SOME MODELS FOR PREDICTING VOLUME OF *POPULUS DELTOIDES*

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Introduction

The ultimate object of all mensurational activity in forests is to calculate or estimate quantity of wood contained in trees. The volume may be calculated after the tree has been felled or when it is standing. For the volume estimation of standing trees, models are most suitable as they can provide scientists a tool to make sound recommendations, to aid the conceptualisation and some times to predict the consequences of an action that would be otherwise expensive, difficult or destructive to do in the real world.

Modelling has a long history in forestry. As early as in mid-1880s, the Central European Foresters were using graphical methods to model the growth and production of forests and these models continued to be used there and elsewhere until the first of the mechanical calculators, in combination with new ideas for statistical analysis, enabled yield and volume tables to be calculated more efficiently. However, the extension of modelling to the other aspects of forestry only really began in earnest as the electronic digital computers became available for use by scientists.

For the present study, *Populus deltoides* G-3 plantation, a selection from Australia quite suitable for mid-hills conditions of Himachal Pradesh, has been taken keeping in view the unique importance in the rural economy of India.

For the prediction of forest volume/ biomass etc. there is ample literature available now. Stiell (1957) and Woessner (1973) proposed regression equations for different trees for prediction of different parts of trees like bole, roots, and branches. Wagner (1983) proposed methods for determining of the volume of standing trees using diameter at breast height (dbh), height and diameter at height of 30% of total height. Harding and Griger (1985) developed allometric models $Y = ad^b$ and $Y = ad^bh^c$ where Y is mass, d is dbh and h is height.

Materials and Methods

The observations were recorded on the *P. deltoides* trees grown at the experimental farm of Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. For survey, due to limitations of design we sampled from a subset of the target population which may well be called as sampled population keeping in view that too small a sample will increase the error in

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estimating population parameter and too large a sample will increase the cost for the survey. So, a balance had to be struck between the cost and accuracy in estimation to determine the required sample size and therefore, a simple random sample of size 24 without replacement of the trees was drawn with permissible margin of error of 10 per cent (Cochran, 1972). Sampled trees were cut and the measurements on different characteristics like height (h) in feet, diameter at breast height (d) in feet and actual volume (V), in cubic feet were recorded. The actual volume of these trees were calculated on the basis of frustum of bole of poplar trees, considered as frustum of neloid by Priomoidal formula given by Newton (Chaturvedi and Khanna, 1982).

Regression analysis (Draper and Smith, 1981) is a statistical tool for evaluating the relationship of one or more independent variables to a single continuous dependent variable but before proceeding ahead, it was very essential to judge the characteristic of dependent variable, given independent variable, as stochastic variable. This means that given only few independent variables there is some random variation in the observed value that is in addition to any measuremental error involved in determining the value of dependent variable. For example, different forest stands with the same age, site index, and initial basal area will have different volumes. This difference in volume can be due to the effect of other variables not included in the model. Thus it seems reasonable that volume should be treated as random variable. In true words, it is not possible to predict exactly the volume for a particular tree on the basis of height, diameter and age. Therefore it is unreasonable to expect exact agreement, in predicted volume and the observed volume. For the better interpretation, randomness was checked by run test also. Now one point which also has significant contribution is normality, since presence of non-normality can distort the true level of significance. So, that was checked by W test given by Shapiro and Wilk (Rao *et al.*, 1985). The following models have been tried in the present study:

$$V = a + bd + cd^2 + \varepsilon$$
$$V = a + bd + ch + ed^2h + \varepsilon$$
$$V = ad^b + \varepsilon$$
$$V = a\,(dh)^b + \varepsilon$$
$$V = a \exp\,(d^2 + h^2) + \varepsilon$$
$$\mathrm{Ln}\, V = a + b\,(dh)^{0.5} + \varepsilon$$

Results and Discussion

The various models for predicting volume found during the perusal of literature on the subject were tried in addition to other models which we would guess on the basis of the drawing of the scatter diagram between variables such as : volume vs diameter; volume vs height; Ln of volume vs Ln of diameter and Ln of volume vs Ln of height etc.

But for considering the selection of the model the criterion was adj R^2 and a few models having value of adj R^2 more than 0.90 together with other statistical parameters is given in Table 1. Chi-square test of "goodness of fit" was used to test the goodness of fit of models. The application of chi-square criterion revealed that even the models giving value of adj R^2 as high as 90 per cent may not fall in the category of good fit model as is evident from Table 1 (Sl. 1, 2, 3).

The models developed using transformed data show less value of adj R^2 but they were noted to be good fit models Table 1 (Sl. 4, 5, 6, 7).

Table 1

Models for the volume prediction

Sl.	Models					Adj R^2	R^2	X^2
1.	V = -685.14 (167.98)**	+	1.7987 dh (15.61)			0.9147	0.9184	642.72**
2.	V = -637.13 (237.6)**	+	1.8996 dh (0.3562)**	-	0.0009 h^2	0.9110	0.9188	626.40**
3.	V = -677.97 (235.38)**	+	135.71 d^2 (25.578)**	+	0.0009 h^2 (0.0019)**	0.9105	0.9183	653.04**
4.	Ln V = -2.3937 (1.8511)	+	1.4799 Ln d (0.2126)**	+	1.3407. Ln h (0.3352)	0.9455	0.9503	0.0407
5.	Ln V = -2.8626 (0.5035)**	+	1.4271 Ln d (0.0697)**			0.9478	0.9501	0.0409
6.	Ln V = 4.4583 (0.1668)**	+	0.00779 dh (0.0044)**			0.9339	0.9368	0.0529
7.	Ln V = 5.8207 (0.1482)**	+	0.0669 d^2 (0.0161)**	+	0.0000045 h^2 (0.000004)**	0.9000	0.9087	0.0778

** Significant at 5% level

Figures in parenthesis, given below their corresponding coefficients are standard errors.

It is found that the model having large value of adj R^2 may not pass the test of validation hence models to be recommended must satisfy the criterion of cross-validation. After application of this criterion, the recommended models are :

For n = 12 observations

$$\text{Ln V} = -2.8224 + 1.4239 \text{ Ln dh}$$

$$\text{Ln V} = 4.3990 + 0.008139 (\text{dh})^{0.5}$$

For n = 24

$$\text{Ln V} = -2.8626 + 1.4271 \text{ Ln dh}$$

$$\text{Ln V} = 4.4583 + 0.0079 (\text{dh})^{0.5}$$

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SUMMARY

Cross-validation technique is discussed for the validation purpose of models with brief review of the technique in forestry literature. Results of two volume estimation models have been analysed with definition of few terms viz., apparent error, true error and excess error.

पोपुलस डेल्टायडिस आयतन पूर्व - कथन के कुछ मॉडल

राजीव पाण्डे, एस० पी० ढल, बी०एस० कंवर व एस०डी० भारद्वाज

सारांश

वानिकी वाङ्मय में प्रविधियों की संक्षिप्त समीक्षा से माडलों के सत्यकरण के लिए तिर्यक मान्यकरण रीति का विवेचन किया गया हैं । दो आयतन आगणनों के परिणामों का विश्लेषण कुछ नए पारिभाषिकों अर्थात् दृष्ट विभ्रम, वास्तविक विभ्रम और अधिविभ्रम या त्रुटि की परीभाषा बताते हुए किया गया है ।

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