Short Notes:

Volume equation for *Populus deltoides* plantation in western Terai of Nepal

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Allometric equations for estimating timber volume of *Populus deltoides* in plantation trial of *Populus deltoides* were developed. Direct measurement of 60 trees in western Nepal was done for this purpose. Six models were tested with simple linear regression analysis technique. The best fit equation for volume was quadratic (0.1500 - *0.0205DBH + 0.00105*DBH*^{2}) with diameter at breast height as an independent variable. Model recommended for estimating volume is based on diameter at breast height, because of the simplicity, easy to measure accurately in the field and the most common variable recorded in forest inventories. This model gave highest degree of determination (R^2=0.88), and lowest standard error among the tested models.

Keywords: Populus deltoids, volume, equation

Populus deltoides is an exotic species introduced from India into Nepal in early eighties. Plantation trials in the countries showed that it can be well grown in the Terai region of Nepal (Jackson, 1994). The species posses many commercial characteristics such as easy to saw and work, good carving qualities, less insects and pest, which enable for its promotion in private forestry as well as community plantation (Singh and Negi, 2001). Butwal plywood factory established trials of number of *Populus* clones in 1986 (Jackson, 1994) at Jogikuti, near Butwal. In 1998 it was handed over to Department of Forest Research and Survey (DFRS). In forestry practices volume prediction equation is useful when volume of specified part of tree is required for research , commercial utilization and valuation purpose. In Nepal prediction equations of twenty one Spp. (*A. pindrow, A. catechu, A. cordifolia, A. nepalensis, a, latifolia, B. malabaricum, C, toona, D. sissoo, E. jambolana, H. excelsum, L. parviflora, M. champaca, P. roxburghii, P. wallichina, Q.* spp, *S. wallichi, S. robusta, T. tomentosa, T. nudiflora, T.* spp,) were derived by Sharma and Pukkala (1990). Thapa (1999) reported about the prediction equation of biomass of five spp (*A. catechu, D. sissoo, E. comaldulensis and E. tereticonis*). However there is lack of prediction volume equation of *Populus deltoids* in plantation hence this study is carried out aiming to derive the best fit model for P. *deltoides.*

Materials and methods

This study was carried out in plantation trial of *P. deltoides* at Jogikuti which is located about 4-km southeast of Butwal town in Rupandehi district, in the western development region of Nepal. It lies in the Terai/Bhabar region. The latitude and longitude of the site are 27^0 42' N and 83^0 28' E respectively. The site flat and elevation is 205 masl . The site contains well drained loamy soil with a pH range of 6 to 6.5. Soil depth is very deep (>100cm). There is no gravel content on the top soil. The site falls in the sub-tropical zone .More than eighty per cent of the total rainfall occurs between June to October. Average annual rainfall was 2452 mm. Mean maximum and minimum temperatures were 30^{0}c and 20^{0}c respectively. April and May were the hottest months where as January was the coldest month (6 months dry season). The absolute maximum and minimum temperature at Butwal were 45^{0}c in May and 4.3^{0}c in (average of 15 years record by department of hydrology and meteorology). The site was originally Sal (*Shorea robusta*) forest with tree associates like *Terminalia alata*, *Terminalia belerica*, *Lagerstroemia parviflora* and shrubs like *Hollarhena antidyscentrica*.

We clear felled a hectare of poplar plantation stocks in April, 2005 with an objective of replacing the sites

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with other research trials i.e. NTFPs. The destructive sampling of *P. deltoides* was used to estimate the volume. In total 60 individual trees were harvested destructively for measurement. Height and DBH (at 1.3m) were recorded before felling the trees. After felling each tree was divided into different sections up to 10 cm top diameter. Diameter of upper end and lower end of each section was recorded in the field. Sectional volume was calculated with using *Smalian's Formula* and then total volume of individual tree was obtained by adding sectional volume. Data were fed into Excel program and SPSS-11. Six different models were tested in order to find out the best prediction model having greater R^2, lesser standard error and higher F value.

Results and discussion

Descriptive statistics of measured 60 trees is given in Table 1. Average DBH is 20.12 cm while average height is 15.8 m. Standard deviation of the dbh is 4.0 and height is 2.3.

Table 1: Descriptive statics of the the measured tree

	DBH (cm)	Height (m)
Mean	20.12	15.80
Std. Error of Mean	.51	.29
Median	18.70	15.05
Std. Deviation	4.01	2.31
Variance	16.13	5.34
Range	19	10.40
Minimum	13	10.40
Maximum	32	20.80

Relationship between DBH and volume

Under bark volume was plotted against their respective DBH and scattered diagram (see fig 1) was plotted then abnormal data were sorted out which gave final diagram as follows.

Pearson Correlation was found 0.968 (significant at 0.01 levels) between volume under bark and DBH. Correlation coefficient indicates values and the number of cases or data sets. The absolute value (i.e. 0.968) indicates the strength of relationship and it seems significant, stronger and positive relationship between the diameter at breast height DBH and volume.

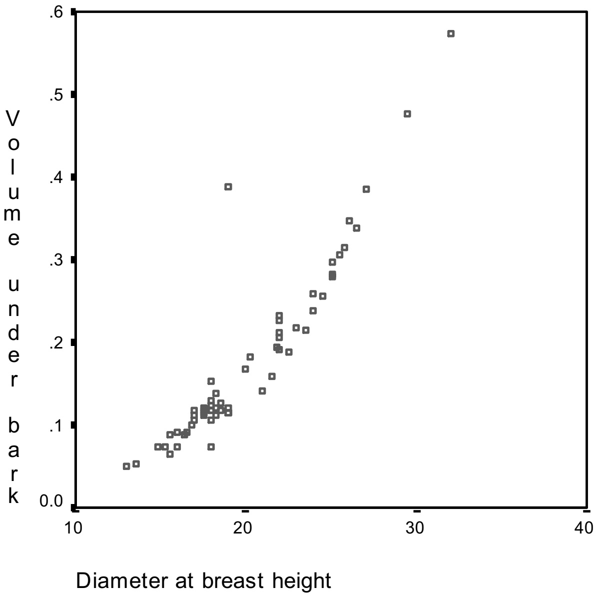


Fig 1: Scatter diagram Volume under bark and DBH

Six different regression models were tested in order to select the best model, which predict most variability remained in the data. Models were,

Linear; ý= a +bx .... *(1)*

Logarithmic, ý= a +lnx.. *(2)*

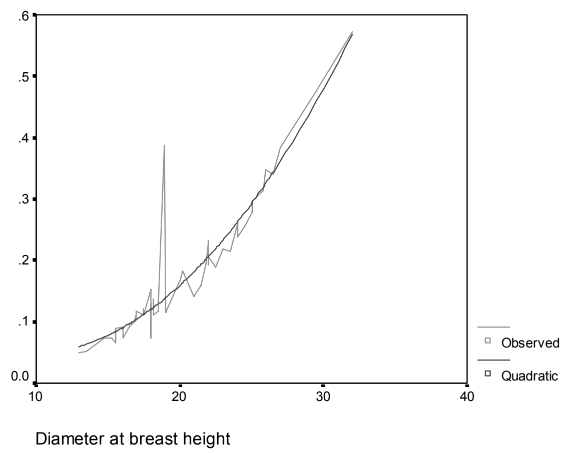
Quadratic; ý= a +bx +cx².. *(3)*

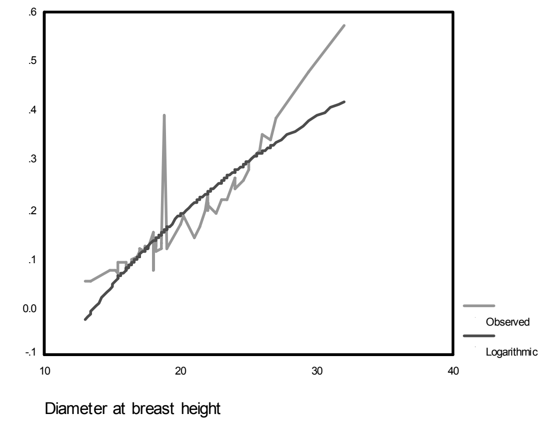
Cubic; ý= a +bx +cx²+ dx³ .... *4)*

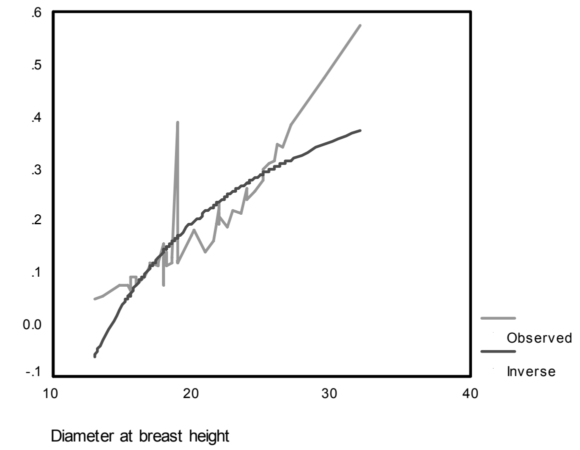
Power, ý= a x^b.. *(5)*

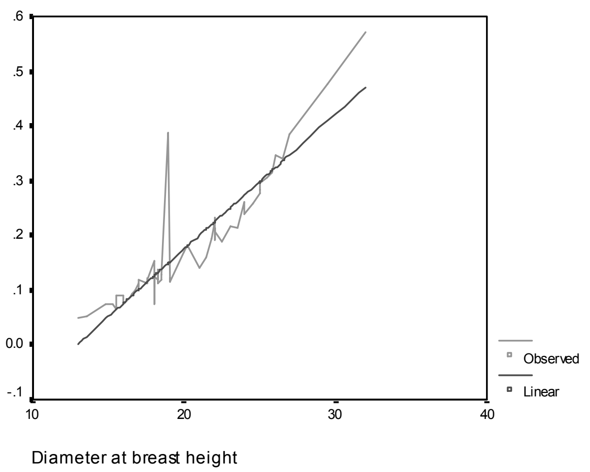
Inverse, ý= ae^{bx} .... *(6)*

Where, timber volume (big wood stem volume as described by Calliez , 1980)dependent variabl (Y)and DBH independent variable (X), a, b, c, d are regression are parameter of estimate.









Our assumption is that valid model has always higher degree of determination, relatively lower standard error. Thus no bias can be found with in the prediction (Sharma *et al.*, 1990). The residuals are normally distributed and their variance remains constant over the range of variation in diameter.

Our first criterion for model evaluation is adjusted R^2 value which is the proportion of variation in the dependent variable explained by the regression model. We also calculated the value of adjusted R squared to correct R squared to more closely reflect the goodness of fit of the model in the population.

Model and parameters are presented in Table 2. First tested model was linear and it has R^2= 0.846 and adjusted R^2= 0.84 where as logarithmic model has lesser adjusted R^2 (0.79). Among the six models the highest adjusted R^2 value was obtained in power model i.e. 0.89. It was also found that quadratic and cubic model has equal adjusted R^2 value (0.88). Inverse model has least adjusted R^2 i.e. 0.72. Our second criterion of model evaluation is standard error the model which has lesser standard error has better predictability. Table 2 depicts that power model has the highest standard error i.e. 0.178 even though it has higher adjusted R^2= 0.89 while quadratic and cubic models have the least standard error i.e.0.037. Regarding F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). If the significance value of the F statistic is small (smaller than say 0.05) then the independent variables will do good job in explaining the variation in the dependent variable. Table 2 shows that F statistic ranges from 145 of model cubic to highest 505 of power model. Therefore all models revealed highly significant i.e. value (0.000). Hence among six candidate models we have chosen, quadratic model

Table 2: Regression model and their regression parameters

Model	R^2	$ADJR^2$	SEE	F	Parameter of Estimate			
					a	b	c	d
1. Linear	0.846	.0.84	.0.042	320.23	-.317	.02465		
				(.000)	(.000)	(.000)		
2. Logarithmic	0.797	0.79	.0481	228.11	-1.3006	.49587		
				(.000)	(.000)	(.000)		
3. Quadratic	0.887	0.88	0.037	218	0.150086	-0.0205	0.00105	
				(0.000)	(.000)	(.00007)	(.000)	
4. Cubic	0.886	0.88	0.037	145	-0.25363	0.037	-0.00163	0.0000403
				(.000)				
5. Power	0.897	0.89	0.178	505	0.000049	2.6968		
				(.000)	(.000)	(.000)		
6. Inverse	0.731	0.72	0.056	158.35	.01474	.12735		
				(.000)	(.000)	(.000)		

Fig in parenthesis shows significant value of the parameter

(0.1500 - *0.0205DBH + 0.00105*DBH*^{2}) to be the best model because it has greatest adjusted R Square (R^2 =.0.88), lowest standard error i.e. 0.037 (Table 2). Though power model seems highest R^2 it has highest standard error i.e. 0.178. The volume, hence, obtained is the cubic meter volume of big stem lower cross cut at the smaller end on diameter at 4 cm. The volume predicted is without bark since the pricing of the timber is traditionally based on debarked logs in Nepal (Sharma and Pukkala, 1990). However the equation above mentioned has some limitation such as it is derived from the even aged plantation crop and need to be verified on other sites because samples are taken from only one site in western Terai. For this reasons the prediction may not be accurate in the case of individual trees such equations are found to work well when applied repeatedly on several trees and the result aggregated, such as computation of stand volume (Jayaraman, 2000).

Conclusion

Volume function is suitable for quadratic ((0.1500-*0.0205DBH+0.00105*DBH*^{2}) model although all above mentioned models seem statistically sound (F value highly significant) to predict the volume taking diameter as an independent variable. The diameter based *Populus* volume equation presented in this paper provides a simple tool for volume estimation in field research and commercial calculation before harvest and valuation of the stand.

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Reference

Caillez, F. 1980. **Forest Volume estimation and Yield prediction.** Vol (22) FAO Rome.

Hawkins, T. 1987. Biomass and Volume table for *Eucalyptus camaldulensis*. ,*Dalbergia sisso, Acacia auriculiformis* and *Cassia siamea* in the Central/ Bhabar Terai of Nepal. Oxford forestry institute, Department of Plant sciences, University of Oxford.OFIOccasional paper.

Das, D. K. and Chaturvedi, O. P. 2005. Structure and function of *Populus deltoides* agroforestry system in eastern India. *Agroforestry System* **65**: 215-221.

Jakson, J. K. 1994. **Manual of Afforestation in Nepal**. Vol (2) Forest Research and Survey Center, Kathmandu-668p.

Jayaraman, K. A. 2000. **Statistical manual for Forestry Research**. FORSPA Publication No. 25. Forestry research Support program for Asia and Pacific (FORSPA) . FAO Bankok- 188p.

Segura, M. 2005. Allometric Model for Tree volume and Total above ground biomass in tropical humid forest in Costarica. *Biotropica* **37 (1)**: 2-8.

Sharma E. R. and Pukala T, 1990. **Volume equation and biomass prediction of forest trees of Nepa**l, Publication 47. Forest Research and Statistics Division, babarmahal Kathmandu.

Singh, S. P. and Negi, A. 2001. Utilization of poplar for wood composites. *The Indian Forester* **127 (2):** 154-159

Thapa, H. B. 1999. Prediction models for above ground wood of some fast growing trees of nepals Eastern Terai. *Banko Janakari*, **(9)**: 28-35.