Caspian J. Environ. Sci. 2018, Vol. 16 No. 2 pp. 111~119
©Copyright by University of Guilan, Printed in I.R. Iran

CJES
Caspian Journal of Environmental Sciences

[Research]

Allometric equations for determining volume and biomass of *Acer monspessulanum* L. subsp. *cinerascens* multi-stemmed trees

Afroonde A.[1], **Kiani B.***[1], **Attarod P.**[2]

1. *Department of Forest Sciences, Faculty of Natural Resources, Yazd University, Yazd, Iran*
2. *Department of Forest Sciences, Faculty of Natural Resources, Tehran University, Tehran, Iran*

* *Corresponding author's E-mail: bnkiani@yazd.ac.ir*

(Received: Dec. 23. 2017 Accepted: April 25. 2018)

ABSTRACT

Due to the importance of *Acer monspessulanum* in Iranian mountain forests, a study was carried out to reliably estimate its woody biomass and growing volume via allometric equations. Four transects, five trees in each were chosen randomly. The characteristics of standing trees including: diameter at root collar, height, number of stems and crown width were measured, then trees were finally cut down. Trunk and branches were separated and weighed. Some disks were taken and moved to the laboratory to determine the dry/fresh weight ratio and wood specific gravity and subsequently to calculate the dry weight of trunk, branch as well as aboveground biomass. Linear regression analysis was conducted to create allometric equations. Results showed that there was a strong and significant correlation between volume/biomass of *Acer monspessulanum* and quantitative characteristics of standing trees. The most robust predictors of volume and aboveground biomass were found to be crown width and crown area ($R^2 = 0.83$) followed by equivalent diameter at root collar ($R^2 = 0.81$). The normalized root-mean-square error amounts were found to be under 20% for most models especially for predicting biomass of branches. Tree height combined with equivalent diameter at root collar (EDRC) explained 87% of the variations in volume and biomass, creating precise models. It is concluded that crown diameter and EDRC can predict biomass and the volume of *A. monspessulanum* as a multi-stemmed tree with high accuracy and precision.

Key words: Allometric equations, Biomass, Modeling, Multi-stemmed, Prediction.

INTRODUCTION

Volume and biomass estimation of forest trees is very important in forest resource planning. Calculating the volume in standing trees is more difficult than in fallen trees with lower accuracy. Therefore, we have to find a reliable method to estimate standing volume. Several methods have been used by different researchers to estimate the volume of forest trees. However the accuracy of these methods highly depends on the type of forest (Pourshakoori & Hassanzad 2007). Calculating the volume of multi-stemmed trees using simple formulas is nearly impossible since most of the stems have small diameter with collections of about ten stems forking from the ground. Therefore, introducing the allometric equations to estimate their volume would be helpful. The most accurate method to estimate biomass of trees is a method in which the tree is entirely cut and divided to separate organs, dried and weighted (Basuki *et al.* 2009). Then allometric equations showing the relation between weight and size of each organ can be derived (JICA, 2005). Allometric equations are tools for estimating total weight of tree or tree parts by measuring diameter at breast height (DBH), tree height and other variables (Komiyama *et al.* 2008). Allometric equations are regression-based equations directly convert measurements of diameter and sometimes height to the total tree biomass (Losi *et al*. 2003). As a brief literature, in a study carried out by Panahi *et al*. (2011) in Iran National Phytology Garden, biomass and leaf carbon reserve were investigated using allometric equations in *Pistacia atlantica* forests considering crown width as the most effective variable on leaf biomass and carbon reserve. Zhou *et al*. (2007) improved two sets of allometric equations for predicting biomass of multi-stemmed *Eleagnus angustifilia* trees in Montana. Sohrabi & Shirvani (2012) also investigated the allometric relations for estimating crown and trunk biomass for *Pistacia atlantica* trees. Williams & Gresham (2006), Bakhtiarvand Bakhtiari (2011) and Parsapour *et al*. (2013) also employed allometric equations and introduced the best correlation and the most proper model for different parts of trees. Zewdie *et al*. (2009) calculated aboveground biomass of a coppice forest in central mountains of Ethiopia using allometric relations. The results showed that aboveground biomass had a linear relation with age of coppicing. Fu & Wu (2011) found a nonlinear regression equation based on tree height and crown width that was very suitable for estimating aboveground biomass of multi-stemmed mangrove trees in Quanzhou Bay, China. Cienciala *et al*. (2013) indicated that equivalent diameter at breast height predicts 98.8% of variations in aboveground biomass of *Prosopis* spp. in Santo Antano islands, West Africa. Miller (2016) found that total basal area was a suitable predictor to estimate biomass of multi-stemmed poplar trees in Mishigan. The purpose of this study was to introduce allometric equations for reliable estimation of volume and biomass in multi-stemmed trees of *Acer monspessulanum*. The equations would possibly make precise estimation of standing volume and aboveground biomass in this valuable species that can be regarded in forest management.

MATERIALS AND METHODS

Study site

This research was carried out in Baghe-Shadi protected forest is managed by Iranian Institute of Environmental Protection (11665 ha, 29° 42' 50'' - 29° 50' 41'' N, 54° 05' 35'' - 54 ° 14′ 35'' E, 1840-2664 m a.s.l.). The forest is located in South Yazd Province (240 km south of Yazd city) and belongs to Iran-Touran biogeoclimatic zone. The main forest species were *Pistacia atlantica* (F. & M.), *Acer monspessulanum* subsp. *cinerascens* (Boiss.), *Amygdalus scoparia* (Spach.) and *Amygdalus eleagnifolia* (Spach.). The slope was gentle in most area, with a mean inclination of about 20%. The area has a semi-arid climate with mean annual temperature and precipitation of about 17.4 °C and 285 mm, respectively.

Sampling Strategy

Habitat of *A. Monspessulanum* trees was firstly positioned in the topography map of study area with scale 1:80000. Transect sampling method was selected for the area and several transects were determined randomly in specified zones. Starting points coordinates were recorded along with azimuth. Five trees with different dimensions were selected randomly in four transects (totally 20 trees in study area) in November 2015. Characteristics of trees including trees height (with Sunnto clinometer), stem numbers, crown width (with tape measure), crown area and diameter of stems at root collar (with caliper) were measured prior to cutting the trees. Equivalent diameter at root collar (EDRC) for each tree was calculated by equation 1.

$$EDRC = \sqrt{d_1^2 + \cdots + d_n^2} \qquad (1)$$

where d_1 to d_n are stem diameters ($d \geq 2.5$ cm) and EDRC is equivalent tree diameter at root collar (Junior *et al*. 2014). The trees were ultimately harvested and then trunks and branches were separated. Noteworthy, leaves biomass was not calculated as trees were cut during leafless period (we could not get permission to cut trees in growth season, as the study site was located in a protected area). All trunks and branches were weighted separately for each tree (by digital balance with an accuracy of ± 0.05 g). Discs were taken from trees at root collar and DBH points to determine the specific gravity of wood.

Lab measurements

Dry weight of samples was measured by a digital scale (with an accuracy of ± 0.05 g) after keeping in oven (80 °C for 48 h). The coefficient derived from the ratio of dry weight to fresh weight of the samples was considered as an expansion factor, employing for measuring dry weight of all trunks and branches. The water displacement method was applied to obtain trunk volume. This method provides a better estimation of volume for species that have big hollow sections (Cornelissen *et al*. 2003). After determining the volume, specific gravity of woods was calculated as below (Vahedi & Metaji 2013):

$$\rho = M / V \quad (2)$$

Where ρ is specific gravity (kg m^{-3}), M is sample dry weight (kg) and V is sample volume (m^3). As wood dry weight and specific gravity were given, trunk volume of each tree was calculated. Also woody biomass of trees was determined for branches and trunks (aboveground biomass except leaves).

Statistical analysis

The validity of the models was evaluated by illustrating normality graphs and error value distribution. The normalized root means squared error (NRMSE) and coefficient of determination (R^2) were calculated to determine the best model. The more close the NRMSE to zero, the more precise the model (Andrei 2014). So, NRMSE in ranges of 10 - 20 and 20 - 30 shows the proper and the average precision of the model respectively, while the values more than 30%, show model unreliability (Singh *et al*. 2008).

The best models with the highest R^2 and the least NRMSE were selected. Error independency and normality were tested by Durbin-Watson and Shapiro-Wilks tests respectively to assure model reliability.

In the case of logarithmic transformation, a bias Correction factor ($SE^2/2$) proposed by Baskerville (1972) was used to calculate model errors. All analysis were conducted using SPSS version 21 except the scattergram that was created using Excel 2013.

RESULTS

Correlation analysis showed that there was a linear relation between all dependent and independent variables. With respect to the multiplicity of graphs, only two graphs regarding crown area-aboveground biomass and EDRC-tree volume were illustrated (Fig. 1). The results of modeling for estimating dependent variables (trunk dry weight, branch dry weight, tree and trunk volume) against EDRC as independent variable showed that EDRC is suitable estimator for aboveground biomass ($R^2 = 0.81$) and as shown in Table 1 for the tree volume ($R^2 = 0.81$).

Results showed that the least NRMSE was related to branch dry weight (10.93), explaining this independent variable provided the most precise model. Results of modeling for estimating the volume and biomass of *A. monspessulanum* trees with crown width are presented in Table 2. Crown width was found to be a suitable predictor for branch dry weight ($R^2 = 0.85$) and also for trunk volume and aboveground biomass ($R^2 = 0.83$). Model for branch dry weight had the least NRMSE value and was the most precise one.

Tree height as independent variable was a proper predictor for tree volume ($R^2 = 0.7$) and also for branch dry weight ($R^2 = 0.68$).

The most precise model was found to be appropriate for tree volume estimation (Table 3). Obviously models for height were less strong than crown width and EDRC.

It seems that a combination between tree height and other specifications could improve prediction capability.

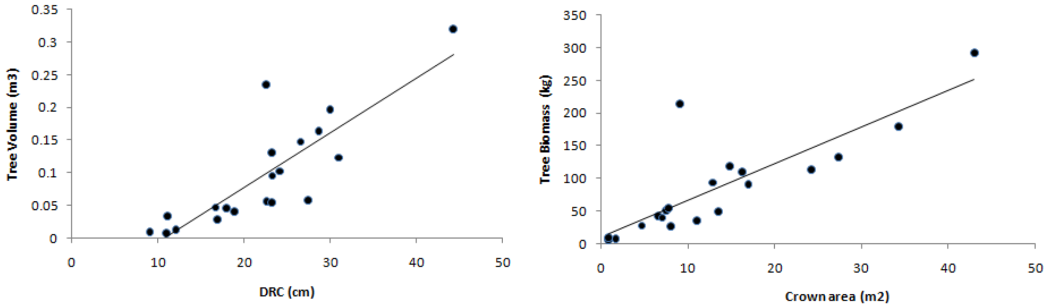

Fig. 1. Scattergram for reviewing the linear relation of variables: EDRC against tree volume (left) and crown area vs. tree aboveground biomass (right).

Table 1. Models for predicting dependent variables based on EDRC.

Dependent	Model	R^2	SE	RMSE	NRMSE
Trunk DW	Log Y= -1.59 + 2.22 log X	0.684	0.271	28.14	20.61
Tree DW	Log Y= -1.38 + 2.38 log X	0.816	0.203	40.65	14.16
Branch DW	Y= -53.04 + 4.72 X	0.792	20.83	19.76	10.93
Tree V	Log Y= -4.38 + 2.41 log X	0.807	0.212	0.044	14.10
Trunk V	Log Y= -4.59 + 2.25 log X	0.676	0.280	0.030	20.27

* D.W. = Dry Weight V= Volume

Table 2. Models for predicting dependent variables based on crown width.

Dependent	Model	R^2	SE	RMSE	NRMSE
Trunk DW	Log Y = 0.44 + 1.66 log X	0.688	0.269	28.97	21.25
Tree DW	Log Y = 0.79 + 1.8 log X	0.837	0.191	43.89	15.25
Branch DW	Log Y = 0.45 + 2.008 log X	0.857	0.197	20.87	11.55
Tree V	Log Y= -2.18 + 1.83 log X	0.834	0.197	0.047	15.06
Trunk V	Log Y= -2.53 + 1.69 log X	0.686	0.276	0.032	21.62

Table 3. Models for predicting dependent variables based on height.

Dependent	Model	R^2	SE	RMSE	NRMSE
Trunk DW	Y = -78.43 + 27.18X	0.623	22.88	21.70	15.91
Tree DW	Y = -159.99 + 58.94X	0.679	43.88	41.63	14.5
Branch DW	Log Y=-0.67 + 3.59logX	0.685	0.292	29.86	16.52
Tree V	Y = -0.18 + 0.06X	0.703	0.046	0.044	14.10
Trunk V	Y =-0.08 + 0.03X	0.641	0.024	0.023	15.54

As shown in Table 4, stem number was a proper estimator for tree volume and biomass. Model for trunk volume had the most accuracy and lowest NRMSE value (13.59). Generally, it seems that the number of stems could estimate 70% of variations in aboveground biomass and volume of *A. monspessulanum* trees. Models fitted on data for estimating volume and biomass by tree crown area were shown in Table 5. Results showed that crown area was a suitable predictor for tree volume and biomass ($R^2 = 0.83$).

This variable also estimated branch dry weight accurately ($R^2 = 0.85$). Multivariate models created by stepwise linear regression were presented in Table 6. Tree height and EDRC were significant to present in models. Two-variable models could improve prediction capability from 2% to 14% in contrast to simple ones and increased precision considerably.

Table 4. Models for predicting dependent variables based on stem numbers.

Dependent	Model	R2	SE	RMSE	NRMSE
Trunk DW	Y= -8.41 + 9.089X	0.726	19.53	18.53	13.59
Tree DW	Log Y = 1.11 + 1.12 log X	0.734	0.244	42.12	14.67
Branch DW	Log Y = 0.84 + 1.198 log X	0.690	0.290	31.02	17.16
Tree V	Log Y = -1.84 + 1.124 log X	0.708	0.261	0.048	15.38
Trunk V	Y = -0.008 + 0.01X	0.685	0.023	0.022	14.86

Table 5. Models for predicting dependent variables based on crown area.

Dependent	Model	R^2	SE	RMSE	NRMSE
Trunk DW	Log Y = 0.53 + 0.83 log X	0.688	0.269	28.91	21.20
Tree DW	Log Y = 0.88 + 0.90 log X	0.837	0.191	41.13	14.32
Branch DW	Log Y = 0.55 + 1.004 log X	0.857	0.197	17.28	9.56
Tree V	Log Y= -2.08 + 0.91 log X	0.834	0.197	0.045	14.42
Trunk V	Log Y = -2.44 + 0.84 log X	0.686	0.276	0.032	21.62

Table 6. Multivariate models for predicting dependent variables.

Dependent	Model	R^2	SE	RMSE	NRMSE
Tree DW	Y= - 130.07 + 6.03 EDRC + 18.57 H	0.87	26.2	28.41	9.9
Branch DW	Y= -84.8 + 3.67 EDRC + 3.2 H	0.85	18.1	14.76	9.2
Tree V	Y= -0.149 + 0.007 EDRC + 0.023 H	0.87	0.028	0.014	9.9

DISCUSSION

All independent variables in this paper had a significant correlation with aboveground biomass and volume, providing high accurate models. In most cases, logarithmically converted data had better fit than untransformed ones especially in data sets that include outlying observations (Feng *et al*. 2014). This situation probably occur frequently when sample size is small (as in our study). In this case a correction factor was applied to adjust model errors that increased amount of errors a little. The most accurate models for estimating dry weight of branches were related to crown area. Crown area and width were found to be suitable predictors for estimating the volume and biomass of *A. monspessulanum* trees. It was in consistent with the study of Conti *et al*. (2013) once estimating shrubs biomass in Argentina, and also with that of Kuyah *et al*. (2012) on trees in farmlands of Kenya, as well as that of Goodman *et al*. (2014) in tropical forests of Peru. Conversely Zhou *et al*. (2007) found that crown diameter is not a suitable predictor for multi-stemmed *Eleagnus Angustifoilia* L. because of its ununiformed crown distribution.

Parsapour *et al*. (2013) found that diameter at breast height (DBH) provided a high accurate model to predict biomass of four poplar species ($R^2 = 0.95$). Therefore, it was expected that the equivalent diameter at root collar (EDRC) presented a superior model for biomass estimation. Also Cienciala *et al*. (2013) found that equivalent diameter at breast height is a suitable predictor for biomass of *Prosopis* spp. in Santo Antao islands, West Africa. Our results showed that EDRC was a suitable predictor for the biomass of *A. monspessulanum* trees, where the variables of crown area and crown width were not available. Considering the method of calculating EDRC higher amounts of this variable relates to thicker stems. It can be concluded that higher EDRC has a clear effect in volume and consequently biomass increscent. However we applied equivalent diameter at root collar instead of EDBH and found it suitable. Whereas in the studies of Mitsopoulos & Dimitrakopoulos (2007) on *Pinus halepensis* Mill., that of Litton (2008) on *Metrosideros polymorpha* and that of Cai *et al*. (2013) on ten tree species in Northeast China, diameter at breast height was the most significant determinant of crown fuel biomass, total biomass and aboveground live biomass respectively.

Top height of trees could predict 70% of variations in volume and biomass. Hierro *et al*. (2000) showed that the diameter of the highest stem was the best estimator for determining the biomass of *Condalia erinacea*. In the present study, it was not possible to accurately determine the highest stem as the crowns were entangled. Stem numbers showed significant relation to biomass and volume of *A. Monspessulanum* trees, estimating 70% of variations with acceptable precision. Noteably, all stems of *A. Monspessulanum* showed sufficient growth, whereas in some species such as *Haloxylon ammodendron* (C A Mey) with increasing the number of stems, their diameter decreased. So that, the number of stems could not be a well predictor for biomass and volume estimation, particularly in young shrubs.

In the present study, we found that EDRC (for multi-stemmed trees regarded as DBH) in combination with tree height could predict 87% of variations in aboveground biomass and volume. However multivariate models were not suitable in prediction capability, whereas provided more precise results than simple models. According to the study of Ebuy *et al*. (2011), tree height and diameter at breast height provided predicting up to 77 % of variations in above ground biomass of 12 trees belonging to three species at Yangmbi in Congo. Cole & Evel (2006) showed also that the allometric equations generally fit well to the data. So that, in most cases, over 50% of the observed variations in biomass could be explained by diameter and height. Tree height and crown width were also suitable predictors for biomass of mangrove trees (Fu & Wu 2011).

Ketterings *et al*. (2001) found that regression parameters for exponential models varied in different sites. It should be pointed out that estimates of aboveground biomass and their changes over the time extremely depends on the source of allometric data. Allometric studies often rely on samples that are too small to selecte in a statistically valid manner from the population of interest (Brown *et al*. 1999). There are some limitations, however, in tree cut as we were encountered in this study. Other potential errors in estimation may also result from differences in biomass allocation or morphology from one forest system to another. Multi-stemmed trees form an important component of the woody vegetation in forest ecosystems (Matula *et al*. 2015). However, lack of a clear methodology for reliable measurement and estimation of their woody biomass is evident. In this research we found that the volume and aboveground biomass of multi-stemmed *A. monspessulanum* can be predicted accurately and precisely according to standing tree specifications. Allometric equations provided in this study can be used as a non-destructive method to estimate the amount of wood per unit area and are considered to be valuable tools in managing mountain forests. They make great assistance to forest managers for planning forest yield and quantifying wood production obtained from this species.

REFERENSES

Andrei, D 2014, Prequalification criteria for pavement inspectors, Civil Engineering Department, California State Polytechnic University, 11 p.

Bakhtiarvand Bakhtiari, S 2011, Assessment of Carbon estimation methods for conifers and broadleaves trees in Mobarake Steel plantation. MSc. Dissertation, Faculty of Natural Resources and Earth Science. Shahrekord University, Shahrekord, Iran, 112 p.

Baskerville, GL 1972, Use of logarithmic regression in the estimation of plant biomass. *Canadian Journal Of Forest Research,* 2: 49-53.

Basuki, TM, Van Laake, PE, Skidmore, AK & Hussin, YA 2009, Allometric equations for estimation the above-ground biomass in tropical lowland Dipterocarp forests. *Forest Ecology and Management,* 257: 1684-1694.

Brown, SL, Schroeder, P & Kern, JS 1999, Spatial distribution of biomass in forests of the eastern USA. *Forest Ecology and Management,* 123: 81-90.

Cai, S, Kang, X & Zhang, L 2013, Allometric models for aboveground biomass of ten tree species in Northeast China. *Annals of Forest Research,* 56: 105-122.

Cienciala, E, Centeio, A, Blazek, P, Soares, M & Russ, D 2013, Estimation of stem and tree level biomass models for *Prosopis juliflora/ pallida* applicable to multi-stemmed tree species. *Trees*, 27: 1061-1070.

Cole, Th, G & Ewel, JJ 2006, Allometric equations for four valuable tropical tree species. *Forest Ecology and Management,* 229: 351–360.

Conti, G, Enrico, L, Casanoves, F & Diaz, S 2013, Shrub biomass estimation in the semiarid Chaco forest: a contribution to the quantification of an underrated carbon stock. *Annals of Forest Science,* 70: 515–524.

Cornelissen, JHC, Lavorel, S, Garnier, ES, Bachmann, N, Gurvich, DEC, Reich, PB, Steege, H, Morgan, HD, van der Heijden, MGA, Pausas, JG & Poorter, H 2003, A handbook of protocols for standardization and easy measurement of plant functional traits worldwide. *Australian Journal of Botany,* 51: 335–380.

Ebuy, J, Lokombe, JP, Ponette, Q, Snowa, D & Picard, N 2011, Allometric equation for predicting aboveground biomass of three tree species. *Journal of Tropival Forest Science,* 23: 125-132.

Feng, Ch, Wang, H, Lu, N, Chen, T, He, H, Lu, Y & Tu, X 2014, Log-transformation and its implications for data analysis. *Shanghai Archives of Psychiatry,* 26: 105-109.

Fu, W & Wu, Y 2011, Estimation of aboveground biomass of different mangrove trees based on crown diameter and tree height. *Procedia Environmental Sciences,* 10: 2189-2194.

Goodman, RC, Philips, OL & Baker, TR 2014, The importance of crown dimensions to improve tropical tree biomass estimates. *Ecological Applications,* 24: 680–698.

Hierro, J, Branch, LC, Villarreal, D & Clark, KL 2000, Predictive Equation for Biomass and Fuel Characteristics of Argentine shrubs, *Journal of Range management,* 53: 617-621.

JICA, Japanese International Cooperation Agency (2005) Manual of biomass survey and analysis. Forestry Research and Development Agency, Japan, 23 p.

Junior, LR, Engel, VL, Parrotta JA, Melo, AC & Re, DS 2014, Allometric equations for estimating tree biomass in restored mixed-species Atlantic forest stands. *Biota Neotropica,* 14: 1-9.

Ketterings, MQ, Coe, R, Noordwijk, VM, Ambagua, Y & Palm, A 2001, Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management,* 146: 199-209.

Komiyama, A, Ong, JE & Poungparn, S 2008, Allometry, biomass, and productivity of mangrove forests: A review. *Aquatic Botany,* 89: 128–137.

Kuyah, Sh, Muthuri, C, Jamnadass, R, Mwangi, P, Neufeldt, H & Dietz, J 2012, Crown area allometries for estimation of aboveground tree biomass in agricultural landscapes of western Kenya. *Agroforestry Systems,* 86: 267–277.

Litton, CM 2008, Allometric Models for predicting aboveground biomass in two widespread woody plants in Hawaii. *Biotropica*, 40: 313–320.

Losi, CJ, Siccama, TG, Juan, RC & Morales, E 2003, Analysis of alternative methods for estimating carbon stock in young tropical plantations. *Forest Ecology and Management,* 184: 355-368.

Matula, R, Damborská, L, Nečasová, M, Geršl, M & Šrámek, M 2015, Measuring biomass and carbon stock in resprouting woody plants. *PLOS ONE*, 10: 1-14.

Miller, R 2016, Developing an algorithm to predict single-tree biomass weight from stem diameter measurements in young hybrid poplar energy plantations in Michigan. Michigan State University. Forest Biomass Innovation Center, Research report, 3p.

Mitsopoulos, ID & Dimitrakopoulos, AP 2007, Allometric equations for crown fuel biomass of Aleppo pine (*Pinus halepensis* Mill.) in Greece. *International Journal of Wildland Fire,* 16: 642–647.

Parsapour, MK, Sohrabi, H, Soltani, A & Iranmanesh, Y 2013, Allometric relation for estimating biomass of four species of poplar in Chaharmahal va Bakhtiari province. *Iranian Journal of Forest and Poplar Research,* 21: 571-528.

Pourshakoori, F & Hassanzad, A 2007, The most appropriate method for estimating forest volume in Guilan Province. *Iranian Journal of Pajouhesh va Sazandegi* 77:24-31.

Panahi, P, Pourhashemi, M & Hasaninejad, M 2011, Estimation of leaf biomass and leaf carbon sequestration of *Pistacia atlantica* in

National Botanical Garden of Iran. *Iranian Journal of Forest,* 3: 1-12.

Singh, AK, Tripathy, R & Chopra, UK 2008, Evaluation of CERES-Wheat and CropSyst models for water-nitrogen interactions in wheat crop. *Agricultural Water Manageement,* 95: 776–786.

Sohrabi, H & Shirvani, A 2012, Allometric equations for estimating standing biomass of Atlantic Pistachio (*Pistacia atlantica* var. *mutica*) in Khojir National Park. *Iranian Journal of Forest,* 4: 55-64 (In Persian).

Vahedi, AA & Mettagi, A 2013, Amount of carbon sequestration distribution associated with oak tree's (*Quercus castaneifolia* C.A. May) bole in relation to physiographical units of Hrcanian natural forests of Iran. *Iranian Journal of Forest and Poplar Research* 4: 716-728 (In Persian).

Williams, TM & Gresham, CA 2006, Biomass accumulation in rapidly growing loblolly pine and sweet gum. *Biomass and Bioenerg*. 30: 370- 377.

Zewdie, M, Olsson, M & Verwijst, T 2009, Above-ground biomass production and allometric relations of *Eucalyptus globulus* Labill coppice plantations along a chronosequence in the central highlands of Ethiopia. *Biomass and Bioenerg*. 33: 423-428.

Zhou, X, Brandle, JR, Schoeneberger, MM & Awada, T 2007, Developing above-ground woody biomass equations for open - grown, multiple - stemmed tree species: Shelterbelt-grown Russian-olive, *Ecological Modelling,* 202: 311-323.

معادلات آلومتریک برای تعیین حجم و زی‌توده درختان چندساقه کیکم (*Acer monspessulanum* L. subsp. *cinerascens*)

افرونده ع.[۱]، کیانی ب.[۱*]، عطارد پ.[۲]

۱ گروه جنگلداری، دانشکده منابع طبیعی، دانشگاه یزد، یزد، ایران
۲ گروه جنگلداری، دانشکده منابع طبیعی، دانشگاه تهران، تهران، ایران

(تاریخ دریافت: ۹۶/۱۰/۰۲ تاریخ پذیرش: ۹۷/۰۲/۰۵)

چکیده

با توجه به اهمیت گونه کیکم در جنگل‌های کوهستانی ایران، مطالعه‌ای به منظور پیشبینی زی‌توده چوبی و حجم سرپای آن از طریق معادلات آلومتریک انجام شد. ابتدا چهار ترانسکت و در هر ترانسکت پنج درخت به طور تصادفی انتخاب شدند. خصوصیات درختان سرپا از جمله: قطر در محل یقه، ارتفاع، تعداد ساقه و عرض تاج اندازه گیری و در نهایت درختان قطع شدند. تنه و شاخه ها از هم جدا و توزین شدند. برای تعیین نسبت وزن خشک به وزن تر و همچنین وزن مخصوص چوب، دیسک‌هایی تهیه و به آزمایشگاه منتقل شد. با استفاده از این دو مشخصه، وزن خشک تنه، شاخه و در نهایت وزن قسمت هوایی به عنوان زیست توده سطح زمین برای تمام درختان قطع شده محاسبه شد. تحلیل رگرسیون خطی برای ایجاد معادلات آلومتریک اجرا شد. نتایج نشان داد که بین حجم / بیوماس گونه کیکم و خصوصیات کمی درختان رابطه معنی‌داری وجود دارد. بهترین متغیرهای پیش‌بینی کننده حجم و زی‌توده روی زمین شامل عرض و مساحت تاج ($R^{۲}$= ۰/۸۳) و همچنین قطر یقه ($R^{۲}$ = ۰/۸۱) بودند. مقدار ریشه نرمال شده میانگین مربعات خطا در اکثر مدل ها بویژه برای پیش‌بینی زی‌توده شاخه‌ها کمتر از ۲۰ درصد بود. ارتفاع درخت در ترکیب با نماینده قطر یقه توانست ۸۷ درصد تغییرات حجم و زی‌توده را پیش‌بینی نموده و مدل‌های دقیقی تولید کند. به عنوان نتیجه، قطر تاج و نماینده قطر یقه می‌توانند زیست توده و حجم گونه کیکم را به عنوان یک درخت چند شاخه با دقت و صحت بالا پیش بینی کنند.

*مؤلف مسئول