ESTIMATION OF CROWN BIOMASS PRODUCTION OF *POPULUS NIGRA* ITALICA MUENCH IN PAKISTAN

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ABSTRACT

In areas where Lombardy poplar (*Populus nigra* Italica Muench) grows in Pakistan crown biomass is lopped at various intensities and the woody branches and foliage components are used as fuelwood and fodder. The objective of this study was to develop simple and practical prediction models using linear regression to estimate crown biomass. Models were developed for green and air-dried branch wood and fodder crown biomass components under different lopping intensities. Tables were produced for each crown biomass component that can be used to formulate management, planning and marketing strategies. Diameter at breast height squared (Dbh^2) and its square proved to be the best independent variables to predict crown biomass weights.

INTRODUCTION

Lombardy poplar (*Populus nigra* Italica Muench) is an economically important tree species for fuelwood, fodder and timber in the dry temperate climatic zone of Pakistan. The tree is propagated on private farmlands and government plantations.

Lopping of poplar is a traditional practice and is generally believed, without any scientific evidence, to be conducive to greater height growth and better bole qualities. Poplar is lopped at various levels of intensity, ranging from up to one-third of the total height of the tree to, in extreme but frequent cases, up to two-thirds of the total tree height. Traditionally accepted rules of thumb for lopping are observed but the practice has never been studied to assess the production of firewood and fodder from lopped poplar trees. This study is designed to provide such estimates.

Research objectives

Presently there is no scientific basis for estimating Lombardy poplar crown biomass production or to predict the yield of fuelwood and fodder from lopped trees. These estimates are needed to facilitate planning and marketing activities by private farmers and field foresters. This study has the following objectives:

1. to develop simple and practical regression models to estimate Lombardy poplar crown biomass in terms of green and air-dried weights of its woody branch and foliage components,
2. to estimate Lombardy poplar biomass yield at various intensities of lopping, and
3. to develop prediction tables for Lombardy poplar crown biomass production.

Growth Characteristics

Lombardy poplar is a widely cultivated fast growing variety of black poplar (*Populus nigra* Linn.) (Sheikh, 1964). Its growth on fertile, wet alluvial soils in river valleys, both in lowlands and mountains, is very rapid. It can attain a height of 40 meters in about 80 years. Height growth when young is very rapid and its adaptability to a variety of ecological conditions is remarkable. At the age of 60 to 80 years, natural decay begins and manifests itself in the death of top branches.

Estimation of crown biomass

During the past two decades research on biomass production by forests has increased (Snowdon, 1985). This increase has been stimulated by greater demands for forest products and the subsequent need to consider more complete utilization of forest products. Bogdanov (1968) emphasized the need for tree crown biomass production estimates to benefit livestock, industry and the rural economy.

Biomass can be determined by many destructive and non-destructive methods (Newbould, 1967). Harrington (1981) used a new double regression technique to avoid destructively sampling whole trees. The mass of branches was regressed on primary branch diameter and these equations were used to estimate total mass of tree crowns. The estimated crown mass was then regressed on trunk diameter.

Relationships have been developed between biomass and easily determinable tree characteristics such as diameter and height to facilitate practical applications (Newbould, 1967 and Snowdon, 1985). Tamm and Ross (1980) established correlations between foliage and branch biomass, and tree measurements of height, crown length, diameter at breast height (Dbh) and diameter at base of crown. They further found that half of the weight of leaves and branches was concentrated in the middle part of the crown for aspen.

Kay (1978) assessed total foliage biomass of Douglas fir in a 53-year-old plantation from Kaingaroa State Forest, New Zealand by weighing sample branches. Regression analysis was used to relate basal diameter below the lowest living branch to foliar biomass. Tuskan and Rensema (1991) used simple linear regression equations to predict individual stem and limb green weights. The coefficients of determination (r^2) were generally highest for total tree green weight, dry weight and volume, and lowest for limb dry weight and volume.

Clark and Schroeder (1975) developed tables from a regression equation showing tree weight and volume and its components by Dbh and total height classes. They also developed simple linear equations to predict green and dry weights of wood and bark in the total tree and components.

Dbh, height and combinations of these variables have been shown to be good predictors of crown biomass. These variables, plus diameter at base of tree crown and base of three separate tree height segments, were collected and analyzed in this study.

METHODS

Site selection and data collection

A Lombardy poplar plantation extending over three acres of fairly uniform site and representing several age and size classes of trees was selected in Skardu District of Pakistan during August 1989. It is above 35 degrees latitude in the dry, cold temperate climate of the Northern Areas, Pakistan.

Nine unlopped trees, three each in 11-20, 21-30 and 31-40 inches girth at breast height size classes were selected using a stratified random sampling procedure. Total height, Dbh, radial growth, total age, diameter at initial crown base, and diameter at residual crown base measurements were recorded for each sample tree. After felling, the tree was divided into tree segments based on its total height. Figure 1 illustrates these segments. They were assumed to be approximately commensurate with lopping levels and were defined as:

Segment 1 - ground level to one-third tree height to represent light-lopping intensity,

Segment 2 - middle one-third of tree height to represent, when combined with segment 1, heavy lopping intensity, and

Segment 3 - upper most one-third of tree height to represent residual crown after heavy lopping.

Total crown biomass of these nine destructively sampled trees was removed and weighed by segment for total crown biomass while foliage was still green and intact during late summer of 1989. Three sample branches of representative sizes from each crown segment were randomly selected. For these sample branches, the foliage was removed from the branches. The foliage and branch wood components were weighed separately to obtain their green weights. The green foliage and branch wood components were then sun-dried for ten days. At the end of this drying period they were reweighed to obtain their air-dried weights.

The ratio of green foliage sample weight to green foliage and branch wood sample weight was multiplied times the total crown segment green biomass weight to obtain the total crown segment green foliage weight by sample branches within crown segment for each tree. The same procedure was used to obtain total crown segment green branch wood weight. By sample branches within crown segment for each tree, the ratio of air-dried foliage sample weight to green foliage sample weight was multiplied times the total crown segment green foliage weight to obtain the total crown segment air-dried foliage weight. The same procedure was used to obtain total crown segment air-dried branch wood weight. Table 1 gives the crown biomass weights for each sample tree by foliage and branch wood component within each crown segment.

Development of the regression models

The data in Table 1 were used to developed predictive equations for green and air-dried weights of tree crown biomass by tree crown segment. Dependent variables of interest in the analysis were:

Total crown biomass, green weight
Total crown biomass, air-dried weight
Total branch wood, green weight
Total branch wood, air-dried weight
Total foliage, green weight
Total foliage, air-dried weight

Independent variables tested as predictors of crown biomass were:

Total crown length
Total tree height
Total crown length/total tree height
Diameter at crown base
Dbh
Dbh^2
Dbh^2 squared (Dbh^4)
Dbh^2*total tree height

These dependent and independent variables were used in linear models of the following form:

$$Y = a + b*X$$

where:

Y is one of the dependent variables
X is one of the independent variables
a and b are regression coefficients

Separate models were developed for estimating total tree crown biomass (the combination of crown segments 1, 2 and 3) as well as the crown biomass for individual crown segments and combinations of crown segments.

RESULTS

The best models to estimate tree crown biomass weights, including both air-dried and green components, proved to be an allometric function with Dbh^2 as the independent variable. This model was used to estimate the total tree crown biomass when all three segments were combined and the total crown biomass when segments 2 and 3 were combined. The sole exceptions were models associated with the estimation of crown biomass in segment 3. In its case the square of Dbh^2 was the best predictor. Each of the equations and their statistics are shown in Table 2. These simple linear regression equations adequately predicted crown biomass production for various individual and combined crown segments.

Equations 1 through 6 of Table 2 predict various components of total tree crown biomass for unlopped trees (Figure 1). Using these equations, Table 3 gives estimates of total tree crown biomass for trees ranging in size from 4 to 13 inches in Dbh.

Total tree crown biomass produced from lightly lopped trees (Figure 2) can be derived using a combination of Equations 1 through 12 in Table 2. Total tree green crown biomass is computed by subtracting the green crown biomass estimated by Equation 7 in Table 2 from the green crown biomass estimated by Equation 1 in Table 2. By using the same procedure and Equations 2 through 6 and 8 through 12 in Table 2, respectively, other crown biomass components from lightly lopped trees can be estimated. Table 4 uses this procedure to compute estimates of crown biomass that would be produced from lightly lopped trees ranging in size from 4 to 13 inches in Dbh. These predictions represent a situation similar to pruning poplar trees up to one-third of their heights leaving the remaining two-thirds of the tree crown intact. We have defined this as being analogous to a light lopping.

Total tree crown biomass produced from heavily lopped trees (Figure 3) can be derived using a combination of Equations 1 through 6 and 13 through 18 in Table 2. Total tree green crown biomass is computed by subtracting the green crown biomass estimated by Equation 13 in Table 2 from the green crown biomass estimated by Equation 1 in Table 2. By using the same procedure and Equations 2 through 6 and 14 through 18 in Table 2, respectively, other crown biomass components from heavily lopped trees can be estimated. Table 5 uses this procedure to compute estimates of crown biomass that would be produced from heavily lopped trees ranging in size from 4 to 13 inches in Dbh. These predictions represent a situation similar to pruning poplar trees up to two-thirds of their heights leaving the remaining one-third of the tree crown intact. We have defined this as being analogous to a heavy lopping.

DISCUSSION

The percent distribution of foliage and branch wood crown biomass components, both green and air-dried weight, across all diameter classes remained close to a 50:50 ratio.

For trees between 6 and 8 inches Dbh, crown biomass weights of segments 1, 2 and 3 tended to follow a 1:2:1 ratio. This is similar to the findings of Tamm and Ross (1980) which stated that half of the weight of leaves and branches of the aspen that they studied was concentrated in the middle part of the crown. The reason for segment 1 having smaller crown biomass contents can be explained by the fact that this portion of the tree height is partially devoid of live crown near ground level due to animal browsing and the removal of lower branches as a browse-proofing measure.

To validate our results we wanted to compare our crown biomass estimates with previously published estimates. We were unable to find previously published crown biomass estimates for Lombardy poplar. However, Tuskan and Rensema (1991) studied the clonal differences between four poplar clones grown in eastern North Dakota, USA. A clone named "Siouxland" was determined to be most similar to Lombardy poplar. The green foliage biomass prediction for 6-inch diameter class trees of that clone was 30.6 pounds. This compares favorably with our estimate for the same biomass component (Table 3), and helps confirm the reliability of the predicted weights provided in this study. The reliability of our air-dried foliage biomass prediction was strengthened since the predicted values of dry foliage in both studies was 11 pounds.

A comparison of predicted green and air-dried branch weights between our study and trees of the "Siouxland" clone were 31 to 39 and 12 to 21 pounds, respectively. This variation could be attributed to the different branching habits of the two poplars which essentially represent different species.

CONCLUSIONS

Crown biomass equations for Lombardy poplar were developed and used to predict foliage and branch wood biomass. To help field foresters and farmers better estimate foliage and branch wood biomass yields under different management regimes, tables were developed which estimate the yields one can expect under light and heavy lopping of individual trees. These tables should provide valuable information for management of poplar in Pakistan.

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TABLE 1. Sample tree crown biomass by crown segment.

CROWN BIOMASS SEGMENT 1

Tree No.	Tree Dbh (in.)	Green Weight Total (lbs.)	Green Weight Branch (lbs.)	Green Weight Foliage (lbs.)	Air-dry Weight Total (lbs.)	Air-dry Weight Branch (lbs.)	Air-dry Weight Foliage (lbs.)
1	6.4	17	8	9	5.9	3.1	2.8
2	6.0	15	8	7	5.5	3.2	2.3
3	4.5	6	3	3	2.3	1.2	1.1
4	8.3	25	12	13	9.6	4.7	4.9
5	8.0	21	13	8	7.9	5.0	2.9
6	7.3	8	4	4	3.2	1.6	1.6
7	10.2	40	19	21	15.0	7.6	7.4
8	10.5	44	23	21	15.9	8.5	7.4
9	12.7	36	17	19	13.5	6.6	6.9

CROWN BIOMASS SEGMENT 2

Tree No.	Tree Dbh (in.)	Green Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)	Air-dry Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)
1	6.4	40	21	19	14.0	8.0	6.0
2	6.0	32	15	17	11.8	5.4	6.4
3	4.5	18	8	10	6.5	3.0	3.5
4	8.3	68	33	35	25.9	12.9	13.0
5	8.0	65	35	30	23.9	13.3	10.6
6	7.3	54	28	26	21.6	11.2	10.4
7	10.2	56	26	30	21.2	9.2	12.0
8	10.5	60	30	30	22.7	10.7	12.0
9	12.7	48	21	27	18.2	8.6	9.6

CROWN BIOMASS SEGMENT 3

Tree No.	Tree Dbh (in.)	Green Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)	Air-dry Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)
1	6.4	12	5	7	4.0	2.0	2.0
2	6.0	16	7	9	6.2	2.8	3.4
3	4.5	7	4	3	2.6	1.5	1.1
4	8.3	17	8	9	6.2	3.0	3.2
5	8.0	18	8	10	6.6	3.2	3.4
6	7.3	24	11	13	9.1	4.4	4.7
7	10.2	68	31	37	26.1	12.9	13.2
8	10.5	74	38	36	28.2	15.6	12.6
9	12.7	152	74	78	53.9	26.4	27.5

TABLE 2. Regression equations developed for predicting crown biomass components of Lombardy poplar.

Dependent Variable	Ind. Var.	Eqn No.	a	b	r^2	SEE	Mean Y
Segments 1, 2 & 3							
Green Weight							
Total Biomass	Dbh^2	1	8.8295	1.4591	0.994	5.5	115.7
Branch Biomass	Dbh^2	2	5.8835	0.6936	0.978	4.9	56.7
Foliage Biomass	Dbh^2	3	2.9460	0.7656	0.993	3.1	59.0
Air-dry Weight							
Total Biomass	Dbh^2	4	3.8156	0.5359	0.987	2.98	43.06
Branch Biomass	Dbh^2	5	2.7974	0.2586	0.971	2.13	21.73
Foliage Biomass	Dbh^2	6	1.0182	0.2773	0.983	1.71	21.32

Segments 2 & 3							
Green Weight							
Total Biomass	Dbh^2	7	4.4793	1.1968	0.993	4.7	92.1
Branch Biomass	Dbh^2	8	3.1100	0.5691	0.983	3.5	44.8
Foliage Biomass	Dbh^2	9	1.3693	0.6278	0.991	2.8	47.3
Air-dry Weight							
Total Biomass	Dbh^2	10	2.2153	0.4382	0.988	2.27	34.30
Branch Biomass	Dbh^2	11	1.6563	0.2112	0.976	1.56	17.12
Foliage Biomass	Dbh^2	12	0.5590	0.2270	0.983	1.42	17.18
Segment 3							
Green Weight							
Total Biomass	$(Dbh^2)^2$	13	2.1529	0.005754	0.983	6.6	43.1
Branch Biomass	$(Dbh^2)^2$	14	0.5513	0.002826	0.981	3.4	20.7
Foliage Biomass	$(Dbh^2)^2$	15	1.6016	0.002928	0.980	3.6	22.4
Air-dry Weight							
Total Biomass	$(Dbh^2)^2$	16	1.2057	0.002061	0.977	2.77	15.88
Branch Biomass	$(Dbh^2)^2$	17	0.6657	0.001027	0.967	1.65	7.98
Foliage Biomass	$(Dbh^2)^2$	18	0.5401	0.001034	0.977	1.38	7.90

Note: a - Regression model coefficient
b - Regression model coefficient
r^2 - Coefficient of determination
SEE - Standard error of estimate
Mean Y - Average value of biomass component

TABLE 3. Crown biomass of unlopped trees.

Tree	Green Weight			Air-dried Weight		
Dbh (in.)	Total (lbs.)	Branch (lbs.)	Foliage (lbs.)	Total (lbs.)	Branch (lbs.)	Foliage (lbs.)
4.0	32	17	15	12.4	6.9	5.5
5.0	45	23	22	17.2	9.3	8.0
6.0	61	31	31	23.1	12.1	11.0
7.0	80	40	40	30.1	15.5	14.6
8.0	102	50	52	38.1	19.3	18.8
9.0	127	62	65	47.2	23.7	23.5
10.0	155	75	80	57.4	28.7	28.7
11.0	185	90	96	68.7	34.1	34.6
12.0	219	106	113	81.0	40.0	41.0
13.0	255	123	132	94.4	46.5	47.9

TABLE 4. Crown biomass from lightly lopped trees.

Tree Dbh (in.)	Green Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)	Air-dried Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)
4.0	9	5	4	3.2	1.9	1.3
5.0	11	6	5	4.0	2.3	1.7
6.0	14	7	7	5.1	2.8	2.3
7.0	17	9	8	6.4	3.5	2.9
8.0	21	11	10	7.9	4.2	3.7
9.0	26	13	13	9.5	5.0	4.5
10.0	31	15	15	11.4	5.9	5.5
11.0	36	18	18	13.4	6.9	6.5
12.0	42	21	21	15.7	8.0	7.7
13.0	49	24	25	18.1	9.2	9.0

TABLE 5. Crown biomass from heavily lopped trees.

Tree Dbh (in.)	Green Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)	Air-dried Weight Total (lbs.)	Branch (lbs.)	Foliage (lbs.)
4.0	29	16	13	10.7	6.0	4.7
5.0	40	21	19	14.7	8.0	6.8
6.0	52	27	25	19.2	10.1	9.1
7.0	64	33	32	23.9	12.3	11.6
8.0	76	38	38	28.5	14.5	14.0
9.0	87	43	44	32.5	16.3	16.2
10.0	95	46	49	35.6	17.7	17.9
11.0	99	48	51	37.3	18.4	18.9
12.0	97	47	51	37.0	18.1	19.0
13.0	89	42	47	34.3	16.5	17.8

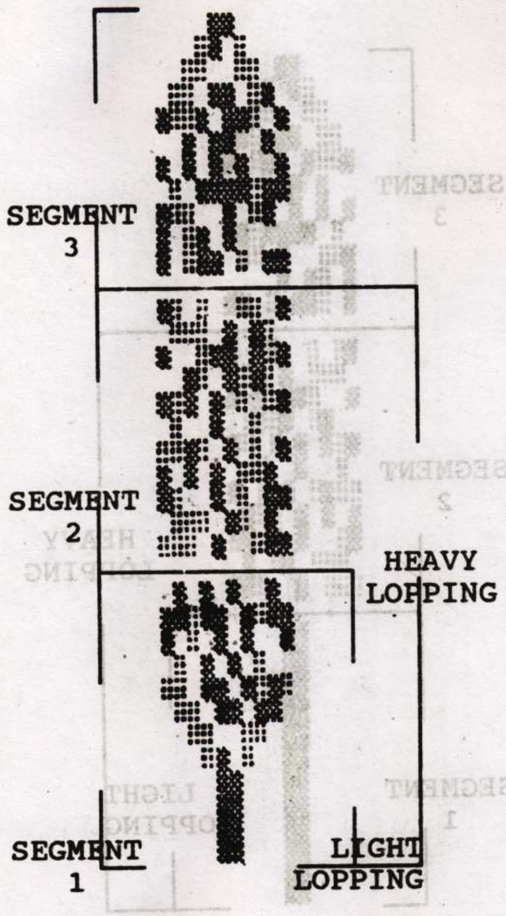

FIGURE 1. Crown segments and lopping intensities.

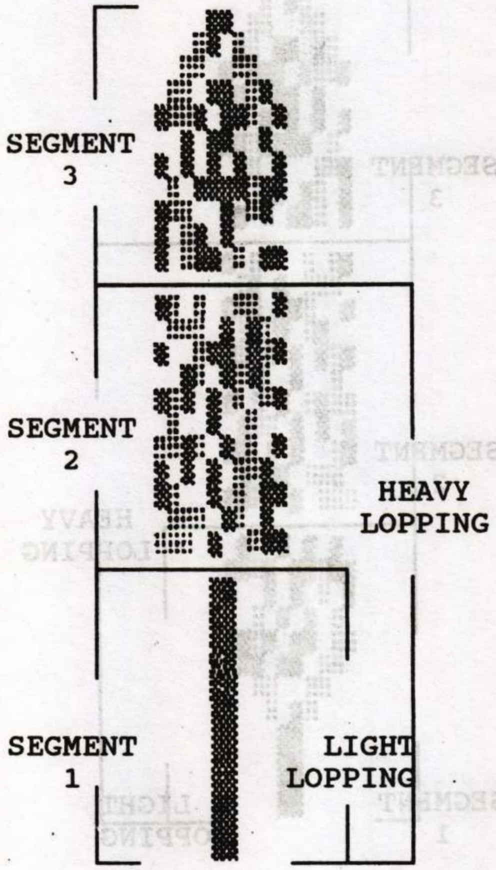

FIGURE 2. Light lopping intensity.

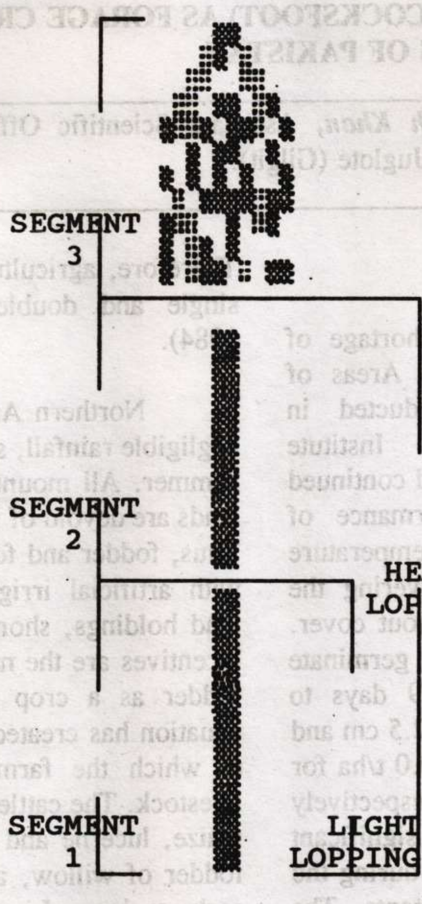

FIGURE 3. Heavy lopping intensity.