

**Above ground herb layer productivity and biomass under different light
gaps and varied stem density in the forests of Uttara Kannada, Western
Ghats, Karnataka.**

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ABSTRACT

Tree, Shrub and herb layer biomass productivity estimation was undertaken in Uttara Kannada, a Western Ghats district in Karnataka in differentially managed forests. In addition to biomass, light gap in these sample sites was also estimated to understand the relationship between the light interception pattern at different canopy layers and their productivity. Our studies indicate that the tree biomass productivity decreases and herb productivity increases with increasing light gap. However, the herb biomass productivity attains maximum at 40-60% light gaps than in plots with no trees or 100% light gap indicating highest herb biomass in forests managed for leaf manure than in grasslands. This further indicates that partial shading enhances herb layer productivity. Thus a strategy of undertaking of agroforestry in villages to enhance the total biomass productivity to meet the village needs was suggested

Key words: Biomass, Productivity, Light gaps, stem density, Western Ghats

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Introduction

Organisms compete over various resources that they depend for their growth and survival. In a forest ecosystem, the trees, shrubs and herbs compete for light, nutrients and moisture to maximise their fitness (Knoop and Walker, 1985; Anderson and Sinclair, 1993). Trees being tall and occupy larger space on ground modify resources that are available (Kessler and Breman, 1991; Vetas, 1992) and produce either detrimental or beneficial effects for shrubs and herbs. In most situations the herb layer productivity is lower under tree canopy (Grunow *et al.*, 1980; Sandford *et al.*, 1982, Puri, *et al.*, 1982; Pandey *et al.*, 2000) where in some situations the productivity is higher (Tiedemann and Klemmenson 1977; Ovalle and Avendano, 1987).

Understorey species and tree seedlings in tropical forests respond positively to increased light availability leading to sizeable difference in carbon accumulation (Percy 1983, Chazdon 1986, Chazdon *et al.*, 1996, Montegmory and Chazdon 2002) Two species, *Euphorbia* and *Claoxylon* showed significant growth due to enhanced light availability in Hawaiian rainforest (Percy 1983) Thus it is important for the understorey species either herbs or tree seedlings or shrubs or understorey trees to respond to light availability quickly in order to garner biomass for its growth and survival. Though studies have dealt with various factors determining the biomass production in different layers of the canopy such as shrub, herb and tree layers, but not many have really dealt the issues concerning the maximising the biomass produced in a given area of forest or agriculture land. Varying needs of forest dependent people such as grass for the livestock and trees for their local use compel them to maintain lesser density of trees in the forest. In this paper we examine the light gaps and biomass accumulation in differentially managed forests and optimal levels of biomass at the tree and herb layers.

Materials and Methods

Study area

The study was conducted in Uttara Kannada district (13°55' to 15°31'N lat., 74°9' to 75°10' E long) of the Western Ghats part of peninsular India (Figure 1). Comprising an area of 10,200 km², the district is hilly terrain with gentle slopes and broad valleys, with an altitude ranging from the sea coast to a little over 1000 m. It is one of the most forested tracts of southern India. Topographically the district can be divided into three zones: the flat and narrow coast, abruptly rising ridge and the flat and elevated eastern zone that joins the Deccan Plateau. The

district experiences southwest monsoon and the rainfall received mostly between June and September. Annual rainfall in the district ranges from 350 cm near the coast to more than 500 cm along the ridge of the hills. The eastern side of the district receives about 120 cm of rainfall annually. Natural vegetation of the district is evergreen/semi-evergreen type along slopes and moist deciduous type towards east of the ridge. Puri (1960) has classified the forest facing the western slope as tropical wet evergreen type and included the eastern part in the tropical moist deciduous forest type. Champion and Seth (1968) have classified the forest on the western slope as tropical evergreen type and included the forest of the eastern zone in the category of south Indian moist deciduous type. Considering the abundance of species, Pascal (1988) classified the vegetation of the lower elevation of the district as *Persea macarantha-Diospyros-Holigarna* series type. According to him, the summits of the plateau are covered with *Memecylon umbellatum-Syzygium cuminii-Actino-daphne angustifolia* series type of forests. In evergreen/semi-evergreen forests (henceforth called evergreen forests) *Hopea wightiana*, *Bischofia javanica*, *Holigarna arnot-tiana*, *Flacourtia montana* and *Ixora brachiata* species dominate the canopy; the undergrowth consists of *Strobilanthus* sps, *Calamus* sps and *Uvaria* sps. In moist deciduous forests *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Terminalia tomentosa*, *T. paniculata* and *T. bellerica* are the emergent tree species and the undergrowth includes species such as *Psychotria dalzellii*, *Eupatorium odoratum*, *Wagatea spicata* and *Ziziphus* sps. Based on rainfall and vegetation types, the district can be broadly divided into evergreen/semi-evergreen forest zone and drier secondary/moist deciduous zone. The forests of the district have been classified administratively as reserve forests (RFs), minor forests (MFs) and leaf-manure forests (LMFs). The RFs account for more than 60%, MFs form about 15% and the LMFs, locally known as 'Soppina bettas', constitute about 5% of the total geographical area of the district. The management system is different for these three forest categories: (i) in RFs, wood and timber extraction is highly regulated by the state and the accessibility to the people is banned; (ii) in MFs, extraction of forest products is not regulated and it is an open access system, meant for meeting biomass demands of local people, and (iii) in LMFs, leaf and dry wood extraction is permitted only to the assigned farmers under certain privileges. A description of the study sites is given Bhat et al., (2000).

Methods

Representative areas from two forest categories, viz. RFs and MFs were selected in evergreen and moist deciduous vegetation zones which fall in Sirsi and Kumta blocks of the district. In each forest category, plots measuring 100 X 100 m (one ha) were demarcated. There were a

total of eight one-ha forest plots representing four RFs, two of which were from the above-Ghat area (i.e. in the moist deciduous forest zone) and the other two were from the coastal area (i.e. in the evergreen forest zone); four MFs, two of which were from a higher elevation and the other two from the coastal area. All woody plants (which include tree-saplings, shrubs, lianas, climbers, etc.) with a circumference of ≥ 10 cm at breast height (i.e. at 132 cm) were enumerated as trees. For convenience during the enumeration, each plot was split into five strips (20 X 100 m) and each tree was numbered with embossed metal tag. At the time of enumeration, branches of a tree with a circumference of 10 cm at the breast height were noted as stems and they were marked as A, B, C, etc. and their girth at breast height (GBH) was measured. A black strip was painted on each tree and stem at the breast height. Plants were identified to the species level, but in case of uncertainty they were identified up to genera or family level and in the case of doubtful entities they were called as unknown I, II, III and so on.

In each hectare of sampled area, 100 points (approximately at 10 m away from each point) were chosen randomly and at each point canopy gap was measured. A person stood at each point, and noted whether the canopy was open or closed right above the head. If sky was observed, the point took the value 1, otherwise zero. If the branch or leaf was observed then the point was indicated as closure of canopy and recorded as zero. A sum of all values recorded in the plot directly indicates % canopy gap or opening. Biomass productivity of tree, shrub and herb layer was followed using Prasad *et al.*, (1987).

Results and Discussion

In the forests of Uttara Kannada, variation in stem density and biomass was high indicating the management regimes and the topography may be influencing them. The tree density was highly variably from 306 stems per ha in Bidralli to 1619 in Nagur forests. Similarly shrub and total stem density was also low in Santagal (11,550/ha, and 12,514/ha respectively) and high in Bidralli (65,680/ha and 65,986/ha respectively) forests. Light gap was lowest in Nagur (12%) and high in Mirzan (61%). However, the other two sites Divgi and Nagur cross were open lands without any tree cover recording 100% of light gap. Herb biomass production was high in Sugavi (10.896 tons/ha) and low in Nagur (0.524 t/ha); tree biomass was high in Nagur (314 t/ha) and low in Mirzan (66.15); shrub biomass was high in Chandavar (2.18 t/ha) and low in Santagal (0.038 t/ha); and total biomass was high in Nagur (315 t/ha) and low in Mirzan (70.99 t/ha). In Divgi and Nagur cross, that were devoid of trees, had 1.6 and 4.5 t/ha

herb layer respectively. Though there is a significant negative relation between tree biomass productivity and herb biomass productivity, the difference in means of herb biomass between Minor forest and reserve forest is not significant because of Bidralli. though reserved forest had less number of trees than minor forest and much higher herb biomass.

There was significant variation found in biomass production and light gap regimes in forests with different management practices (Table 1). Average light gap was significantly high (49.5) in minor forests as compared to reserve forests (20.5%) indicating the minor forests were relatively more open. Consequent to openness, tree density (428 /ha) in minor forests was less as compared to reserve forests (895.25), though not statistically significant. The other parameters that were statistically significant were tree and total biomass in the forests. These results indicate that light gap and tree biomass are highly dependent.

The relation between light gap and herb layer productivity is non-linear, though significant indicating lower biomass accumulation in lower and higher light gaps. However, the light gap of around 50% would result in maximum herb layer productivity (Figure 1a). The relation between shrub biomass and light gap though is negative but not significant (-0.545). Tree biomass seem to influence the total biomass significantly indicating much of the above ground biomass contributed by tree layer (Figure 1b and c). The relation of light gap and tree biomass is negatively linear and significant ($r = -0.946$, figure 1b), similarly the relation between light gap and total biomass ($r = -0.947$, figure 1c) indicating light is highly influencing factor for standing biomass

In many places, as in Uttara Kannada district, forests are being used for various purposes such as deriving small timber, non-timber products and grass for the local people (Murthy *et. al.*, 2002). Under such situations forests are used for deriving biomass at different layers such as tree and ground layer. In Uttara Kannada district, there are leaf manure forests that are under the control of the areca landowners, who maintain the forest for tree leaf production to be used as leaf manure and the floor for grazing their cattle. Under these situations a density that maximises the above ground biomass and the ground layer grass biomass would be optimal to meet their demands. Though grass biomass is determined by the light gaps, the grass biomass recorded in low light gaps and high light gaps are lower. Lower grass or herb biomass production under lower light gaps are primarily because of limitation of space and light, while the similar pattern in high light gaps are primarily because of the nature of habitats. Open

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grasslands devoid of trees are normally characterised by highly water and nutrient leached areas with shallow and less fertile soils and therefore productivity may be less. though abundant light is available. As seen here, the tree biomass is almost double in the reserve forests and the herb layer productivity is less than half that of minor forests. Thus, it could be concluded that a tree density of around 400 per ha would lead to sufficient biomass at tree and herb layer in order for the community to derive desired benefits from the forests. Studies relating to agro-forestry systems in semi-arid regions of Karnataka (Bhaskar et. al., 1992) indicate that nearly 500 plants per ha would yield approximately two third of the normal yield of castor, horse gram, red gram and finger millet crops indicating the total biomass could be enhanced using both the herb layer crops and trees. Similarly in slash and burning system in northeastern region in India a tree density of 180 per ha was observed with high productivity of cereal crops (Uma shankar, 2001). The results of this study and the experience elsewhere also indicate that the Agro-forestry option seems more appropriate to enhance biomass productivity to meet the rural needs and to decrease the reliance on the already depleting forests. Further the study indicates, a threshold light gap is essential for maximum above ground herb layer productivity. Majority of cereal crop plants and grasses being C4 plants that require sufficient light and has the ability to capture carbon dioxide at lower concentrations, this strategy of maintaining a suitable light gap with multi-layered crops would enhance the total biomass production per unit area.

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References

1. Anderson, L. S., and Sinclair, F. L., 1993, Ecological Interactions in agroforestry systems, Agroforestry abstracts, 6: 57-91
2. Bhaskar, V, Rao, N S., Reddy, B. G M., Vedavyasa, K., Ravishankar, H M., and Venkatesh, R., 1992, Comparative studies of the associated soil moisture regimes and their productivity in an agroforestry system, In "Calder, I. R., Hall, R. L., and Adlar, P. G., "Growth and water use efficiency of forest plantations", publications.
3. Champion, H. G., and Seth, S. K., 1968 A revised survey of Forest types of India, Government of India Press, Nasik, India.
4. Chazdon, R.L., Percy, R. W., Lee, D. W., Fetcher, N., 1996, Photosynthetic response of tropical forest plants to contrasting light environments. In: Mulkey, S. S., Chazdon, R.

- L., Smith, A. P., (eds), Tropical forest plant eco-physiology, Chapman and Hall, New York, pp 5-55
- 5 Grunow, J. O., Groeneveld, H. T., and DuToit, S. H. C., 1980. Above ground dry matter dynamics of the grass layer of a South African tree Savanna. *Journal of Ecology*, 68: 877-889
 6. Kessler, J. J., and Breman, H., 1991. The potential of agroforestry to increase primary production in the Sahelian and Sudanian zones of West Africa. *Agroforestry Systems*, 13: 41-62
 - 7 Knoop, W. T., and Walker, B. H., 1985, Interactions of Woody and herbaceous vegetation in a South African Savanna, *Journal of Ecology*, 73: 235-253
 8. Montegmory, R. A., and Chazdon, R. L., 2002, Light gradient partitioning by tropical tree seedlings in the absence of canopy gaps. *Oecologia*, 131: 165-174
 - 9 Murthy, I. K., Bhat, P. R., Ravindranath, N. H., and Sukumar, R., Quantification and financial evaluation of non-timber forest products flows in Uttara Kannada district, Western ghats, Karnataka. Ms under publication in MYFOREST
 10. Pandey, C. B., Pandya, K.S., Pandey, D., and Sharma, R. B., 2000, Growth and productivity of rice (*Oryza sativa*) as affected by *Acacia nilotica* in a traditional agroforestry system, *Tropical Ecology*, 40(1): 109-117
 - 11 Pascal, J. P., 1988, Wet evergreen forests of Western Ghats of India, Institute de Francais Pondicherry, India
 12. Percy, R. W., 1983, The light environment and growth of C3 and C4 species in the understorey of a Hawaiian forest. *Oecologia*, 58: 26-32
 13. Chazdon, R.L., 1986, Physiological and morphological basis of shade tolerance in rain forest understory palms. *Principes*, 30: 92-99
 14. Puri, G. S., 1960, Indian Forest Ecology, Oxford Book Co., New Delhi, India
 - 15 Puri, S., Singh, S., and Khara, A. 1992, Effect of wind break on the yield of cotton crop in semi-arid region of Haryana, *Agroforestry systems*, 18: 183-195
 - 16 Sandford, W. W., Usman, S., Obot, S. E. O., Isichei A. O., and Wari, 1982, Relationship of woody plants to herbaceous production in Nigerian savanna. *Tropical Agriculture*, 59: 315-318
 17. Tiedemann, a. R., and Klemmenson, J. O., 1977, Effect of mesquite tree on vegetation and soils in the desert grasslands. *Journal of Range Management*, 26: 27-29

- 18 Uma shankar, 2001, Increasing biomass scarcity in northeastern India: Options with the villagers, In (A Arunachalam, A., and M. L., Khan. (eds) Sustainable Management of Forests - India, International Book Distributors, Dehradun, India.
- 19 Vetas, O. R., 1992. Micro-site effects of tree and shrubs in a dry savanna. *Journal of Vegetation Science*, 3: 337-344

Table 1: Biomass production and stem density of different layers in Reserve and Minor forests of Uttara Kannada district.

	Reserve Forest (mean \pm SD)	Minor Forest (mean \pm SD)	T value	P value
Tree density	895.25 \pm 552.89	428.0 \pm 111.44	1.65	0.19
Shrub density	39,292.5 \pm 22,419.53	34,145.0 \pm 24,094.03	0.313	0.765
Total stem density	40,187.75 \pm 22,233.72	34,573.0 \pm 24,147.08	0.34	0.74
Light gap	20.5 \pm 13.7	49.5 \pm 8.73	3.57	0.016
Basal area	28.03 \pm 5.49	18.39 \pm 7.14	2.13	0.07
Herb Biomass	3.138 \pm 3.71	8.016 \pm 3.51	1.91	0.104
Tree biomass	242.575 \pm 56.8	129.015 \pm 46.62	3.198	0.018
Shrub Biomass	0.5694 \pm 0.5128	0.6928 \pm 0.996	0.22	0.83
Total Biomass	246.28 \pm 53.55	137.72 \pm 45.25	3.09	0.021

Table 2: Correlation coefficients between Tree density, shrub density, light gap, herb biomass, tree biomass and shrub biomass.

	Tree density	Shrub density	Light gap	Herb Biomass	Tree biomass	Shrub Biomass
Shrub density						
Pearson's r	0.3240					
Spearman's r	0.2727					
Light gap						
Pearson's r	-0.8220	-0.5450				
Spearman's r	-0.8303	-0.4424				
Herb layer productivity						
Pearson's r	-0.4090	0.3710	0.1240			
Spearman's r	-0.3420	0.0091	0.3061			
Tree biomass						
Pearson's r	0.9030	0.5510	-0.9460	-0.1490		
Spearman's r	0.8424	0.5151	-0.9030	-0.3300		
Shrub Biomass						
Pearson's r	0.0740	0.5500	-0.3460	0.0610	0.1810	
Spearman's r	0.3420	0.7939	-0.5050	0.3242	0.3697	
Total Biomass						
Pearson's r	0.8910	0.5710	-0.9480	-0.1110	0.9990	0.1910
Spearman's r	0.8394	0.5121	-0.9000	-0.3212	0.9970	0.3667

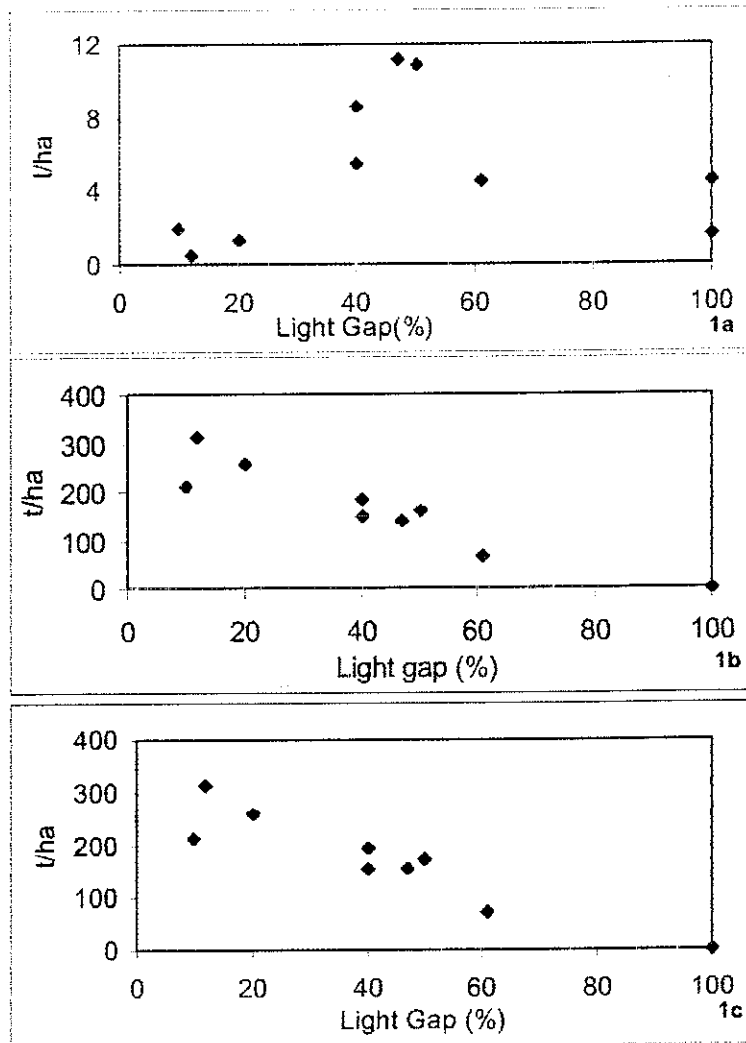


Figure 1: Relation of herb biomass (t/ha), tree biomass (t/ha) and total biomass (t/ha) with light gap (%) **1a** indicates a quadratic relation between herb biomass with light gap ($r^2 = 0.652$, $F = 6.57$, $p < 0.02$) **1b** indicates a linear relation between tree biomass and light gap ($r^2 = 0.8957$) **1c** indicates linear relation between light gap and total biomass including shrub biomass ($r^2 = 0.8978$)