Developing local volume tables for three important tree species in Nawalparasi and Kapilvastu districts

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The local volume tables of specific species are very important to estimate the timber volume of standing trees but precise site-specific volume tables are lacking for three important tree species, namely *Dalbergia sissoo*, *Shorea robusta* and *Terminalia alata*. Therefore, this study was carried out to develop local volume tables and determine the form factors of these species using destructive and non-destructive methods. Kapilvastu and Nawalparasi districts were selected for this study. Altogether, 188 vigorous trees were selected for measurement, out of which 156 (52 trees for each species) were from destructive sampling and 32 were standing trees. The data of destructive sampling trees of three species were used in developing the models for under bark timber volume up to 10 and 20 cm top diameters. Thirty-two data (12 for *S. robusta*, 10 for *T. alata* and for *D. sissoo* each) of standing trees were used to validate the models of three species. A number of cross sections were made and actual volumes of stem, butt log, other sections and top portion were calculated using cylindrical, Newton's, Smalian's and cone formulae, respectively. The cylindrical volume was estimated based on diameter at breast height. The form factor was determined from the ratio of actual and cylindrical volumes. The diameter and height relationship was made and, based on this; the smooth curve was drawn to develop the local volume tables. The results showed that estimated form factor of 10 cm and 20 cm top diameter of selected species varied from 0.50 to 0.69. In addition, local volume tables are developed for stem volume based on diameter under bark.

Key words: Cylindrical volume, destructive sampling, diameter at breast height, diameter height ratio, form factor

The concept of volume table for the forest trees was first introduced by Heinrich Cotta in around 1804 (Clark, 1902). An extensive study was carried out for many years to collect data for constructing the first volume table. This early study was mainly of Norway spruce.

The approach of the forest management demands both the current levels of volume of growing stock and the future potential growth. The current level of the growing stock can be obtained through forest inventories and the future growth can be assessed from a current inventory by using growth and yield models (Methol, 2001). Individual tree based volume measurements are the primary data for estimating stand volume per ha. per se for fixed area. Volume table is a tabular statement showing the volume with respect to diameter of specific area. Globally, volume table keeps a significant role for volume calculation of standing trees (Husch *et al.*, 2003; Jayaraman, 2000). The local volume table is prepared based on the limited data set to show the volume. Therefore, such volume tables are applied for the confined areas. In fact, there are several factors that affect precision of the volume table. Some major factors are stand density, site quality, local climate, soil condition, altitudinal gradient, aspect, inter- and intra-specific competition (Avery and Burkhart, 2000). The volume table of one tree species is not used for another tree species (Khanna and Chaturvedi, 1982). Three important tree species namely, *Shorea robusta*, *Dalbergia sissoo* and *Terminalia alata* were selected for this study as they are abundant in the study area and their timber value is high at the local level.

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Current interest in multiple product timber harvesting has generated a need for improved volume prediction for individual tree and yield prediction for stands. Knowledge of total volume is no longer sufficient. Now we need to know what portion of a tree can be used for specific products, and we need to identify the entire array of products that can be obtained from specific stands. However, estimation of stem volume directly is tedious, laborious, and costly. There are very limited volume tables of tree species in Nepal. Volume equations developed by Sharma and Pukkala (1990) and compiled by Tamrakar (2000) are used to calculate the volume of trees in Nepal. There are several issues raised about these volume tables specifically what is the source, application scopes and limitation of the volume table in Nepal. Moreover, no any record is found about the development of local volume table in Nepal. Specifically, *D. sissoo*, *S. robusta* and *T. alata* are major tree species in Terai. So, the volume tables of these species are essential to estimate the growing stock. The aim of this study was to prepare local volume tables of the selected three tree species determining the form factors and diameter-height ratio for individual species.

Materials and methods

Study area

The forests in Kapilvastu and Nawalparasi districts were purposively selected for this research work to represent tree vigour, species and site quality in these districts. It is assumed that the study sites will represent the cluster of Kapilvastu and Nawalparasi districts. The data were collected from two sites in these two districts (Fig. 1), which represent different management regimes and geographical area of the Terai forest.

According to the climatic data of Department of Hydrology and Meteorology as stated by Jackson (1994), the mean annual precipitation is 2452 mm of which more than 80% falls from June to September and monthly average maximum and minimum temperature are 31.4°C and 17.7°C, respectively.

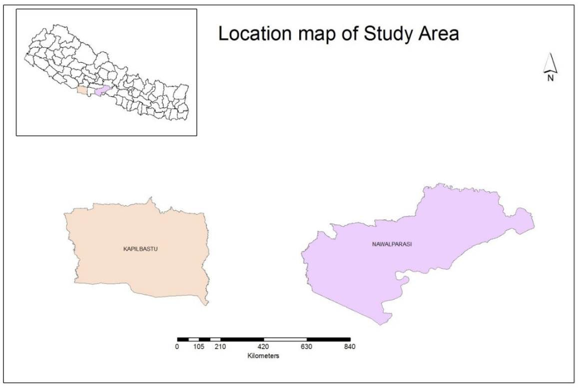

Fig. 1: Location map of study area

According to Ojha *et al.* (2008), Sal forest consists of more than 80% Sal trees. Other associated tree species are Bajhi (*Anogeissus latifolia*), Asna (*Terminalia alata*), Amala (*Phyllanthus emblica*), Barro (*Terminalia belerica*), Bhalayo (*Semicarpus anacardium*), botdhairo (*Lagerstroemia parviflora*), Harro (*Terminalia chebula*), Jamun (*Syzygium cumini*), Kalikath (*Myrsine semiserrata*), Karma (*Adina cordifolia*), Rajbriksha (*Cassia fistula*) and Sindure (*Mallotus philipinensis*).

Tree selection and felling

One-hundred eighty eight (156 trees felled, 32 trees standing) representative healthy trees having straight and clear bole were selected randomly (52 felled trees for each species). The main stem was cut into different sections maintaining the least taper. However, the data of standing trees were not used in developing the model.

Data collection

The diameter at breast height and height of selected trees were recorded before felling. The diameter of both ends and at the centre of each section and its length were recorded.

The data was collected using the ODK Collect Tool (Fig. 2) specially customized for the study. The ODK Collect Tool is available from the Google Play Store for Android based Smart phones for easy data collection from the field after developing field data collection format compatible to ODK using the Google platform. The data collection format was more related to the destructive and standing tree measurements in the field and it basically includes the standing parameters to measure and the destructive data on biomass of different parameters.

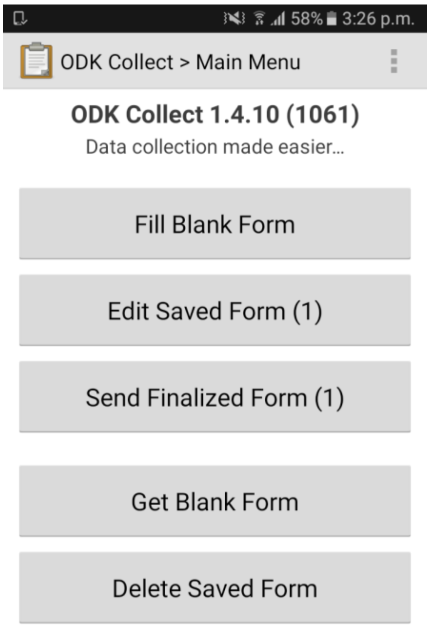

Fig. 2: ODK Interface used for field data collection

Data analysis

Calculation of actual volume from destructive sample tree data

The data were analyzed using Microsoft excel and SPSS tools. Actual volume of each section was calculated applying the following formulae:

Volume calculation

a) Volume of lowest section (stump)

$$V = S \times L \text{ --------------------------------- } (1)$$

(Assuming section as a cylinder)

b) Volume of first section (next to stump assuming Neoloid shape) using Newton's formula

$$V = (S_1 + 4S_m + S_2)/6 \times L \text{ ---------- } (2)$$

c) Volume of other sections (next to the first section considering paraboloid shape) using Smalian's formula

$$V=(S_1 + S_2)/2 \times L \text{ ------------------------- } (3)$$

d) Volume of top most sections using cone formula

$$V = (S_1 + S_2 +\sqrt{(S_1 \times S_2)})/3 \times L \text{ -------------}(4)$$

Form Factor (FF)

The following formula was used to calculate form factor.

$$FF = Va/(S \times L) \text{ ---------------------------}(5)$$

Where, V is the volume of the section, S is cross-section area, s_1, s_2, s_m are areas of one end, other end and middle part of the section, L is the length of the section, FF is the form factor and Va is actual volume of tree

Validation of volume equations

Under bark volume of thirty-two data of standing trees (12 data of *S. robusta*, 10 data of *T. alata* and *D. sissoo* each) were calculated using the following models of Sharma and Pukkala (1990) and used for validating the selected models.

$$Ln\ (v)= a + b\ Ln\ (d)+ c\ Ln\ (h) \text{ -------------}(6)$$

where Ln means logarithm, v=volume in m^3, d=diameter at breast height in cm, h=tree height in m and a, b, and c are parameters.

$$Ln\ (v_1/v) = a + b\ Ln\ (d) \text{ ------------------- } (7)$$

$$Ln\ (v_2/v_t) = a + b\ Ln\ (d) \text{ ------------------- } (8)$$

Where, v_1 is the volume of tree top beyond 10 cm top diameter in m^3, v is the total stem volume in m^3, v_2 is the volume between 10 cm and 20 cm top diameters in m^3, v_t is the total timber volume in m^3 and d is the diameter at breast height in cm.

The validity of the equation was determined by applying the equation (∑actual volume – ∑predicted volume/∑actual volume*100) (Hawkins, 1987).

Development of volume tables

The assumption of local volume table is that the same tree diameter may have identical height and same volume of a specific species, which is only possible in a small locality or a single homogenously structured-stand.

The models presented in annex 1 were used to estimate under bark volumes up to 10 and 20 top diameters of *S. robusta*, *T. alata* and *D. sissoo* and the local volume tables are presented in that annex

Results

Relationship between diameter at breast height and height

Specially, the R^2 value of *S. robusta* were 0.902 and 0.854 for 10 cm and 20 cm top diameter. Furthermore, the R^2 values of *T. alata* were 0.861 and 0.754 for 10 cm and 20 cm top diameter respectively. The R^2 values of *D. sisso* were 0.903 and 0.834 for 10 cm and 20 cm top diameter, respectively.

Form factor

The form factors (FFs) differed according to species and diameter classes. The value of FF was high in low diameter class as compared to the large diameter class. The similar FF (0.65 and 0.66) was found in DBH class of less than 10—20 cm for 10 cm top diameters of *S. robusta* and *T. alata*, respectively (Table 1). The lower values of FFs were around 0.5 in DBH class of more than 40 cm for 10 cm and 20 cm top diameters of *D. sissoo*, *S. robusta* and *T. alata*. The FF value was 0.5 in DBH class of more than 40 cm for 10 cm top diameter of *D. sissoo*. The community forest inventory guideline considers 0.5 as a form factor (MoFSC, 2004) considering the relation between cylindrical volumes are double than the actual volume due to tapering. The data gaps on the FF in table 1 are basically due to the limited measurability of the ratio on that DBH class.

Local volume tables and its relationship

Local volume tables

The DBH range used in developing under bark volume models was 10 to 70 cm for *S. robusta* and *T. alata* and 10 to 50 cm for *D. sissoo*. The volume presented in local volume tables is based

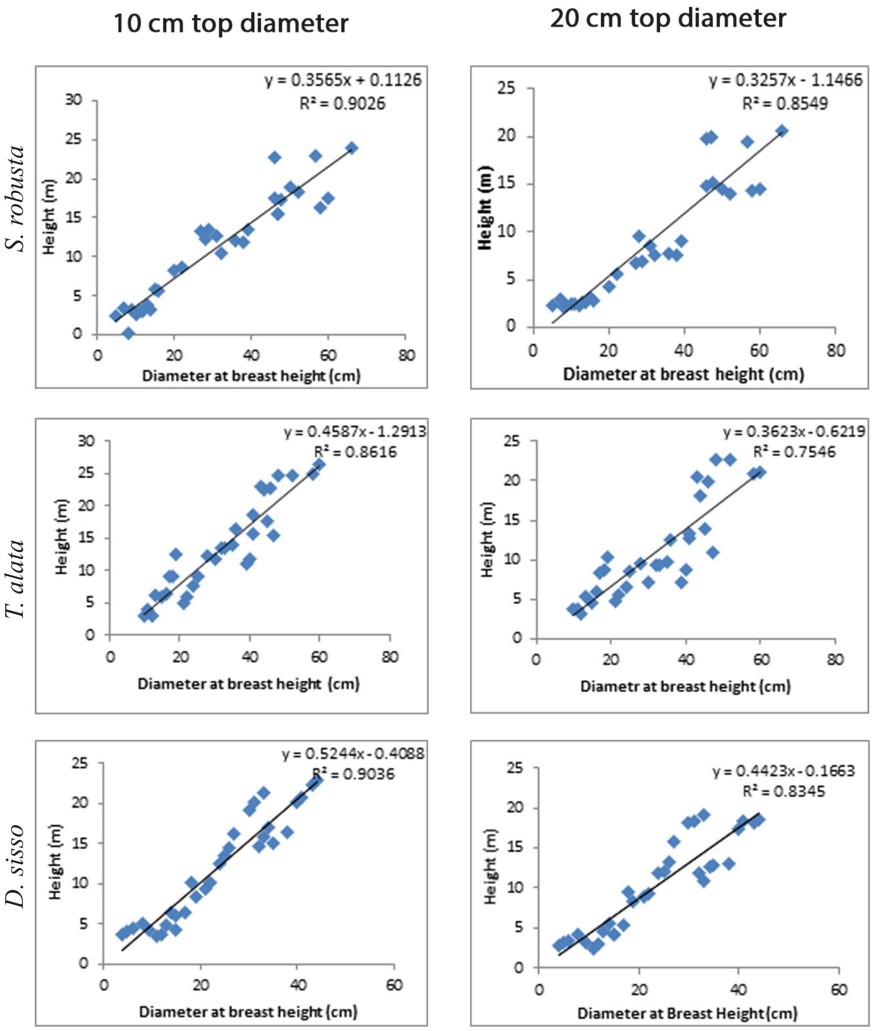

Fig. 3: Relationship between diameter at breast height and height of the tree at 10 cm and 20 cm top diameters of three tree species

Table 1: Form factor of *D. sissoo*, *S. robusta* and *T. alata* in different DBH classes

DBH class (cm)	*D. sissoo*		*S. robusta*		*T. alata*	
	FF for 20 cm top diameter	FF for 10 cm top diameter	FF for 20 cm top diameter	FF for 10 cm top diameter	FF for 20 cm top diameter	FF for 10 cm top diameter
>40	0.51	0.50	0.52	0.51	0.53	0.52
30-40	0.53	0.52	0.54	0.53	0.56	0.55
20-30	0.55	0.54	0.58	0.57	0.59	0.58
10-20	-	0.56	-	0.65	-	0.66
<10	-	-	-	-	-	-

on diameter (Annex 1). The volume of 30 cm DBH of *S. robusta* was 0.7034 m^3 whereas it was about 3.5714 m^3 for 70 cm DBH up to 10 cm top diameter.

Relationship between diameter and volume
The strong relationship between diameter at breast height (DBH) and actual volume up to 10 cm top diameter was found in *D. sissoo*. The R^2 was higher in relationship between DBH and volume up to 20 cm top diameter in *S. robusta*, *T. alata* and *D. sissoo* than the relationship between

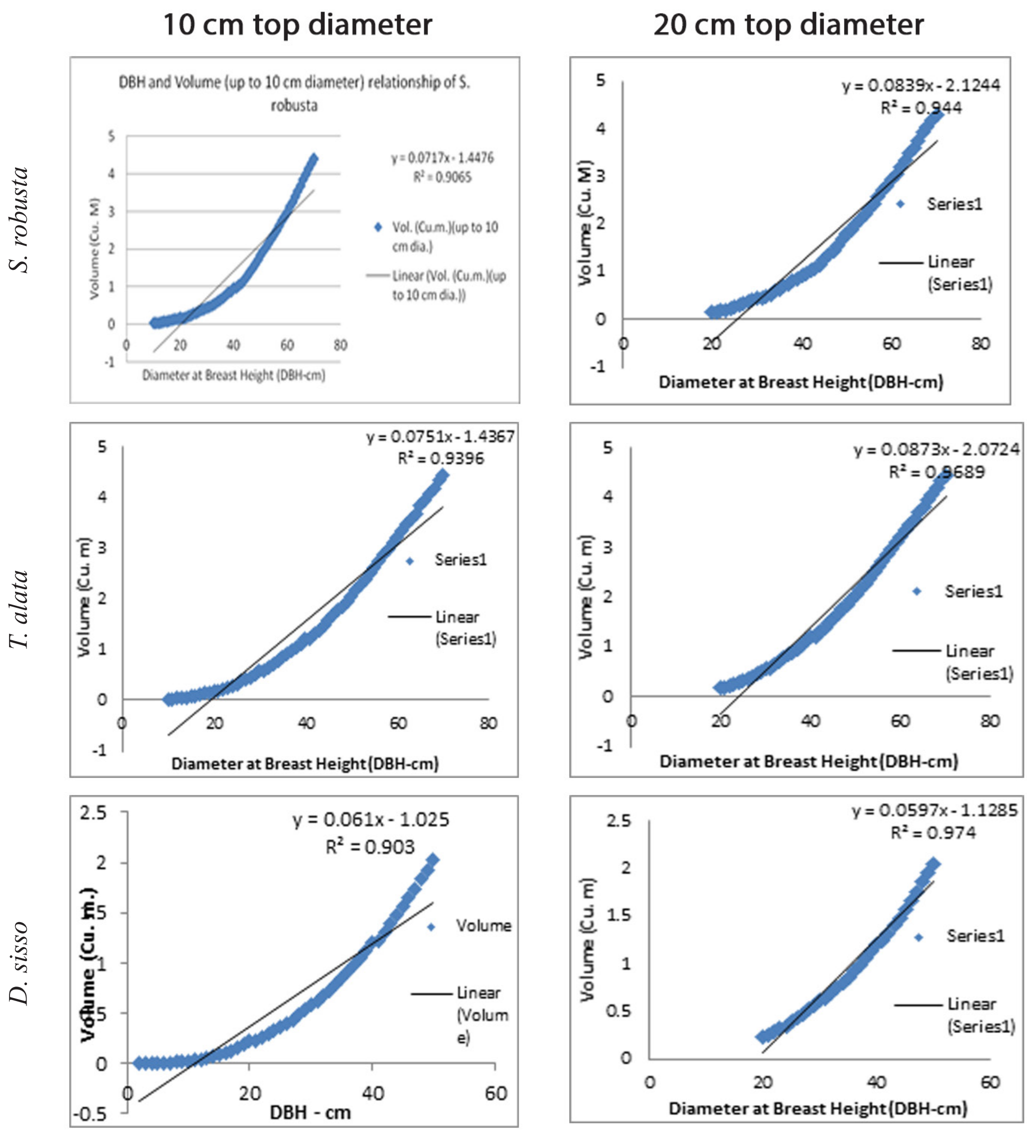

Fig. 4: Relationship between diameter at breast height and actual volume for 10 cm and 20 cm top diameters of three tree species (timber volume excludes stump volume

DBH and volume up to 10 cm top diameter in these tree species (Fig. 4).

Relationship between actual and predicted volume

It has been used to measure the variation in the dependent variable being explained by the independent variable i.e. the larger the R^2 value, the better the result. The trend line shows 0.9909 and 0.9989 R^2 values in *S. robusta*, 0.9981 and 0.999 R^2 values in *T. alata* and 0.997 and 0.9987 R^2 values in *D. sissoo* for 10 cm and 20 cm top diameter (Fig. 5), respectively.

Validation

The selected equations were checked by using the data of standing trees to test the predicted volume against the actual volume of sample trees for all species. It was found that there was an over estimation of 7.5% for *S. robusta* (up to 10 cm top diameter) whereas an underestimation of 19.1% and 22.1% for *T. alata* and *D. sissoo* (up to 10 cm top diameter), respectively. Likewise, there was

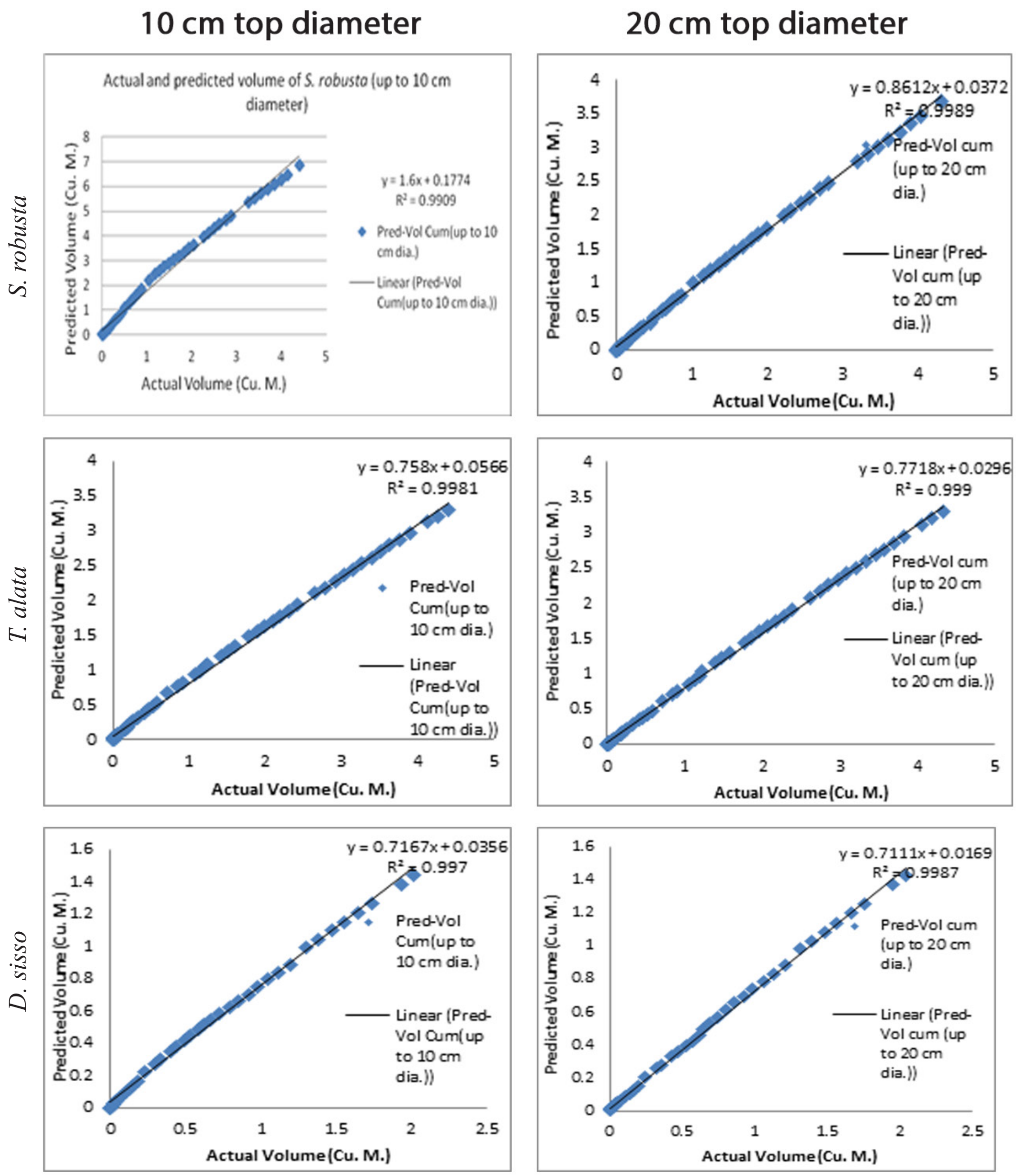

Fig. 5: Relationship between actual and predicted volume

an underestimation of 10.4%, 20.3% and 26.2% for *S. robusta*, *T. alata* and *D. sissoo* (up to 20 cm tree top diameter), respectively (Table 2).

Table 2: Validation of predicted volume from the standing tree measurement

Latin name	Prediction error (%), volume up to $D_{10\ cm}$	Prediction error (%), volume up to $D_{20\ cm}$
S. robusta	-7.49	10.43
T. alata	19.09	20.3
D. sissoo	22.14	26.16

Note: (-) ve means over estimation, (+) ve means under estimation

Conclusion

The form factors varied from 0.50 to 0.69 for *D. sissoo*, *T. alata* and *S. robusta*. The volume up to 10 cm top diameter of *S. robusta* ranged from 0.7034 to 3.5714 m^3 for a DBH range of 30 to 70 cm.; *T. alata* had volume in a range of 0.814 to 3.814 m^3 for a DBH range of 30 to 70 cm and 0.805 to 2.025 m^3 for *D. sissoo* attaining DBH in a range of 30 to 50 cm for up to 10cm top diameter. The volume of *S. robusta* ranged from 0.366 to 3.686 m^3 for a DBH range of 30 to 70 cm.; *T. alata* had volume in a range of 0.538 to 4.018 m^3 for a DBH range of 30 to 70 cm and 0.642 to 1.822 m^3 for *D. sissoo* attaining DBH in a range of 30 to 50 cm for up to 20 cm top diameter. The local volume tables can be used for *S. robusta*, *T. alata* and *D. sissoo* in Nawalparasi, and Kapilvastu districts. Further, refinement of the volume tables is necessary if it is felt. The endorsement from the government authority is necessary to implement the local volume tables at the field level. The coordination among the district and national stakeholders is essential during the implementation of such kind of project and generating data.

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