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Full Length Research Paper

Biomass expansion factors of *Olea ferruginea* (Royle) in sub tropical forests of Pakistan

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Wood biomass gives information about total productivity of the forest as well as individual tree. *Olea ferruginea* (Royle) which is small and evergreen is widely distributed in native sub tropical forests of Pakistan and extensively used as fuelwood domestically. This study was carried out in the sub tropical forests of Pakistan at 33° 38' north and 73° 00' east latitude and longitude, respectively, and at an elevation of 917 m. Trees with exploitable diameter were selected randomly from the entire forest. Destructive sampling techniques were used for measuring biomass (kgm^{-3}) in all the tree components. For this purpose, 5 trees were felled and the biomass of each component of the tree including main stem, branches, leaves, twigs and roots were estimated separately using volume, weight and density. The generic data of wood density (kgm^{-3}) was used to determine the biomass (kg). The study showed that average contribution of stem portion of the tree was 49.01% of the total tree biomass, and branches showed 31.17%, leaves 1.98%, twigs 1.05% and roots 16.65% of the total tree biomass. So, it was found that the major part of the total tree biomass was present in the stem portion of *O. ferruginea.* Total volume of the tree was also found to be dependent on the diameter of the tree. Mean volume of the tree was 0.475 ± 0.07 m^3. The prepared biomass expansion factor will be helpful in estimating productivity, carbon stocks and yield of the forest.

Key words: Biomass, biomass expansion factor, tree volume, *Olea ferruginea.*

INTRODUCTION

Since ancient times, man has relied on biomass of trees as an important non-renewable energy source. Biomass, which is currently the fourth largest energy source in the world includes firewood plantations, agricultural residues, forestry residues, animal wastes, etc. (Reddy, 1994). Biomass of a tree is defined as "the mass of woody part (stem, bark, branches and twigs) of trees, alive or dead, shrubs and bushes, excluding stumps and roots, foliage, flowers and seeds". Forest biomass is an important supplier of fodder, feed and fuel (Rawat and Nautiyal, 1988). The quantity of biomass in a forest determines the potential amount of carbon (C) that can be added to the atmosphere or sequestered on the land when forests are managed for meeting emission targets (Brown et al., 1999). Biomass serves as an estimator of the cellulosic material- a potential renewable energy resource and indicator of carbon stock in the tree (Sorin, 2007). Estimation of biomass is therefore very important from environmental as well as economical point of view.

Biomass and fuel wood is an important source of household energy especially in the rural areas of Pakistan. Fuel wood and other forest based biomass comprises of branches, poles, split wood, cones, bark, leaves and needles. It may also include shrubs cut or uprooted (Siddiqi et al., 1995). This study was aimed at determining the biomass expansion factor of *Olea ferruginea,* commonly known as kahu or Indian olive. In Pakistan, it is found on the lower hills of Azad Kashmir, Punjab, NWFP, Baluchistan and in the hills on the west side of Indus in Sindh. Indian olive is grown widely in the forests of the country and most of the communities depend on it for their livelihood and rural heath. While considering it worldwide, studies on estimation of biomass are very few, whereas in Pakistan, this number is even more less. So, there is a need for such studies.

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Table 1. Summary of relationship and regression model applied.

S/N	Tree component	Relationship type	Model	r^2
1	Stem	Quadratic	$Y= -1095.25 + 91.87X -1.44X^2$	0.99
2	Branches	Quadratic	$Y= 547.82 - 31.13X + 0.68X^2$	0.99
3	Roots	Quadratic	$Y= -43.13 + 7.13X - 0.05X^2$	0.99
4	Leaves	Quadratic	$Y= 37.28 - 3.06X + 0.07X^2$	0.99
5	Twigs	Quadratic	$Y= 8.87 – 0.75X + 1.44X^2$	0.99
6	Volume	Quadratic	$Y= -0.320 + 0.041X - 1.44X^2$	0.99

Research on this species had never been done before,neither in Pakistan nor worldwide. The results of biomass estimation of species can be used for determining the productivity of the forest type in which that particular species is found, for understanding carbon pool changes, for determining the volume of trees of different age and diameter classes and for developing the biomass expansion factor (BEF) for the tree.

This study was aimed at developing the biomass expansion factors for different tree components (stem, branches, leaves, twigs and roots) of *O. ferruginea* having exploitable diameter and at the estimation of the volume of exploitable diameter trees of *O. ferruginea.*

MATERIALS AND METHODS

Study area

The site selected for this study was the forests of Lehterar, situated in the subtropical forests of Pothwar. It lies at 33° 38' north latitude and 73° 00' east longitude and at an elevation of 917 m. The maximum average temperature was 27°C and minimum average temperature was 5°C with average humidity of 50%. The mean annual rainfall ranged between 30 and 50 inches or 750 and 1250 mm (Sheikh, 1993). The density of *O. ferruginea* in Lehterar forest was 55 trees ha^{-1}.

Design of inventory

The whole study was divided into three different steps. Field work included activities from felling of the 5 selected trees of exploitable diameter (24 cm) to the weighing of the leaves separated from the branches. Samples were taken from the study area during 2009-2010 for two seasons. The labeled samples from the felled tree were brought to the laboratory. These bags were then placed in the oven for 24 h at a temperature of 70°C. After obtaining all the necessary data required for biomass estimation, calculations were carried out. Biomass for each component was calculated separately. For stem and branches, the following relation was used (Nizami et al., 2009):

Biomass (kg) = Volume (m^3) x Density (kg/ m^3)

Weight of leaves and twigs was taken directly as their biomass. The biomass of roots of each tree was assumed to be 20% of the total biomass of the tree (Montagu et al., 2000; Jenkinson, 1990). Simple random sampling technique was adopted in the selection of trees. Relationship between tree biomass and diameter was determined by regression analysis. Relationships were determined between stem, branches, twigs and volume of the tree with diameter.

RESULTS AND DISCUSSION

Biomass of all the tree components was analyzed using Sigma plot version 11. Among the tree components, stem had the maximum and twigs had the minimum contribution to the total tree biomass (Figure 8). Various predictions models were tried and polynomial quadratic model was used to analyze the results of each component of the tree (stem, branches, leaves, twigs and roots) (Table 1). Results indicated a strong relation between diameter of the tree and the biomass of stem, branches, stem, leaves, twigs and roots (Figures 1 to 5). Total biomass of the tree and the biomass of the tree components increased with the increase in diameter. Mean value of stem biomass was calculated to be 331.33 ± 35.53 kg. Mean value of the branches biomass was 210.75 ± 20.95 kg. The results showed that the biomass values of leaves also increased with the increase in diameter (Figure 3). The mean biomass value was 13.39 ± 3.42 kg. The biomass of twigs was also taken directly as their weight. The results showed that the biomass values of twigs also increased with the increase in diameter (Figure 4). The total contribution of stem biomass was 45.63% in *Acacia nilotica* (Singh and Toky, 1995). Aboveground accumulated biomass was allocated equally to fruits and vegetative growth, which in turn was partitioned into 30% for leaves and 70% for stems, branches and trunk in *Olea europea* (Villalobos et al., 2006). The mean biomass value was 7.11 ± 1.84 kg. Mean calculated value of root biomass was 112.55 ± 11.81 kg (Table 2). The volume of the main stem was calculated by taking the diameters of both thick and thin end and the length of the stem (Brain and Nieuwenhuis, 2005). Mean calculated value of the stem volume was 0.29 ± 0.03 m^3. Volume of the branches also increased with increase in diameter of the tree. Mean calculated value was 0.18 ± 0.01 m^3 and mean calculated total volume of the tree was 0.475 ± 0.07 m^3. A

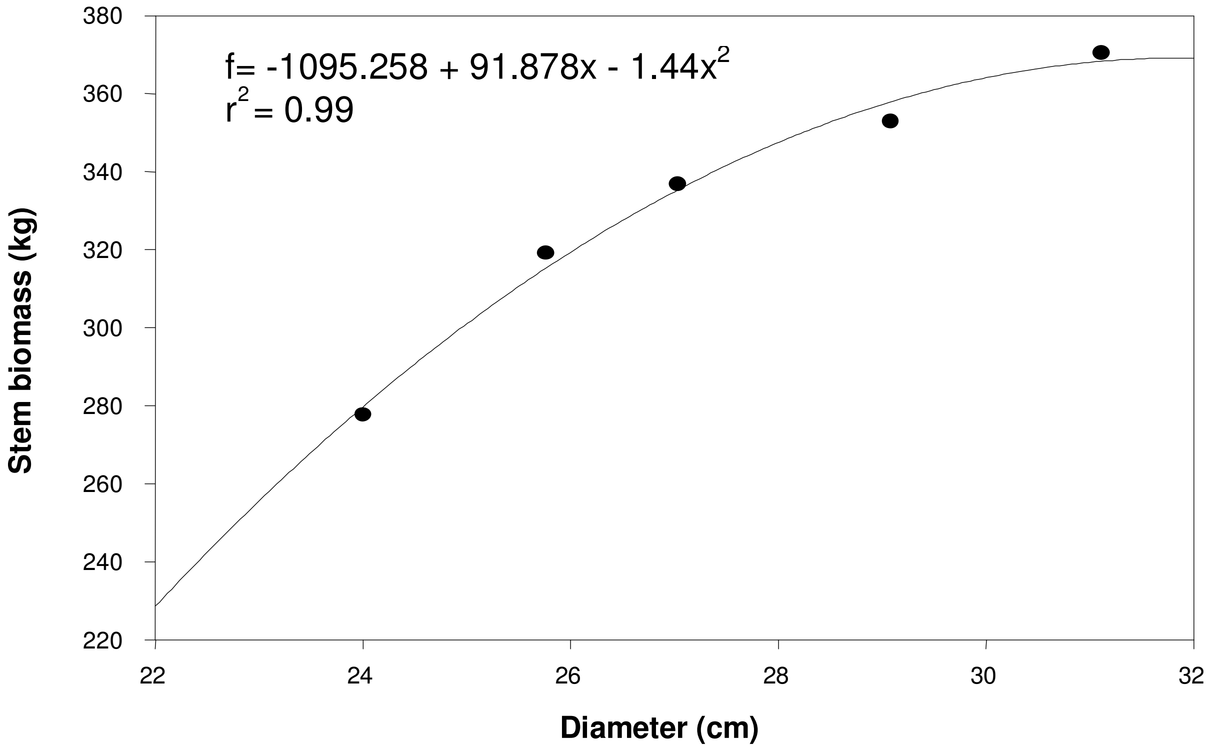

Figure 1. Relationship between diameter (cm) and stem biomass (kg).

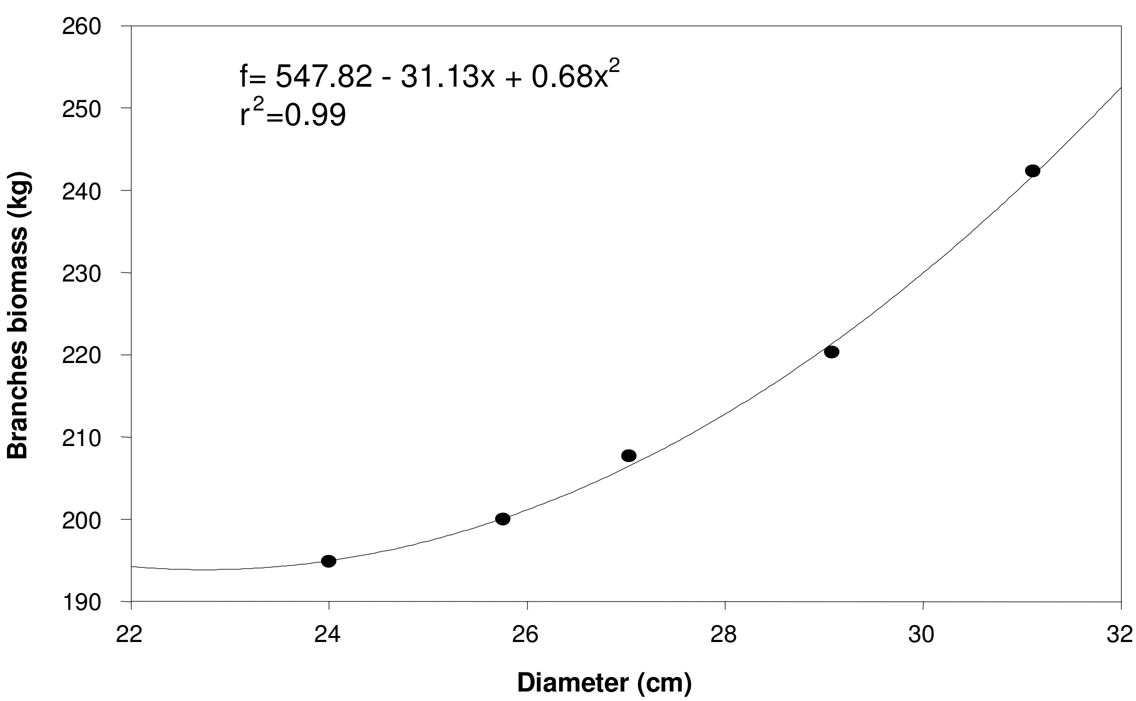

Figure 2. Relationship between diameter (cm) and branches biomass (kg).

strong dependence of total tree volume was also found in the diameter of the tree (Figure 7).

In this study, the exploitable diameter was used as criteria for the felling of trees. The felled trees had diameter

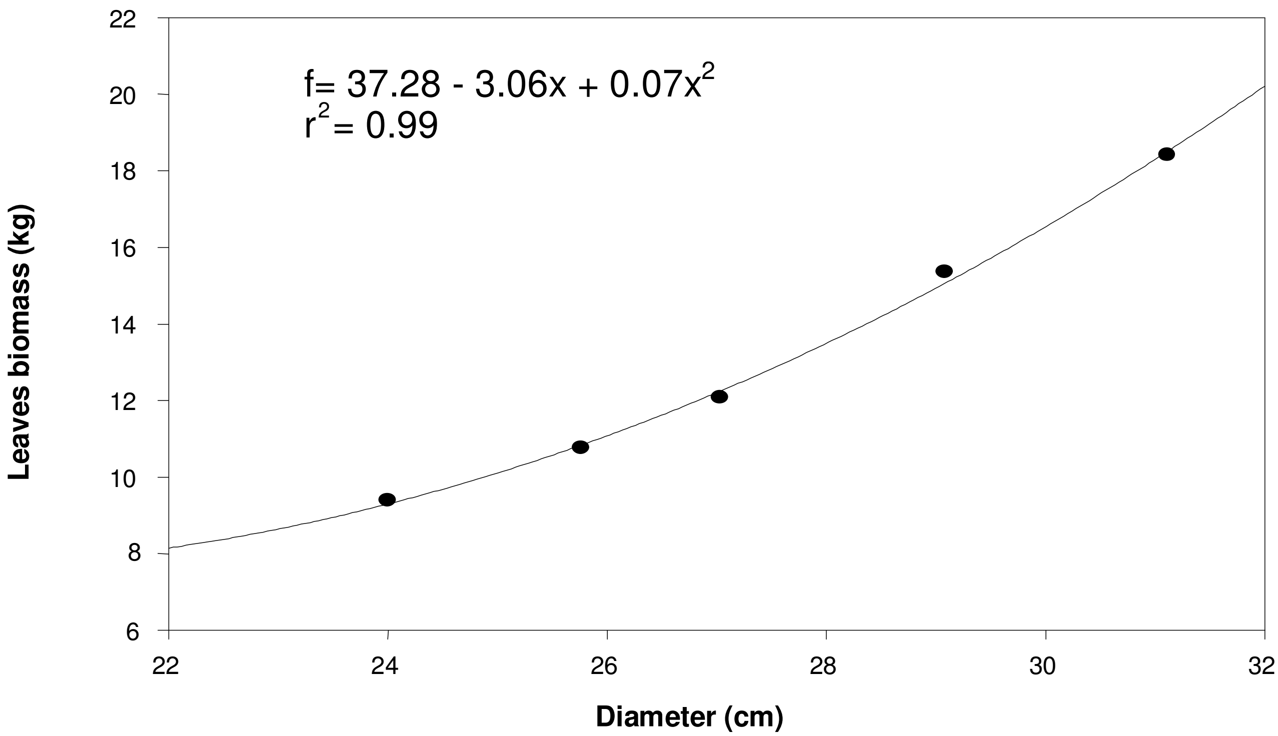

Figure 3. Relationship between diameter (cm) and leaves biomass (kg).

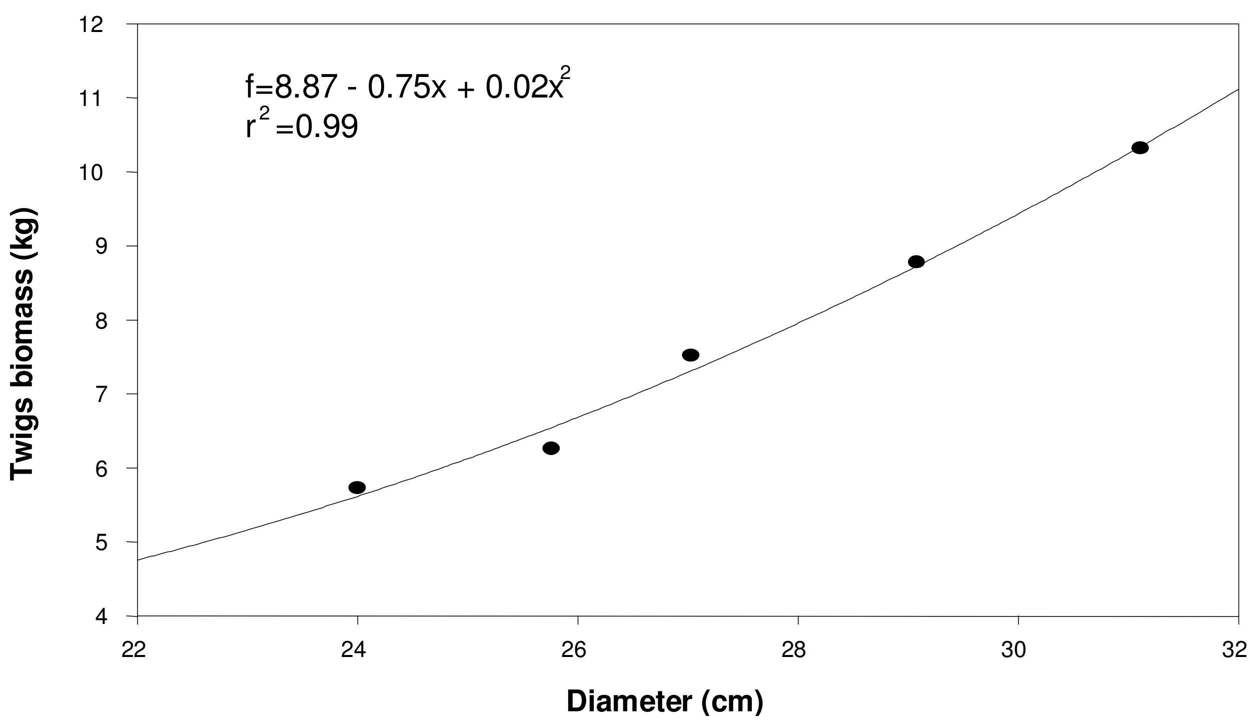

Figure 4. Relationship between diameter (cm) and twigs biomass (kg).

equaled to or more than the exploitable diameter (≥24 cm). Broadbent et al. (2008) also carried out a study on the estimation of biomass variation in individual tree species with respect to diameter and felled the trees

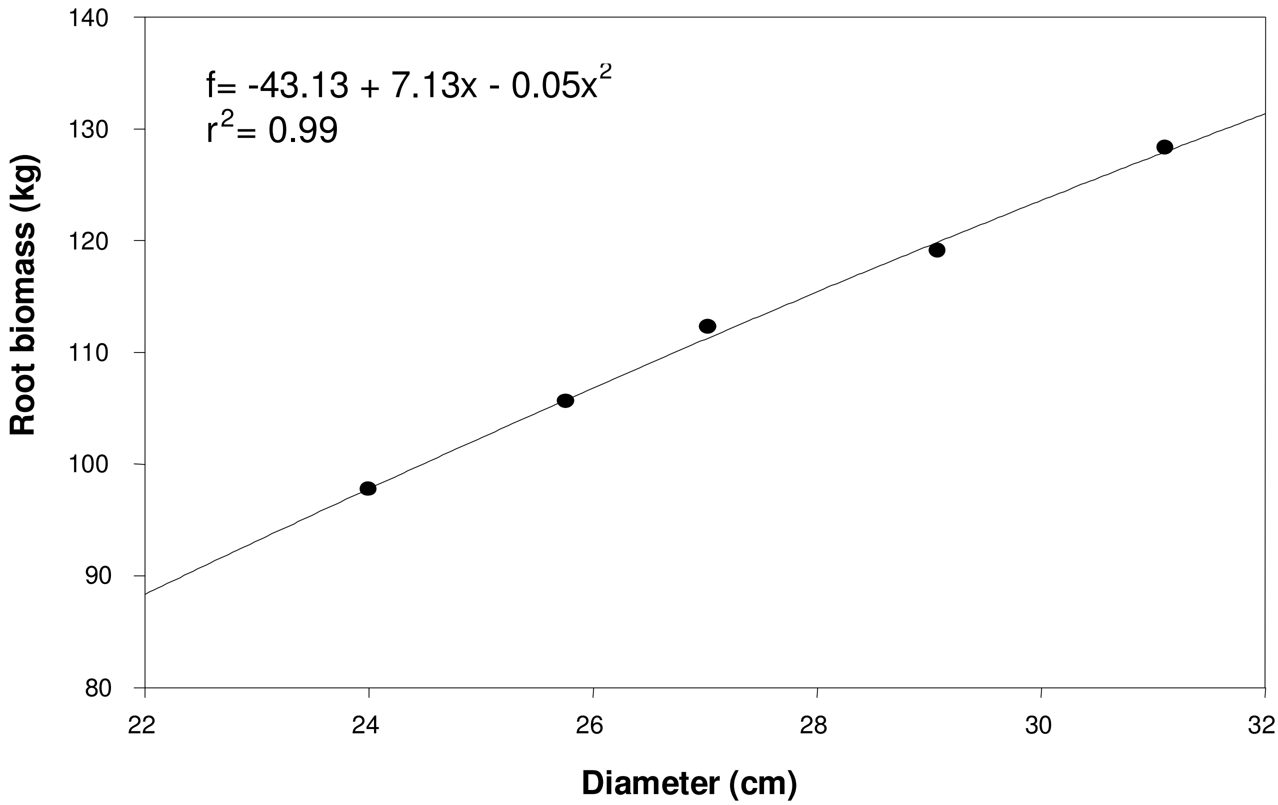

Figure 5. Relationship between diameter (cm) and root biomass (kg).

Table 2. Contribution of each tree component in BEF.

Component biomass (Kg)	Mean	Standard deviation	BEF (%)
Stem	331.336	35.538	49.015
Branches	210.751	20.950	31.177
Leaves	13.391	3.420	1.981
Twigs	7.112	1.840	1.052
Roots	112.551	11.813	16.650

BEF, Biomass expansion factor.

having diameter greater than or equal to 20 cm (≥20 cm). In a similar study with *Euterpe oleracea*, trees of diameter ≥30 cm were felled (Cole and John, 2006) for biomass allocation. Selection of the trees for felling was also done by some scientists on the basis of age of the trees. Trees of ages 5, 7, 11, 13 and 17 were felled for the estimation of biomass in *A. nilotica* (Tandon et al., 2004). The study revealed that the average biomass of *O. ferruginea* was 675.98 kg. In this study, the value of the coefficient of determination for the biomass of leaves was 0.99, whereas it was estimated to be 0.94 in *E. oleracea* (Cole and John, 2006). In this study, the estimated coefficient of determination for the biomass of the stem was 0.96, whereas in *E. oleracea*, it was estimated to be 0.95 (Cole and John, 2006). Total standing biomass (including AGBM and BGBM) in India was estimated by Chhabra et al. (2002) for Scrub forest as 8683.7 Mt. The (biomass expansion factor) BEFs were estimated from the study (Table 2) and the values of BEFs for stem, branches, needles and twigs of *Pinus carabaea* were found to be 71.39, 9.14, 2.78 and 1.31, respectively (Khadka, 2000).

This study showed that average contribution of stem portion of the tree was 49.01% of the total tree biomass, and branches showed 31.17%, leaves 1.98%, twigs 1.05% and roots 16.65% of the total tree biomass (Figure 6). So, it was found that the major part of the total tree biomass was present in the stem portion of *O. ferruginea.* Total volume of the tree was also found to be dependant on the diameter of the tree. Mean volume of the tree was 0.475 ± 0.07 m^3. Prepared biomass expansion factor will

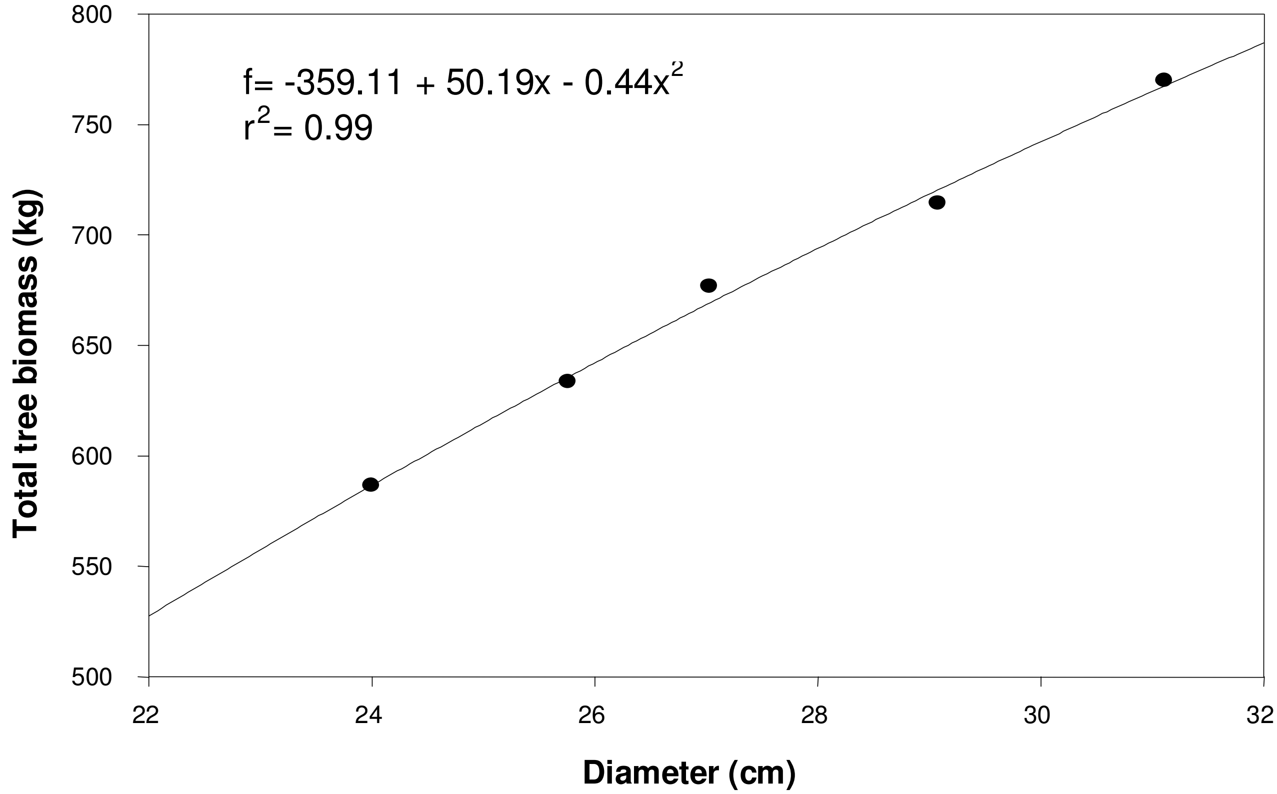

Figure 6. Relationship between diameter (cm) and total tree biomass (kg).

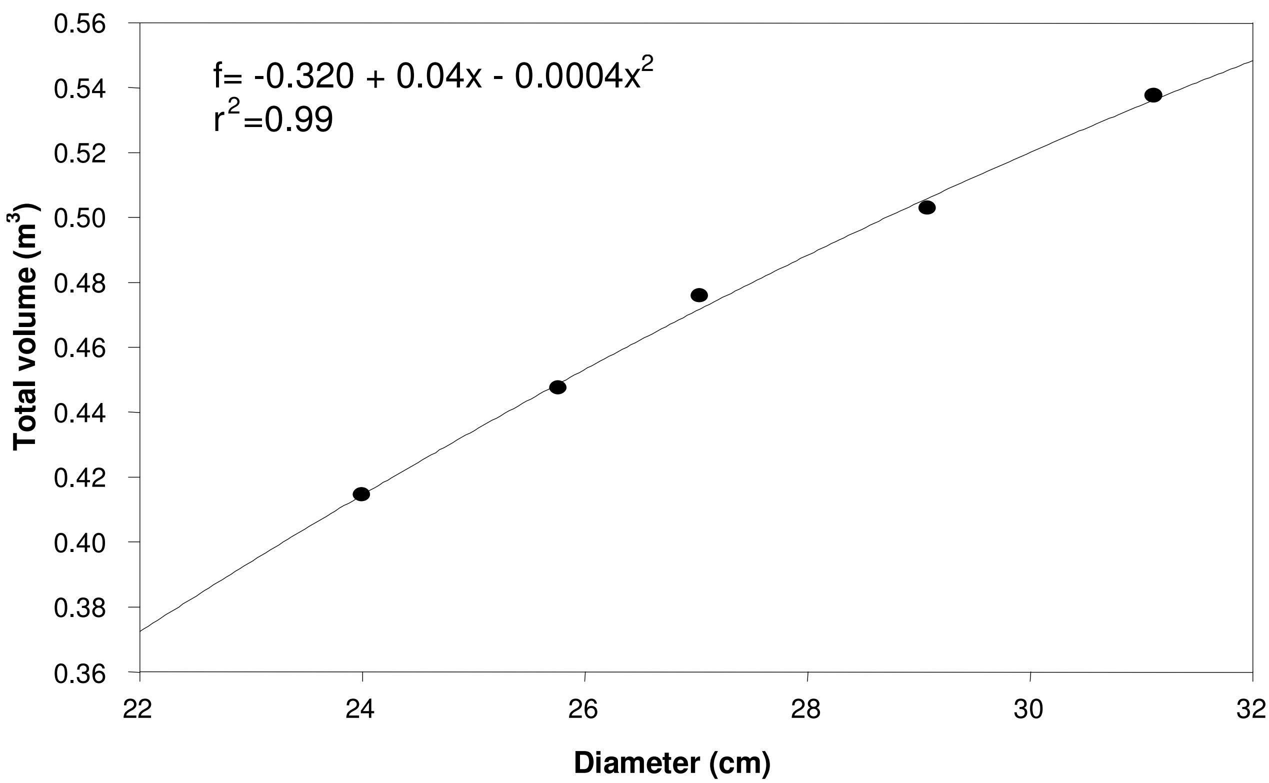

Figure 7. Relationship between diameter (cm) and total tree volume (m^3).

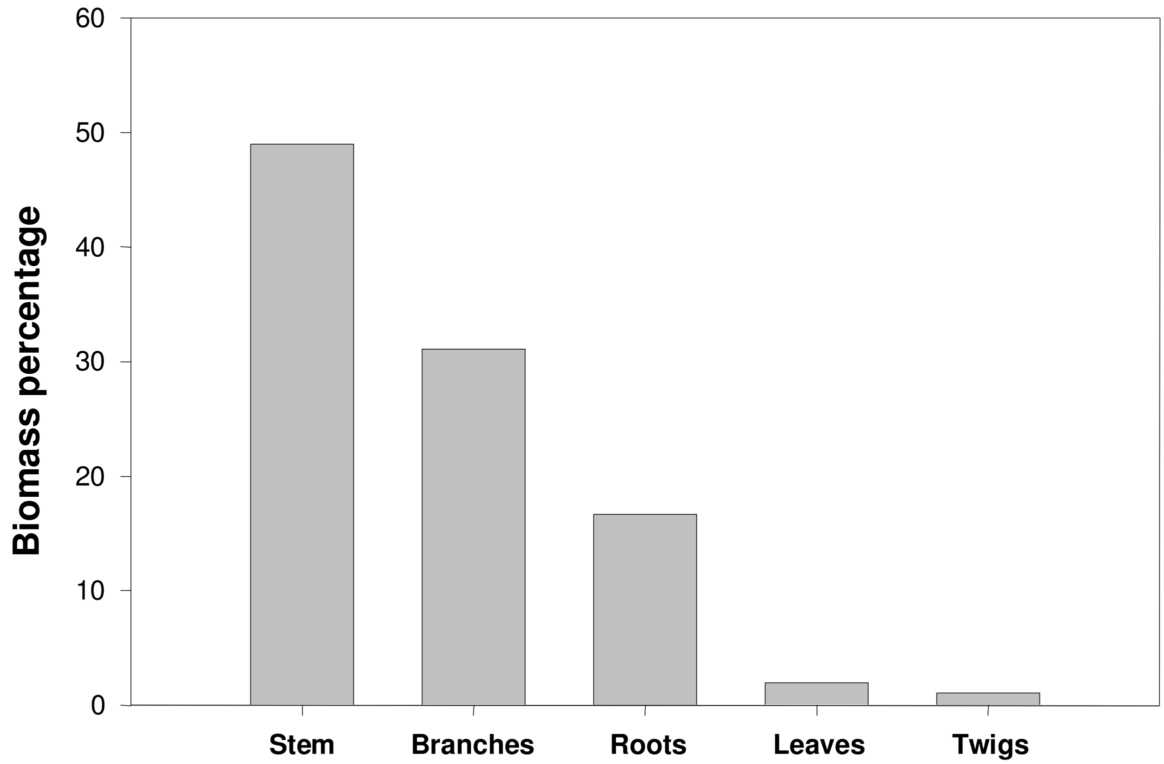

Figure 8. Biomass percentage of all tree components.

be helpful in estimating productivity, carbon stocks and yield of the forest.

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