among study sites [1, 2, 5]. In this paper we studied the relationship between the stem diameter, tree height, biomass and basal area and the climate.

The pair comparisons indicated that the differences in stem diameter, biomass and basal area between Dong Rui and Lach Sung estuary, and between Xuan Thuy national park and Lạch Sung estuary were also significant ($p < 0.05$) (Table 3). The differences in the mangrove forest structure could be caused by the differences in climatic condition. However, other environmental conditions such as soil, substrate and tidal, etc. could be other factors affecting the mangrove forest structure [1, 2, 5].

3.3. Relationship betweem climate condition and mangrove forest structure

3.3.1. Relationship betweem mangrove forest structure and temperature

The relationships between the structural characteristics of mangrove forest and temperature are shown in Figure 2. Stem diameter, tree height, basal area and biomass had positive linear relationship with annual average temperature and January average temperature. Stem diameter, tree height, basal area and biomass increase if annual average temperature and January average temperature increase. Our result in this study was also consistent with the findings of Mendez-Alonzo (2008), Pool (1977) and Novitzky (2010) [13, 14, 15].

The goodness of fit of all the regression equations to measured data was assessed by considering regression coefficient (R^2) and F-test. A consistently low positive regression coefficient of less than 0.66 was found among the variables stem diameter, tree height, basal area, biomass, annual average temperature and January average temperature). The highest regression coefficient was found between biomass and annual average temperature ($R^2 = 0.66$) and the lowest was found between tree high and January average temperature ($R^2 = 0.35$). The rather low correlation coefficients found in this study could be explained by the fact that we only consider the temperature condition, while other environmental factors such as soil, substrate, tidal, etc. could also affect mangrove forest [1, 2, 5]. Although the correlation coefficients of the regression equations were low, the F-test result showed that all models were statistically significant at the p-value of 0.05. It means that the models fit measured data well.

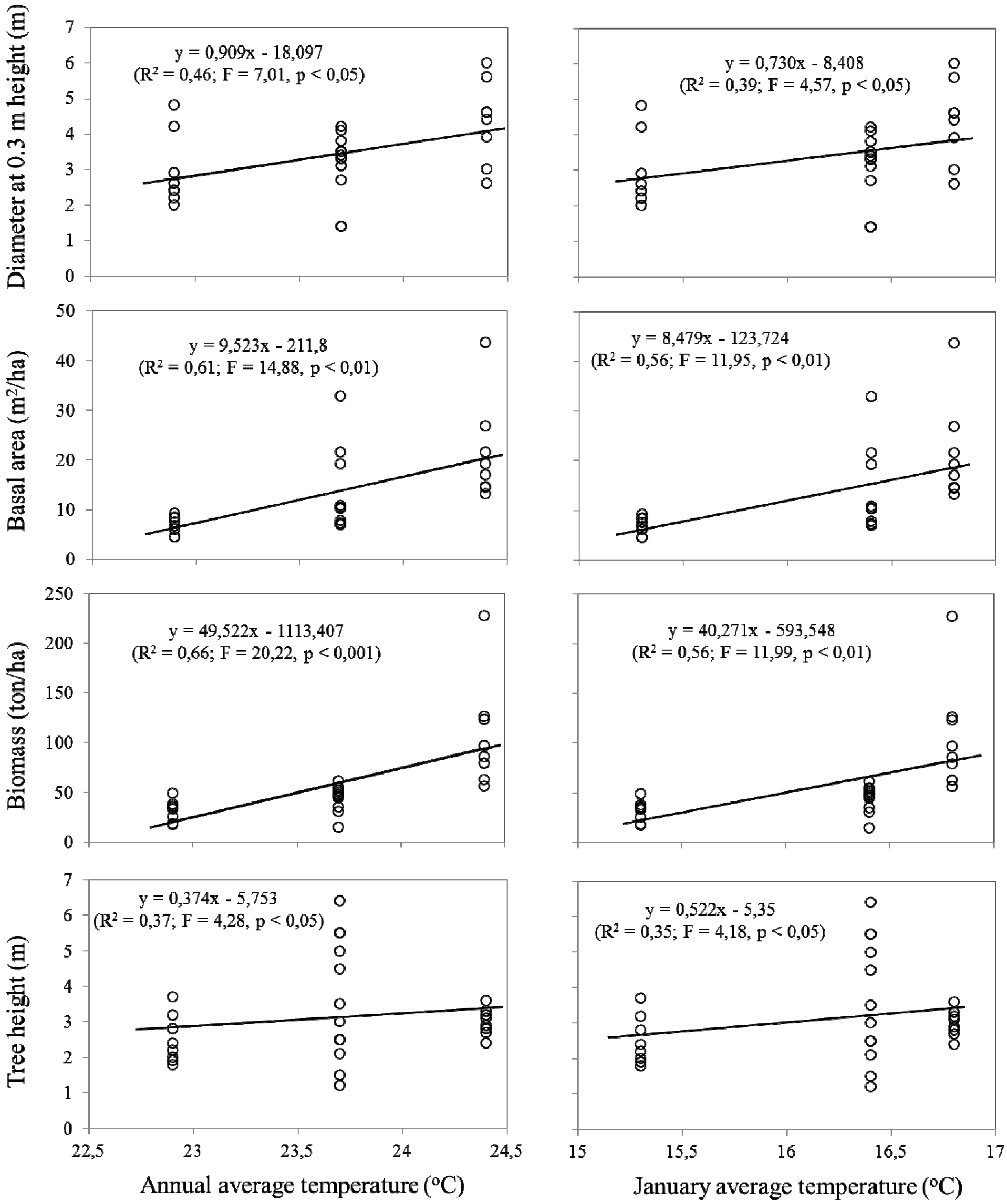

Figure 2. Relationship betweem mangrove forest structure and temperature on northern coast of Vietnam.

3.3.2. Relationship betweem mangrove forest structure and rainfall

The relationships between the structural characteristics of mangrove forest and annual average rainfall are shown in Figure 3. Unlike relationship with temperature, stem diameter, tree height, basal area and biomass had negative linear relationship with annual average rainfall. Stem diameter, tree height, basal area and biomass decrease if annual average rainfall increases.

A consistently low regression coefficient was also found among variables stem diameter, tree height, basal area and biomass, and annual average rainfall. The highest regression coefficient was found between basal area and annual average rainfall (R^2 = 0.59) and the lowest was found between biomass and annual average rainfall (R^2 = 0.29). These low correlation coefficients could be also explained by the fact that we only consider the rainfall condition, while other environmental factors such as soil, substrate, tidal ... could also affect mangrove forest [1, 2, 5]. Moreover, the F-test result also indicated that all models were statistically significant at the p-value of 0.05.

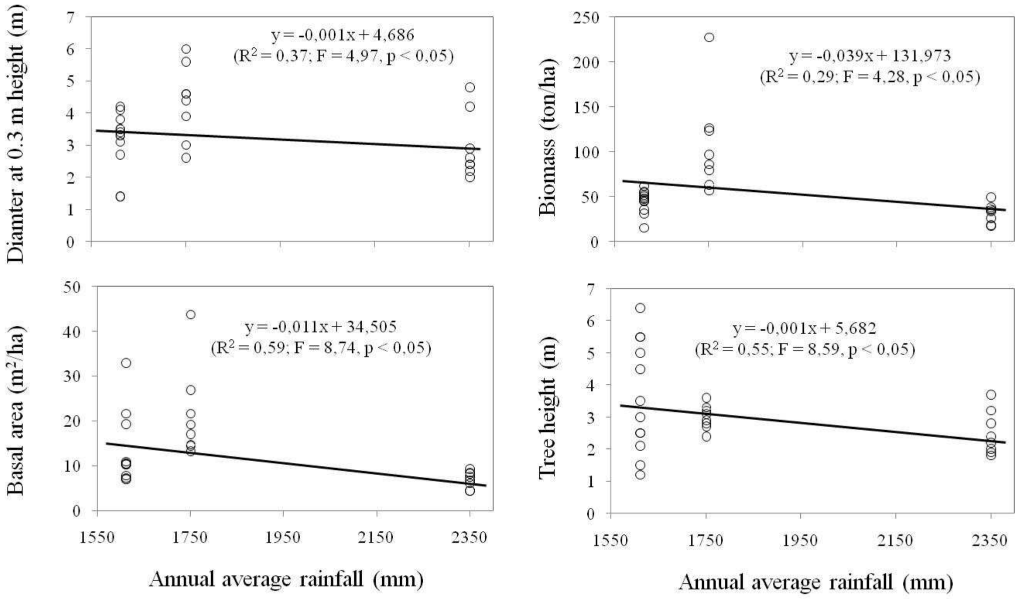

Figure 3. Relationship betweem mangrove forest structure and rainfall on northern coast of Vietnam.

The results of both relationship between mangrove forest structure and temperature, and relationship betweem mangrove forest structure and rainfall could countribute to construction of multiple linear regression models of temperature, rainfall and other factors for predicting the change of mangrove ecosystems.

4. CONCLUSION

The differences in mangrove forest structure (stem diameter. biomass and basal area), climate condition (temperature and rainfall) among study sites were significant ($p < 0.05$). Stem diameter, tree height, basal area and biomass had positive linear relationship with annual average temperature and January average temperature, and negative linear relationship with annual rainfall.

The study results also indicated that there were a weak but significant relationship between stem diameter and annual average temperature (R^2 = 0.46, $p < 0.05$); stem diameter and January average temperature (R^2 = 0.39, $p < 0.05$); stem diameter and annual average rainfall (R^2 = 0.37, $p < 0.05$); tree height and annual average temperature (R^2 = 0.37, $p < 0.05$); tree height and January average temperature (R^2 = 0.35, $p < 0.05$); tree height and annual average rainfall (R^2 = 0.55, $p < 0.05$); basal area and annual average temperature (R^2 = 0.61, $p < 0.01$); basal area and January average temperature (R^2 = 0.56, $p < 0.01$); basal area and annual average rainfall (R^2 = 0.59, $p < 0.05$); biomass and annual average temperature (R^2 = 0.66, $p < 0.01$); biomass and January average temperature (R^2 = 0.56, $p < 0.01$); biomass and annual average rainfall (R^2 = 0.29, $p < 0.05$).

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