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BASAL AREA AND DIAMETER INCREMENT IN LONG TERM RESEARCH SITES IN TROPICAL FORESTS OF INDIA

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ABSTRACT

Estimates of basal area in long term research sites of tropical forests, basal area increment and pattern of mortality in tropical rain forests (TRF) and rate of diameter growth in different forest types is given. estimates of basal area ranged around 43 m^2 /ha in tropical rain forests to around 30-35 m^2 /ha in moist deciduous forests and around 13 m^2/ha in dry deciduous forests. the rate of basal area increment per year in tropical rain forests for the pioneer species was 5.3%, canopy species 3.22%, middle storey species 2.02% and for under storey species 1.87%. the overall rate of basal area increment was 2.06 % per year in TRFs of western ghats of india. the average rate of diameter increment for species in the western ghat ranged between 3 to 3.5 mm per year.

Key words : Basal area, Diameter increment, Tropical forests, Long term research

Introduction

Some of the oldest long term research sites (LTRS) in the tropical forests of the world perhaps exist in India. These sites have different names: linear tree increment plot, linear increment plot, linear sample plot or permanent preservation plot. The common feature of all these plots is generally their linear shape and the object of their creation was to record periodic diameter or girth measurements of trees. In some sites only commercially important species were monitored, while in others all trees above 10 cm diameter breast height (dbh) were measured. In some cases sites were also created observe the ecological and phenological aspects and to serve as a site for botanizing. In some of these sites trees have been classified on the basis of size of the crown into large, medium and small and were also categorized into dominance classes as dominant, co-dominant, dominated and suppressed. These were done to study the differential rates of diameter growth dependent upon crown and dominance classes.

The earliest LTRS were established in the West Coast region for *Hopea parviflora* in 1911. Subsequent to this, during 1930s, there were concerted efforts for establishing such sites in 2 main regions: in northern India in *Shorea robusta* forests of Uttarakhand, Uttar Pradesh, Bihar and West Bengal; and in South India in tropical rain forests (TRF) of Karnataka, Tamil Nadu and Kerala. Later, during 1950s in parts of Karnataka and in early 1980s in parts of Maharashtra more sites were created in moist deciduous and dry deciduous teak bearing forests, respectively. At present nearly 100 such LTRS exist in India and majority of them are in reasonably good shape, with the exception of sandalwood plots, which have been practically destroyed.

Location of LTRS in different states and forest types

The largest number of sites are in *Shores robusta* dominated moist deciduous forests (43), followed by *Tectona grandis* forests (23) and tropical rain forests (20). More number of sites for *S. robusta* is in Uttarakhand, followed by West Bengal and Bihar. Similarly, more number of sites for *T. grandis* is in Karnataka, followed by Maharashtra and Kerala. For TRF more number of sites is in Karnataka followed by Kerala, Assam and Tamil Nadu. There are sites in Montane Hill forests of Tamil Nadu and Maharashtra, and in some of the old teak plantations of 1844 and 1872 in Kerala and Tamil Nadu, respectively. Similarly there are sites in Red Sanders plantations in Andhra Pradesh. There were sites for sandalwood forests, which have been lost.

Sites in tropical rain forests

These sites are in Karnataka, Kerala, Tamil Nadu, Assam and Andaman Island. They represent the characteristic vegetation of the area. The first among them was established during 1930s in the Western Ghats. Some of them have been well maintained and have generally been measured at 5-year interval. Besides giving an indication about the rate of growth of species, the sites have also given good information about the pattern of mortality in various TRF species (Rai, 1981a).

In a unique and very important ongoing study a permanent sample plot of 5 ha was set up in 1990 at

The overall rate of Basal Area increment was 2.06 % per year in Tropical Rain Forests (TRFs) and the average rate of diameter increment for species ranged between 3 to 3.5 mm per year in the Western Ghat.

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Uppanagala in Kadamakal Reserve Forest of Kodagu district of Karnataka, where 3870 trees belonging to 59 species are being monitored for their rate of diameter growth periodically. Vernier dbh tapes have been fixed to the trees by which diameter increment to the extent of 0.02 mm can be recorded. Some results are reported (FIP undated) in this paper in Table 2.

There are a large number of increment plots for *Hopea parviflora* in Dakshin Kannada district of Karnataka. Several of these plots were continuously maintained and they were in reasonably good shape in 1979.

Sites in moist deciduous forests

These LTRS can be broadly grouped into three categories as follows: (i) Predominantly *Shorea robusta* forests, (ii) Predominantly teak bearing forests, and (iii) Non-teak forests. These are described below.

Sites in Shorea robusta forests

The earliest LTRS of *Shorea robusta* were established in parts of Uttarakhand and Bengal during 1920s and 1930s. The largest number of sites is around Haldwani and Ram Nagar in Uttarakhand. In these sites, only trees of *Shorea robusta, Adina cordifolia* and *Terminalia tomentosa* were measured and tagged, while the trees of other species though measured, were not tagged. Whereas in some of the sites in West Bengal trees of all the species have been measured and tagged. The periodicity of measurement has not always been 5 years. The pattern of mortality and rate of growth in various diameter classes in these forests has been reported (Mathauda, 1958).

Sites in Teak forests

Majority of these sites are in the moist deciduous forests of Karnataka, some are in Maharashtra and one in Kerala. Teak is a dominant species in these sites and other associates generally are *Lagerstroemia, lanceolata, Terminalia paniculata, Xylia xylocarpa* and bamboos. Majority of the sites were created in 1950s and they were measured regularly. The rate of diameter growth of trees from the sites of Karnataka has been reported (Rai, 1978, 1979, 1980, 1987, 1990).

Sites in non-Teak forests

Some of the oldest sites in this type of forests were created in parts of Maharashtra. These forests do not have teak although they fall in the moist deciduous zone. The dominant species is *Pterocarpus marsupium* and other associates are *Lagerstroemia parviflora, Dalbergia latifolia, Saccopetalum tomentosum, Xylia xylocarpa,* etc. The rate of growth of several species from these forests has been reported (Mathauda, 1955).

Sites in dry deciduous forests

These type of sites have were created during 1980s in Maharashtra and in 1990s in Tamil Nadu. Majority of them in Maharashtra have *Tectona grandis* as the main species and the other associates are *Grewia tiliaefolia, Lagerstroemia parviflora, Anogiessus latifolia, Diospyros melanoxylon,* etc.

The Mudumalai LTRS (50 ha plot) in Tamil Nadu was established in 1988 and is being maintained as a forest dynamics plot and is studied intensively. In this plot teak is an associate while the main species are *Lagerstroemia lanceolata* and *Terminalia tomentosa*.

Results and Discussion

Estimates of basal area in tropical forests of India

The estimates of basal area (BA) for 93 LTRS has been made (Rai, 1996) as given in Table 1.

- The BA in TRF of Assam was 41.9 m^2/ ha (average of 2 sites) and it was 44.5 m^2/ ha (average of 8 sites) in Karnataka. In Kerala, in the Silent Valley area, the BA measured in 10 plots ranged between 40-80 m^2/ ha. In a tropical forest in Wynad, Kerala, the BA was 42.8 m^2/ha. In the Montane Hill forests in Karian Shola at Top slip in Tamil Nadu, which was 44.8 m^2/ha. In similar vegetation near Pune in Maharashtra, it was 50.3 m^2/ ha.
- In semi-evergreen forests of Karnataka, it was 35.5 m^2/ha and in Maharashtra it was 35.5 m^2/ha. In another Shola forests at Ootacamund, the BA was 34.8 m^2/ha.
- In the moist deciduous *Shorea robusta* forests in Uttarakhand and Uttar Pradesh the average of 27 sites gave a BA of 34.5 m^2/ha (range was from 20.2 to 67.6). In West Bengal the average BA of 7 sites was 58.7 m^2/ha (range was from 27.1 to 75.7).
- In the moist deciduous teak forests of Karnataka, the average BA for 15 sites was 29.7 m^2/ha (range was 21.6 to 47.8).
- In a non-teak moist deciduous forest in Maharashtra, the basal area was 27.3 m^2/ ha.
- In Dry Deciduous *Shorea robusta* forests in Bihar, the average basal area was 27.0 m^2/ha.
- In dry deciduous teak forests of Maharashtra the average basal area for 5 sites was 12.6 m^2/ha (range was 9.8 to 14.4).
- In dry deciduous forests dominated by *Lagerstroemia lanceolata*, *Terminalia tomentosa* and *Anogeissus latifolia* with less of teak the BA was 25 m^2/ha.

Table 1: Average basal area per hectare in the long term research sites in different tropical forest types in India

Forest type	Location	Basal area m^2/ha	Range of BA m^2/ha	No. of sites
Tropical rain forest	Assam	44.9		2
	Karnataka	44.5		8
	Kerala		40 to 80	10
	Kerala	42.8		1
Montane sub tropical	Tamil Nadu	44.8		1
	Maharashtra	50.3		1
Shola	Tamil Nadu	34.8		1
Semi-evergreen	Karnataka	33.5		1
-do-	Maharashtra	35.5		1
Moist deciduous (*S. robusta*)	Uttarakhand +Uttar Pradesh	34.5	20 to 67.6	27
-do-	West Bengal	58.7	27.1 to 75.7	7
Teak	Karnataka	29.7	21.6 to 47.8	15
Non-teak	Maharashtra	27.3		
Dry deciduous (*S. robusta*)	Bihar	27.0	25.5 to 28.5	2
Dry deciduous teak	Maharashtra	12.6	9.8 to 14.4	5
Dry deciduous -less teak	Tamil Nadu (Mudumalai)	25		1

Annual aasal area increment and survival pattern in tropical rain forests

The rate of basal area increment over a period of 36 years for 95 species individually, and for the forest as a whole has been estimated as percentage increase per year (Rai, 1983). Based on the habit of growth the species were classified into four categories namely: pioneers, canopy, middle storey and under storey. The rate of basal area increment per year in these forests for the pioneer species was 5.3%, canopy species 3.22%, middle storey species 2.02% and for under storey species 1.87%. The overall rate of basal area increment for the 4 sites was 2.06 % per year and in terms of real increase it was 0.505 m^2/ha/year.

Rate of mortality among various species across the DBH class was also studied. As expected the pioneer species have quicker turn over and over a period of 36 years there was 47% mortality among them. The species which form the top canopy have longer life span; the rate of mortality among them was only 25% over the same period. As opposed to this, the rate of diameter growth and consequently the rate of basal area increment for the pioneer species were higher (5.3%) and it was relatively low for the top canopy species (3.22%).

Rate of annual diameter increment

From the analysis of the data following results are reported. The study sites in moist teak zone can be distinguished in 3 different categories; Teak as a predominant associate, teak as an associate and teak absent or rare. There was no marked difference in rates of growth between the first two categories. However, variation in the rate of growth was observed depending upon the location of the site. Annual diameter increment of 64 species is given in Table 2. Some details are given below:

- Average annual diameter increment of *Dalbergia latifolia* ranged between 2.0 and 3.0 mm while that of *Xylia dolabriformis* ranged between 2.1 and 3.1 mm (Rai, 1978).
- The rate of diameter growth of *Hopea parviflora* in the West Coast of India on alluvial soils was higher (12.5 mm per year) in the trees of 11 to 20 cm diameter class, however, the general rate of growth ranged between 2.9 to 5.7 mm per year (Rai, 1979a).
- The rates of diameter growth of *Vitex altissima* and *Lannea coromandelica* which are representative of semi-evergreen forests but also occur sometimes on moist sites in moist deciduous forests was studied (Rai, 1979b). The rate of diameter increment in *Vitex altissima* was 4 mm per year which is higher than many species found in the same type of forests. Similarly rate of diameter increment in *Lannea coromandelica* was more (2.7 mm per year) in moist deciduous forests as compared to 1.8 mm in dry deciduous forests.
- The rate of diameter increment of sandalwood computed from the old available data gave an increment of around 2.7 cm/per year (Rai and Sharma, 1986). Maximum diameter increment was generally seen in the middle diameter range of 40–55 cm for most species.
- Rate of diameter growth of a number of species has been reported (Rai, 1989).

Table 2: Rate of annual diameter increment in tropical forests of India

S.N	Species	Normal habitat*	Mean dia increment mm / yr	Source
1	*Adina cordifolia*	M	2.9	Rai , 1989
2	*Anogiessus latifolia*	M/D	3.9, 2.9	Mathauda, 1955; Rai, 1989
	Artocarpus heterophyllus	T/S	2.39	FIP
3	*Artocarpus hirsute*	T/S	4.8	Rai and Sharma, 1993
4,5	*Bauhinia lawii, B. racemosa*	M	1.3, 2.1	Rai, 1989
6	*Calophyllum polyanthum*	T	3.95	FIP
7	*Careya arborea*	S/M	2.1, 2.4	Rai, 1985; Rai , 1989
8	*Cinnamomum* spp	T	4.79	FIP
9	*Cleistanthus collinus*	D	3.0	Mathauda, 1955
10	*Cryptocarya bourdillonii*	T	2.4	FIP
11	*Cryptocarya wightiana*	T	2.2	Rai, 1980 a
12	*Dalbergia latifolia*	S/M	2.1, 2.1, 2.5, 3.4	Mathauda, 1955; Rai, 1978; Rai, 1989 ; Rai and Sharma, 1990
13	*Dillenia pentagyna*	M	3.3, 3.7	Rai, 1987; Rai , 1989
14	*Dimocarpus longan*	M	2.14	FIP
15-20	*Diospyros assimilis, D. candolleana, D. microphylla, D. oocarpa, D. paniculata, D. pruriens*	T	3.1, 2.1, 2.5, 1.7, 1.6, 0.65	Rai, 1981; Rai , 1981 a; FIP
21	*Dipterocarpus indicus*	T	4.2	Rai, 1981 a
22	*Drypetes elata*	T	1.87	FIP
23	*Emblica officinalis*	M/D	2.5	Rai, 1989
24 - 26	*Garcinia spp., Garcinia gummi-gutta, Garcinia morella*	T	1.1, 1.99, 1.33	Rai, 1981 a, FIP
27	*Garuga pinnata*	S	2.7	Mathauda, 1955
28	*Grewia tilaefolia*	M/D	3.1, 3.3	Rai, 1989; Rai and Sharma, 1993
29	*Heritiera papilio*	T	2.08	FIP
30	*Holigarna arnottiana, H. nigra*	T	2.33, 2.30	FIP
31-33	*Hopea parviflora, H. wightiana, H. ponga*	T/S	4.4, 2.2, 1.88	Rai, 1979 a; Rai, 1981 b, FIP
34	*Knema attenuate*	T	1.8, 1.54	Rai, 1981 b, FIP
35	*Lagerstroemia lanceolata*	M	3.0, 3.7;	Rai, 1980 b; Rai, 1989,
36	*Lagerstroemia parviflora*	M/D	2.4	Mathauda, 1955
37	*Lannea coromandelica*	M/D	2.7, 2.3, 1.8	Rai, 1979b; Rai, 1989; Mathauda, 1955
38	*Lophopetalum Wightianum*	T	3.32	FIP
39	*Mangifera indica*	T	1.34	FIP
40	*Mesua ferrea*	T	3.2; 2.6 to 5.5; 2.41	Rai, 1981 a; Rai and Sharma, 1986 (5 sites); FIP
41	*Mitragyna parviflora*	M	4.9	Rai, 1989
42	*Myristica dactyloides,*	T	1.2, 1.4	Rai, 1981 b, FIP
43	*M. malabarica*	T	1.4	Rai, 1981 b
44	*Olea dioca*	S	2.0	Rai, 1981 a
45	*Palaqium elipticum*	T	0.95	FIP
46	*Pterocarpus marsupium*	M/D	3.0	Mathauda, 1955
47	*Salmalia malabarica*	T/M	2.9	Mathauda, 1955
48	*Santalum album*	D	2.5	Rai and Sharma, 1986
49	*Shorea robusta*	M/D	3.3	Rai, 1981
50	*Spondias acuminata*	S/M	5.4	Rai, 1989
51	*Stereospermum suaveolence*	S/M	3.6	Rai, 1989
52	*Syzygium gardneri*	T	3.7, 2.87	Rai, 1981 b, FIP
53	*Syzygium laetum*	T	1.10	FIP
54	*Tectona grandis*	M/D	3.6, 3.5, 3.1	RAi, 1981; Rai, 1989; Rai and Sharma, 1990
55-58	*Terminalia alata, T. belerica, T. paniculata and T. paniculata*	M/D	2.6, 3.6, 3.0, 3.6	Rai, 1985; Mathauda, 1955; Rai, 1980 b; Rai, 1989
59	*Vateria indica*	T	2.8	FIP
60	*Vepris bilocularis*	T	2.2	Rai, 1981 b
61	*Vitex altissima*	S/M	4.0	Rai, 1979 b
62	*Wrightia tinctoria*	D	1.7	Rai, 1989
63	*Xeromphis spinosa*	M/D	3.2	Rai, 1989
64	*Xylia dolabriformis,*	M	1.7, 2.7, 2.4	Mathauda, 1955; Rai, 1978; Rai and Sharma, 1990

***Note (i):** **T=** Tropical Rain Forests; **S=** Semi-evergreen Forest; **M=**Moist Deciduous Forest; and **D=** Dry Deciduous Forest

(ii) In some cases a species has been studied by more than one author or on more than one site, therefore there are more than one figure of mean rate of diameter increment.

Real purpose of these study sites would be served if they can be carefully studied to assess the impact of anthropogenic pressure and relative changes that have taken place in the species composition in these forests. As expected on certain sites where there were recurrent fires the thorny species like Lantana and Eupatorium have invaded. Similarly in parts of West Bengal (where there is better distribution of rainfall) a process of succession has been observed wherein several of the pioneer species such as *Macaranga peltata, Callicarpa lanata, Erythrina* spp. etc. were replaced by more mesophytic species within a span of 20-25 years. These sites can be an excellent example for studying the rate of succession in these forests.

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