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Original Article

Estimating diameter at breast height (DBH) from diameter at stump height (DST) in triple mixed stands in the region of Artvin in Turkey

Artvin yöresindeki üçlü karışık meşcerelerde kütük çapı ile göğüs çapı ilişkisi

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ABSTRACT

Diameter at breast height is used as an independent variable in the calculation of most tree or stand parameters because it can be measured easily and has high correlation with tree variables. But, it is necessary to estimate the size of the DBH of the tree concerned to have knowledge of the tree which has been separated from the area. In this study, DST-DBH relationships were investigated on stands where Oriental Spruce (So), Scots Pine (Ps) and Eastern Black sea Fir (Fb) were mixed. For this purpose, 206 trees (69 So, 69 Ps and 68 Fb) were used which were cut from 23 different sample areas taken in fully closed SoPsFb and PsSoFb stands in Artvin. According to the statistics analysis; models that best explain the variability of the DBH are power for spruce, quadratic for pine and linear models for fir. These models can explain the variance of DBH in triple mixed stands by 95.2% for spruce, 96.5% for pine and 96.4% for fir, and standard errors of models are 1.850, 1.598 and 1.643 respectively. As a result, these models, which at a certain height of success in predicting DBH, can be used by practitioners at fully closed triple mixed stands in Artvin.

Keywords: Diameter at breast height, diameter at stump height, regression analysis, triple mixed stands

ÖZ

Göğüs çapı, kolay ölçülebilir olması ve diğer ağaç değişkenleriyle yüksek korelasyona sahip olmasından dolayı, tek ağaç veya meşcere parametrelerinin birçoğunun hesaplanmasında bağımsız bir değişken olarak kullanılmaktadır. Ancak ormanlık alandan ayrılmış olan ağaç hakkında bilgi sahibi olabilmek için göğüs çapı büyüklüğünü tahmin etmek gerekmektedir. Bu çalışmada, Doğu Ladini (L), Sarıçam (Çs) ve Doğu Karadeniz Göknarı (G) karışık meşcerelerinde göğüs çapı-kütük çapı ilişkisi araştırılmıştır. Bu amaçla Artvin'de tam kapalı olan LÇsG ve ÇsLG meşcerelerinden alınan 23 farklı örnek alandan kesilmiş olan 206 ağaç (69 adet L, 69 adet Çs ve 68 adet G) verisi kullanılmıştır. Yapılan istatistiksel analizlere göre, göğüs çapındaki değişkenliği açıklayan en iyi modeller Ladin'de power, Sarıçamda kuadratik ve Göknarda ise doğrusal modeller olmuştur. Bu modellerin üçlü karışık meşcerlerde göğüs çapı değişkenliğini açıklama oranları Ladin için %95,2, Sarıçam için %96,5 ve Göknar için de %96,4 ve bu modellerin hataları da sırasıyla 1.850, 1.598 ve 1.643 şeklinde bulunmuştur. Sonuç olarak, göğüs çapını tahmin etmede belli başarı seviyesinde olan bu modeller, Artvin'deki tam kapalı üçlü karışık meşcerelerde uygulayıcılar tarafından kullanılabilir olarak bulunmuştur.

Anahtar Kelimeler: Göğüs çapı, kütük çapı, regresyon analizi, üçlü karışık meşcereler

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INTRODUCTION

The most basic variable, used for measurements made in sample areas, is the diameter at the breast height (DBH) in forestry applications (Kangas and Maltamo, 2006; Bettinger et al, 2018). The most common measure used to calculate the dimensions of living and dead trees is DBH. The height of the breast is accepted as 4.5 feet (1.37 meters) from the ground level (Bettinger et al., 2009; 2018).

The diameter at breast height (DBH) corresponding to a height of 1.3 meters is measured in all of the repeated forest inventory (Pretzsch, 2009). Because the DBH is the main variable, which is easy to measure and highly correlated with many dependent variables of a single tree. (Vanclay, 1994). Therefore; the DBH is the dependent variable which uses the most common numerous fields including the calculation of the tree volume, the identification of the stand structure, and the selection of the sample plots for the inventory (Dorado et al., 2006; Mısır, 2010).

Many features such as height, volume, biomass, double bark thickness and crown wide can easily be calculated using the measure of DBH. Especially stand volume which is one of the most important variables in forest management is usually assessed based on the DBH and height of the tree (Rupsys & Petrauskas, 2010; Ogana, Osho & Varela, 2018), so DBH is an important parameter for the tree volume. The most commonly used variable DBH when estimating the tree volume in forestry (Kalıpsız, 1999). Therefore, the volume equations used the most common in the forestry is the single entry tree volume equations which depend on the DBH (Kalıpsız, 1999; Şenyurt, 2012).

Table 1. The relationship studies between DST - DBH in Turkey

Tree species	Researchers
Calabrian pine	Uğurlu & Özer, 1977
Scots pine	Özer, 1981
Fir	Forestry Research Institute, 1981
Oriental beech	Forestry Research Institute, 1982
Black pine and Scots pine	Yavuz, 1996
Ash	Yavuz, 2000
Black pine, Cedar and Calabrian pine	Özçelik, 2005
Fir, Oriental beech and Black pine stands	Durkaya & Durkaya, 2011
Scots pine	Şenyurt, 2012
Oriental beech	Ercanlı et al., 2015
Chestnut	Sağlam et al, 2016
Red pine and Black pine	Sakıcı & Yavuz, 2016
Oriental beech and Kazdağı Fir mixed stands	Sakıcı & Özdemir, 2017

As a result of overturning, breakage, drying or the illegal cutting of trees, only the stumps remain in the forested areas, so it is necessary to know the DBH in order to estimate the tree volume separated from these areas. In such cases, it is necessary to use these stump dimensions to estimate the DBH and volume of the tree (McClure, 1968; Bylin, 1982; Kozak, & Omule 1992; Wharton, 1984; Chhetri, & Fowler, 1996; Corral-Rivas et al., 2007; Özçelik et al., 2010; Milios et al., 2016). That is why foresters are usually faced with the problem of determining and confirming the DBH of felled trees (Shrivastava, & Singh, 2003). Foresters who are usually confronted with the problem of determining the DBH of felled trees, can estimate the volume of felled trees using the relationship model of DST-DBH (Diéguez-Aranda et al., 2003; Şenyurt, 2012). In this way the models estimating DBH using stump measurements will also benefit forest managers as well as researchers (Chhetri, & Fowler, 1996). The determination of DBH is possible by regression and correlation studies between DST values as independent variables and DBH as dependent variables. (Shrivastava, & Singh, 2003).

The studies on the relationship model between DST and DBH in Turkey were given in Table 1 (Uğurlu & Özer, 1997; Forestry Research Institute, 1981; Forestry Research Institute, 1982; Giray, 1982; Yavuz, 1996; Yavuz, 2000; Özçelik, 2005; Durkaya & Durkaya, 2011; Şenyurt, 2012; Ercanlı et al., 2015; Sağlam et al, 2016; Sakıcı & Yavuz, 2016; Sakıcı & Özdemir, 2017).

In this study, the aim was to model the regression analysis of the relationship between the DST and the DBH for all species separately in the triple mixed stands (Oriental spruce, Scots pine and Eastern Black sea Fir) of Artvin.

MATERIALS AND METHODS

Material

Within the scope of the study, for the purpose of determining the relationship between the DST and the DBH; A total of 206 tree data were used from 23 different sample areas cut from the fully closed Oriental spruce-Scots pine-Eastern Black sea fir (SoPsFb) and Scots pine-Oriental spruce-Eastern Black sea fir (PsSoFb) triple mixed stands spreading in Artvin. In the triple mixed stands, the sample plots were selected from places where the three tree species were located and adjacent to each other. In

Table 2. Statistical information about sample trees

Tree species	Variable	n	Mean	Standard deviation	Minimum (cm)	Maximum (cm)
O. spruce	DST (cm)	69	27.2	9.6	9.3	57.1
	DBH (cm)		23.4	8.2	8.3	52.1
S. pine	DST (cm)	69	34.7	10.2	13.5	57.0
	DBH (cm)		29.8	8.6	10.9	44.0
E.B. fir	DST (cm)	68	27.3	10.3	10.5	56.7
	DBH (cm)		24.4	8.7	9.4	46.1

O.spruce: Oriental spruce; S.pine: Scots pine; E.B. fir: Eastern Black Sea fir the triple mixed stands where sample areas were taken, almost equal number of trees were selected from each species, and statistical information on these sample trees is given in Table 2.

Method

Within the scope of the study, DST-DBH relationships for each species were investigated using DST and DBHs separately measured for Oriental spruce, Scots pine and Eastern Black sea fir species. According to Pond, & Froese (2014); choosing the most accurate model to estimate DBH from the DST is very important in terms of repositioning the tree, predicting the state of the tree before leaving the habitat, or estimating the volume of the tree separated from the forest area. For this reason, while the DST-DBH relationships were being investigated, the most appropriate regression models were used for the distribution of each tree species (modal 1-5; Table 3).

Table 3. Mathematical expressions of the models selected for evaluation

Mathematical form	Model	
$dbh = b_0 + b_1\,dst$	Linear	(1)
$dbh = b_0 + b_1\ln(dst)$	Logarithmic	(2)
$dbh = b_0 + b_1 d_{st} + b_2 dst^2$	Quadratic	(3)
$dbh = b_0 (dst^{b1})$	Power	(4)
$dbh = e^{(b0 + (b1 / dst))}$	S-Curve	(5)

dbh: diameter at breast height, dst: diameter at sump height, b_0, b_1 and and b_2: regression parameters

The regression analyzes of the study were made by using the SPSS statistical program (SPSS 19.0 Institute Ins., 2010) and the following five success criteria were taken into consideration in determining the success from the tested models (modal 6-10).

Adjusted Coefficient of Determination (R^2_{adj})

$$R^2adj. = 1 - \left(\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\,(n-1)}{\sum_{i=1}^{n}(y_i - \bar{y}_i)^2\,(n-p)}\right) \quad (6)$$

Root Mean Squared Error (RMSE)

$$RMSE = \sqrt{\frac{\sum(y_i - \hat{y}_i)^2}{n-p}} \quad (7)$$

Mean Error (ME)

$$ME = \frac{\sum(\hat{y}_i - y_i)}{n} \quad (8)$$

Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{\sum|\hat{y}_i - y_i|}{\sum y_i} x100 \quad (9)$$

Total Percentage Error (TPE)

$$TPE = \frac{\sum \hat{y}_{i_i} - \sum y_i}{\sum y_i} x100 \quad (10)$$

Ethics committee approval is not required for this research.

RESULTS AND DISCUSSION

The adjusted coefficients of determination, standard errors, mean errors, mean absolute error percentages, total error percentages, significance levels and F ratios for the 5 different regression models tested in the study are in Table 4 and their coefficients are also given in table 5.

According to the results, the models that reflect best the relationship between the DST and the DBH are determined as power for Oriental spruce, quadratic for Scots pine and linear model for Eastern Black sea fir. These models are able to explain the

Table 4. Success criteria of DST and DBH models

Tree species	Modal	R^2_{adj}.	R	RMSE	R	ME	R	MAPE	R	TPE	R	F	P	ΣR
O. spruce	1	0.945	(3)	1.917	(3)	-1.0E-12	(2)	6.13	(2)	-4.5E-12	(2)	1180.38	0.000*<	(11)
	2	0.891	(5)	2.712	(5)	-1.3E-12	(3)	7.98	(4)	-5.5E-12	(3)	556.55	0.000<	(20)
	3	0.945	(2)	1.927	(4)	5.2E-13	(1)	6.17	(3)	2.2E-12	(1)	584.30	0.000*<	(11)
	4	**0.952**	**(1)**	**1.850**	**(2)**	**-0.07**	**(4)**	**6.08**	**(1)**	**-0.30**	**(4)**	**1363.69**	**0.000<**	**(12)**
	5	0.899	(4)	1.818	(1)	-0.27	(5)	8.28	(5)	-1.16	(5)	592.04	0.000<	(20)
S. pine	1	0.960	(3)	1.716	(2)	-1.4E-12	(1)	4.34	(3)	-5E-12	(1)	1632.62	0.000*<	(10)
	2	0.945	(5)	2.009	(4)	3.1E-12	(2)	5.04	(4)	1.1E-11	(2)	1172.73	0.000<	(17)
	3	**0.965**	**(2)**	**1.598**	**(1)**	**1.6E-11**	**(3)**	**3.97**	**(1)**	**-5.4E-11**	**(3)**	**946.46**	**0.000<**	**(10)**
	4	0.973	(1)	1.729	(3)	-0.02	(4)	4.30	(2)	-0.05	(4)	2434.01	0.000<	(14)
	5	0.947	(4)	0.076	(5)	-0.16	(5)	5.67	(5)	-0.54	(5)	1218.78	0.000<	(24)
E.B. fir	**1**	**0.964**	**(3)**	**1.643**	**(3)**	**-3.2E-13**	**(1)**	**4.95**	**(3)**	**-1.3E-12**	**(1)**	**1818.06**	**0.000<**	**(11)**
	2	0.942	(5)	2.093	(4)	-1.5E-11	(3)	6.63	(4)	-6.1E-11	(3)	1094.96	0.000<	(19)
	3	0.971	(2)	1.484	(1)	-2.8E-12	(2)	4.55	(1)	-1.1E-11	(2)	1104.13	0.000*<	(8)
	4	0977	(1)	1.625	(2)	-0.02	(4)	4.82	(2)	-0.1	(4)	2806.05	0.000<	(13)
	5	0.945	(4)	2.439	(5)	-0.20	(5)	7.23	(5)	-0.83	(5)	1146.22	0.000<	(24)

*There are meaningless parameter/parameters in these models

R^2_{adj}: Adjusted Coefficient of Determination; RMSE: Root Mean Squared Error; MAPE: Mean Absolute Percentage Error; TPE: Total Percentage Error; R: Range; ΣR: Total range

Table 5. Model coefficients by species

		Tree species					
		O. spruce		S. pine		E.B. fir	
Model	Parameter	Value	p	Value	p	Value	p
1	b_0	0.798	0.257*	1.252	0.093*	**1.781**	**0.000**
	b_1	0.833	0.000	0.823	0.000	0.830	0.003
2	b_0	-46.861	0.000	-58.376	0.000	-43.842	0.000
	b_1	21.861	0.000	25.211	0.000	21.124	0.000
3	b_0	1.621	0.323*	**-4.187**	**0.020**	-2.004	0.077*
	b_1	0.773	0.000	**1.170**	**0.000**	1.120	0.000
	b_2	0.001	0.577*	**-0.05**	**0.001**	-0.005	0.000
4	b_0	**0.988**	**0.000**	0.896	0.000	1.050	0.000
	b_1	**0.959**	**0.000**	0.988	0.000	0.952	0.000
5	b_0	3.968	0.000	4.183	0.000	3.995	0.000
	b_1	-20.923	0.000	-26.057	0.000	-20.261	0.000

*Shows meaningless parameter

O.spruce: Oriental spruce; S.pine: Scots pine; E.B. fir: Eastern Black Sea fir

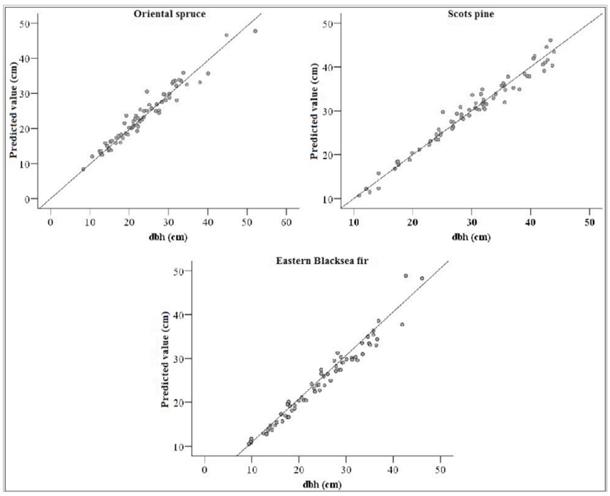

Figure 1. Relationship between model results and measured values

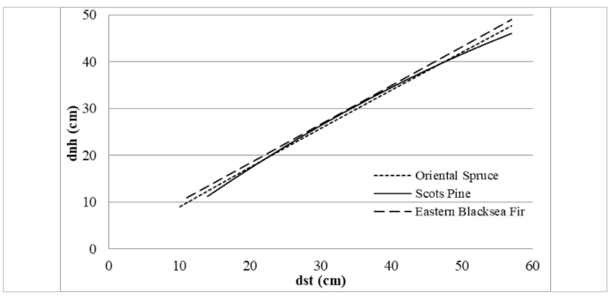

Figure 2. DST – DBH relation for three species according to model results
DST: diameter at stump height; DBH: diameter at breast height

Table 6. Models of relationship between DST and DBH according to tree species

Tree species	Model
O. spruce	$dbh = 0.988 \times dst^{0.959}$
S. pine	$dbh = -4.187+1.170 \times dst - 0.05 \times dst^2$
E.B. fir	$dbh = 1.781 + 0.830 \times dst$

O.spruce: Oriental spruce; S.pine: Scots pine; E.B. fir: Eastern Black Sea fir

variability of the DBH in SoPsFb or PsSoFb triple mixed stands by 95.2% in Oriental spruce, 96.5% in Scots pine and 96.4% in Eastern Black sea fir.

The most successful models, which were determined at the results of sorting according to error values, are given below with their coefficients (Table 6). Additionally the relationship between the results of these models and their measured values are shown in Figure 1 and also the graphics of these models in Figure 2.

The distributions of standardized residuals, which are the difference measured between predicted values obtained from the selected models and the observed values, are shown in Figure 3 and also the distributions according to standardized predicted values of standardized residuals are shown in Figure 4.

CONCLUSION

As a result of tests and calculated error criteria, the models which have a suitable reliability level for fully stocked SoPsFb and PsSoFb triple mixed stands in Artvin were obtained. The

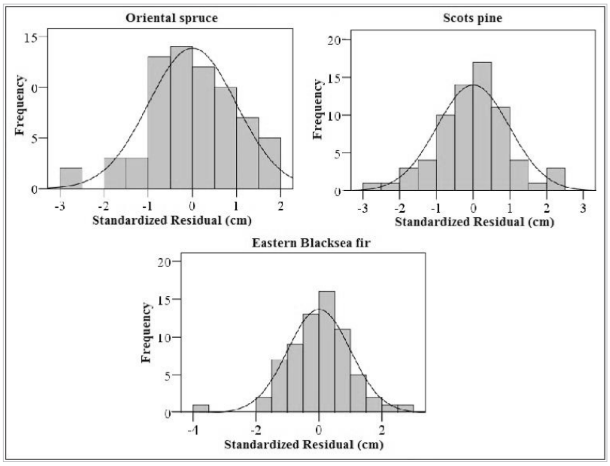

Figure 3. Distribution of standardized residuals for three species

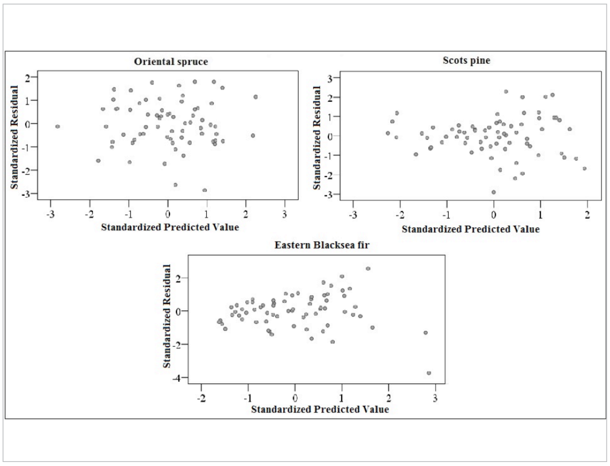

Figure 4. Distribution of standardized residuals according to standardized predicted values

Table 7. Diameters at breast height (DBH) corresponding to the diameters at breast height (DST) for O. spruce, S. pine and E.B. fir

	O. spruce	S. pine	E.B. fir		O. spruce	S. pine	E.B. fir
dst (cm)		dbh (cm)		dst (cm)		dbh (cm)	
10	9.0	-	-	34	29.0	29.7	30.0
11	9.8	-	10.9	35	29.8	30.6	30.8
12	10.7	-	11.7	36	30.7	31.4	31.7
13	11.6	-	12.6	37	31.5	32.2	32.5
14	12.4	11.2	13.4	38	32.3	33.0	33.3
15	13.3	12.2	14.2	39	33.1	33.8	34.1
16	14.1	13.2	15.1	40	33.9	34.5	35.0
17	14.9	14.2	15.9	41	34.7	35.3	35.8
18	15.8	15.2	16.7	42	35.5	36.0	36.6
19	16.6	16.2	17.5	43	36.4	36.8	37.5
20	17.5	17.2	18.4	44	37.2	37.5	38.3
21	18.3	18.1	19.2	45	38.0	38.2	39.1
22	19.1	19.1	20.0	46	38.8	38.9	40.0
23	20.0	20.0	20.9	47	39.6	39.6	40.8
24	20.8	21.0	21.7	48	40.4	40.3	41.6
25	21.6	21.9	22.5	49	41.2	41.0	42.4
26	22.4	22.8	23.4	50	42.0	41.7	43.3
27	23.3	23.7	24.2	51	42.8	42.3	44.1
28	24.1	24.6	25.0	52	43.6	43.0	44.9
29	24.9	25.5	25.8	53	44.4	43.6	45.8
30	25.7	26.4	26.7	54	45.2	44.3	46.6
31	26.6	27.2	27.5	55	46.0	44.9	47.4
32	27.4	28.1	28.3	56	46.8	45.5	48.3
33	28.2	28.9	29.2	57	47.6	46.1	49.1

O.spruce: Oriental spruce; S.pine: Scots pine; E.B. fir: Eastern Black Sea fir; dbh: diameter at breast height; dst: diameter at stump height adjusted coefficients of determination for the models obtained are above 95% and are similar to other studies. These developed models will serve as a tool for detecting the DBH values of Oriental spruce, Scots pine or Eastern Black sea fir which of felled trees from SoPsFb or PsSoFb triple mixed stands. Thus, the volume of felled trees will be able to be calculated. Lastly, through these models, the DBH-DST table, which is valid separately for the three types, was also created (Table 7). These models and the created table can be used in the range of 9-57 cm for Oriental spruce, 14-57 for Scots pine, and 11-57 cm for Eastern Black sea fir in the Oriental spruce, Scots pine and Eastern Black sea fir for triple mixed stands which are spread in the region of Artvin in Turkey. Apart from that, other models having a meaningful parameters will be alternatively preferred for stands where the selected models do not give proper results.

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REFERENCES

- Bettinger, P., Boston, K., Siry, J. P., Grebner, D. L., 2010. Forest Management and Planning. Academic press.
- Bettinger, P., Izlar, B., Harris, T., Cieszewski, C., Conrad, J., Greene, D., Mech, A., Shelton, J., Siry, J., Kane, M., Merry, K., Baldwin, S., Smith, J., 2018. Handbook of land and tree measurements. Harley Langdale, Jr. Center for Forest Business, University of Georgia, Athens, GA. 323 p.
- Bylin, C.V., 1982. Estimating dbh from stump diameter for 15 southern species. Res. Note 50-286. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 3 [CrossRef]
- Chhetri, D.B.K., Fowler, G.W., 1996. Estimating diameter at breast height and basal diameter of trees from stump measurements in Nepal's lower temperate broad-leaved forests. *Forest Ecology and Management* 81(1-3): 75-84. [CrossRef]
- Corral-Rivas, J.J., Barrio-Anta, M., Aguirre-Calderón, O.A., Diéguez-Aranda, U., 2007. Use of stump diameter to estimate diameter at breast height and tree volume for major pine species in El Salto, Durango (Mexico). *Forestry* 80(1): 29-40. [CrossRef]
- Diéguez-Aranda, U., Anta, M.B., Dorado, F.C., Murias, M.B., 2003. Estimating diameter at breast height and stem volume from stump dimensions for six timber species in Galicia (Northwestern Spain). *Forest Systems* 12(2): 131-139.
- Dorado F.C., Diéguez-Aranda, U., Anta, M.B., Rodríguez, M.S., Gadow, K.V., 2006. A generalized height-diameter model including random components for radiate pine plantations in northwestern Spain. Forest Ecology Management 229: 202-213.
- Durkaya, B., Durkaya, A., 2011. Relations Between Breast Height Diameter-Stump Diameter and Stump Height for Uludag Fir, Beech and Anatolian Black Pine Trees in Zonguldak-Ulus Forest Enterprize. *Kastamonu University Journal of Forestry Faculty* 11(1): pp. 9-17.
- Ercanli, İ., Gunlu, A., Başkent, E. Z., 2015. Mixed effect models for predicting breast height diameter from stump diameter of Oriental beech in Göldağ. *Scientia Agricola* 72(3): 245-251. [CrossRef]
- Forestry Research Institute., 1981. Forestry Research Institute Bulletin, No: 3, 4 and 5. Ankara.
- Forestry Research Institute., 1982. Forestry Research Institute Bulletin, March Research Bulletin, Ankara.
- Giray, N., 1982. Relationship of diameter at stump height, diameter at breast height, diameter at half the total tree height on trees. Forestry Research Institute Bulletin. July Research Bulletin, 28: 69-79.
- Kalıpsız, A. (1999), Dendrometer, İstanbul University Faculty of Forestry Publication, no. 3194-354, İstanbul.
- Kangas, A., Maltamo, M. (Eds.)., 2006. Forest inventory: methodology and applications (Vol. 10). *Springer Science & Business Media*. [CrossRef]
- Kozak A, Omule S.A.Y., 1992. Estimating stump volume, stump inside bark diameter and diameter at breast height form stump measurements. *Forestry Chronicle* 68(5): 623-627. [CrossRef]
- McClure, J. P., 1968. Predicting tree dbh from stump measurements in the southeast. U.S. For. Serv. Res. Note S.E-99: 4.
- Mısır, N., 2010. Generalized height-diameter models for *Populus tremula* L. stands. African Journal of Biotechnology. 9:4348-4355.
- Milios, E., Kitikidou, K. G., Dalakouras, V., Pipinis, E., 2016. Diameter at Breast Height Estimated From Stumps in Quercus Frainetto int. the Region of Evros in Northeastern Greece. *Cerne* 22(3): 337-344. [CrossRef]
- Ogana, F.N., Osho, J.S.A. Gorgoso-Varela, J.J., 2018. An approach to modeling the joint distribution of tree diameter and height data. *Journal of Sustainable Forestry* 37(5): 475-488. [CrossRef]
- Özçelik, R., 2005. Relationships Between the Diameter Stump Height (d0.30) and Diameter Breast Height (d1.30) for Pinus nigra, Cedrus libani, and Pinus brutia in Mut Forest Enterprise. *Süleyman Demirel University Journal of Forestry Faculty* 9(3).
- Özçelik, R., Brooks, J.R., Diamantopoulou, M.J., Wiant Jr, H.V., 2010. Estimating breast height diameter and volume from stump diameter for three economically important species in Turkey. *Scandinavian Journal of Forest Research* 25(1): 32-45. [CrossRef]
- Özer, E., 1981. Finding the diameter at breast height by taking advantage of the diameter at stump height in Scots pine. Forestry Research Institute Bulletin, Ankara. No: 53, Vol: (27) 20-23.
- Pond, N. C., Froese, R. E., 2014. Evaluating published approaches for modelling diameter at breast height from stump dimensions. *Forestry: An International Journal of Forest Research* 87(5): 683-696.
- Pretzsch, H., 2009. Forest dynamics, growth and yield. In Forest Dynamics, Growth and Yield (pp. 1-39). Springer Berlin Heidelberg. [CrossRef]

- Rupsys, P., Petrauskas, E., 2010. The bivariate Gompertz diffusion model for tree diameter and height distribution. *Forest Sciences* 56(3): 271–280.
- Sağlam, F., Sakıcı, O.E., Seki, M., 2016. Stump diameter and diameter at breast height relationship for Chestnut (Csatanea sativa Mill.) stands in Kastamonu coastal region. International Forestry Symposium (IFS 2016), 7-10 December 2016, Kastamonu, Turkey, 514-520.
- Sakıcı, O.E., Yavuz, H., 2016. The relationship between diameter at stump height and diameter at breast height in Red pine-Black pine mixed stands, Scientific Research Symposium in Turkish World, 29-31.05.2016, Celalabat, Kırgızistan, 679-686.
- Sakıcı, O.E., Özdemir, G., 2017. Stump Diameter and Diameter at Breast Height Relationships for Oriental Beech and Kazdağı Fir at Mixed Stands in Karabük. *Kastamonu University Journal of Forestry Faculty* 17(2): 298-306.
- Shrivastava, M.B., R.A. Singh., 2003. Interrelationships among crown diameter, diameter at breast height and stump diameter of silver fir trees. Paper submitted to the XII World Forestry Congress, Quebec City, Canada. Available from: http://www.fao. org/docrep/ARTICLE/WFC/XII/0902-B4.HTM (accessed November 6, 2017).
- SPSS. Institute Inc., 2010. IBM SPSS Statistics 19 Core System User's Guide, SPSS Programming and Data Management, 426 s.
- Şenyurt, M., 2012. The Relationships Between Diameter Stump Height (d0.30) and Diameter Breast Height (d1.30) for Scotch Pine (Pinus sylvestris (L.)) in West Black Sea Region. *Artvin Coruh University Journal of Forestry Faculty* 13(1): 79-87.
- Uğurlu, S., Özer, E., 1977. Finding the diameter at breast height by taking advantage of the diameter at stump height in Calabrian pine, Forestry Research Institute Bulletin, Ankara. Vol: 23 No: 1: 71-77.
- Vanclay, J.K., 1994. Modelling forest growth and yield: applications to mixed tropical forests. School of Environmental Science and Management Papers, 537.
- Wharton. E.H., 1984. Predicting diameter at breast height from stump diameters for Northeastern tree species. (Vol. 322) US Department of Agriculture, Forest Service Northeastern Forest Experiment Station.
- Yavuz, H., 1996. Relationships of diameter at the stump height-diameter at breast height-diameter at half of total tree height and calculation of bark volume relation to our Scots Pine and Black Pine tree species in Taşköprü Forest sub-district directorate. Karadeniz Technical University Faculty of Forestry Spring term seminars, Seminar No: 2: 67-75.
- Yavuz, H., 2000. Determination of the relationship between the diameter at stump height-the diameter at breast height for the Ash tree species. Karadeniz Technical University Faculty of Forestry Fall term seminars, Seminar No: 7: 10.