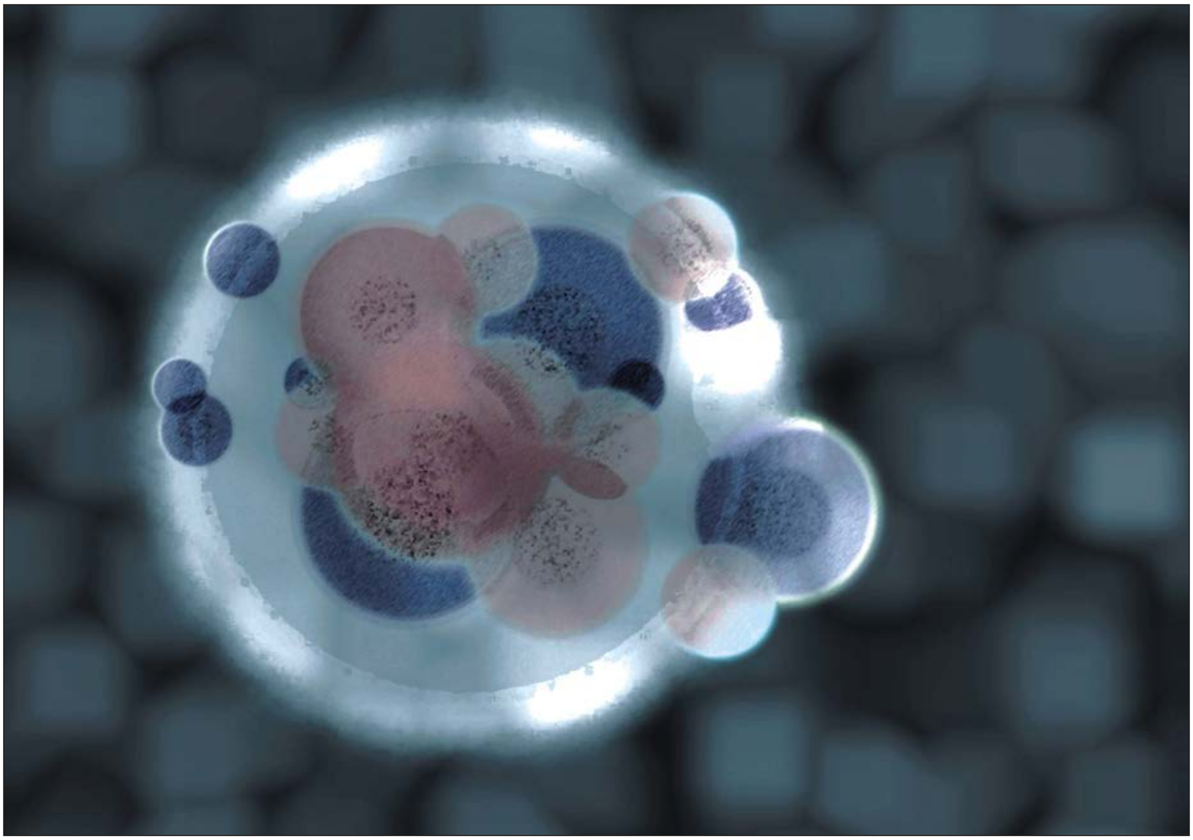

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Allometric Relations for Young *Kandelia candel* (L.) Blanco Plantation in Northern Vietnam

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Abstract: In Southeast Asia in general and Vietnam in particular, mangrove plantations cover a vast area of coastal line and they are till in young stage. A precise estimation of the biomass is necessary for evaluation and management of the plantation. Therefore, through assessing forest structure, this study would address on estimation of biomass of young mangrove plantations. Study plots were set up in 1, 5, 6, 7, 8, 9 and 10 year old *Kandelia candel* (L.) Blanco plantations in Thai Binh River Mouth, Northern Vietnam. Twenty six tree individuals in the plots were harvested. Tree height (H); diameter at 0.3 m in height (D), D*H; D^2 and D^2*H were used as variables for estimate plan parts, leaf (w_L), branch-stem (w_{BS}), propagules (w_P) and total dry weight (w_T). Allometric relationships were satisfied the best when stem diameter at 0.3m height was used as variables. The results may be useful in assessing productivity during the early stages of mangrove reforestation.

Key words: Mangroves, allometric, Northern Vietnam

INTRODUCTION

Mangroves are amongst the most important and productive of ecosystems in tropical and subtropical regions (Ong, 1993). They provide products such as timber, fuel wood and nursery grounds for many commercially important aquatic organisms (Peter, 1999). In Vietnam, mangroves have been traditionally exploited as building materials, charcoal, firewood, tannin, food, bird feathers, honey, herbal medicines and many other forest products (Hong and San, 1993). In addition, mangroves stabilize coastlines, in many cases they promote coastal accretion and provide a natural barrier against storm, cyclones, tidal bores, flooding and other potentially damaging natural force (Tri *et al.*, 1998). Furthermore, the 2004 December 26th tsunami may provide the stimulus for better understanding of what mangroves can do for human well-being. It is now found that wherever the mangroves occur or have been regenerated, the damage due to tsunami is minimal (Williams, 2005).

However, the coastal line where mangroves are found is also the place where human population are expanding rapidly, thereby, mangrove forests are under the great population pressure and suffer severe depletion. Exploitation of the resources, conversion of mangroves to others such as shrimp ponds, agriculture cultivations, salt pans, human settlements, port and industrial estates, as well as environmental impacts have contributed to the decline and degradation of mangrove resources (Hong and San, 1993; Ong *et al.*, 1995). Mangrove deforestation is contributing to a serious decline on coastal fisheries and aquaculture production, coupled with salinization of coastal agricultural land, soil erosion and subsidence and degradation of clean water supplies. The livelihoods of the local coastal communities have been disrupted or totally lost by the destruction or degradation of mangroves (Hong and San, 1993).

Recently, however, human society has begun to appreciate the benefits of mangroves and there is a growing awareness of the impacts of the forest loss. There are also increasing efforts by governments, NGOs and local communities around the world to conserve, rehabilitate and manage mangroves sustainably. Vietnamese people with the support of international organizations have been doing their best to replant mangroves. In Vietnam, a significant proportion of mangrove areas were destroyed in the past, but many have been restored. Most of the restored mangroves are still in young stage.

The variability of environmental conditions, such as climate, geomorphology, edaphic factors, tides and the history of the forest reflect on the structural characteristics of mangrove forests. After Lugo and Snedaker (1974), Mall *et al.* (1991) and Woodroffe (1985), there are several studies on comparison among biomass data and equations from areas which are different in

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geography such as Day *et al.* (1987), Seanger and Snedaker (1993) and Tam *et al.* (1995). In fact, the need to obtain specific data for each geographical area has led to an increase in studies on the biomass of mangroves. There have researches on that direction such as Aksornkoae (1982), Clough *et al.* (1997), Komiyama *et al.* (2000, 2002), Mall *et al.* (1991), Tam *et al.* (1995) and Woodroffe (1985). However, it is essential to have an acceptable method for assessment of biomass of juvenile or young plantation mangroves, as well as mature forests if management of the resources for a sustainable future use is to be successful.

With 3,200 km long coastline, mangroves in Vietnam have contributed significantly to the environment and socio-economic lives of coastal dwellers. In spite of the fact that mangroves are known as a vital ecosystem, studies on mangroves in Vietnam, especially biomass of the forest is still limited.

From the above description we confirm that we should stress the scarcity of study that have addressed on the biomass of young mangrove plantations in Northern Vietnam. In this study, amount of tree samples of different stand ages of *Kandelia candel* (L.) Blanco plantations in Thai Binh River Mouth, Northern Vietnam are investigated and based on those information, allometric relations for estimate biomass of young *K. candel* are established.

MATERIALS AND METHODS

Research site: The study site was set in Thuy Truong Commune, Thai Binh River Mouth. Thuy Truong is one of the 5 coastal communes of Thai Thuy District, Thai Binh Province (20°42'N, 106°24'E) (Fig. 1). Whole coastline of the commune is covered by about 1,000 ha of mangrove plantation which have been planted in from the year 1994 to 2002 (including *Kandelia candel* interplanted with *Sonneratia caseolaris*) (DRC and VNRC, 1994, 2002).

The coastal tidal area is flat with minor slope toward the sea. The slope of the bottom floor is 0.5/1,000 (Mazda *et al.*, 1997). The soil type is mainly muddy sand. Tidal regime of the area is irregular diurnal with large amplitude (maximum reached at 3.6-3.7 m, minimum at 1.0 m) (Muon, 1995). Thai Thuy is located in the monsoonal tropical area and the climate varies in two distinct seasons. Mean temperature in winter is 16.7°C while in the hottest summer month the mean temperature is as high as 29.1°C. The average humidity is 84%. Annual precipitation in Thai Binh Province is 1600-1800 mm per year. Salinity in coastal water bodies in Thai Binh fluctuates clearly difference between two seasons. In the rainy season, the salinity level remains only 2.4-6.6‰ and in the dry season, the salinity amounts to 9.5-22.0‰ (Muon, 1995).

Methods: Three plots of 10×10 m were set up in 1 to 6 year-old of *K. candel* plantations and 2 plots of 30×30 m (which divided in to 9 of 10×10 m subplots) were established in 8 to 10 year-old plantations.

For estimating the above ground biomass of the stand, 26 trees of *K. candel* including 1, 5, 6, 7, 8, 9 and 10 year-old trees were investigated in order to examine allometric relations. Tree height (H) and diameter at 0.3 m in height (D) were measured. All those trees were harvested at ground level and fresh weight of branch and stem (w_{BS}) (stem and branches were weighed together, so we use the symbol BS to indicate both of those parts), leaf (w_L) and reproductive organ (propagules) (w_P) were

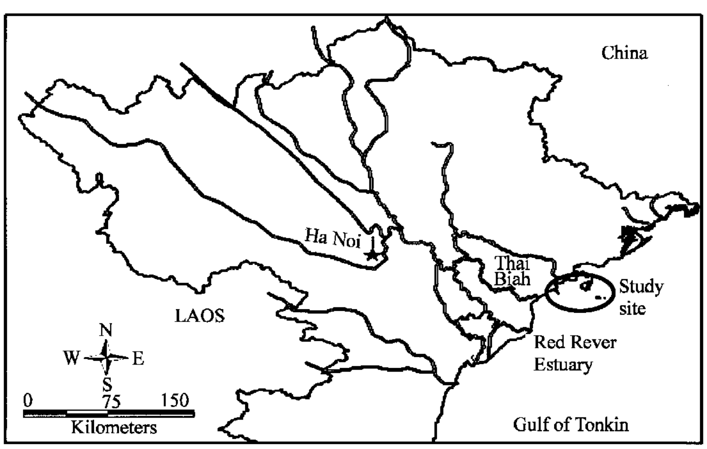

Fig. 1: Map of the study site

measured *in situ*. Dry weight of those plant part samples were also weighed after 2 day oven dry. The total dry weight of those plant parts (w_{BS}, w_L, w_P) were estimated by the dry/fresh weight ratios for each part. Allometric relationships were examined using variables relating to the D and H of trees (D, H, D^2, D*H, D^2*H).

RESULTS

Table 1 shown data of 26 harvested individuals of *K. candel*. Allometric relationships between $D_{0.3}$ and dry weight of plant parts leaf (w_L), branch-stem (w_{BS}), propagules (w_P) and total dry weight (w_T) were presented in Fig. 2. The relationship between the weight (w_p, w_L, w_{BS} and w_T) and $D_{0.3}$ were statistic allometric relation for stand age. Table 2 represented relationships of w_L, w_{BS}, w_P and w_T to H; D*H; D^2 and D^2*H when they were used as variables. In the relationship for leaf, branch and stem, propagules and total dry weigh of an individual tree shown the highest correlation when the variable D was adopted (0.92; 0.94; 0.18 and 0.94, respectively).

All equations had value of p less than 0.0001 but the equation of relationship between dry weight of propagule and diameter had p = 0.05 (Table 3).

Table 1: Size and dried weight of 26 individuals harvested from *K. candel* plantation in Thai Binh River Mouth, Northern Vietnam

Tree No.	D (mm)	H (cm)	Propagure (g)	Leaf (g)	Stem + Branch (g)	Total (g)
1	33.4	150	88.0	26.4	492.3	606.7
2	38.2	182	66.0	13.2	738.5	817.7
3	36.6	201	44.0	26.4	461.5	531.9
4	50.9	245	88.0	52.8	1,107.7	1,248.5
5	57.3	230	22.0	39.6	1,169.2	1,230.8
6	60.5	268	132.1	237.4	984.6	1,354.0
7	63.7	240	66.0	39.6	1,230.8	1,336.4
8	101.9	168	347.3	241.6	2,799.5	3,388.4
9	140.1	230	173.0	295.2	3,312.2	3,780.4
10	63.7	140	82.7	127.3	812.6	1,022.6
11	101.9	176	304.3	158.1	1,532.1	1,994.5
12	80.5	150	52.4	184.9	1,103.7	1,341.0
13	83.7	200	170.5	159.8	1,380.8	1,711.1
14	60.5	118	70.5	65.8	595.6	731.9
15	66.8	145	98.7	98.7	569.7	767.1
16	76.4	138	17.6	102.0	621.5	741.1
17	74.8	131	77.6	148.0	1,139.5	1,365.1
18	89.1	135	41.9	387.0	3,656.6	4,085.4
19	52.5	104	30.6	141.8	1,520.6	1,693.0
20	49.3	110	71.5	118.7	889.9	1,080.0
21	74.8	120	99.5	212.0	1,638.9	1,950.3
22	8.0	62		2.6	7.0	9.6
23	11.0	64		1.7	8.7	10.3
24	11.0	52		0.7	6.0	6.7
25	6.0	24		0.6	2.0	2.6
26	7.0	48		0.9	5.0	5.9

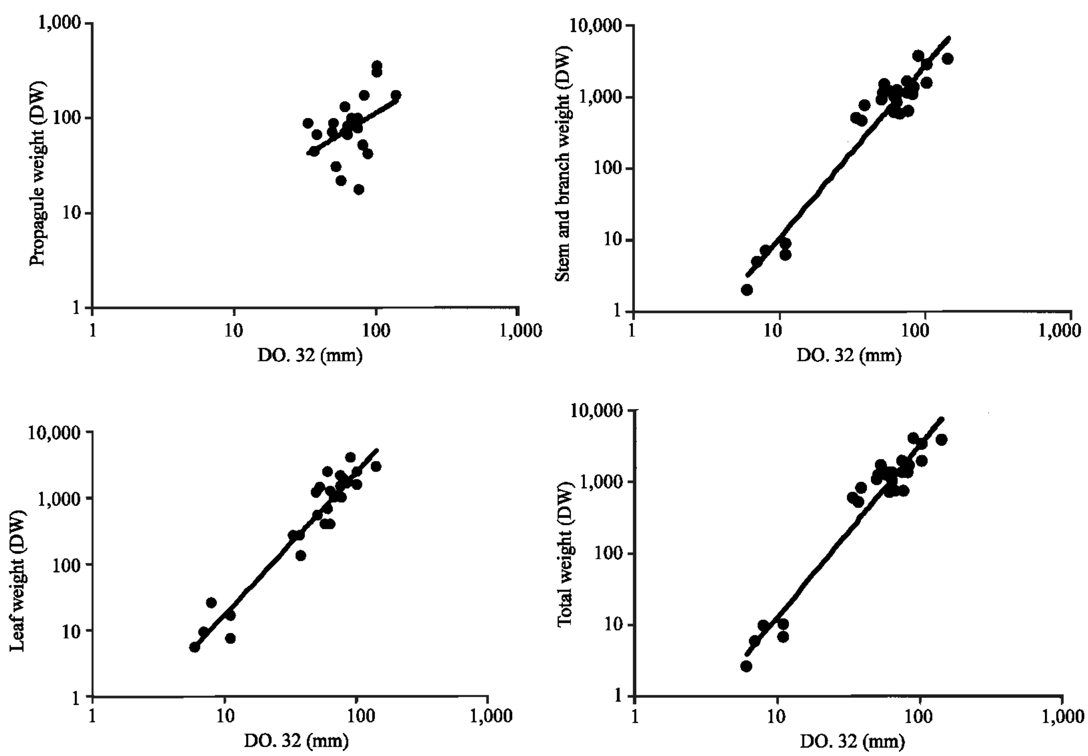

Fig. 2: Relationship between $D_{0.3}$ and w_p, w_L, w_{BS} and w_T. (Straight lines are given by allometric relation in Table 3)

Table 2: Allometric relation of different parts of trees with different variables

Variable	Leaf	Branch	Propaglue	Total
D (cm)	$y = 1.73x^{2.16}$	$y = 11.0x^{2.42}$	$y = 14.4x^{0.90}$	$y = 13.3x^{2.41}$
	$r^2 = 0.92$	$r^2 = 0.94$	$r^2 = 0.18$	$r^2 = 0.94$
D^2	$y = 1.73x^{1.08}$	$y = 11.0x^{1.21}$	$y = 14.4x^{0.459}$	$y = 13.3x^{1.21}$
	$r^2 = 0.92$	$r^2 = 0.94$	$r^2 = 0.18$	$r^2 = 0.94$
DH	$y = 0.01x^{1.31}$	$y = 0.02x^{1.53}$	$y = 0.40x^{0.76}$	$y = 0.03x^{1.52}$
	$r^2 = 0.85$	$r^2 = 0.94$	$r^2 = 0.22$	$r^2 = 0.94$
D^2H	$y = 0.07x^{0.82}$	$y = 0.23x^{0.95}$	$y = 1.35x^{0.46}$	$y = 0.29x^{0.95}$
	$r^2 = 0.89$	$r^2 = 0.95$	$r^2 = 0.22$	$r^2 = 0.95$
H	$y = 0.0001x^{2.63}$	$y = 4E\text{-}05x^{3.32}$	$y = 3.11x^{0.63}$	$y = 5E\text{-}05x^{3.30}$
	$r^2 = 0.59$	$r^2 = 0.75$	$r^2 = 0.06$	$r^2 = 0.75$

Where: y denoted for dry weight of leaf (L), branch and stem (BS), propagule (P) and total above ground biomass (TT); x denoted for different variables concerning to diameter and height

Table 3: Allometric regression equations between plant dry weight components and diameter based on harvested data for estimating biomass of specific components of planted *K. candel*

Plant components	Regression equations	r^2 value	P
Leaf	$w_L = 1.73*D^{2.16}$	0.92	<0.0001
Branch-Stem	$w_{BS} = 10.96*D^{2.42}$	0.94	<0.0001
Propagule	$w_P = 14.42*D^{0.90}$	0.18	= 0.05
Total	$w_{TT} = 13.33*D^{2.41}$	0.94	<0.0001

DISCUSSION

The relationships between diameter at 0.3 m height and tree organs were well satisfied allometric relation (Fig. 2, Table 2 and 3). The coefficient of determination was the highest between $D_{0.3}$ and w_{BS} and exceeded 0.92 for all the components except for the propagules. For leaf and propagule, wide deviations were found in smaller diameter trees (Fig. 2). Our found results are in good agreement with Clough (1992) that allometric relationships between diameter and the biomass of leaf and propagules are generally less robust than those for stem or total biomass because leaf and propagules are more easily be broken off the tree by strong winds. Moreover, leaf and propagules biomass may also vary seasonally event with the same age.

As mentioned above, in the study, the allometric relation for estimating biomass of different components of *K. candel* were satisfied the best when using diameter at 0.3m height as independent variable. It was suggested by several researches (Clough *et al.*, 1997; Komiyama *et al.*, 1988, 2000; Tam *et al.*, 1995) that estimation of biomass based on a combination of tree height and diameter was less significant. A close relationship between height and biomass was not found in our mangroves because of branching of main stem at very early growing stage and consequently shorter trees. The measurement of D is easier to obtain in the field than H. Moreover, height of individual trees was also difficult to measure accurately in a closed, extensive canopy. Not only the allometric relation given the best fit to the data but the technique was also found the most convenient to apply. The variable of diameter at 0.3 m in height was also be used to predicted biomass components in Biscayne National park, Florida, USA by Michael *et al.* (2001), in Satun Province, Southern Thailand by Komiyama *et al.* (2000).

South East Asia in general and north of Vietnam in particular, a large area of *K. candel* has been planted in recent years. Specific studies on estimation of biomass of young plantation *K. candel* are limited. Our found allometric relationships in Table 3 are very useful to estimate the above ground biomass of young plantation *K. candel*.

More and more mangroves of the world are affected by human activities and all may be influenced by global changes in climate or sea level. To assess the health of mangrove forests, or to evaluate the environmental impacts of specific management actions, it is necessary to develop monitoring system that address fundamental ecosystem characteristics, such as diversity, structure and productivities. Ideally, sampling methods should be applicable in forests in all stages of development, including very young or small-statured mangroves forests. If the founded results prove reliable after additional testing, they may provide especially useful in assessing productivity during the early stages of mangrove reforestation. Our mangroves are of limited extent, man's influence on the forests in the past has been intense. It is hope that future exploitation of mangroves in the area will be preceded by environment impact assessments which will include estimates of biomass using the allometric relations elaborated in this study.

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