Quantification of nutrient content in the aboveground biomass of teak plantation in a tropical dry deciduous forest of Udaipur, India

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ABSTRACT: This study was designed to evaluate the quantification of the nutrient content of aboveground biomass of teak plantation in a tropical dry deciduous forest of Udaipur, Rajasthan, India. The nutrient contents in the total biomass of teak in the plantation were 165.47 kg/ha N, 20.96 kg/ha P, 35.06 kg/ha K, 49.29 kg/ha Ca, 31.52 kg/ha Mg, 4.27 kg/ha Na, 4.06 kg/ha S and 3.21 kg/ha Cl. In total, 42.93% of the dry matter accounted for crown biomass (leaves, branches, twigs and reproductive parts), which in turn accounts for 60.93% N, 58.63% P, 54.30% K, 51.40% Ca, 62.5% Mg, 53.62% Na, 59.85% S and 60.74% Cl of the aboveground biomass, whereas 57.07% of the dry matter account for trunk biomass (bole bark and bole wood), which in turn accounts for 39.07% N, 41.37% P, 45.70% K, 48.6% Ca, 37.5% Mg, 46.38% Na, 40.15% S and 39.26% Cl.

Keywords: *Tectona grandis* Linn. F.; dry matter; aboveground biomass; nutrient concentration; nutrient content

Tectona grandis is considered to be an important tree species in Rajasthan forest, in the western parts of India. The total area with this species is approximately 10.5 ha, planted mostly by forest persons. The knowledge of nutrient quantity in the nutrient stock of the soil, above- and belowground biomass is of fundamental importance to the understanding of a forest ecosystem. A deeper insight into nutrient dynamics is also a precondition for guaranteeing ecological sustainability in these forest plantations (George et al. 1990). Nutrient content in the aboveground biomass increases from boreal to tropical forests (Nambiar, Brown 1997). In tropical forests, most of the nutrients can be found in the active tree tissues, such as leaves (Whittaker et al. 1979).

The amount of nutrients is accumulated in litter and other aboveground deposits in the forests, due to the low activity of decomposing organisms in tropical forests inhibited by low temperatures and/or drought (Kimmins 1987). Furthermore, nutrient absorption in forest plantations is closely associated with the increase in biomass and attains its maximum in the initial stage of a rotation period (Miller 1989). According to Van Den Driessche (1984) conifers tend to have a higher proportion of leaf biomass than broadleaved trees. In contrast to broadleaved trees, a major percentage of total nutrient content can be found in the leaves of conifers, although nutrient concentration in the leaves of conifers is lower than in broadleaved trees. It seems to be a general observation that nutrient contents in tree compartments vary with the species. Lugo (1992) found significant differences in biomass and nutrient accumulation for N, P, and K in different tropical plantation species under similar climatic conditions in India, thus emphasizing the different nutrient-use efficiencies of the species involved. Plantation species of the genus *Acacia*, *Pinus*, *Euca-*

lyptus, Dalbergia, and *Tectona* play a major role in the supply of Indian wood industry.

A few studies have been carried out on teak plantations, such as (*i*) Litter production and nutrient return in an age series by George et al. (1990); (*ii*) Production and nutrient dynamics of reproductive components by Karmacharya and Singh (1992); (*iii*) Nutrient cycling by George and Verghese (1992); however, there is a lack of knowledge concerning the quantification of nutrient content in the aboveground biomass of teak plantation in a tropical dry deciduous forest of Rajasthan, western India. Therefore, the main objective of the present study is to quantify the nutrient content of aboveground biomass in a 10 years old stand of teak plantation.

MATERIALS AND METHODS

The site was located between 23°3'–30°12'N longitude and 69°30'–78°17'E latitude in a tropical dry deciduous forest in the Aravally range of Rajasthan, India. There are three seasons per year: winter (November to February), summer (April to mid-June), and a rainy season (mid-June to mid-September). The months of October and March are transitional periods and are known as autumn and spring, respectively. The climate of Rajasthan is tropical with a maximum of 46.3°C and a minimum of 28.8°C during summers. Winters are a little cold with the maximum temperature rising to 26.8°C and the minimum dropping to 2.5°C. The average annual rainfall of the area is 610 mm. Approximately 90% of the rainfall is received from June to September. The average maximum temperature ranges from 42.3 to 46°C and a minimum of 28.8°C during summers and minimum dipping to 26 to 2.5°C, respectively. The soil is alluvial, yellowish brown to deep medium black and loamy with rocky beds. According to the classification of Champion and Seth (1968), the present forest area is categorized under group 5A/(1b) as 'tropical dry deciduous forest'.

The experimental stand was planted in 1998–1999. A homogeneous area was selected for this experiment according to the criteria, i.e. soil type, soil bulk density, and productive vegetation area. Rectangular sampling areas of 30 × 40 m (altogether 1,200 m^2) were established. All tree diameters at breast height (*dbh*, in cm) were measured within the experimental area. The heights of 10% of the trees were measured. Also, height (*h*, in m) estimation was carried out using the following model:

$$\log h = (b_0 + b_1/dbh)^2 + 1.30$$

Tree volume (v, in m^3) was calculated by the equation:

$$v = b_0 + b_1 \times dbh^2 \times h$$

Mean diameter and mean height, tree number, basal area, as well as tree volume over bark were calculated for each sampling area. Bole wood, bole bark, twig, branch, foliage, and reproductive parts of nine trees (one tree in each diameter class) were collected for subsequent nutrient analysis. The samples were dried in an oven for 72 hours at temperatures ranging from 65 to 75°C, until a constant weight was attained. Finally, samples were weighed with an analytical balance in order to obtain dry weight (d.w). The samples were ground in the Wiley mill and then passed through 1.0 mm sieve.

Quantification of tree biomass

Biomass of the trees was determined by using the "Complete tree harvesting" technique. First of all diameter at breast height (dbh) of all the trees was measured and grouped into different diameter classes e.g., 3.0–4.0, 4.1–5.0, 5.1–6.0, 6.1–7.0, 7.1–8.0, 8.1–9.0, 9.1–10.0, 10.1–11.0, 11.0–12.0 and so on (Table 1). In a 10-years-old plantation 50 cm aboveground height was selected for diameter measurement instead of breast height. Tree density (number of trees per ha) and stand basal area (πr^2 density) were calculated. Three representative trees of each diameter class were harvested. Foliage, twigs, branches, bole wood, bole bark, and reproductive parts were separated. Total fresh weight and sample fresh weight of each component were measured on site. The samples were dried in the laboratory and their constant weight was recorded. Sample fresh weight was converted into total dry weight. They were summed up to get the tree biomass of the stand for different diameter classes.

Table 1. Distribution of diameters at breast height (dbh) in the experimental site stand of teak plantation, Udaipur, Rajasthan, India

Diameter class (cm)								
3.0–4.0	4.1–5.0	5.1–6.0	6.1–7.0	7.1–8.0	8.1–9.0	9.1–10.0	10.1–11.0	11.1–12.0
5	17	39	42	55	31	9	1	5

Table 2. Concentration of nutrients (% ± 1.s.e.) in the soil from the site of teak plantation, Udaipur, Rajasthan, India

Soil depth (cm)	Organic carbon	N	P	K	Ca	Mg	Na	S	Cl
0–10	1.79 ± 0.038	0.49 ± 0.043	0.021 ± 0.005	0.39 ± 0.022	0.31 ± 0.023	0.037 ± 0.022	0.21 ± 0.014	0.059 ± 0.02	0.13 ± 0.026
10–20	1.62 ± 0.027	0.39 ± 0.039	0.017 ± 0.012	0.31 ± 0.011	0.28 ± 0.015	0.032 ± 0.013	0.18 ± 0.018	0.055 ± 0.051	0.11 ± 0.047
20–30	1.45 ± 0.031	0.33 ± 0.026	0.013 ± 0.018	0.27 ± 0.016	0.17 ± 0.004	0.024 ± 0.027	0.16 ± 0.047	0.048 ± 0.037	0.10 ± 0.019

Table 3. Concentration of nutrients (% ± 1.s.e.) in the aboveground biomass of teak plantation, Udaipur, Rajasthan, India

Component	N	P	K	Ca	Mg	Na	S	Cl
Bole wood	0.69 ± 0.05	0.09 ± 0.07	0.17 ± 0.04	0.23 ± 0.83	0.12 ± 0.23	0.021± 0.74	0.017 ± 0.13	0.013 ± 0.47
Bole bark	0.75 ± 0.08	0.11 ± 0.09	0.19 ± 0.42	0.38 ± 0.89	0.16 ± 0.03	0.024 ± 0.05	0.021 ± 0.25	0.016 ± 0.06
Branch	0.82 ± 0.09	0.15 ± 0.11	0.23 ± 0.38	0.31 ± 0.03	0.23 ± 0.01	0.030 ± 0.93	0.029 ± 0.06	0.023 ± 0.76
Twig	1.24 ± 0.03	0.17 ± 0.27	0.27 ± 0.02	0.33 ± 0.06	0.28 ± 0.78	0.034 ± 0.34	0.033 ± 0.43	0.028 ± 0.72
Foliage	2.68 ± 0.05	0.21 ± 0.06	0.33 ± 0.82	0.47 ± 0.11	0.36 ± 0.08	0.039 ± 0.09	0.046 ± 0.52	0.037 ± 0.02
Reproductive parts	2.81 ± 0.04	0.26 ± 0.23	0.39 ± 0.01	0.51 ± 0.23	0.41 ± 0.04	0.042 ± 0.03	0.051 ± 0.04	0.039 ± 0.08

Table 4. Nutrient contents (kg/ha) in different components of the aboveground biomass of teak plantation, Udaipur, Rajasthan, India

Component	Biomass (kg/ha)	N	P	K	Ca	Mg	Na	S	Cl
Bole wood	7,204 (44.70)	49.70 (30.03)	6.48 (30.90)	12.24 (34.93)	16.56 (33.59)	8.64 (27.43)	1.51 (35.36)	1.22 (30.04)	0.94 (29.28)
Bole bark	1,993 (12.37)	14.94 (9.028)	2.19 (10.44)	3.78 (10.77)	7.57 (15.35)	3.18 (10.08)	0.47 (11.01)	0.41 (10.09)	0.32 (9.96)
Branch	3,170 (19.67)	25.99 (15.70)	4.75 (22.66)	7.29 (20.80)	9.82 (19.94)	7.29 (23.13)	0.95 (22.24)	0.92 (22.66)	0.73 (22.75)
Twig	1,853 (11.50)	22.97 (13.88)	3.15 (15.02)	5.00 (14.26)	6.11 (12.39)	5.18 (16.43)	0.63 (14.75)	0.61 (15.05)	0.51 (15.88)
Foliage	1,059 (6.57)	28.38 (17.15)	2.22 (10.59)	3.49 (9.94)	4.97 (10.09)	3.81 (12.08)	0.36 (8.43)	0.48 (11.82)	0.39 (12.16)
Reproductive parts	836 (5.19)	23.49 (14.19)	2.17 (10.35)	3.26 (9.30)	4.26 (8.64)	3.42 (10.85)	0.35 (8.19)	0.42 (10.34)	0.32 (9.97)
Total	16,115	165.47	20.96	35.06	49.29	31.52	4.27	4.06	3.21

Values in the parentheses are the relative percentage of nutrient contents of different components

Nutrient quantification in aboveground biomass

Macro-nutrient stock (kg/ha) in the aboveground biomass was calculated on the basis of biomass estimation (kg/ha) and the macro-nutrient concentrations (%) obtained in the present study. The sum of the values for each component provided the total nutrient content (kg/ha) of aboveground biomass.

Nutrient quantification in different layers of soil

Three composite soil samples for each stratum 0–10, 10–20 and 20–30cm depth were collected during the different seasons (i.e. winter, summer and monsoon). Samples were air dried, ground to pass through a 2 mm sieve and used for nutrient analysis. The amounts of nutrients in each stratum of soil were estimated from bulk density, soil volume and nutrient concentration values. The volume of soil per hectare for a soil stratum multiplied by the bulk density gave the weight of the soil, which in turn multiplied by the corresponding nutrient concentration yielded the nutrient content in that particular stratum. The amounts of nutrients estimated for the different strata were summed to obtain total nutrient content down to 30 cm depth.

The nutrient concentrations of N, P, K, Ca, Mg, Na, S and Cl were obtained using the methods of Soil and plant analysis by Piper (1950), Modern methods of plant analysis by Peach and Tracy (1956) and Jackson (1958) for Soil chemical analysis and Plant analysis – Research methods by Narwal et al. (2007).

RESULTS AND DISCUSSION

Different nutrient concentrations in different tree species can be due to environmental conditions or genetic characteristics of the species (Nambiar, Brown 1997). Soil nutrient concentrations decreased with increasing soil depth. In general, the concentration of nutrients in soil decreased with an increase in the plantation age. In the present study, a greater proportion of nutrients occurred in the surface soil (Table 2) reflecting the massive inputs of nutrients to the soil through litterfall. This pattern of nutrient distribution is in agreement with the reports of Tsutsumi (1971).

Nutrient concentrations of the different tree components are related to the production of above- and belowground biomass, stand density, and soil. The concentrations of N, P, K, Ca, Mg, Na, S and Cl in the components of the aboveground biomass of teak plantation are shown in Table 3. It is evident that most of the nutrients are concentrated in the reproductive parts and leaves. Similar results were found by Bargali et al. (1992) in a *Eucalyptus* plantation and Lodhiyal et al. (2002) in a shisham forest. The elevated nutrient concentration in the leaves (especially N, K, and Ca) makes this tree component an important reserve of bioelements, although it represents only a small percentage of the whole tree biomass. Higher concentrations of Ca are found in bark (Table 3). Sharma and Pande (1989) found that bark is a tree component with the highest concentrations of Ca in hybrid *Eucalyptus* in 5 and 7 years old stands, and in *Acacia auriculiformis* in 3, 5, 7 and 9 years old stands. The highest concentrations of Mg were also found in leaves and reproductive parts, which has already been proved in several species at different stand ages (Chaturvedi, Singh 1987; Bargali et al. 1992; Turvey, Smethurst 1994).

The highest concentrations of P and K are found in the leaves and reproductive parts, whereas the lowest are in the bole wood and bole bark. However, the lowest concentrations of N, P, K, Ca, Mg, S and Cl are found in the wood, which implies that it is generally rich in C, H, and O. Mean nutrient contents in the aboveground biomass of teak plantation are shown in Table 4. The nutrient contents in the total biomass of teak in the plantation were: 165.47 kg/ha N, 20.96 kg/ha P, 35.06 kg/ha K, 49.29 kg/ha Ca, 31.52 kg/ha Mg, 4.27 kg/ha Na, 4.06 kg/ha S and 3.21 kg/ha Cl. Considering the usual subdivision into crown and trunk biomass, 42.93% of the dry matter accounted for crown biomass (leaves, branches, twigs and reproductive parts), which in turn accounts for 60.93% N, 58.63% P, 54.30% K, 51.40% Ca, 62.5% Mg, 53.62% Na, 59.85% S and 60.74% Cl of the aboveground biomass, whereas 57.07% of the dry matter account for trunk biomass (bole bark and bole wood), which in turn accounts for 39.07% N, 41.37% P, 45.70% K, 48.6% Ca, 37.5% Mg, 46.38% Na, 40.15% S and 39.26% Cl estimated. Nutrient content in the aboveground biomass of teak plantation follows the order: N > Ca > K > Mg > P > Na > S > Cl (Table 4). This result is similar to that found by Chaturvedi and Singh (1987) in a pine forest, Rawat and Singh (1988) in an oak forest and by Bargali et al. (1992), in a *Eucalyptus plantation,* in Central Himalaya, India.

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Kvantifikace živin v nadzemní biomase teakové kultury na stanovišti tropického suchého listnatého lesa v Udaipur (Indie)

ABSTRAKT: Cílem práce bylo kvantifikovat živiny v nadzemní biomase teakové kultury vysazené na stanoviště tropického suchého listnatého lesa v oblasti Udaipur, Rajasthan v Indii. Obsah živin v celkové biomase 10leté kultury teaku činil 165,47 kg/ha N, 20,96 kg/ha P, 35,06 kg/ha K, 49,29 kg/ha Ca, 31,52 kg/ha Mg, 4,27 kg/ha Na, 4,06 kg/ha S a 3,21 kg/ha Cl. Na celkové sušině se biomasa koruny (listy, větve, drobné větvičky a reprodukční orgány) podílela 42,93 %, přitom v koruně obsažený podíl prvků z celkové nadzemní biomasy činil 60,93 % N, 58,63 % P, 54,30 % K, 51,40 % Ca, 62,5 % Mg, 53,62 % Na, 59,85 % S a 60,74 % Cl. Biomasa kmene (kůra a dřevo) se na celkové sušině podílela 57,07 %, přičemž participace prvků v biomase kmene představovala z celkové nadzemní biomasy 39,07 % N, 41,37 % P, 45,70 % K, 48,6 % Ca, 37,5 % Mg, 46,38 % Na, 40,15 % S a 39,26 % Cl.

Klíčová slova: *Textona grandis* Linn. F.; sušina; nadzemní biomasa; koncentrace živin; obsah živin

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