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Interannual litter study in Teak plantation site of Raigarh Forest, Chhattisgarh, India

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Key words: Teak plantation, Lakha, Litter fall production, plantation floor litter, decomposition.

Abstract

The Lakha teak plantation site has situated in sub tropical deciduous forest area of Chhattisgarh. Teak is a major tree species with 32 other forest tree species in the plantation site. The study of ground leaf litter production in respect to rainfall variation from 2005-2011 shows that the average (±se; n=20) annual leaf litter production varied between 881 and 1370 g dry mass m-2 year-1. The 70-90% litter was produced in the dry seasons and 55-70% in wet seasons. On annual basis mean (±se; n=20) the highest total litter fall production varied 7.67±0.31Mg/ha/year in 2009 and lowest 6.00±0.33 Mg/ha/year in 2011. The plantation floor litter mass found highest 6.54±0.31 Mg/ha in year 2006 and 5.03±0.25 Mg/ha in year 2010. The decomposition of litters found highest in annual rates 13.87±1.06 Mg/ha/year in 2005 and 11.08±0.84 Mg/ha/year in 2010.

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Introduction

Forest tree crops has been found to be ecological sound, environmentally sustainable and economically profitable (Singh *et al.,* 1990). It increases soil organic matter and ensures efficient recycling of plant nutrients through leaf litter and plant turnover (Buresh and Tian, 1990). Leaf litter is an important component of tree cropping system. This is because it builds up on the forest floor and creates a layer of nutrient and litter on the soil. It is a major source of soil organic matter as it returns nutrients back to the soil through nutrient recycling. It reduces nutrient loss through leaching and erosion (Sunita and Uma, 1991). It also increases biological activities by providing biomass and suitable microclimate for various micro-organisms responsible for the release of mineral nutrients in available form to trees. It improves soil structure, water infiltration and water holding capacity of the soil. Lai (2002) reported that planting of perennial trees on degraded land in the tropic helps mitigate green house effect through carbon sequence. Tropical forests that experience larger annual variations in rainfall, such as tropical dry or semi deciduous forests, are thought to exhibit larger seasonal fluctuations in litter production, with peak litter production occurring during the dry season (Gaur and Pandey, 1978; Wieder and Wright, 1995; Sundarapandian and Swamy, 1999; Sanches *et al.,* 2005).

Litter decomposition dynamics in tropical systems also appear to be closely related to seasonal and inter annual cycles of rainfall and temperature. Compared to temperate forests, decomposition dynamics are rapid in the tropics because of high rainfall and temperature (Cornejo *et al.*, 1994; Aerts, 1997). In seasonal tropical forests, forest floor litter mass can increase substantially during the dry season because drought stimulates leaf litter production and inhibits decomposition (Austin and Vitousek, 2000). As soon as rainfall ensues during the transition between the dry and wet seasons there can be a transient pulse of litter decomposition (Wieder and Wright, 1995), which can have a proportionally large effect on the magnitude and direction of annual net ecosystem CO_2 exchange (Saleska *et al.,* 2003, Vourlitis *et al.,* 2005). To show the importance of leaf litters (Carbon & Nitrogen storage and cycling) in the sub tropical forest of Riagarh especially in Lakha teak plantation site, it was essential to quantify the production of leaf litters. So, this study was to quantify the leaf litter production and litter decomposition in interannual pattern and cordinated with variations in rainfall and temperature.

Materials and methods

Study area

This study was conducted in Lakha plantation site situated in northern part of Raigarh District of Chhattisgarh, India (20°20' to 23°15' N Latitude and 82°55 to 84°24' E longitude). This plantation site is located 234 m above sea level in a sub tropical and monsoonal climate. Vegetation with this ecotone consists of sub tropical dry and moist deciduous forest (Champion and Seth, 1968) which is on the north- western fringes of Raigarh district. The main forest tree species found in the Lakha plantation site and its surrounding area are Sal (*Shorea robusta*), Teak (*Tectona grandis*), Saja (*Terminalia tomentosa*), Baheda (*Terminalia belerica*), Palash (*Butea monosperma*), Haldu (*Adina cordifolia*), Tendu (*Diospyros melanoxyton* Roxb.) etc. In the year 1957, 10 hectare area of Lakha forest site was clear felled and planted with Teak (*Tectona grandis* Linn. F) but other miscellaneous forest tree species are also present. There are approximately 32 other species of forest trees with Teak of 10-20 cm diameter are present (Table1). The maximum canopy height of Teak plantation 20-30 m and basal area of trees 15 cm diameter is 269/ ha and 17.3 m^2/ha respectively (Table 1). Leaf area index varies between 4.2 m^2 m^{-2} in the wet season and 1.2 m^2 m^{-2} in the dry season (table 1) reflecting the sub deciduous nature of the plantation site. The plantation area consists of granites uncomfortably over line by "Lower Vindhayan" rocks. The latter consist of purple and green shale's mostly calcareous fine granite, sand stones and variously colored quartzite (Kumar, 1972).

Soils are acidic (pH = 5.1), sandy (90.1% sand), well-drained nutrient-poor quartzarenic neosols with low organic matter content (1.7%) (Khanna and Motiramani, 1972). The concentrations of available P (4.7 mg g^{-1}) and exchangeable cations (Ca and Mg) are in the surface (0 – 20 cm) soil. The annual temperature at Raigarh is 13°C in winter and 45°C respectively. Rainfall near Raigarh receives an average of 1639.2 mm respectively. But Raigarh also experiences a 2-3 month dry season both forecast and to interpolate time series (Gaur and Pandey, 1978; Nayak and Shrivastava, 1985; Edwards and Coull, 1987).

Field measurement and data analysis

In the teak plantation site above ground litter production (>1 mm diameter) was measured from January 2005 – 2011 in 20-randomly located 1 m^2 collectors. Litter traps were constructed of 1 mm mesh nylon fabric attached to a wooden frame and were elevated off the ground to avoid soil and water contamination (Sala and Austin, 2000). Litter accumulated in each collector was retrieved monthly, washed with distilled water, separated into leaves, twigs, and reproductive (flowers and fruits) fractions, dried at 65 – 70°C for 72 h, and weighed on a digital balance. Litter fall is expressed as the dry mass per unit ground area over a period of one month (Mg ha^{-1} $month^{-1}$). The plantation floor mass was collected monthly between January 2005 – 2011 within a 25x25 cm quadrate that was randomly placed adjacent to each litter fall collector (n = 20). Average monthly measurements of air temperature were made at the top of a 40 m tall tower (12 – 14 m above the teak canopy) using a shielded relative humidity sensor. The precipitation was measured every 30 min at the top of the eddy flux tower using a tipping-bucket rainfall gauge. However, gaps in data collection precluded use of the rainfall data measured on site and data obtained from a manual rain gauge that was read daily at the Raigarh agriculture centre located 5 km of the study site was used instead. Rainfall data collected by the manual rainfall guage were highly correlated to data collected on-site. Litter production and the plantation floor litter mass were sampled on a monthly basis, but unfortunately data for some months are lacking (~18% and 27% of all litter production and plantation floor litter mass data respectively). Time series analysis consisting of auto-regressive, integrated moving average models were used to fill gaps in the litter production and plantation floor litter mass time series (Edwards and Coull, 1987). Litter decomposition was calculated over monthly intervals between January 2005 – 2011 from the above- ground litter production (P) and plantation floor litter mass (F) data using a mass balance approach (Xu and Hirata, 2002), where the change in the surface plantation floor mass over each month (dF/dt) was defined as the difference P minus the mass of litter lost from decomposition (D); $dF/dt = P-D$ (a). Setting $dF/dt = 0$, the rate constant for litter decomposition (k, $month^{-1}$) was estimated from P and F as; $k= P/ (P+ F)$ (b); The rate of net decomposition (D) over each month was calculated as; $D = F_{t+} P_{tadj}-F_{t+1}$ ©. Here F_{t+1} was the plantation floor litter mass of the next month and P_{tadj} and F_t and the litter production and plantation floor litter mass of the current month, respectively (Wieder and Wright, 1995). Ptadj in equation (c) was adjusted for the potential for litter decomposition in the litter fall trap. In using a mass balance approach to estimate decomposition rates, it was assumed that: (a) litter fall began to decompose as soon as it landed in a litter fall trap, (b) litter fall decomposed at the same rate in the traps and on the ground and (c) litter decomposition follows a simple exponential decay function. Data are reported as mean (±SE; n = 20) values unless specified. The composite seasonal trend in litter dynamics was calculated by averaging a given variable measured for a particular month over the study period, and bootstrap re-sampling (Efron and Tibshirani, 1993) was used to estimate the random error (95%

confidence interval) about the mean monthly values. Time series analysis consisting of cross-correlation analysis was used to determine the correlation between monthly rainfall and a given litter variable.

Results and discussion

Rainfall and temperature

Annual rainfall varied between 1230 and 1970 mm during the January 2005 – 2011 in the study period (Fig. 1), Defining the dry season as the number of consecutive months when rainfall <50 mm, the dry season extended over 3 months in 2005, 2006 and 2008 and 4 months during the other years. Rainfall was consistently <50 mm in June – August, but rainfall was also ≥50 mm in June-July (2005 – 2006) and August (2008) during the years with a longer dry season. Peak rainfall generally occurred in the months of July-August, but there were large monthly variations in rainfall (Fig. 1).

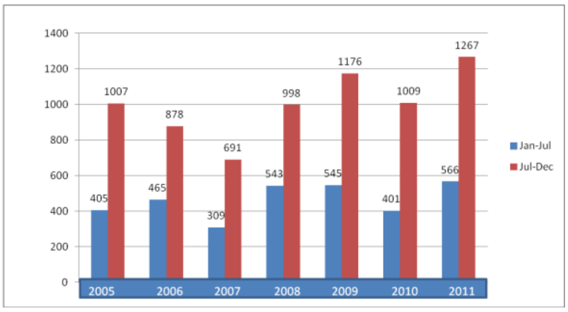

Fig. 1. Total rainfall in years 2005-2011.

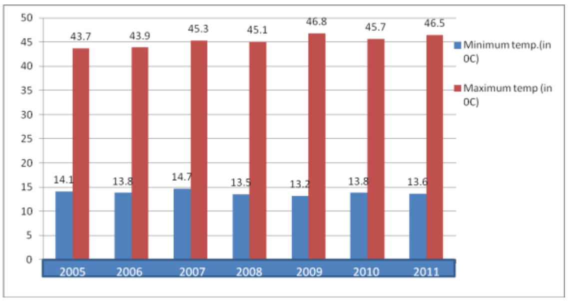

Fig. 2. Minimum and Maximum temperature in years 2005-2011.

Air temperature also varied over seasonal and inter-annual time periods and on average air temperature was lower during the dry season than the wet season (Figure 2). Average annual temperature varied minimum 13°C in 2010 to a maximum of 46°C in 2006.

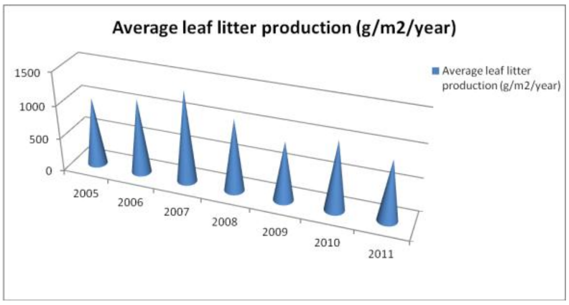

Fig. 3. Average (±SE; n=20) leaf litter production for year 2005 to 2011.

Litter production

The average (±se; n = 20) annual leaf litter production varied between 881 and 1370 g dry mass m^{-2} $year^{-1}$ over the study period (Figure 3) and in general leaf litter production was significantly higher in the year 2007 during least rainfall (Figure 3). Leaf litter accounted for the majority of the litter produced, comprising 70 – 90% in the dry season and 55 – 70% in wet season of total litter production. These seasonal patterns cause leaf litter production to be negatively correlated with rainfall during the wet seasons and positively correlated with rainfall. The magnitude and seasonal pattern of leaf litter production observed here, as well as the proportion of leaf litter to the total litter production, is comparable to results reported for other seasonal forests in India (Sundarapandian and Swamy, 1999) and northeast Brazil (Morellato 1992, Smith et al. 1998). On annual basis mean (±SE; n=20) total lowest litterfall production varied between 6.0±0.33 Mg/ha/year in 2011 to as high as 7.67± 0.31 Mg/ha/year in 2009 (Table 2). The annual rates of leaf litter production observed here are similar to the publication of (Morellato, 1992, Clark *et al.,* 2001, Luizão *et al.,* 2004, Malhi *et al.,* 2004).

Plantation floor litter mass exhibited a steady decline from a high of 6.54±0.31 Mg/ha in year 2006 to a low of 5.03±0.25 Mg/ha in year 2010. This long term trend in forest floor mass appeared to be closely related to temporal trends in total litter input. The decay constant is widely used to quantify variation in the rate of litter decomposition between teak and other species. Net decomposition varied subsequently over monthly timescales but had a less discrenable seasonal and interannual pattern and cross correlation analysis revealed that annaul patterns of decomposition were significantly correlated with annual pattern of rainfall.Annual rates of decomposition varied between 11.08±0.84 Mg/ha/year in 2010 to 13.87±1.06 Mg/ha/year in 2005 (Table 2).

Conclusions

Overall the result shows that leaf litter production dynamics of the sub tropical deciduous forest was directly altered rainfall variability and indireclty altered plantation floor litter mass and decomposition kinetics through its effect on litter production. Annual variations in litterfall dynamics were coincident with associated variations in rainfall.

Table 1. Selected Structural Characteristics of the Teak plantation in Lakha area of Chhattisgarh*.

Structural Characteristics (Units)	**Value**
Maximum canopy height (m)	20-30
Density (trees ha^{-1})	269
Species richness (species)	Teak and 32 other forest tree species
Basal area ($m^2 ha^{-1}$)	17.3
Average trunk diameter (cm)	15.0
Roughness length	1.9
Zero plane displacement height (m)	20.4
Average (±SD) LAI (m^2 m^{-2})	
Wet season	4.2±0.9
Wet-dry transition	3.0±0.9
Dry season	1.2±0.6
Dry-wet transition	4.6±0.8

*Density, species richness, and average trunk diameter data are for trees with a diameter breast height >10 cm. Leaf area index (LAI) data.

Table 2. Annual (±SE; n=20 plots) leaf litter production, plantation floor litter mass and litter decomposition of a Lakha teak plantation site near Raigarh

Year	Leaf litter production (Mg/ha/year)	Plantation floor litter mass (Mg/ha)	Decomposition (Mg/ha/year)
2005	6.01±0.34	5.81±0.35	13.87±1.06
2006	6.05±0.28	6.54±0.31	12.43±0.99
2007	6.43±0.29	5.01±0.26	12.21±1.01
2008	7.23±0.42	6.04±0.29	11.56±0.98
2009	7.67±0.31	6.33±0.34	12.04±0.89
2010	6.57±0.35	5.03±0.25	11.08±0.84
2011	6.00±0.33	5.25±0.32	11.67±0.88

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