Herb layer productivity under different light gaps in the forests of Western Ghats of Karnataka, India

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Abstract: A productivity estimation of tree, shrub and herb layer biomass 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. The studies indicate that tree biomass productivity decreases and herb productivity increases with increasing light gap. However, the herb biomass productivity attains maximum height at 40–60% light gaps than in plots with no trees or 100% light gap indicating that highest herb biomass is found in forests managed for leaf manure than in grasslands. This further indicates that partial shading enhances herb layer productivity. Thus, a strategy of undertaking agroforestry in villages to enhance the total biomass productivity to meet the needs of the villages was suggested.

Keywords: biomass; productivity; light gaps; stem density; Western Ghats.

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1 Introduction

Organisms compete over various resources that they depend on for their growth and survival. In a forest ecosystem, trees, shrubs and herbs compete for light, nutrients and moisture to maximise their fitness (Knoop and Walker, 1985; Anderson and Sinclair, 1993). Trees are tall and occupy a larger space on ground, therefore, they can 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 a tree canopy (Grunow, Groeneveld and DuToit, 1980; Sandford *et al.*, 1982; Puri, Singh and Khara, 1992; Pandey *et al.*, 2000). However, in some situations the productivity is higher (Tiedemann and Klemmendson, 1977).

Understorey species and tree seedlings in tropical forests respond positively to increased light availability leading to a 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 the 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 the biomass it requires for 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, not many have really dealt with the issues concerning the maximising of 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 a lesser density of trees in the forest. In this paper, the light gaps and biomass accumulation in differentially managed forests and optimal levels of biomass at the tree and herb layers are examined.

2 Materials and methods

2.1 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. Comprising an area of 10,200 km^2, the district has a hilly terrain with gentle slopes and broad valleys. The altitude ranges from the seacoast 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 southwest monsoon sets over the district 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. The natural vegetation of the district is of the 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 cumini*i–*Actinodaphne angustifolia* series type of forests. In evergreen/semi-evergreen forests (henceforth called evergreen forests) *Hopea wightian*a, *Bischofia javanic*a, *Holigarna arnottian*a, *Flacourtia montana* and *Ixora brachiata* species dominate the canopy; the undergrowth consists of *Strobi-lanthus* sp, *Calamus* sp and *Uvaria* sp. In moist deciduous forests *Xylia xylocarp*a, *Lagerstroemia lanceolat*a, *Terminalia tomentos*a, *T. paniculata* and *T. bellerica* are the emergent tree species and the undergrowth includes species such as *Psychotria dalzell*i, *Eupatorium odoratu*m, *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). Of the total geographical area of the district the RFs account for more than 60% of the area, MFs form about 15% and the LMFs, locally known as ‘Soppina bettas’, constitute about 5%. The management system is different for these three forest categories:

- in RFs, wood and timber extraction is highly regulated by the state and accessibility is banned
- in MFs, extraction of forest products is not regulated and it is an open access system, meant for meeting biomass demands of the local people
- 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 in Bhat *et al.* (2000).

3 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 × 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 (that is in the moist deciduous forest zone) and the other two were from the coastal area (that is 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, and the like) with a circumference of ≥10 cm at breast height (at 132 cm) were enumerated as trees. For convenience during the enumeration, each plot was split into five strips (20 × 100 m) and each tree was numbered with an 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, and so on 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 percentage of canopy gap or opening. Biomass productivity of tree, shrub and herb layer was followed using the method used by Prasad *et al.* (1987).

4 Results and discussion

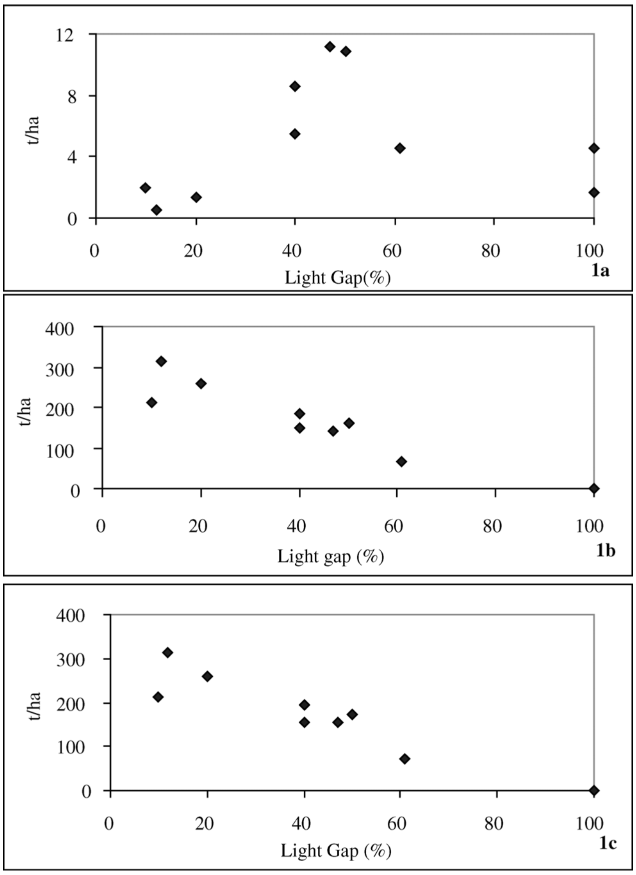
In the forests of Uttara Kannada, variation in stem density and biomass was high indicating that the management regimes and the topography might be influencing them. The tree density was highly variable from 306 stems per ha in Bidralli to 1619 in Nagur forests. Similarly shrub and total stem density 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 t/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). Divgi and Nagur cross, which were devoid of trees, had 1.6 and 4.5 t/ha of 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 a 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.

Table 1 Biomass production and stem density of different layers in reserve and minor forests of Uttara Kannada district

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

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 ($r^2 = 0.8978$)



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). Though the relation between shrub biomass and light gap is negative, it is not significant (–0.545). Tree biomass seems to influence the total biomass significantly indicating that the tree layer contributes much of the above ground biomass (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 a highly influencing factor for standing biomass. The results are similar to the one obtained in other parts of tropics (Percy, 1983; Chazdon, 1986; Chazdon *et al.*, 1996; Montegmory and Chazdon, 2002).

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 grasslands devoid of trees are normally highly characterised by water and nutrient leached areas, with shallow and less fertile soils. Therefore, productivity may be less in these areas, 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/ha would lead to sufficient biomass at tree and herb layer so that the community may derive the desired benefits from the forests. Studies relating to agroforestry 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 the slash and burning system in the northeastern region of India a tree density of 180/ha was observed with a high productivity of cereal crops (Uma shankar, 2001). The results of this study and the experience elsewhere also indicate that the agroforestry option seems more appropriate to enhance biomass productivity to meet the rural needs and to decrease reliance on the already depleting forests. Further, the study indicates a threshold light gap is essential for maximum above ground herb layer productivity. The majority of cereal crop plants and grasses are C_4 plants that require sufficient light and have 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

Anderson, L.S. and Sinclair, F.L. (1993) 'Ecological interactions in agroforestry systems', *Agroforestry Abstracts*, Vol. 6, pp.57–91.

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. (Eds.): *Growth and Water Use Efficiency of Forest Plantations*, Sage publications, New Delhi.

Bhat, D.M., Naik, M.B., Patgar, S.G., Hegde, G.T., Kanade, Y.G., Hegde, G.N., Shastri, C.M., Shetti, D.M. and Furtado, R.M. (2000) 'Forest dynamics in tropical rainforests of Uttara Kannada district in Western Ghats, India', *Current Science*, Vol. 79, No. 7, pp.975–985.

Champion, H.G. and Seth, S.K. (1968) *A Revised Survey of Forest Types of India*, Government of India Press, Nasik, India.

Chazdon, R.L. (1986) 'Physiological and morphological basis of shade tolerance in rain forest understorey palms', *Principes*, Vol. 30, pp.92–99.

Chazdon, R.L., Percy, R.W., Lee, D.W. and 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.

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*, Vol. 68, pp.877–889.

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*, Vol. 13, pp.41–62.

Knoop, W.T. and Walker, B.H. (1985) 'Interactions of woody and herbaceous vegetation in a South African Savanna', *Journal of Ecology*, Vol. 73, pp.235–253.

Montegmory, R.A. and Chazdon, R.L. (2002) 'Light gradient partitioning by tropical tree seedlings in the absence of canopy gaps', *Oecologia*, Vol. 131, pp.165–174.

Murthy, I.K., Bhat, P.R., Ravindranath, N.H. and Sukumar, R. (2002) 'Quantification and financial evaluation of non-timber forest products flows in Uttara Kannada district, Western ghats, Karnataka', *My Forest*, Vol. 38, No. 3, pp.237–246.

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*, Vol. 40, No .1, pp.109–117.

Pascal, J.P. (1988) *Wet Evergreen Forests of Western Ghats of India*, Institute de Francais Pondicherry, India.

Percy, R.W. (1983) 'The light environment and growth of C_3 and C_4 species in the understorey of a Hawaiian forest', *Oeclogia*, Vol. 58, pp.26–32.

Prasad, S.N., Hegde, H.G., Bhat, D.M. and Hegde, M. (1987) 'Estimates of standing biomass and productivity of tropical moist forests of Uttara Kannada district, Karnataka, India', *CES Technical Report No. 19*, Bangalore, India.

Puri, G.S. (1960) *Indian Forest Ecology*, Oxford Book Co., New Delhi, India.

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*, Vol. 18, pp.183–195.

Sandford, W.W., Usman, S., Obot, S.E., Isichei, A.O. and Wari (1982) 'Relationship of woody plants to herbaceous production in Nigerian savanna', *Tropical Agriculture*, Vol. 59, pp.315–318.

Tiedemann, A.R. and Klemmendson, J.O. (1977) 'Effect of mesquite tree on vegetation and soils in the desert grasslands', *Journal of Range Management*, Vol. 26, pp.27–29.

Uma shankar (2001) 'Increasing biomass scarcity in northeastern India: options with the villagers', in: Arunachalam, A. and Khan, M.L. (Eds.): *Sustainable Management of Forests - India*, International Book Distributors, Dehradun, India.

Vetas, O.R. (1992) 'Micro-site effects of tree and shrubs in a dry savanna', *Journal of Vegetation Science*, Vol. 3, pp.337–344.