DEVELOPMENT OF PREDICTION REGRESSION EQUATIONS FOR BIOMASS ESTIMATION IN POPULAR MONOCULTURE PLANTATIONS IN THE PUNJAB (INDIA)

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ABSTRACT

India is one of the countries where Populus genes with all 6 species namely P. Ciliata, P. laurifolia, P. gamblei, P. euphratica, P. alba, P. Jaquemontiana var. glauca, are growing well. While considered the economic importance of exotic poplar clones fast growth and ability to provide substantial production as commercial wood on a short rotation basis, their hybrids / clones were tried in various agro-climatic conditions in Punjab. Having realized that P. deltoides and P. xeuramericana are the two species/hybrids, which have succeeded well. These were tried on large scale in the Tarai and plains of Punjab, Haryana, Himachal Pradesh, U. P. etc. (Tewari 1992 & 93)

Poplar is a large tree reaching over 25 m in height and 100 to 130 cm in girth (GBH) in the short period of 10-12 years only. It is shallow rooted and spreads widely. The tree tops develop a tail straight bole. The main branches forms conical crown. It is deciduous, and the leafless period remains upto 3 - 5 months in winter season. They prefer deep, well drained, nutrient rich soil. They are susceptible to even light fires.
Poplars are grown in Agro-forestry along with cash crops in Punjab. The growth of poplars in this Agro-forestry system is very encouraging.

The methodology adopted for all the experiments conducted and studies undertaken were the same for all monoculture and mixed plantation sites in Poplar species. During estimation of Diameter and height correlation and selection of sample trees for harvesting, there is always a high correlation between DBH, height and weight of tree, that’s why measurement of diameter and height has been universally recognised to be a reliable measure for growth of trees. Thus, it becomes essential to measure all the DBH (diameter at breast height 1.37m) and height of some of the trees in a sample plot. Regression of height and diameter can be used to estimate the height of the remaining trees, a free hand curve may also serve the purpose.

The data obtained using stratified tree technique method of Art and Marks (1971) by harvesting the sample trees, within sample plots of different sizes (10 x 10m, 15 x 15m, 20 x 20m, 25 x 25m, 30 x 30m and 50 x 50m) laid out according to the size of the land area in Poplar plantations. The DBH and heights of 15 representative sample trees covering the entire diameter range of each plot were recorded in sample plots and correlation (diameter & height) was established by having regression coefficient (R2) values. The entire diameter range was then divided into different diameter classes. Three sample trees from each diameter class (close to the mean DBH of that class) were harvested, in each plantation for biomass estimation and development of best suitable prediction regression equations for biomass estimation in Poplar forest plantations in the Punjab state of India.

**Keywords:** Poplar tree, Agro-forestry, Prediction equation, Diameter class, Biomass etc.


http://www.iaeme.com/IJM/issues.asp?JType=IJM&VType=11&IType=9

1. **INTRODUCTION**

Studies on Biomass are essential to estimate the net primary productivity, understanding nutrient dynamics, organic and energy transfers, predicting the effects of tree utilization, management procedures or other disturbances on the productivity and stability of forest stands. These studies are of special interest to the grower as they help to judge the performance of the species in terms of total biological production and also to assess the nutrient drain on tree harvesting of the species for commercial purposes on the total biomass. Increase in nutrient content of standing tree crop with stand age has direct bearing on the total biomass of the stand.

It’s observed to have marked increase in the number of studies on forest biomass during the past decades realising that total organic production is important, instead of considering the forest a production system for wood only. This is probably due to increasing pressure placed on forests by the community for different forest products, search for renewable source of raw materials etc. In addition to the productive role, the growing concern of well being of forest ecosystems has resulted in the appearance of numerous publications on forest biomass throughout the world (Porade 1980, Bradstock 1981), including India (George 1977, Chaturvedi, 1983, Kaul et al. 1983, Bhatia 1984, Mathur et al. 1984, Vimal 1984, Kushalappa 1984, Negi 1984, Gurumurty et al. 1984, Negi & Sharma, 1987, Pande et al. 1986, 87, 88, 89, Negi et al 1988, Pal & Raturi 1988, 90, 91, Sharma et al. 1988, Tandon et al. 1988, 89, 91
Bisht, 2000), but in most of the studies only above ground biomass has been estimated / calculated.

Using stratified mean-tree-technique is undoubtedly the best to estimate the biomass of various tree components but at many times the mean tree of mean diameter may not necessarily be mean tree for weight determination. In order to resolve difficulty of felling standing green trees at sites, where biomass estimation is highly required, such regression equations are needed. Various regression equations have been worked out by scientists on the basis of easily measurable parameter for Poplar and other trees plantation.

Negi et al. (1988) described methods for biomass estimation in forest ecosystems with their limitations and applicability; some comparison have also been made between the conventional stratified tree techniques and other methods, but the regression technique has been found satisfactory for wider applications or where the destructive sampling is not desirable. The above ground biomass increases with age and the maximum was recorded at tree age of 15 years. Kaul et al. (1983) have studied the biomass of 8 years, Kaul and Sharma (1983) in 10 years and Raizada and Srivastava (1989) in 14 years old plantations of *P. deltoides* of Dehra Dun. Singh et al. (1990) have estimated biomass and productivity of 3 *P. deltoides* (G3) plantations of Tarai regions of central Himalaya. Organic productivity studies in *Populus deltoides* plantations of some regions of U.P. by Tandon et al. (1991) report the total above ground biomass to be 27 to 192 t ha$^{-1}$ and the total biomass to be 30 to 217 t ha$^{-1}$ in 3, 5, 7, 9 and 11 years of stand age.

The importance of understorey vegetation contribution to the forest floor as well as of biomass and productivity of the ecosystem as a whole has been recognized by few workers. Understorey vegetation effects on the nutrient contents of litter fall and soil of red pine and birch stands in Northern Minnesota were studied by Tappeiner and Alm (1975) and they found that the undergrowth layers have less effect on nutrient cycling but add significantly to the total dry weight of the litter fall.

There are limited studies on biomass productivity and various other aspects of tree species (Rajvanshi and Gupta 1985, Sharma et al. 1988, Pal and Raturi 1990, Gupta and Rajvanshi 1991, Singh et al. 1994, Bisht 2000). For Punjab particularly this is a pioneering work in which biomass has been calculated by harvesting trees at various sites and prediction equations have been developed for future references.

Most of the forests in Punjab, because of intensive agriculture are confined along the canals, roads, railway lines and drains. Trees are planted in one to several rows and in some cases 15-30 rows. Block plantations are relatively few in number. The common species alongside growing are of Poplar, Kikar (*Acacia nilotica*), Eucalypts (*E. hybrid*), Khair (*A. catechu*) and Sissoo (*Dalbergia sissoo*) etc.

The need for a more comprehensive understanding of woodland as ecosystem has gained importance with the multiple use concept of forests, changes in utilization trends and realization of maximum productivity. Thus, introduction of fast growing species like Poplar and Eucalyptus etc. for plantation purposes have reduced the gap of commercial demand and supply of major forest produce to some extent. To reduce the tremendous pressure on our natural forests, ‘Monoculture’ of fast growing, short rotation forest species are preferred for afforestation practices, which has invited great controversies particularly growing of Eucalyptus and Poplar as monoculture. For better wood production also some other indigenous tree species were converted into monoculture by removing associate trees of lesser timber values and called ‘kukat’ (bad wood), which again invited lot of controversies. Lot of studies has been carried out in India on Eucalypts, Poplars, Sissoo and Khair. No work has been done on biomass, productivity and nutrient retention / nutrient loss through complete harvesting from the sites of all these species in Punjab. Thus, the present study was undertaken in Poplar species grown as monoculture in selected districts of Punjab state.
2. Study Site

The ‘Punjab’ consists of two Persian words Panj (five) and Ab (Water and Rivers), which mean “the land of five rivers”. Before partition the state had five rivers namely The Sutlaj, The Beas, The Ravi, The Chenab, and The Jhelam. However, it lost the Chenab and Jhelam to west Punjab in Pakistan during partition in 1947. Subsequently in 1966, the state was reorganize again. The present state of Punjab has an area of 50,362 sq. km and is located between 29°30’ and 32°32’ N Latitude and 73°55’ and 76°50’ E Longitude. This state lies in the northwestern part of India between 2 rivers, the Ravi and the Ghagger. This land locked state shares its boundaries with other Indian states viz. Haryana and Rajasthan (to its South), Himachal Pradesh (on its North-East), Jammu and Kashmir (on the North), as well as with neighboring like Pakistan (on the West). Administratively, the state is divided into 18 districts and has 157 towns and 12,329 villages. The districts of Punjab are Amritsar, Bhatinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Moga, Mohali, Muktsar, Nawanshahar, Patiala, Ropar and Sangrur (Map 1). Out of the 24.29 million people of the state 66.1% is rural population and 33.9% is Urban.

![District map of Punjab showing study sites](http://www.mapsofindia.com)

**Figure 1** District map of Punjab showing study sites

2.1. a Topography

The outermost range of the southern slopes of the Shiwaliks forms the northern boundary of the state. These scattered ranges lie in the districts of Gurdaspur, Hoshiarpur, and Ropar. The rising Himalayas led to the creation of the Shiwaliks. The Shiwaliks strata deposited from the middle Miocene to the middle Pleistocene. The rising of Shiwaliks covered a period of 14 million years and these are comparatively young mountains in the stratified geological record of the world. Most of the Shiwaliks sediments were derived as alluvial detritus by denudation of the newly risen mountains. The total length of the Shiwaliks in Punjab is 130 km. This range varies in its width from 3.3 km in the south (Ropar) to 16 km in the north (Gurdaspur). The altitude also varies from 300m to 700m. Thus, the Shiwaliks from a very narrow strip physiographically, while the rest of the state lies in the plains of northern India. The vast plain can be conveniently divided into 2 distinct zones, the larger moist plain descending from the Shiwaliks region, and the smaller semi arid areas bordering Rajasthan. Thus geographically, Punjab is an interesting
state for studying biodiversity. This is emphasized by the fact that it lies sandwiched between the desert of Rajasthan and the humid Himachal Pradesh.

**Topographically**, the state is characterized by a reversal of slope and presents a considerable variety of relief’s. The whole geographical area of the state is 5.04 million ha and is divided into 3 physiographic regions as:-

(i) Shiwaliks hills (ii) Foothills of Shiwaliks & (iii) Eastern and Western alluvial plains.

### 2.2. b Climate

Climatically, the state is typically subtropical with hot summers and cold winters. The Punjab plains enjoy a semi arid monsoon type of climate characterized by a deficiency of rainfall over the greater part. The region experiences the usual 3 seasons; winter, summer, and monsoon. The heat in summer as well as the cold in winter is extreme. There are also considerable differences in the weather from season to seasons as well as from year to year. The state has three distinct seasons and average annual rainfall is around 480 mm in plains and 960 mm in hilly mountainous regions. The temperatures range from 0°C in winters to 47°C (Max.) during summer.

### 2.3. c Soil

Under the ‘All India Soil and Land use Survey’ the Committee on ‘Natural Resources of Indian Soil’ 27 major soil groups were recognized for Punjab. However, later a ‘Soil Map of India’ recognized only 25 major groups. According to this classification, Punjab’s soil is mostly alluvial. In the Shiwaliks region, Upper tertiary, sedimentary river deposits or alluvial detritus are derived from sub aerial wastes of the mountains swept by down streams. The brownish loamy clays may be inter-bedded with boulders. The soils vary from pure sand to pure clay mixed with gravel and stones. The clay content of the soil is below 10%. The soils contain small quantities of lime. In general, the soils of the Shiwaliks region are broadly categorized into different zones; Bhaber (sub montane zone on steep slopes), Bhangar (upland zone on higher elevation where there is no flooding), and Khadar (riverine zone on lower elevations, prone to annual flooding where alluvial deposits are added by erosion of the Bhangar).

### 2.4. Punjab Agro-Climatic Zones

![Figure 2 Ecoclimatic zones of Punjab](http://www.iaeme.com/IJM/index.asp)
2.5. Experimental Sites

The present study was conducted in *Populus* species plantations of different ages at different sites in 10 Forest Divisions of Punjab namely Amritsar, Ludhiana, Hoshiarpur, Patiala, Muktsar, Jalandhar, Bhatinda, Ferozepur, Faridkot, Roopnagar/Ropar representing three agro-climatic zones of Punjab (Sehgal *et al.* 1990) as clearly shown in the Map 2.

3. MATERIALS & METHODS

3.1. Biomass Estimation

**Biomass** estimate the net primary productivity, understand the nutrient dynamics, organic and energy transfers, predicting the effects of tree utilization, management procedures or other disturbances on the productivity and stability of forest stands.

These studies interest the growers as they help to judge the performance of the tree species in terms of total biological production and assess the nutrient drain on tree harvesting for commercial purposes for total biomass. The increase in nutrient content of standing tree crop with stand age has direct bearing on the total biomass of forest/plantation stands. Little work have been carried out in India on biomass, productivity and nutrient retention/nutrient loss through complete harvesting from the forest sites.

3.2. Methodology

3.2.1. Diameter and height correlation and selection of sample trees for harvesting

Sample plots of different sizes (10 x 10 m, 15 x 15 m, 20 x 20 m, 25 x 25 m, 30 x 30 m & 50 x 50 m) were be laid out accordingly to the size of the area in all the forest tree plantations. Diameter at breast height (DBH) of all the standing trees were measured, then the entire diameter range was divided into different diameter classes. Heights of 15 representative sample trees covering the entire diameter range of each plot were recorded, then correlation between diameter and height was established by calculating regression coefficient (R²) values for all the standing plots. Three sample trees from each diameter class (close to the mean DBH of that class) were harvested in every plantation for estimation of biomass by using **Stratified Tree Technique** method of Art and Marks (1971).

3.2.2. Biomass, productivity calculations

All tree components (leaves, twigs, branches, bark, bole) including roots were separated immediately after felling and their fresh weights recorded in the same fields. The representative samples of each tree components (100 g each of leaves, twigs, branch, bark, fruits) were taken for oven dry weight estimation and chemical analysis for different macronutrients were done later in the laboratory.

The bole portion of the sample trees was cut upto 2 m long sections (billets) for easy weighting. Approximately 5 cm broad disc were removed from the base of each billets for estimation of fresh and dry weights of bark and wood (under bark) and also for the estimation of volume (over bark and under bark) of the main bole (upto a diameter limit of 5 cm over bark) were estimated.

The average diameter from two successive discs was taken to calculate the volume (over bark and under bark) of each section and finally the volume of each section was added up to get the final volume of main bole (over bark and under bark) altogether.

The complete root spreader system of all the sample trees was excavated excluding their fine rootlet. All care was taken to remove the soil particles sticking roots and fresh weight was
taken immediately to prevent their weight loss. Representative roots sample was taken for its dry weight estimation and determining mineral contents later in lab.

The stand biomass (t ha⁻¹) was obtained by multiplying the dry weights of the sample trees by the number of tree in respective diameter classes followed by summation of biomass in each diameter class. For calculating productivity the total biomass values are divided by number of trees per hectare of each study site. Thus productivity per tree per year or productivity per hectare per year is obtained for all the species during filed studies.

3.2.3. Developing Regression equation for biomass estimation

In order to predict biomass and productivity of any forest stand on a regional basis, a set of regressions are derived between easily measurable parameters (DBH & Height) and dry weight of different components (leaves, twigs, branches, bole, bark, root). These equations would obviate a great extent the necessity of destructive sampling, which is not always convenient and possible for various reasons.

The basic data obtained from sample trees felled were used to obtain different regression equations. The sample trees covered fairly wide range of variations in the growth of the species and site factors. The actual figures of dry weight of various tree components of all the trees felled for all species were plotted against D²H values of each tree and the equation or model were tried as:-

\[ \log Y = a + bx. \]

Where ‘Y’ is a biomass component expressed in Kg and ‘X’ is the D²H diameter at breast height & height values ‘a’ & ‘b’ are the regression constants, respectively. The values of ‘X’ was also tried with ‘D’ (Diameter at breast height) and D² also but D²H was found to be best suited for all species of trees.

For validation, regression equation were also worked out on the basis of tree felled and predicted biomass (using these equations) values of trees (from each site with varying diameter & height) were compared with actual biomass of these trees felled.

4. RESULTS AND DISCUSSIONS

4.1. Biomass and Productivity

*Populus species* were introduced in India in 1950 and past studies have been done on their yield at various places (Fotidar, 1983; Lohani, 1979). Kaul & Sharma (1983), Kaul *et al.* (1983) and Raizada & Srivastava (1989) Dwivedi & Sharma (1990), Singh *et al.* (1990) and Tandon *et al.* (1991) have estimated biomass accumulation of *Populus deltoides*. Litter production has been also estimated by Raizada & Srivastava (1989). Several studies dealing with biomass of poplars have been also reported from worldwide elsewhere James & Smith (1977), Bray & Dudkiewicz (1963), Peterson *et al.* (1970) and Pollard (1972), Carter & White (1971), Black (1965), Koerper & Richardson (1980) and Gosz (1980).

Poplar plantation with agriculture crops, along the bunds and in block plantations is quite common in Punjab. Generally *P. deltoides* varieties are grown. Diameter and height correlation has been established as shown in the Fig 1., which was plotted on the basis of enumeration made in the beginning of the study in Amritsar and Faridkot. However, harvesting has been done in farmers field at Hoshiarpur only. One more problem faced was that we couldn’t get trees of different age.

For biomass study 10 trees were harvested from farmers field at Bhagpur village of Hoshiarpur. Although the plantation is even aged (7 years), there were wide variations in the
DBH of all trees ranging from 5 cm to 30 cm and height varied from 5 m to 25 m in the study plot. The spacing between row-to-row and tree-to-tree was 3m x 4m.

The oven dry weights of sample trees felled and biomass calculated are depicted in the Table 1. along with productivity of all the trees felled. The biomass ranged from 24.99 t ha\(^{-1}\) to 291.66 t ha\(^{-1}\). The average total biomass of present study 128.33 t ha\(^{-1}\) of present study is comparable with the results of Kaul et al. (1983) in P. deltoides plantations of Dehra Dun, where they have reported biomass as 126 t ha\(^{-1}\) at 8 years age and 175 t ha\(^{-1}\) has been report by Kaul & Sharma (1983) at 10 years of age. The present biomass, however, is higher than 78.47 t ha\(^{-1}\) biomass of Tandon et al. (1991) at Tarai, U. P. The average productivity is 18.33 t ha\(^{-1}\) yr\(^{-1}\) and peak productivity is 41 t ha\(^{-1}\) yr\(^{-1}\). Since the trees were grown in farmers fields along the bunds in a broad strip, the irrigation, fertilizers applied to farm must have effects on the total biomass.

Other biomass components varied as: leaf biomass (2.18 kg tree\(^{-1}\) to 13.94 kg tree\(^{-1}\)), twig biomass (1.32 to 10.70 kg tree\(^{-1}\)), branch biomass (5.07 to 29.37 kg tree\(^{-1}\)), bark (3.04 to 28.31 kg tree\(^{-1}\)), bole biomass (16.92 to 235.90 kg tree\(^{-1}\)) and root biomass / Below Ground Biomass (BGB) (4.17 to 34.04 kg tree\(^{-1}\)).

The average percentage contributions of the biomass of each tree component to total biomass (above ground & below ground) are given in Table 2. The contribution of individual tree components to total biomass varied as: leaf 5.21%; twig 3.69%, branch 8.66%, bark 8.6%, root 11.16% and bole 62.68%. The percent contributions of all these components in the site is as bole > root > branch > bark > leaf > twig. Singh et al. (1990) have reported biomass of 8 – 10 years clones of P. deltoides (G3) from 119.6 – 171.4 t ha\(^{-1}\), in which Bole accounted for 57.5 – 58.8% of the total biomass. The % contribution of bole in present study is higher which can be attributed to addition of fertilizer by farmers in Punjab.

Tandon et al. (1991) have conducted a study in P. deltoides plantations in Tarai area of U.P. of 7 years of age. The density was 400 tees per hectare. The standing biomass of leaf was 2779, twig 2479, branch 3488, bole 47803, AGB 65761, root 12710 and total biomass 78471 kg ha\(^{-1}\) or 78.417 t ha\(^{-1}\). They have also studied litter production and reported that leaf litter (2073 kg ha\(^{-1}\)) contributes about 71.8% and twig (815 kg ha\(^{-1}\)) about 28.3 %. Nutrients in leaf litter was as n 23.63, P 0.41, K 7.69, Ca 41.35 and Mg 2.29 kg ha\(^{-1}\). where as in twig nutrients were N 4.32, P 0.24, K 3.5, Ca 5.22 and Mg 1.06 kg ha\(^{-1}\).

4.2. Developed Prediction Equations
Regression equations for Tarai, U.P. on the basis of DBH & D\(^2\)H of 7 years of P. deltoides (Tandon et al. 1991), Raizada and Shrivastava (1989) at Dehra Dun at 14 years using DBH & D\(^3\)H, Carter and White (1971) at 7 years of Albama (USA) used D (diameter) as dependable variable. In the present study D\(^2\)H has been found to be most suited.

The relationship between different tree component and D\(^2\)H have been established, which shows linear relationship with all tree component including total biomass Fig. 1. Prediction Equations of Table 3. show positive correlations as correlation coefficient (r\(^2\)) values show significant correlation between these parameters.
Development of Prediction Regression Equations for Biomass Estimation in Poplar Monoculture Plantations in the Punjab (India)

Table 1 Calculated biomass (t tree\(^{-1}\)) and productivity (t tree\(^{-1}\) yr\(^{-1}\)) of *P. deltoides* at Punjab.

<table>
<thead>
<tr>
<th>Forest Div.</th>
<th>Locality / Site</th>
<th>Leaf (kg)</th>
<th>Twig</th>
<th>Branch</th>
<th>Bark</th>
<th>Bole</th>
<th>(Root) BGB</th>
<th>Total biomass (AGB+BGB)</th>
<th>Bio. (t tree(^{-1}))</th>
<th>Bio. (t ha(^{-1}))</th>
<th>Productivity (t tree(^{-1}) yr(^{-1}))</th>
<th>Vol. (DOB) (m(^3))</th>
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<tbody>
<tr>
<td>1.Hoshiarpur Village</td>
<td>Bhagpur Village</td>
<td>2.18</td>
<td>1.32</td>
<td>5.26</td>
<td>3.04</td>
<td>16.92</td>
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</table>

* volume diameter over bark

Table 2 Contribution of different plant components to total biomass of Poplar trees

<table>
<thead>
<tr>
<th>Forest Div.</th>
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<td>13.42</td>
<td>13.33</td>
<td>97.15</td>
<td>17.3</td>
<td>154.99</td>
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<tr>
<td>% Contribution</td>
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<td>3.69</td>
<td>8.6</td>
<td>8.6</td>
<td>62.68</td>
<td>11.16</td>
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</table>

**Leaf**

\[ y = 0.6498x - 1.4621 \]

\[ R^2 = 0.901 \]

**Twig**

\[ y = 0.6443x - 1.5899 \]

\[ R^2 = 0.9096 \]

**Branch**

\[ y = 0.6202x - 1.14 \]

\[ R^2 = 0.9179 \]

**Bark**

\[ y = 0.8476x - 1.9875 \]

\[ R^2 = 0.9732 \]

**Bole**

\[ y = 0.7345x - 0.7168 \]

\[ R^2 = 0.7759 \]

**AGB**

\[ y = 0.7062x - 0.451 \]

\[ R^2 = 0.8566 \]

http://www.iaeme.com/IJM/index.asp
Development of Prediction Regression Equations for Biomass Estimation in Poplar Monoculture Plantations in the Punjab (India)

Table 3 Prediction Equations for biomass Estimation of Populus deltoides in Punjab

<table>
<thead>
<tr>
<th>Independent variable (x)</th>
<th>Dependent Variables Y</th>
<th>Correlation Coefficient ($r^2$)</th>
<th>Regression Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>x = D$^2$H</td>
<td>Leaf</td>
<td>0.9010</td>
<td>Y = 0.6498 X - 1.4621 Eqn. No.-1</td>
</tr>
<tr>
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<td>Twig</td>
<td>0.9096</td>
<td>Y = 0.6443 X - 1.5899 Eqn. No.-2</td>
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<tr>
<td></td>
<td>Branch</td>
<td>0.9179</td>
<td>Y = 0.6202 X - 1.14 Eqn. No.-3</td>
</tr>
<tr>
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<td>Bark</td>
<td>0.9732</td>
<td>Y = 0.8476 X - 1.9875 Eqn. No.-4</td>
</tr>
<tr>
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<td>Bole</td>
<td>0.7759</td>
<td>Y = 0.7345 X - 0.7168 Eqn. No.-5</td>
</tr>
<tr>
<td></td>
<td>Total Above Ground Biomass</td>
<td>0.8566</td>
<td>Y = 0.7062 X - 0.451 Eqn. No.-6</td>
</tr>
<tr>
<td></td>
<td>Root</td>
<td>0.9342</td>
<td>Y = 0.7936 X - 1.6785 Eqn. No.-7</td>
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<tr>
<td></td>
<td>Total Tree Biomass</td>
<td>0.8766</td>
<td>Y = 0.714 X - 0.4272 Eqn. No.-8</td>
</tr>
</tbody>
</table>

Finally, there is considerable scope of minimizing the losses of biomass / nutrients in monoculture plantations through adoption of conservative management practices. This identifies the ways to replenish the nutrient losses as:

- On-site debarking of stem wood / bole should be preferred, as bark contains comparatively high level of Ca, this will help in maintaining Ca level of the soil. In a study reported by Spangenberg (1994) Ca level in the soil is directly correlated with the Ca of bark of a 4.5 years old eucalypt plantation in Eastern Amazonia. So, it is evident that it has a significant role in determining nutrient level of bark part of a tree.
- Other than wood or not utilizable parts like small twigs, leaves should be left on the forest floor.
- Removal of litter should not be allowed from the forest floor as litter adds considerable amount of nutrients to the forest floor / soil.
• Roots contribute good amount of nutrients as has been described earlier, removal of all root parts will further deteriorate the site condition. Hence, lateral roots / fine roots should be left as such underground, which after decomposition will add nutrients to the soil.

• Understorey vegetation should not be disturbed / removed as they contribute a lot for conservation of resource not only in terms of replenishment of nutrients but also by improving the microclimate of the whole ecosystem.

Atmospheric inputs through rains also add the nutrients to the soil as has been described earlier. Hence, to increase the productivity of any plantation of Punjab all these points are to be taken care of sincerely.

REFERENCES


Development of Prediction Regression Equations for Biomass Estimation in Poplar Monoculture Plantations in the Punjab (India)


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