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Establishing Allometric Relationship Using Crown Diameter for the Estimation of above-Ground Biomass of Grey Mangrove, Avicennia Marina (Forsk)Vierh in Mangrove Forests of Sirik, Iran

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ABSTRACT

In this study, the allometric relationships of *Avicennia marina* trees were analyzed in Sirik mangrove forests to estimate the above-ground biomass. In 1975, Sirik mangrove forests with title of Rud-e Gaz and Rud-e Hara Delta was declared as international wetland. *Avicennia marina* trees in this area are multi stem without distinctive diameter at breast height (DBH), so in the first step collar diameter (COD) was used to establish allometric equations. The results of these relationships showed that there is no significant correlation when COD was used as a variable. Therefore, the crown diameter (CD) was used to determine allometric equations. In this regard, the results showed that there is significant correlation between crown diameter (CD) and above-ground biomass. Results showed the total above –ground biomass is 17.16 t ha^{-1}. The stem, branch, and leaf biomass were, respectively, 7.739, 5.419, and 4.002 t ha^{-1}
KEY WORDS: Allometry, Avicennia marina, Crown diameter, Sirik mangrove forest.

1. INTRODUCTION

Mangroves are one of the most productive and bio-diverse marine ecosystems on the earth (Lugo and Snedaker, 1974; Boto et al., 1984). These wetlands found along the coastal zone act as a barrier against cyclones, protect coastal and provide good nursery ground for a number of commercially important aquatic organisms (Raman et al., 2007). These ecosystems are good habitats for some shorebirds and some macrobenthoses such as Fiddler crabs of Genus *Uca* (Bezerra and Cascon, 2006). Mangroves and mangrove ecosystems have been studied extensively but remain poorly understood. With continuing degradation and destruction of mangroves, there is a critical need to understand them better (Kathiresan and Bingham, 2001). Despite the many benefits provided by mangroves, they are under intense pressure from competing resource uses, in particular, firewood collection, and the cutting of mangroves for charcoal production, aquaculture and wood chipping operations. In addition, increased commercial activities and urban development demands are leading to the rapid conversion of mangrove land in developing countries(Bann,1997).Mangrove ecosystems have been exploited and subject to inappropriate management practices in terms of land reclamation and unsustainable forestry, as well as agricultural and aquacultural initiatives (Eong,1995).

Tree biomass is very important for several reasons: the need to make estimates of carbon pools in forests (United Nations,1992) and for studying other biogeochemical cycles (Husch et al., 2003). In addition, tree biomass provides various benefits, including safe habitats, food and timber (Nagelkerken et al., 2008; Walters et al., 2008). Forest biomass is the total of aboveground living organic matter expressed as oven-dry tons per unit area (Brown, 1997). Over the years, forest ecologists have developed various methods to estimate the biomass of forests (Komiyama et al., 2008).

Allometric equations have been developed to satisfy various purposes in forest ecology and management (Wang, 2006). The allometric method is used to estimate the biomass of mangroves. In this survey, the allometric relationships of *Avicennia marina* trees were analyzed in Sirik mangrove forests to estimate the above-ground biomass. Although *Avicennia marina* has been studied for many years in the Pacific region, few studies have been devoted to the Persian Gulf and Oman sea formations (Khan, 1982; Basson et al., 1987; Ormond et al., 1988; Abdel-Razik, 1991; Zahran et al., 1993; Dodd et al.,1999).

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2. MATERIALS AND METHODS

2.1. Study area

This survey was conducted in Sirik mangrove forest. The forest covers an area of 773 ha (Taghizadeh, 2007) and is located in south of Iran in close to Hormuz Strait in Oman sea (26° 19´ N, 057° 05´ E) (Fig. 1). Mangrove forests in Sirik, are the mixture of *Avicennia marina* and *Rhizophora mucronata* trees. These forests have spread in several creeks such as: Azini creek,Khairi creek,Chari creek and Garendhoo creek. In 1975, Sirik mangrove forest was declared as an international wetland under the title of Rud-e Gaz and Rud-e Hara Delta with an area of 16500 ha.

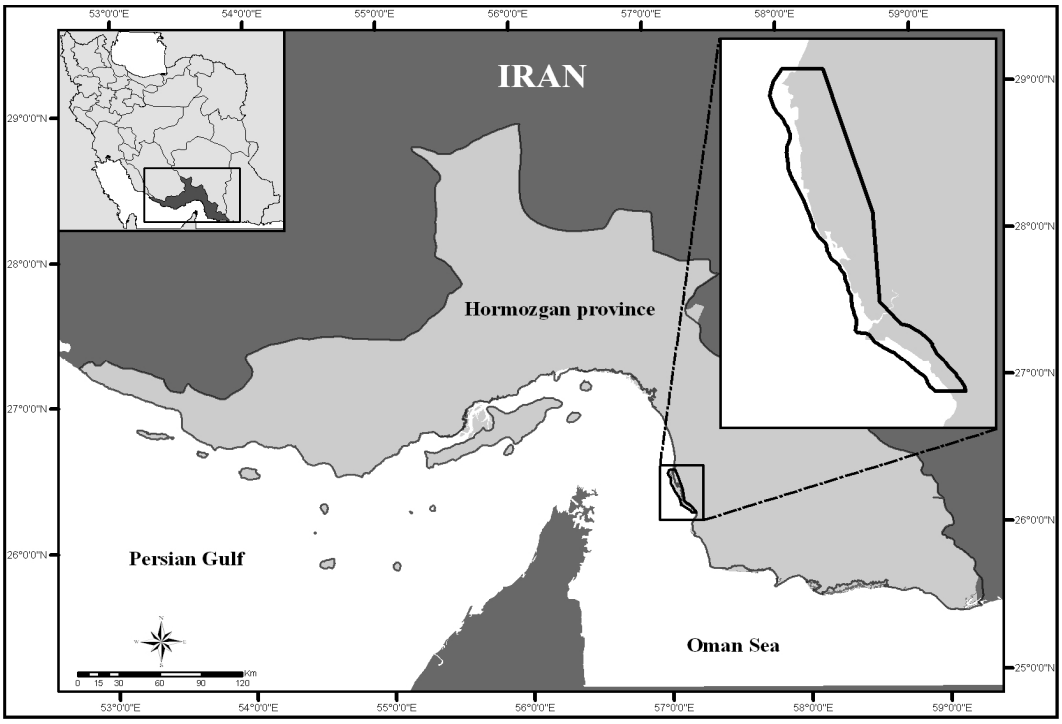

Fig.1. Location of Sirik mangrove forest

2.2 .Data collection

We used of transect line plots method (English et al., 1997). In October 2009, three transects and twelve, 100 m^2 sampling plots, each being 100 m far from the other, were established. In this area, *Avicennia marina* trees are multi stem without distinctive diameter at breast height (DBH); therefore, the collar diameter (COD) was measured. The stem height (H) and the crown diameter (CD) of all trees in each sampling plot were also measured. As a result, to estimate the above-ground biomass of the forest, after receiving the certificate from Iranian Department of Environment and Hormozgan Office, as many as 8 trees were cut to establish allometric equations and estimation of above –ground biomass. For each tree, the stem, branches, and leaves were weighted. The dry weights of these plant parts (W_S, W_B, and W_L) were calculated from the conversion ratios given by the dry/fresh weight ratios for samples in each plant part(Komiyama et al.,2000).

2.3. Analysis

DBH is the common variable to study allometric relationships of mangroves. Since *Avicennia marina* trees in this area are multi stem with no distinctive diameter at breast height (DBH), in the first step we used the collar diameter (COD) to establish allometric equations. The results of these relationships showed that there is no significant correlation when COD was used as a variable. Consequently, the crown diameter (CD) was used to establish allometric equations.

The usual procedure for crown diameter measurement is to take the average of the diameter of the crown's widest point and a second measurement at right angles (Husch et al., 2003).

3. RESULTS

3.1. Stand characteristics

The stand characteristics of *Avicennia marina* trees in sampling plots in Sirik area are presented in table 1.

Table 1.Stand characteristics of *Avicennia marina* trees in sampling plots in Sirik area

S.P number	Mean stem height (m)	Mean collar diameter(cm)	Mean crown diameter(m)
1	3.13	19.1	2.03
2	4.25	31.05	4.6
3	3	9.87	2.06
4	3.5	21.27	3.8
5	3.28	22.92	3.85
6	1.06	5.97	1.45
7	2.23	14.69	3.45
8	1.21	7.36	1.52
9	3.43	20.63	4.69
10	2.65	21.94	4.46
11	1.25	8.26	1.81
12	3.6	10.18	5.3

3.2. Above-ground biomass estimation

Table 2 shows the characteristics of 8 sample trees that were cut for estimation of biomass.

Table 2. The characteristics of 8 sample trees that were cut for estimation of biomass

Tree number	Stem height (m)	Collar diameter(cm)	Crown diameter(m)	Leaves biomass (dry weight kg)	Stem biomass (dry weight kg)	Branch biomass (dry weight kg)
1	2.58	13.37	3.35	5.194	11.675	3.826
2	3.35	17.51	6.1	13.852	29.949	24.489
3	2.6	19.1	4.3	5.627	12.69	7.142
4	2.1	14.01	3.4	1.298	5.076	2.142
5	3.1	28.82	4.2	3.679	11.675	17.857
6	1.55	7.32	1.7	0.865	2.538	0.51
7	1.74	8.91	2.63	3.463	6.852	1.785
8	1.26	5.57	1.5	0.865	0.761	0.255

Using the data from 8 sampled *Avicennia marina* trees, the allometric relationships for W_S, W_B, and WL (kg) were examined with the variable of crown diameter (CD) (m), (Figs. 2-4). Statistical analysis was undertaken using statistical product and service solutions (SPSS).

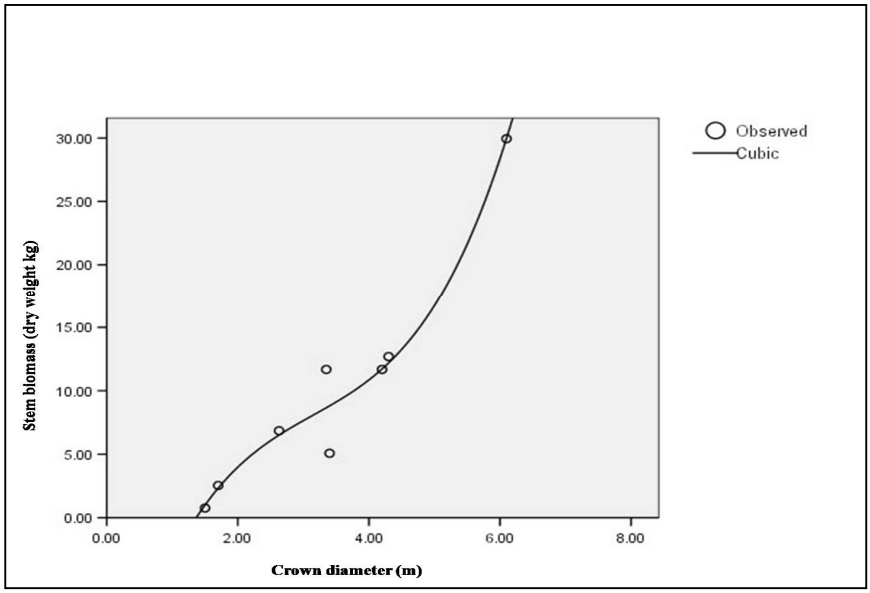

Fig.2. Allometric relationship for the stem weight of *A. marina* trees.

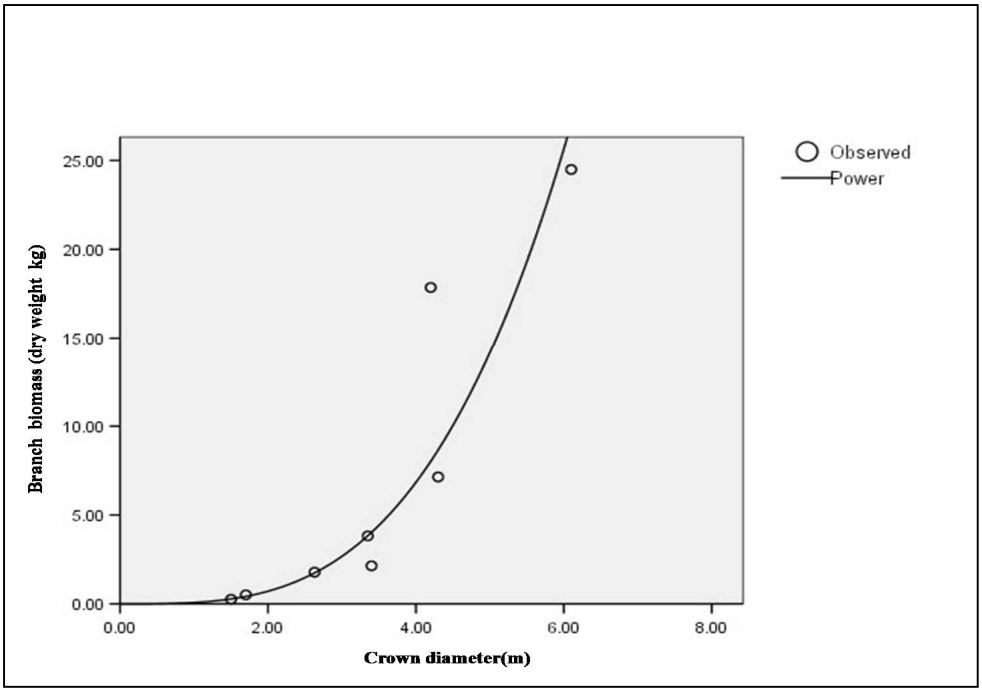

Fig.3. Allometric relationship for the branch weight of *A. marina* trees.

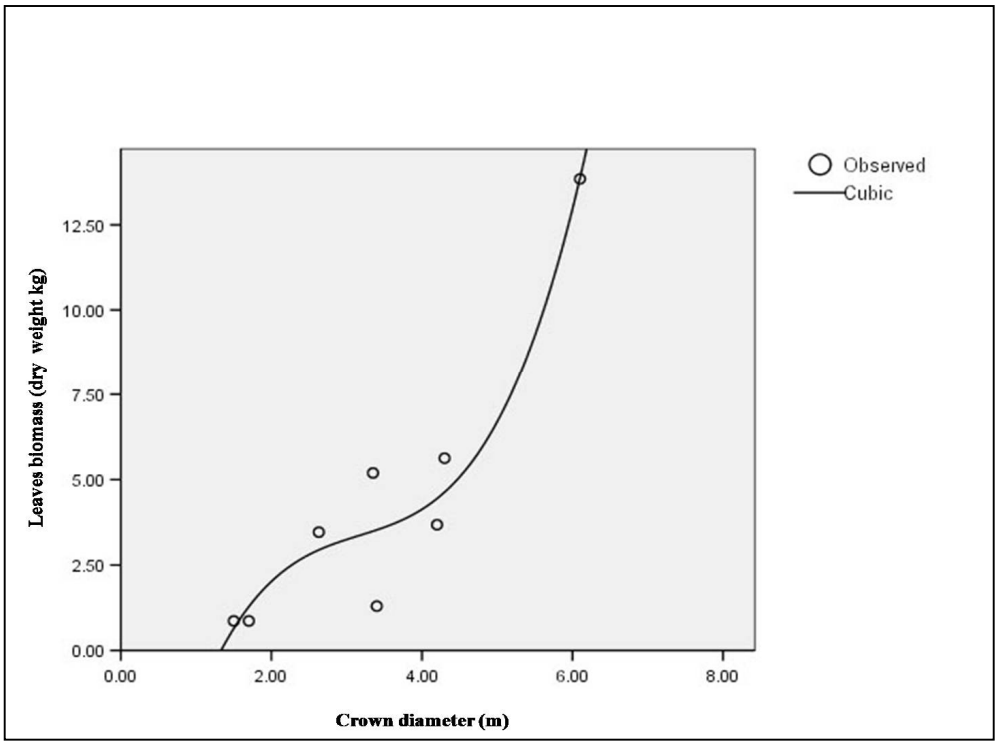

Fig.4. Allometric relationship for the leaf weight of *A. marina* trees.

Allometric equations for W_S, W_B, and W_L (kg) are presented below:

$$W_S = -17.217 + 18.346.CD - 4.915.CD^2 + 0.521.CD^3 \quad r^2=0.96 \quad (1)$$

$$W_B = 0.074.CD^{3.269} \quad , r^2=0.937 \quad (2)$$

$$W_L = -9.61 + 10.904.CD - 3.223.CD^2 + 0.339.CD^3 \quad , r^2=0.922 \quad (3)$$

W_S, W_B, and W_L of *Avicennia marina* trees were estimated by using Eqs. (1)- (3), these equations were applied to the 64 trees in the 12 sampling plots. Results showed the total above –ground biomass is 17.16 t ha^{-1}. The stem, branches, and leaves biomass were, respectively, 7.739, 5.419, and 4.002 t ha^{-1}

4. DISCUSSION

The above-ground biomass of *Avicennia marina* trees in Sirik area is low in comparison with other studies. Sirik area is located in high-latitude (26° 19´ N, 057° 05´ E). In high-latitude (>24° 23´N or S), primary forests mostly have an above-ground biomass of around 100 t ha^{-1} (Komiyama et al.,2008).Although the above-ground biomass of low formations of *Avicennia marina* var. *eucalyptifolia* in New Zealand is reported to be 6.8 t ha^{-1} (Woodroffe, 1985).

The highest above-ground biomass in high-latitude areas was reported for an *Avicennia marina* forest that was estimated 341 t ha^{-1} (Mackey, 1993). However the above-ground biomass of *Avicennia marina* trees in Sirik area is low because mangrove forests in this area are mixture of *Avicennia marina* and *Rhizophora mucronata* trees with dominance of *Rhizophora mucronata* trees (Danehkar,2005). *Rhizophora mucronata* is an exotic species that has been introduced to this area 100 years ago and it has nowadays become an invasive species. In addition, Sirik Mangrove forests are located in an arid environment with an approx 164 mm precipitation per year (Taghizadeh, 2007). So, in a situation like this, mangrove forests commonly cannot reach their ideal growth. On the other hand, 15 years of drought from 1995 to 2009 in this area, has damaged these forests.

Allometric equations for mangroves have been developed for several decades to estimate biomass and subsequent growth (Komiyama et al., 2008). Most studies have used allometric equations for single-stemmed trees, but mangroves sometimes have multi-stemmed tree forms, as often seen in *Rhizophora*, *Avicennia*, and *Excoecaria* species (Clough et al., 1997; Dahdouh Guebas and Koedam, 2006). Diameter at breast height (DBH) has been used in many allometric relationships in various studies (Putz and Chan, 1986; Tamai et al., 1986; Clough and Scott, 1989; Ong et al., 1995). In addition, researchers have used DBH in allometric equations and above-ground biomass estimation for *Avicennia marina* trees (e.g., Fromard et al., 1998; Imbert and Rollet, 1989; Comley and McGuinness, 2005). Since *Avicennia marina* trees in this area are multi stem with no distinctive diameter at breast height (DBH), in the first step, we used collar diameter (COD) to establish allometric equations. The results of these relationships showed that there is no significant correlation when COD was used as a variable. Consequently, the crown diameter (CD) was used to establish allometric equations. The results showed that there is a significant correlation between crown diameter (CD) and above-ground biomass.

Regarding the results of this study, in areas in which there is not significant correlation between DBH and above-ground biomass, researchers are able to test the crown diameter (CR) to establish allometric relationship and above-ground biomass.

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