The Efficiency of The Tree Crown in The Expression of Growth For Pinus Brutia Ten Trees Growing in Atrush Region Northern Iraq

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Abstract

The study was conducted on Pinus brutia Ten. trees growing in Atrosh region northern Iraq, which are natural forests of different age. We have taken different measurements of (200) trees to estimate the growth efficiency in both basal area and volume depending on crown projection area of the tree as independent variable. Several linear and nonlinear equations have been obtained through which we can estimate growth and know the role of each of these elements in growth efficiency. For Crown efficiency depending on the basal area (CEBg) denoting the crown projection area (CPA) the nonlinear equation \(CE_{Bg} = -0.99964 + CPA^{0.00009851}\) was chosen, as \(R^2 (72.52)\) and SE (0.00002) and D-W (1.87). We also found The efficiency of the crown depending on the growth on base area (CEbg) denoting the of the crown projection area (CPA) and the height of the tree (H). Also the nonlinear equation was chosen depending on the scales used \(CE_{Bg} = -1.99964 + CPA^{0.00009904} + H^{0.0001598}\) was the value of \(R^2 (75.77)\), SE (0.00002) and D-W (1.81). For Crown efficiency depending on the growth in volume (CEVg) in terms of Crown projection area (CPA) the nonlinear equation \(CE_{Vg} = -0.9980154 + CPA^{0.0000182}\) was chosen as \(R^2 (70.11)\) and standard error SE (0.0001) and D-W (1.55), we also found Crown efficiency depending on the growth in volume depending on crown projection area and the height of the tree, the nonlinear equation \(CE_{Vg} = -1.99922 + CPA^{0.0001515} + H^{0.0001598}\) was chosen which the value of \(R^2 (69.44)\), SE (0.0001) and D-W (1.55).

Keywords : Crown, Efficiency, Growth, Volume , Nonlinear.

1. Introduction

The original habitat is the Proteus pine tree. Pinus brutia Ten. is a Mediterranean basin region, growing in Turkey, Iran, Georgia, Uzbekistan, northern Iraq, western Syria, Palestine, Lebanon and Cyprus [1]. It is a medium-sized tree of gymnosperms and belongs to the coniferous family Pinaceae. The tree reaches a length of 20 to 35 meters, the STEM is wide up to about one meter in diameter, the bark is thick reddish-orange and is vertically slotted at the base and peeled at the top, the leaves are conical in shape, complete with a pair of leaves in a single sheath cylindrical cones 10-11 cm long and 4-5 cm wide. At the base, the cone is initially green, turning at maturity to a bright reddish brown. [2,3], estimated Crown projection area (CPA), and the area covered by the crown, and defined LAI per tree as the ratio of total leaf area and Crown Mscat area and this ratio can be large even for simple crown shapes. Since the total area of the leaves usually increases more quickly with dbh than with the projected crown area, this ratio increases with the size of the tree. The crown of the tree is the point of interaction between the tree and the atmosphere and performs many important processes such as the reduction of solar radiation, water retention and the change of the carbon state and most of these processes part of the photosynthesis process carried out by all the green parts of the tree as carbon (CO2) is converted into another form.

2. Materials and Methods

The study area is located in the Atrush forest of the Sheikhhan district. In Dohuk governorate in northern Iraq, it is located at a length of 43° 20’ 20” E – 43° 21’ 40” E and two circles of width (51 20” N - 36° 52 10” N) and at an altitude of (780-950) m above sea level. There are also several other species in the area, such as Acorns (Quercus infectoria), Hawthorn (Craequs azarolus), almond (Prunus amycdalus), (Paliurus spaina-christi) and sumac (Rhus coriaria). The Atrush Forest also enjoys the spread of various plant coverings such as grasses, grasses and pastoral plants [6]. Since different temperatures result in a difference in the germination level of the seeds as well as in the growth rates, leaf formation and flowering events.
at certain dates and times that suit each species, the plant species whether trees or other plants differ in their heat needs to grow and develop naturally during the growing seasons, and were the Pinus brutia Ten trees, which Its growth requirements are from temperatures between a minimum temperature(2.5) cº and a maximum temperature (50) cº [7].

2.1.Filed Measurement

The following field measurements we need to make the different equations .

2.1.1.Tree height (m)

It is the vertical distance between the base of the leg at ground level to the top of the tree and is measured using the haka, which contains several measures depending on the approximate height of the tree where the scale was selected (15) m [8], if two upper and lower readings were taken and the distance between the data and categories were distributed as shown in Table (1) and the table was converted into an iterative runway as shown in Figure (1).

\[
\text{Tree height} = \text{upper reading} \pm \text{lower reading} \times \frac{\text{horizontal distance}}{\text{scale}}
\]

Table 1. Shows the frequency distribution of tree height (m) categories for Atrosh forest study trees.

| Categories (m) | mean of category (m) | Frequency |
|----------------|----------------------|-----------|
| 1-3            | 2                    | 1         |
| 3-5            | 4                    | 20        |
| 5-7            | 6                    | 73        |
| 7-9            | 8                    | 90        |
| 9-11           | 10                   | 16        |

Figure 1. Shows the histogram of tree height categories ( H ).

2.1.2.Diameter breast height (dbh)

It is intended to measure the straight line passing through the center of the tree from both ends of the tree i.e. the outside of the trunk we used the caliper tool we take two measurements perpendicular to the diameter breast height (130 cm approximately dbh) to reduce errors and then divide by 2, and from Figure (2) shows the distribution of.

Table 2. Shows the frequency distribution of (dbh) diameter classes of study samples.

| Categories | Mean of category (cm) | Frequency |
|------------|-----------------------|-----------|
| 5.7        | 5.95                  | 15        |
| 7.9        | 7.95                  | 28        |
| 9-11       | 9.95                  | 35        |
| 11-13      | 11.95                 | 51        |
| 13-15      | 13.95                 | 51        |
| 15-17      | 15.95                 | 8         |
| 17-19      | 17.95                 | 5         |
| 19-21      | 19.95                 | 5         |
| 21-23      | 21.95                 | 0         |
| 23-25      | 23.95                 | 0         |
| 25-27      | 25.95                 | 0         |
| 27-29      | 27.95                 | 2         |
2.1.3. The thickness of the last two growth rings

It is done using the tool (increase borer) and is done by installing it at the height of the chest level and start drilling at a certain distance and then extract the drill and take the measurement tool (vernear).

2.1.4. Crown width (m)

It is obtained by taking down imaginary drops from the ends of the crown and taking more than 3 measurements according to The Shape of the crown and then dividing them by their number to increase accuracy.

2.1.5. Basal area (m²)

Depending on the diameter at breast height dbh [8], \( BA = 0.00007854 \times d^2 \). The cross-sectional area represented by the basal area of the tree when it is large will transfer more water and nutrients to the crown, which will result in the formation of a large biomass [9]. He found a linear relationship between the area of succulent wood at dbh (basal area and leaf mass) and this relationship also depends on the quality of the site.

2.1.6. Finding the growth difference of the basal area (m²)

Find the diameter minus the thickness of the last two growth rings and then find the basal area for two years ago, by finding the total basil area minus the inner basal area.

\[
B_g = BA_2 - BA_1
\]

\( B_g \) = Growth in the basal area
\( BA_2 \) = Total basal area
\( BA_1 \) = Inner basal area

2.1.7. Finding the tree volume (m³)

Based on the equation of [6] in calculating the volume of the protean pine trees in northern Iraq, the data and categories were distributed as shown in Table (3) and the table was converted into an iterative runway as shown in Figure (3).

\[
\text{volume} = 0.01238 - 0.00001 \times H^{3.96} + 0.00004 \times D^2 \times H
\]

H= height of the tree
D= Diameter breast height.
Table 3. Shows the frequency distribution of tree volume categories for study trees (m$^3$).

| Categories (m$^3$) | Mean of category (m$^3$) | Frequency |
|-------------------|--------------------------|-----------|
| 0.001_0.005       | 0.003                    | 34        |
| 0.005_0.009       | 0.007                    | 52        |
| 0.009_0.013       | 0.011                    | 64        |
| 0.013_0.017       | 0.013                    | 34        |
| 0.017_0.021       | 0.015                    | 4         |
| 0.021_0.025       | 0.017                    | 6         |
| 0.025_0.029       | 0.019                    | 2         |
| 0.029_0.033       | 0.021                    | 1         |
| 0.033_0.037       | 0.023                    | 3         |

Figure 3. Shows the frequency distribution of volume categories of *Pinus brutia* Ten. trees in Atrush (m$^3$).

2.1.8. *Find growth in volume for the last two years (m$^3$)*

$$V_2 - V_1 = V_g$$

$V_g$ = volume growth
$V_2$ = total volume
$V_1$ = volume for the last two years

It's found by finding the volume two years ago and then subtracting it from the current volume, so we get the growth in volume for the last two years.

2.1.9. *Crown projection area (m2)*

Several readings are taken of the radius of the crown, (the distance between the edge of the crown and the trunk of the tree), table (4), and then find the average for readings which we find from the crown projection area as a circle as shown in Figure (4). Area of circle = $r^2 \times \pi$

Table 4. Shows categories and iterations of the crown projection area (m$^2$).

| Categories (m$^2$) | Mean of category (m$^2$) | Frequency |
|-------------------|--------------------------|-----------|
| 1.4               | 2.5                      | 12        |
| 4.7               | 5.5                      | 40        |
| 7.10              | 8.5                      | 70        |
| 10_13             | 11.5                     | 39        |
| 13_16             | 14.5                     | 14        |
| 16_19             | 17.5                     | 12        |
| 19_22             | 20.5                     | 6         |
| 22_25             | 23.5                     | 2         |
| 25_28             | 26.5                     | 0         |
| 28_31             | 29.5                     | 1         |
| 31_34             | 32.5                     | 1         |
| 34_37             | 35.5                     | 2         |
| 37_40             | 38.5                     | 1         |
2.1.10. **Finding the efficiency of the crown depending on the basal area growth of the tree CEBg**

\[ CEB_g = \frac{B_g}{CPA} \]

- \( CEB_g \) = Crown efficiency depending on the basal area growth
- \( B_g \) = Growth in the basal area
- \( CPA \) = crown projection area

2.1.11. **Find crown efficiency depending on volume growth CEVg**

\[ CE_{Vg} = \frac{V_g}{CPA} \]

- \( CE_{Vg} \) = crown efficiency depending on volume
- \( V_g \) = Growth in volume
- \( CPA \) = crown projection area

### 3. Results and Discussion

#### 3.1. Crown efficiency depending on the basal area growth by the crown projection area (CEBg)

Several equations have been found linking the growth efficiency of the basal area to the significance of the crown projection area as shown in Table (5).
Table 5. Shows Crown efficiency equations based on, growth in basal area denoting crown projection area CPA for the *Pinus brutia* Ten. Trees.

| No | Equation | R² | SE | MAE | D-W |
|----|----------|----|----|-----|-----|
| 1  | CE<sub>Bg</sub> = 0.0002832 - 0.00001045*CPA | 71.25 | 0.00002 | 0.00002 | 1.70 |
| 2  | CE<sub>Bg</sub> = (0.4466 - 0.002616*CPA)<sup>10</sup> | 73.60 | 0.0061 | 0.0050 | 1.77 |
| 3  | CE<sub>Bg</sub> = 0.000385 - 0.00006652*<sup>√</sup>CPA | 73.15 | 0.00002 | 0.00002 | 1.68 |
| 4  | CE<sub>Bg</sub> = 0.000397 - 0.00009849*log(CPA) | 72.52 | 0.00002 | 0.00002 | 1.56 |
| 5  | CE<sub>Bg</sub> = 0.0002264 - 0.00000754*CPA + 0.000232*1/CPA | 73.11 | 0.00002 | 0.00002 | 1.64 |
| 6  | CE<sub>Bg</sub> = -0.9996+CPA<sup>0.00000831</sup> | 72.52 | 0.00002 | 0.00002 | 1.87 |
| 7  | √(CE<sub>Bg</sub>) = 0.01725-0.0004009*CPA | 73.04 | 0.0009 | 0.0007 | 1.73 |
| 8  | log(CE<sub>Bg</sub>) = -8.04176 - 0.06265*CPA | 73.59 | 0.1480 | 0.1207 | 1.79 |

From the table (5) equation number (6) was chosen where the value of R² (72.52), standard error (0.00002) and D.W (1.87) so this equation was preferred over the rest of the equations and was performed by a residual analysis as in Figure (5) and also the equation was converted into a graph as in Figure (6).

**Figure 5.** A residual analysis shows the nonlinear relationship between Crown efficiency based on basal area growth with crown projection area of *Pinus brutia* Ten. equation (6).

**Figure 6.** Shows the nonlinear relationship between Crown efficiency based on growth in basal area with crown projection area CPA for *Pinus brutia* Ten. trees equation No. (6).
3.2. Crown efficiency depending on the basal area growth denotes crown projection area and tree height (CEBg)

In order to increase the accuracy of the equation and to know the effect of the total tree height of the tree on the efficiency of growth in the basal area, the tree height was added to the equation as an independent variable as shown in Table (6).

Table 6. Shows Crown efficiency based on growth in basal area with crown projection area and tree height for studied for Pinus brutia Ten. Trees.

| No | Equation | \( R^2 \) | SE | MAE | D-W |
|----|----------|-----------|----|-----|-----|
| 1  | \( CE_{Bg} = 0.0002899 - 0.000009713*CPA - 0.00000237*H \) | 73.40 | 0.00002 | 0.00002 | 1.84 |
| 2  | \( CE_{Bg}=( 0.4473 - 0.00249*CPA - 0.0003443*H)^{10} \) | 74.83 | 0.0058 | 0.0048 | 1.93 |
| B | polynomial function |
| 3  | \( CE_{Bg} = -1.99964+(CPA)^{0.00009904}+(H)^{0.00001599} \) | 75.77 | 0.00002 | 0.00001 | 1.81 |
| C | Non-linear regression equation |
| 4  | \( \sqrt{CE_{Bg}} = 0.01742 - 0.0003779*CPA - 0.0000691*H \) | 74.71 | 0.0009 | 0.0007 | 1.88 |
| 5  | \( \sqrt{CE_{Bg}} = 0.017105 - 0.0003754*CPA - 0.000008627*(H)^{5} \) | 75.11 | 0.0008 | 0.0007 | 1.87 |
| D | logarithmic form equations |
| 6  | \( \log(CE_{Bg}) = -8.02829 - 0.0598259*CPA - 0.0076399*H \) | 74.71 | 0.1417 | 0.1150 | 1.95 |
| 7  | \( \log(CE_{Bg}) = -8.05671 - 0.05916*CPA - 0.000010907*(H)^{4} \) | 75.04 | 0.1407 | 0.1149 | 1.93 |

From Table (6) equation number (3) was chosen where the value of \( R^2 \) (75.77), SE (0.00002) and D.W (1.81 )and the equation was subjected to a residual analysis as in Figure (7), through which we observe the random distribution of deviations, which confirms the accuracy of the equation and its usability and representation of the equation graphically as in Figure(8).

**Figure 7.** Showing the residual analysis showing the efficiency of the crown based on growth in the basal area with the crown projection area and the tree height of the for Pinus brutia Ten. trees studied for equation No.( 3).
3.3. Crown efficiency depending on volume growth (CEVg)

Several equations have been obtained to estimate the efficiency of the crown by indicating the crown projection area of the *Pinus brutia* Ten. trees in the Atrush region as shown in Table (7).

| No  | Equation                                                                 | R²    | SE    | MAE   | D-W   |
|-----|--------------------------------------------------------------------------|-------|-------|-------|-------|
| 1   | CEVg = 0.00152 - 0.0000474*CPA                                           | 61.86 | 0.0003| 0.0003| 1.60  |
| 2   | CEVg = (0.528482 - 0.00265617*(CPA))10                                    | 64.88 | 0.0085| 0.0070| 1.58  |
| 3   | CEVg = 0.00146 - 0.00003566*CPA - 0.00009629*(CPA)²                      | 62.09 | 0.0001| 0.0001| 1.61  |
| 4   | CEVg = 0.0016177 - 0.0000522308*CPA - 0.0000406102*1/CPA                 | 62.14 | 0.0001| 0.0001| 1.61  |
| 5   | CEVg = -0.998015 + CPA - 0.0043562                                       | 70.11 | 0.0001| 0.0001| 1.53  |
| 6   | √CEVg = 0.0399749 - 0.0000789708*CPA                                     | 64.03 | 0.0025| 0.0021| 1.58  |
| 7   | log(CEVg) = -6.3574 - 0.05394*CPA                                        | 64.90 | 0.1737| 0.1421| 1.58  |
| 8   | log(CEVg) = -2.5114 - 3.50989*(CPA)⁻¹                                      | 53.10 | 0.1809| 0.1556| 1.48  |

From Table (7) equation number (5) was chosen where the value of R² (70.11), the standard error SE (0.0001) and D-W (31.5) carried out a residual analysis to show deviations that are distributed randomly, which indicates the accuracy of the equation as in Figure (9). The relationship between the efficiency of the crown depending on the volume growth with the crown projection area of the *Pinus brutia* Ten. was illustrated by a graph as in Figure (10).

Figure 8. Shows the nonlinear relationship showing the efficiency of the crown depending on the growth in the basal area with the crown projection area and the tree height of the for *Pinus brutia* Ten. trees studied for equation No. (3).

Figure 9. Showing the residual analysis of the relationship between the efficiency of the crown based on growth in volume by the crown projection area of the *Pinus brutia* Ten. trees in Atrosh for equation No. (2).
Figure 10. Represents the nonlinear relationship between the efficiency of the crown depending on the growth in volume by denoting the crown projection area of the *Pinus brutia* Ten. trees in Atrosh for equation No.(2).

3.4. Crown efficiency depending on the growth in volume by the crown prediction area and the height of the tree.

Tree height was added as a second independent variable to the equation to see the effect of tree height on growth as shown in Table (8), which included several linear and nonlinear equations.

Table 8. Represents the relationship between Crown efficiency depending on growth in volume denoting Crown prediction area(CPA) and tree height(H).

| No | Equation                                                                 | R²   | SE   | MAE  | D-W    |
|----|--------------------------------------------------------------------------|------|------|------|--------|
| 1  | CE

*Vg* = 0.00102 - 0.00005449*CPA + 0.00008106*H                             | 68.30| 0.0001| 0.0001| 1.52   |
| 2  | CE

*Vg* = -0.001053 - 0.000573*(CPA)\(^{0.4}\) + 0.002381*(H)\(^{0.2}\)     | 71.26| 0.0001| 0.0001| 1.53   |
| 3  | CE

*Vg* = -1.9992+(CPA)\(^{0.000553}\) +*(H)\(^{0.000056}\)                   | 69.44| 0.0001| 0.0001| 1.55   |
| 4  | CE

*Vg* = 0.03135 - 0.0008985*CPA + 0.00139*H                               | 72.40| 0.0021| 0.0017| 1.53   |
| 5  | CE

*Vg* = -0.003367 - 0.009251*CPA\(^{0.4}\) + 0.03952*(H)\(^{0.2}\)        | 72.82| 0.0021| 0.0017| 1.52   |
| 6  | log(CE

*Vg*) = -6.96542 - 0.05929*CPA + 0.09488*H                             | 74.45| 0.1348| 0.1056| 1.54   |
| 7  | log(CE

*Vg*) = -8.01651 - 0.6053*(CPA)\(^{0.4}\) + 1.4596*(H)\(^{0.3}\)       | 73.72| 0.0137| 0.1073| 1.52   |

From Table (8), equation number (3) was chosen as R² (69.44), SE (0.0001) and D-W (1.55) the equation has been subjected to a residual analysis as in Figure (11), which shows the distribution of deviations randomly confirming the accuracy of the equation and figure (12) shows the nonlinear equation (3) by a graph.

Figure 11. Shows the efficiency of the crown depending on the growth in volume by denoting the crown prediction area of the *Pinus brutia* Ten. trees in Atrosh for equation No.(3).
Figure 12. Shows the nonlinear relationship between the efficiency of the crown depending on the growth in volume by denoting the area of the crown projection area and the height of the tree for equation number (3).

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