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MODELING THE RELATIONSHIP BETWEEN THE DIAMETER AND HEIGHT OF *PINUS BRUTIA TEN*. TREES GROWING IN ZAWITA NATURAL REGION IN NORTHERN IRAQ

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Abstract

Different regression programs were used to develop regression equations that connect the total height of the tree as dependent variable and the diameter at breast height of it as independent variable. Study samples were collected from Zawita natural region by choosing 300 pine trees randomly based on the simple random samples, and these trees are grown naturally and free from insect and pathological infections. Six statistical measure were used to differentiate between the equations in order to choose the best there of the following nonlinear equation was reached to :

$h{:}2.7027+0.4112\,d-0.0006d^2$

R2=.76 S.E=1.65

RSS=823.3 Bias= -0.00056

Then a table for estimating the height was prepared depending on the diameter of the pine trees (*Pinus brutia Ten.*) growing in Zawita natural region.

Introduction

Many region trees grow naturally in Zawita region, most important of which are *Pinus brutia ten.*, Juniper, *Pistacia palaestina* and Oak. Therefore, these types need permanent management to preserve them from different effects, whether environmentally or by the local communities surrounding the region.

The relationship between the height (h) and diameter at breast level (dbh) is the most important indictors by which we can notice any urgent change over these types during their growth period, and also we use it basically in specifying the size of tree and plantation, and also the biomass produced by this type or that; further, this relation is used to observe the variation that can be traced in the growth occurred in the regions at the same age and site degree.

The great importance of determining the total height of the tree and its great and moral impact as it is the main determinant of the total light that the tree can receive and used by the tree later in the process of photosynthesis, and it appears in the form of growth in that tree. In general, the measurement of tree height needs longer time as compared to the diameter at the breast level, at the same time, the measurement of diameter is more accurate and faster than tree height.

Therefore, the preparation of this relationship model, in which the height is the dependent variable and the diameter the independent variable, serves to reduce the measurement costs and the time required to conduct it. Many researchers found a relationship between the tree diameter and its total height, as there is a strong connection between them as referenced by man researchers, among them (Curtis, 1967) and (Sharma & Parton, 2007).

The region administrator is concerned about the relationship of diameter at breast level and the total height of tree, because he depends thereon in making many administrative decisions in region organization, as this relationship affects the wood product quality such as lignin and cellulose and consequently affects the important characteristics of the stalk such as degree of hardness and others (Poorter *et al.,* 2006).

Thus, the accurate height data is of great importance in different activities of the forest administrator to manage the forest well and sustainably, as through using an easy to use measurement such as diameter at the breast height, we can estimate a hard to measure variable (height) accurately and quickly (Zhang *et al.,* 1995), and because of this there are a number of mathematical models published by many researchers, among which the model prepared by (Gonzalez, 2007) along with the equations that estimated the total height of the pine trees (*Pinus brutia* ten.) growing in the mountainous area of the Kahraman Mountains in Turkey (Avsar, 2004).

Malimbwi *et al.,* (1994) prepared a mathematical model between h – dbh to estimate the size and biomass, and (Sharma, 2007) for Cine pine a model of the relationship between the diameter and height of this type. Furthermore, there are variations in the trees of the same type in the same plantation. Thus, there are differences in size at the same height along with the occurrence of variations in heights and diameters as a result of the difference in densities and ages and site degree (Huang *et al.,* 1992), and the equations derived shall be evaluated in accordance with different statistical measures in order to select the best equation (Zhang *et al.,* 1995).

Therefore, our objective from this study is to find a relationship between h–dbh for *Pinus brutia ten.* growing in Zawita natural region, because the diameter measurement is more accurate and easier than height measurement which entail time and cost upon measuring.

Materials and Methods

This study was conducted on the mixed region spread in Zawita area in the northern Iraq, which consists different types of region trees, most significant of which are *Pinus brutia ten.*, Juniper, *Pistacia palaestina*, and Oak. This region is located between the two latitudes (4304447.30 – 431139.67) east and latitude (365624.04 – 365108.45) ranging (669 – 1319) m from sea level. This site is located with formations of the mountainous area and the average rain rate for the last fifteen years is 749 mm/year, with an average low temperature of 13.4 Celsius while the average high temperature is 24.9 for the last ten years, and the soil of site is featured with characteristics, among which, that the soil texture is sandy-muddy and interaction degree is almost neutral 7.80 and the organic material formation is 5.63.

Since the region is not of vast area and grows on single site degree, therefore simple random inventory was chosen in selecting the samples that represent the reality of these types, and accordingly 300 trees were chosen randomly within the scope of diameters and heights spread in the region, and these were not affected by environmental factors and grown naturally and representing the region reality and the following measures were taken from each tree:

Diameter at breast level/cm

Through using Caliber device, we have measured diameters, so that the measurement is at the breast height and vertical on the longitudinal axis of the tree.

Total Height/m

The total height was taken through Haga device and distance tape, by measuring the top of the tree and the base of the tree, and the distance between the observer and the tree.

Then the following mathematical relationship was applied:

Tree height = (reading to tree top + or – reading to tree base)/(100) × horizontal distance.

The mathematical methods of modeling the most modern methods of preparing the mathematical equations, thereby it was used in finding the relationship between the diameter and height of the pine trees, as the most accurate and latest methods as compared with the old classical methods including the graphical method based on the personal experience, and the same applies to the Alignment chart method, as these methods spread rapidly because there are many programs available on computer such as STATAGRAF, SPSS and SAS in deriving different mathematical models, whether linear or non-linear (simple or multiple).

Statistical Measures used in the Differentiation of Equations

1. The Coefficient of Determination (R^2): whose value is between 0 – 1

   R^2 = (Residual SS/ Corrected SS)

2. The Estimated Standard Error (h) :

$$S.E. = \sqrt{\frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)}{n}}$$

3. Total squares of biases of original values for estimated Residual SS in both types the original and indirect.

4. Bias

$$Bias = (1/n) \times \sum\left(Y_i - \hat{Y}_i\right)$$

n = views

Y_i = true view value

$\hat{Y}_i$ = estimated view value

5. Unbiased testing (Ohtomo 1956)

6. Graphing of Equations: this test is conducted for the remaining equations in the competition list depending on the statistical measures in differentiation, in which the straight line represented by each equation in terms of the shape, Y section and inclination with the straight line stripped of any error, which passes through the point of origin and make an angle of 45 with the two axis (Prodan 1968).

We have analyzed the preliminary data collected from the field, in order to learn about its characteristics and how much it represents the community from which it was collected, therefore, the most important statistical characteristics were taken (table1).

And since the preliminary graphic representation of the relationship between diameter and height for pine trees give us an idea about the nature of the relationship between both variables, linear or non-linear, so this relationship was drawn as in fig. 1.

Table 1: Some statistical characteristics of *Pinus brutia ten.*, growing in Zawita region.

Variables	No. of Sample Tree	*Pinus brutia* Ten.
Minimum Diameter/cm	300	8.4
Maximum Diameter/cm	300	57.5
Range	300	49.1
Standard Deviation	300	7.77
Variance	300	60.50
Minimum Height /m	300	4.0
Maximum Height /m	300	23.0
Range	300	19.0
Standard Deviation	300	3.37
Variance	300	11.40

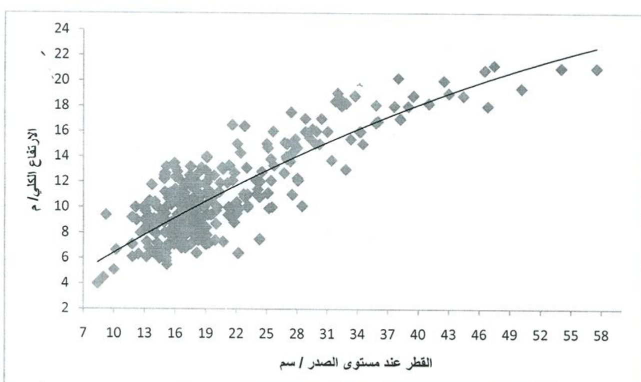

Fig. 1: For the relationship between the diameter at breast level and total height of *pinusbrutia ten.*, growing in Zawitaregion.

Fig. 1 gave us an idea about the nature of the relationship that I may represent, so the possible mathematical models that may express this relationship were sought, in order to be used in deriving the special mathematical model, and we have reach to the most important possible models to prepare the mathematical equation in table 2.

Table 2: Some of the suggested mathematical models in this field.

No.	Models	Model Suggested
1	$H=1.3+b_0d^{b1}$	Non-linear regression
2	$H=b0+b_1d$	Simple regression
3	$H= b_0+b_1d^2$	Simple regression
4	$H= b_0+b_1d+b_2d^2$	Polynomial model
5	$H= b_0+b_1\ d^{b1}$	Non-linear regression
6	$H= b_0+b_1(1/d)$	Simple regression
7	$H= b_0+b_1\ \log(d)$	Simple regression
8	$H= b_0+b_1d+b_3\ \log(d)$	Multiple regression
9	$H= b_0+b_1d/(1.3+d)$	Simple regression

Results and Discussion

The direct formula of variable h was used and the following formula [(Ind), $(Ind)^2$, d, d^2, $d^{0.5}$, $1/d^{0.5}$, $1/d^2$) of the independent variable in the regression program available on the statistical program STATAGRAF, as a result thereof we obtained simple regression equations (1-5) along with some accuracy standards, and also we obtained the equations (6-7) which represent the multiple linear regression equations, while the equations (8-10) represents the simple nonlinear regression equations, table 3.

We notice form the above table that the values of Coefficient of Determination ranged (0.76-0.60) and some of these equations (3, 5, 8, 9) had values of Coefficient of Determination ranged (0.66-0.60) along with high values for the total squares of deviations of the original values to the estimated; therefore, it was eliminated from the competition list, and what confirms the step of deleting these equations is giving these(deleted) equations relatively high values for the standards error (S.E).

The rest of equations (1, 2, 4, 6, 7, 10) were subject to differentiation based on (S.E), as a result equations (2, 4) were deleted to give them relatively high values from the rest of equations under competition. Accordingly, equations (1, 6, 7 and 10) compete with each other and that why were subject to more tests because of being close even by Bias measurement. Among measurement that we may use in this case is the unbiased test of (Ohtomo) by linking the h^ values estimated in these competing equations, through straight line equation

Table 3: Mathematical equations for the relationships between diameter at breast level and total height of *Pinus brutia ten.*, growing in Zawita region.

No.	Models	B^0	B^1	B^2	R^2	S.E	RSS	Bias
1	$h\text{-}b_0+b_1d$	3.0964	0.3780	-	0.75	1.66	824.6	-0.00033
2	$h=b_0+b_1d^2$	7.754	0.0064	-	0.71	1.80	971.8	0.00063
3	$h=b_0+b_1 1/d$	19.783	-165.146	-	0.60	2.13	1353.1	-0.00135
4	$h=b_0+b_1In(d)$	-15.399	8.8529	-	0.72	1.79	962.5	-0.0006
5	$h=b_0+b_1(d/(1.3+d)$	-127.642	148.175	-	0.63	2.08	1292.9	-0.00096
6	$h=b_0+b_1(1/d)+b_2d^2$	11.910	061.470	0.0047	0.75	1.71	864.7	0.00057
7	$h=b_0+b_1d+b_2d^2$	2.7026	0.4112	-0.0006	0.76	1.65	823.3	-0.00056
8	$h=b^0\ e^{b1d}$	5.5884	0.0302	-	0.65	1.89	1089.1	-0.00094
9	$h=b_0d^{b1}$	1.180	0.7337	-	0.66	1.86	987.32	-0.00087
10	$h=b^0+b^1d^{b0}$	-8.5955	5.2904	0.4356	0.75	1.65	856.6	-0.00034

$h_i h\hat{}_i=n+m$, from which we can conclude that when h^ values are close or equal to the real h values, the values of m, n should be equal to one or zero respectively, and for this reason table 4 was has been prepared.

We can notice that equations 6, 10 have been eliminated from competition and equations 1, 7 remained, and in order to eliminate the equations, the relationship between the real and the estimated value of the height was illustrated and compared to error-free line, Fig. 2.

Note that equations 1 and 7 are proximate to a great deal, which makes an angle of 45 degree with both axes, and this is confirms that both remaining equations are the more accurate and correct than those eliminated in accordance with Prodan test (1986), so it is not possible to differentiate between them statistically, however, sine equation 7 represents the nature of biological growth in the living organisms, not the simple linear relationship; therefore, we preferred polynomial equation, *i.e.* equation 7.

Table 4: Unbiased test of Ohtomo for some functions of diameter and height of *Pinus brutia ten.*, growing in Zawita region. (Constants values of straight line equation $h_i h\hat{}_i=n+m$ for some competing equations).

No.	Models	n	m
1	$h\text{-}b_0+b_1d$		
6	$h=b_0+b_1In(d)+b_2(Ind)^2$		
7	$h=b_0+b_1d+b_2d^2$		
10	$h=b^0+b^1d^{b0}$		

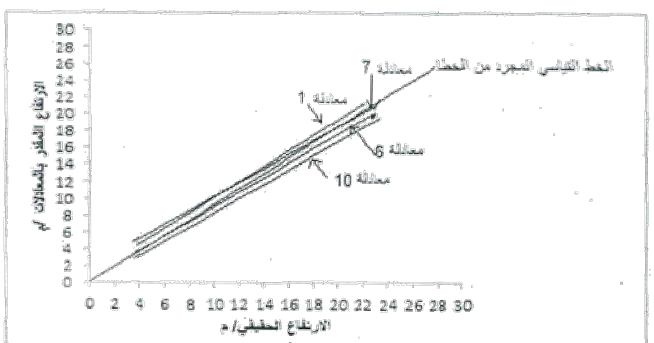

Fig. 2: Relative efficiency of equations (1, 6, 7, and 10) in estimating the height based on equation $h_i h\hat{}_i=n+m$ with the standard error-free line.

Since we are not able to choose a certain equation in which the following statistical argument:

"There must be no relationship between the amount of error occurred in estimating the dependent variable (height) and the independent variable (diameter at breast level), and Fig. 3 clarifies that:

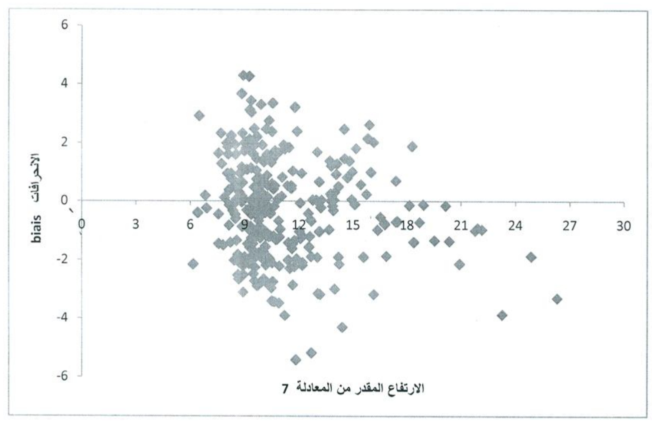

Fig. 3: Random Distribution of Error estimated from equation 7

Based on fig. 3 above, we notice how the error is distributed with respect to the heights estimated by equation 7, which confirm that there is no relationship between them, *i.e.* the error is randomly distributed.

In conclusion, preparing the table that estimates the total height of *Pinus brutia ten.,* growing in Zawita region, makes us able to figure out the diameter at the breast level. Table (4)

$H=2.7027+0.41112d-0.0006d^2$
$R2=0.76$ $S.E=1.65$ $RSS=823.3$ $Bias=0.00056$
$N=2.200$ $m=0.8330$

Table 4: Relationship between the diameter at the breast level and the total height of *Pinus brutia ten.*, growing in Zawita region.

dbh/cm	h/m	dbh/cm	h/m	dbh/cm	h/m
7	5.5	23	12.1	39	18.7
8	5.9	24	12.5	40	19.1
9	6.3	25	12.9	41	19.5
10	6.8	26	13.3	42	19.9
11	7.2	27	13.7	44	20.3
12	7.6	28	14.1	45	20.7
13	8.0	29	14.6	46	21.1
14	8.4	30	15.0	47	21.5
15	8.8	31	15.43	48	22.0
16	9.2	32	15.8	49	22.4
17	9.6	33	16.2	50	22.8
18	10.0	34	16.6	51	23.2
19	10.5	35	17.0	52	23.6
20	10.9	36	17.4	53	24.0
21	11.3	37	17.8	54	24.4
22	11.7	38	18.3	55	24.8

Height – Diameter Model for *Pinus brutia Ten.* grown under natural conditions in Zawita Region Northern of Iraq.

Summary

Number of computer programs were used to develop regression equations from relating the total height of pine trees in it, as depended variables, and diameter at breast level as independent variables.

The data of 300 of pine grown in Zawita region collect of sample random selected and 6 measures of precinct were used.

As a result of WHICH the ploy normal regression equation screened of the study.

$h = 2.7027+0.4112\ d -0.0006d^2$

$R^2 = 0.76$ S.E = 1.65

RSS= 823.3 Bias = -0.00056

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