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LIANAS AND SHRUBS REGENERATION, DISTRIBUTION PATTERN AND DIVERSITY IN TROPICAL FOREST ECOSYSTEM OF CHHATTISGARH

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ABSTRACT

Lianas are important components of tropical forests and have significant impacts on the diversity, structure and dynamics of tropical forests ecosystem, but may also have negative impacts on tree growth and productivity. The study censured lianas and shrubs in four sites (High, medium, low and non-fire zone) were selected; in each of these sites pre-fire and post-fire observation were taken for measuring different parameters. The density (Lianas and shrub) was varied from 1120 to 2480 individuals ha^{-1} during the pre-fire season and 1920 to 3360 individuals ha^{-1} at the time of post-fire season. The Shannon index values were varied from 2.35 to 3.13, equitability 1.28 to 1.37, species richness 0.71 to 1.17, concentration of dominance 0.12 to 0.22 and beta diversity 1.10 to 1.83 during pre-fire season. The total 11 species were recorded during pre-fire season whereas it had increase after the fire (20 species). Abundance to frequency ratio of the study indicated that the most of species showed contagious and random distribution pattern during pre-fire season while in the post-fire most of the species may distributed contagiously, few species were distributed randomly and regularly across the forest sites.

INTRODUCTION

The woody climbing plants, lianas and shrubs are important components of tropical forests. They typically rely on other plants for mechanical support and are abundant, diverse and make a significant contribution (10-25%) to the overall plant diversity in the tropical forests (Gentry and Dodson, 1987; Nabe-Nielsen, 2001). Before the 1980s, limited attention is paid to lianas in the tropical forest. Recent years, however, more and more studies about lianas have been conducted due to the awareness of the important role of lianas in the tropical forest ecosystems (Schnitzer, 2005; Gerwing *et al*., 2006). Even though, the ecology of lianas in most forests is still poorly understood (Mascaro *et al*., 2004).

Lianas constitute an important structural aspect of the tropical forest ecosystem (Parren and Bongers, 2001; Schnitzer and Bongers, 2002; Mascaro *et al*., 2004; Phillips *et al*., 2005). Apart from contributing to biological diversity in moist forests, lianas serve many vital functions in tropical forest ecosystems. These functions include the provision of arboreal pathways for canopy vertebrates and facilitating structural continuity of forest canopy over large distances (Parren and Bongers, 2001). Although lianas are important in the forest ecosystem, they also have negative impacts on growth and productivity of tropical forest trees (Schnitzer and Bongers, 2002). Lianas and shrubs can affect tree growth, through competition for nutrients, light and other resources, or by delaying regeneration of trees following disturbance. For this reason, they are cut as a silvicultural intervention in many managed tropical forests (Parren and Bongers, 2001). Liana cutting combined with other silvicultural thinning and liberation operations result in canopy opening that facilitates regeneration and promotes tree growth. However, one of the unintended effects of the resulting increase in light availability is the chance for the regeneration/ resprouting of lianas (Hegarty and Caballe, 1991) as the increased availability of light may be an advantage for climber regeneration (Putz, 1991; Schnitzer and Bongers, 2002). Indeed, some lianas may react to cutting by vigorous vegetative reproduction of many new stems that can eventually take over the openings created at the expense of the desired tree regeneration (Putz, 1991). Several studies dealing with the floristic and ecological features of the tree layers have been carried out however, the study on lianas and shrubs have neither yet been studied or little research has been done in this areas. To fill this knowledge gap, the present paper reports the regeneration, distribution and diversity of lianas and shrubs species, based on data gained from forest fire areas during pre-fire and post-fire season.

MATERIALS AND METHODS

The study was carried out at Bhoramdeo Wildlife Sanctuary of Kawardha Forest Division in Chhattisgarh, after the repeated reconnaissance survey of Bhoramdeo Wildlife Sanctuary. The study area is located between 21°23′-22°00′ North latitude and 80°58′-82°34′ East longitude. The whole part is hilly and is situated at a height of 600 to 900m from the sea level. The entire area of Bhoramdeo Wildlife Sanctuary is located in the Maikla Range of the Satpura hills. Total four sites were selected; in each of these sites pre-fire and post-fire observation were taken. The vegetation data were collected was analysed in different fire zones (*i.e.,* high, medium, low and non-fire zones). A quadrat, of 5 x 5m size was randomly laid for measuring both lianas and shrubs. The lianas and shrubs were measured at the collar height. Vegetational data were quantitatively analysed for frequency, density, abundance (Curtis and McIntosh, 1950) and A/F ratio (Whiteford, 1949). The relative frequency, relative density and relative basal area values were calculated following Phillips (1959). Diversity indices were calculated following Sagar and Singh (1999).

RESULTS AND DISCUSSION

In the pre-fire season the number of lianas and shrub species was maximum in the high fire zone (*i.e.,* 10 species) and minimum (Table 1) in the non-fire zone (6 species). The medium and low fire zone recorded similar number of species. Maximum density of lianas and shrub (2480 individuals ha^{-1}) was recorded in the medium fire zone and minimum (1120 individuals ha^{-1}) in the non-fire zone. The high and low fire zones showed 2080 individuals ha^{-1} and 1840 individuals ha^{-1}, respectively. The maximum basal area (1.11 $m^2 ha^{-1}$) was recorded for non-fire zone and minimum (0.59 $m^2 ha^{-1}$) for high fire zone (Table 2). The Shannon index values were varied from 2.35 to 3.13, equitability 1.28 to 1.37, species richness 0.71 to 1.17, concentration of dominance 0.12 to 0.22 and beta diversity 1.10 to 1.83. Abundance to frequency ratio of the study indicated that the most of species showed contagious and random distribution pattern during pre-fire season. The values of A/F ratio across the fire zone were varied from 0.02 to 0.30.

In the high fire zone *Bauhinia vahlii* (400 individuals ha^{-1}) and *Ventilago cayculata* (320 individuals ha^{-1}) recorded highest density. The highest basal area values were recorded by the *Zizyphus xylopyra* (0.22 $m^2 ha^{-1}$) and *Butea superba* (0.17 $m^2 ha^{-1}$). The IVI values in this zone ranged from 11.18 to 55.51. The medium fire showed that *Zizyphus xylopyra* (640 individuals ha^{-1}) and *Ventilago cayculata* (480 individuals ha^{-1}) recorded highest density. The basal area value was highest in *Zizyphus xylopyra* (0.31 $m^2 ha^{-1}$) and *Carissa spinarum* (0.10 $m^2 ha^{-1}$). The IVI values in this zone ranged from 25.99 to 99.11. The result in the low fire zone stated that *Ventilago cayculata* (640 individuals ha^{-1}) and *Mimusops hexandra* (400 individuals ha^{-1}) had the highest density followed by *Butea superba*. The highest basal area values recorded by the *Butea superba* (0.27 $m^2 ha^{-1}$) and *Ventilago cayculata* (0.18 $m^2 ha^{-1}$). The IVI values in this site ranged from 17.77 to 84.29. In the non-fire zone the *Mimusops hexandra* (400 individuals ha^{-1}) and *Embelia robusta* (240 individuals ha^{-1}) recorded highest density. The highest basal area values were recorded by *Ventilago cayculata* (0.55 $m^2 ha^{-1}$) and *Butea superba* (0.33 $m^2 ha^{-1}$). The IVI values were ranged from 29.60 to 81.53.

During the post-fire season total 20 species were encountered in the whole forest area. The total density value of the lianas and shrubs species were varied from 1920 individuals ha^{-1} to 3360 individuals ha^{-1} across the fire zones. The basal area was recorded in the range of 0.11 $m^2 ha^{-1}$ to 0.23 $m^2 ha^{-1}$ for medium and high fire zone, respectively. The number of species was noticed maximum in the medium fire zone (15) while minimum in high fire zone (12). The Shannon index values were varied from 3.34 to 3.69, equitability 1.29 to 1.40, species richness 1.45 to 1.72, concentration of dominance 0.083 to 0.114 and beta diversity 1.33 to 1.66. The post-fire study showed that most of the species may

Table 1: Regeneration of lianas and shrubs species in different fire zones during the pre-fire and post-fire season in Bhoramdeo Wildlife Sanctuary

Species	Pre-fire season				Post-fire season			
	High fire zone	Medium fire zone	Low fire zone	Non- fire zone	High fire zone	Medium fire zone	Low fire zone	Non- fire zone
Asparagus recimosus	-	-	-	-	-	+	-	-
Bauhinia racemosa Lam.	+	-	+	-	+	+	+	+
Bauhinia vahlii (W.) A.	+	+	+	-	+	+	+	+
Butea superba Roxb. ex Willd.	+	+	+	+	+	+	+	+
Carissa spinarum D.C.	+	+	+	-	-	-	+	-
Cryptolepsis buchanani	-	-	-	-	+	-	-	-
Dioscaria dremona	-	-	-	-	-	+	+	+
Dioscaria spp Roxb.	+	-	-	-	+	+	+	+
Embelia robusta Roxb.	+	+	+	+	-	-	-	-
Grewia hirsuta	-	-	-	-	-	+	-	+
Holarrhena antidysenterica	-	-	-	-	-	+	-	-
Ichnocarpus frutescens	-	-	-	-	+	+	+	+
Mallotus phillippinensis Muell.	+	+	-	-	-	+	-	+
Mimusops hexandra Roxb.	-	-	+	+	-	-	-	-
Phoenix acaulis	-	-	-	-	+	-	-	-
Smilax macrophlla	-	-	-	-	-	-	+	+
Spatholobus roxburgii Benth.	+	-	-	+	+	-	+	-
Vallaris heyner	-	-	-	-	+	+	+	+
Ventilago cayculata Tul.	+	+	+	+	+	+	+	+
Viavidon spp.	-	-	-	-	-	+	+	+
Waltheria indica	-	-	-	-	+	+	+	+
Zizyphus xylopyra (Retz.)Willd.	+	+	-	+	+	+	+	+

+ indicating presence of the species whereas — indicating absent of the species in different fire zone distributed contagiously, few species were distributed randomly and regularly across the all forest sites. The values of A/F ratio across the fire zone were varied from 0.01 to 0.15.

In high fire zone *Dioscaria spp.* (400 individuals ha^{-1}) recorded highest density followed by *Ventilago cayculata, Bauhinia vahlii* and *Spatholobus roxburgii*, while higher basal area values recorded by the *Cryptolepsis buchanani* (0.09 m^2 ha^{-1}). The IVI values ranged from 10.24 to 47.22. The medially fire affected zone showed that *Dioscaria spp.* recorded highest density (720 individuals ha^{-1}), whereas *Asparagus recimosus, Grewia hirsuta, Ichnocarpus frutescens, Waltheria indica* and *Viavidon spp.* was lowest in density (80 individuals ha^{-1} for each species) among the all species. The basal area ranged from 0.001 (*Asparagus recimosus*) to 0.024 m^2 ha^{-1} (*Butea superba*). The IVI values in this site ranged from 6.07 to 41.82. In case of the low fire zone *Ventilago cayculata* (480 individuals ha^{-1}) and *Dioscaria spp.* (320 individuals ha^{-1}) exhibited higher density, while the maximum basal area was recorded by *Ventilago cayculata* (0.05 m^2 ha^{-1}). The IVI values were ranged from 6.07 to 41.82. Based on the higher IVI values *Ventilago cayculata* and *Dioscaria spp* were recognized as dominant species in this zone. The non-fire zone revealed that *Dioscaria spp.* (320 individuals ha^{-1}) and *Grewia hirsuta* (240 individuals ha^{-1}) recorded highest density value, whereas highest basal area values were recorded by *Butea superba* (0.04 m^2 ha^{-1}) and *Ventilago cayculata* (0.027 m^2 ha^{-1}). The IVI values in this zone ranged from 11.57 (*Waltheria indica*) to 42.56 (*Butea superba*).

Fires occurring naturally have been known over since the evolution of land plants some 350 to 400 million years ago. The first evidence of a wildfire in the world dates back to the early carboniferous era (FAO, 2001). Although humans had introduced fire in the study site forests from the past. Increase fragmentation of forests and continued demand on forest resources has contributed to detrimental changes in the spatial and temporal characteristics of the present fire regime (Kodandapani *et al.*, 2004). An increase in the magnitude of various components of the fire regime has been accompanied by large scale changes in structure, composition and regeneration of the Indian forests. Lasse and Salo (2009) revealed the variation in fire intensity had a clear impact on post-fire recovery in natural conditions. The fire disturbances also clearly enhanced local species richness and diversity. Kodandapani *et al.* (2008) also reported that the forest fires in tropical dry thorn forests had a marginal positive effect on ecosystem diversity, structure and regeneration. The density of lianas and shrub was highest under medium fire zone in both fire season and minimum under non-fire and low fire zones during pre-fire season while it is noticed lower in high fire zone during post-fire season. Natural regeneration potential for lianas and shrubs was recorded more in fire affected zone as compared to non-fire zone. The maximum numbers of species germinates or emerge from perennating organs, or vegetatively or there may be less competition due to open canopy (Perez-Salicrup *et al.*, 2001; Gianoli *et al.*, 2010; Schnitzer *et al.*, 2012). Shrubs are generally believed to increase prolifically after fire due to the fact that heat may stimulate the seed germination of some of the shrub species which may results in an increase in population density (Rodgers *et al.*, 1986). Mishra *et al.* (2008) were also reported similar findings and stated that a higher number of shrubs in the buffer area which having the greater anthropogenic disturbance (Sahu *et al.*, 2008).

Gerwing and Vidal (2002) have reported 2500 individuals/ha for liana and shrubs species. The higher density of shrubs and lianas of the region due to fire derived nutrient deposition (Asner *et al.*, 1997; Chen *et al.*, 2010). Hart *et al.* (1996) found evidence of small widespread fires associated with increased human activities. The forest fire in addition to the intermittent canopy structure provides suitable habitats to the development and high abundance of shrubs and lianas. Kafle (2004) reported that in the protected area irrespective of high species abundance and richness, diversity indices was slightly lower than in burnt area and also stated that protected area contained 71% of total number of shrub species whereas burnt area had higher (79%) shrub species in the sampled area of tropical forest of Thailand. Similar findings in India also made by Kumar and Thakur (2008) and reported that seedling density of shrubs was higher on occasional fire affected sites than control sites. In many ecosystems, fire is a part of the natural regeneration

Table 2: Comparisons of community characters of different forest fire zones of Bhoramdeo Wildlife Sanctuary during pre-fire and post-fire season

Pre-fire season	Characters	High Fire Zone	Medium Fire Zone	Low Fire Zone	Non-Fire Zone
Vegetation Layer	Species	10	7	7	6
Lianas and Shrubs	Density (individuals ha^{-1})	2080	2480	1840	1120
	Basal Area (m^2h^{-1})	0.59	0.65	0.67	1.11
	Shannon Index (H)	3.13	2.67	2.50	2.35
	Simpson's Index (Cd)	0.12	0.16	0.20	0.22
	Species richness (d)	1.17	0.76	0.79	0.71
	Equitability (e)	1.36	1.37	1.28	1.31
	Beta diversity (βd)	1.10	1.57	1.57	1.83
Post-fire season	Species	12	15	14	14
Lianas and Shrubs	Density (individuals ha^{-1})	1920	3360	2640	2160
	Basal Area (m^2h^{-1})	0.23	0.11	0.16	0.17
	Shannon Index (H)	3.34	3.49	3.62	3.69
	Simpson's Index (Cd)	0.114	0.112	0.092	0.083
	Species richness (d)	1.45	1.72	1.65	1.70
	Equitability (e)	1.34	1.29	1.37	1.40
	Beta diversity (βd)	1.66	1.33	1.42	1.42

process, stimulating the germination of certain species clearing space for the invasion and growth of others and releasing a periodic flush of nutrients into the soil (Dawson *et al*., 2002).

Uniyal *et al*. (2010) have reported that the two types of forests behave differently in terms of impact of disturbance on level of species richness, density and diversity. The shrubs species richness was highest in moderately disturbed stand. Higher density and species richness of shrubs in moderately disturbed stand indicate that opening of canopies favours shrubs growth, which given overall stability to the forest ecosystem. In contrary to the present estimates, Uniyal *et al*. (2010) stated the higher density of shrubs recorded under the undisturbed stand. According to Khurana and Saxena (2009), the disturbance occurs in chronic form where a small part of forest is removed at a given time, beside this natural competition, forest fire grazing and deforestation are other important causes of disturbances. Density and abundance of Shrub layer ranged between 52.25 and 97.6 Individuals 100 m^{-2} and 65.25 and 122.13 Individuals 100m^{-2}, respectively. Species richness of shrub layer decreased with decreasing disturbances. Species diversity decreased in similar fashion as species richness. Khurana and Kalpana (2008) also concluded that high value of biodiversity in an area indicated high level of biological disturbances. Verma *et al*. (2009) in his study observed that the forest is composed of 32 species of shrubs and the index of similarity between two altitudes was 0.65 indicating remarkable degree of similarity in species. Rastogi and Rastogi (2007) estimated higher density per ha of shrubs varied between 18800-42112. Total basal cover (m^2 per ha) of shrubs ranged between 0.138-0.952 which is found well within the range of present study. Diversity index varied between 0.743-0.876 for shrubs and similarity index were between 22-48%. Various study also revealed a higher level of disturbance like fire, grazing, felling etc. altered structure, diversity, composition and other characteristics. Vegetation showed a trend of change from its original community structure (Chettri *et al*., 2006; Biswas, 2007; Anitha *et al*., 2007). Negi and Nautiyal (2005) reported 24 species of shrubs for central Himalayas and the diversity value ranges from 3.32 to 3.94 for shrubs and the beta diversity was 1.30, respectively. Pande *et al*. (2002) showed the density of shrubs (100 m^{-2}) was 23.56-41.62 while the range for total basal cover was 9.50-18.81 cm^2/100 m^2 for shrubs. The diversity of shrubs (species richness) was 9-14, concentration of dominance shows reverse trend to diversity and it was 0.13-0.15. Diversity index varies from 1.53-2.31 for shrubs while the beta diversity between 2 sites of forests was 1.25 and 3.67. Barbhuiya *et al*. (2012) calculated the basal area of shrubs 0.37 m^2 ha^{-1} for highly disturbed, 0.60 m^2 ha^{-1} for moderately disturbed and 2.61 m^2 ha^{-1} for undisturbed stand of tropical wet evergreen forest of north east India.

The quantity of humus deposition was optimum under medium fire zone this helps for to easily uptake of nutrients from the soil. Danielle *et al*. (2005) reported that the humus characteristics significantly explained the distribution of understory and other species of the ecosystem. The abundance and distribution of lianas usually depend on abiotic factors including elevation, rainfall and seasonality, soil fertility and disturbance (Gentry, 1991; Balfour and Bond, 1993; Schnitzer and Bongers, 2002; Pitman *et al*., 2002). The liana abundance and diversity are thought to peak in the lowland and decline with increasing latitude and elevation (Gentry, 1991; Schnitzer and Bongers, 2002). On the other hand, lianas abundance is strongly dependent on the availability of tree-fall gaps in dense tropical forest resulted from the natural and/or anthropogenic disturbance (Putz, 1983; Laurence *et al*., 2001; Schnitzer and Bongers, 2002; Schnitzer and Bongers, 2011; Schnitzer *et al*., 2012). The decline of species richness in time after forest fire disturbance might be caused primarily by the elimination of some early species which were over topped and shaded out by rapidly growing woody plants, especially resprouters (Miller, 2000). The effect of declining species richness also documented by Gill *et al*. (1999) as a characteristic in arid and semi-arid forested regions. In this study we found that the protected area contained more species as compared to the severe burnt area after the fire (post-fire season). This suggests that forest fire protection decreased the killing or damaging of the species, which ultimately will lead to increased productivity and organic matter in soil, thus more favorable conditions for growing. This also supports the findings made by Naidu and Sribasuki (1994) that young ones are more badly affected by fire than mature ones.

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REFERENCES

Anitha, K., Balasubramanian, P. and Prasad, S. N. 2007. Tree community structure and regeneration in Anaikatty hills, Western Ghats. *Indian J. Forestry*. **30(3):** 315-324.

Asner, G. P., Seastedt, T. R. and Townsend, A. R. 1997. The decoupling of terrestrial carbon and nitrogen cycles. *Bioscience*. **47:** 226-234.

Balfour, D. and Bond, W. 1993. Factors limiting climber distribution and abundance in a southern African forest. *J. Ecol*. **6:** 93-99.

Barbhuiya, A. R., Arunachalam, A., Panday, H. N., Khan, M. L. and Arunachalam, K. 2012. Fine root dynamics in undisturbed and disturbed stands of a tropical wet evergreen forest in northeast India. *Tropical Ecology*. **53(1):** 69-79.

Biswas, S. R. 2007. Anthropogenic influences on the tropical evergreen Dipterocarp forests of Bangladesh: a phytosociological perspective. *International J. Ecology and Environmental Sciences*. **33(1):** 41-52.

Chen, Y., Randerson, J. T., Van der Werf, R., Morten, G. R., Mu, M. and Kasibhatla, P. S . 2010. Nitrogen deposition in tropical forests from savanna and deforestation fires. *Global Change Biology*. **16:** 2024-2038.

Chettri, S. K., Singh, K. K. and Krishna, A. P. 2006. Anthropogenic pressures on the natural resources in fringe areas of the Khangchendzonga Biosphere Reserve. *International J. Ecology and Environmental Sciences*. **32(3):** 229-240.

Curtis, J. T. and McIntosh, R. P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*. **31:** 434-455.

Danielle, van O., F. Markus, H., de O. Jan Patrick and Rein, de W. 2005. Effect of tree species on within-forest distribution of understorey. *Annual Review of Ecology and Systematics*. **18:** 431-451.

Dawson, T. P., Butt, N. and Miller, F. 2002. The ecology of forest fires. *ASEAN Biodiversity*. **1:** 18-21.

FAO, 2001. *The Global Forest Resources Assessment 2000 - main* *report*. FAO Working Paper, **55:** 189-191, FAO, Rome.

Gentry, A. H. 1991. The distribution and evolution of climbing plants, p. 3-52. In F.E. Puts and H.A. Mooney (Eds.). The biology of vines. Cambridge University, Cambridge England.

Gentry, A. H. and Dodson, C. 1987. Contribution of nontrees to species richness of a tropical rain forest. *Biotropica*. **19:** 149–156.

Gerwing, J. J. and Vidal, E. 2002. Changes in liana abundance and species diversity eight years after liana cutting and logging in an Amazonia forest. *Conservation Biology*. **16:** 544-548.

Gerwing, J. J., Schnitzer, S. A., Burnham, R. J., Bongers, F., Chave, J., DeWalt, S. J., Ewango, C. E. N., Foster, R., Kenfack, D., Martínez-Ramos, M., Parren, M., Parthasarathy, N., Pérez-Salicrup, D. R., Putz, F. E. and Thomas, D. W. 2006. A standard protocol for liana censuses. *Biotropica*. **38:** 256–261.

Gianoli, E., Saldana, A., Jimenez-Castillo, M. and Valladares, F. 2010. Distribution and abundance of vines along the light gradient in southern temperate rain forest. *J. Vegetation Science*. **21**: 66-73.

Gill, M., Woinarski, J. and York, A. 1999. Australia's biodiversity responses to fire. Biodiversity technical report No. 1, Environment Australia. pp. 266.

Hart, T. B., Hart, J. A., Deschamps, R., Fournter, M. and Ataholo, M. 1996. Changes in forest composition over the last 4000 years in the Ituri basin Zaire. In L.J.G. van der Maesen, X.N. van de Burget and J.M. Medenbach de Rooy (Eds.). The Biodiversity of African Plants, pp. 545-563. Proceedings XIVth AETFAT Congress, 22-27 August 1994, Wageningen, The Netherlands.

Hegarty, E. E. and Caballe, G. 1991. Distribution and abundance of vines in forest communities. *In*: Putz, E.F., Mooney, H.A. (Eds.). *The Biology of Vines*, Cambridge University Press, pp. 313-335.

Kafle, S. K. 2004. Effects of Forest Fire Protection on Plant Diversity in a Tropical Deciduous Dipterocarp-Oak Forest, Thailand. Proceedings of the second international symposium on fire economics, planning and policy: A Global View. pp. 465-472.

Khurana, P. and Kalpana 2008. Phytodiversity study in natural forest of Hastinapur. *Indian Forester*. **134(4):** 554-562.

Khurana, P. and Saxena, R. S. 2009. Vegetation analysis along the disturbance gradient in tropical dry deciduous forest of Hastinapur. *Indian Forester*. **135(5):** 678-690.

Kodandapani, N., Cochrane, M. and Sukumar, R. 2008. A comparative analysis of spatial, temporal and ecological characterstics of forest fires in seasonally dry tropical ecosystems in the Western Ghats, India. *Forest Ecology and Management*. **256:** 607-617.

Kodandapani, N., Cochrane, M. A. and Sukumar, R. 2004. Conservation threat of increasing fire frequencies in the Western Ghats, India. *Conservation Biology*. **18(6):** 1553-1561.

Kumar, R. and Thakur, V. 2008. Effect of forest fire on trees, shrubs and regeneration behavior in Chir-pine forest in northern aspects under Solan forest division. Himachal Pradesh. *Indian J. Forestry*. **31(1):** 19-27.

Lasse, R. and Salo, K. 2009. The effect of fire intensity on vegetation succession on a sub-xeric health during ten years after wildfire. *Ann. Bot. Fennici*. **46:** 30-42.

Laurance, W. F., Perez-Salicrup, D., Delamonica, P., Fearnside, P. M., D'angelo, S., Jerozolinski, A., L. Pohl and Lovejoy, T. E. 2001. Rain forest fragmentation and the structure of Amazonian liana communities. *Ecology*. **82:** 105-116.

Mascaros, J., Schnitzer, S. A. and Carsonc, W. P. 2004. Liana diversity, abundance, and mortality in a tropical wet forest in Costa Rica. *For. Ecol. Manage.* **190**: 3-14.

Miller, M. 2000. Wildland fire in ecosystems, effects of fire on flora. *RMRS-GTR-42*. **2:** 275.

Mishra, R. K., Upadhyay, V. P. and Mohanty, R. C. 2008. Vegetation Ecology of the Simplipal Biosphere Reserve, Orissa India. *Applied Ecology and Environment Research*. **6(2):** 89-99.

Nabe-Nielsen, J. 2001. Diversity and distribution of lianas in a neotropical rain forest, Yasun National Park, Ecuador. *J. Trop. Ecol.* **17:** 1-19.

Naidu, C. V. and Srivasuki, K. P. 1994. Effect of Forest fire on Tree Species on different areas of Aeshachalam Hills. *Journal of Tropical Forestry*. **10(III):**115 - 121.

Negi, C. S. and Nautiyal, S. 2005. Phytosociological studies of a traditional reserve forest -Thalke Dhar, Pithoragarh, Central Himalayas. *Indian Forester*. **13(4):** 535.

Pande, P. K., Negi, J. D. S. and Sharma, S. L. 2002. Plant species diversity composition. Gradient analysis and regeneration behaviour of some tree species in a moist temperate Western Himalayan forest ecosystem. *Indian Forester*. **128(8):** 869-885.

Parren, M. P. E. and Bongers, F. 2001. Does climber cutting reduce felling damage in southern Cameroon? *For. Ecol. Manage*. **141:** 175-188.

Perez-Salicrup, D. R., Sork, V. L. and Putz, F. E. 2001. Liana and trees in a liana forest in Amazonian Bolivia. *Biotropica*. **33:** 34-47.

Phillips, E. A. 1959. Methods of Vegetation Study. Holt R and Winston New York USA. pp. 105.

Phillips, O. L., Martínez, R. V., Mendoza, A. M., Baker, T. R. and Vargas, P. N. 2005. Large lianas as hyperdynamic elements of the tropical forest canopy. *Ecology*. **86(5):** 1250-1258.

Pitman, N. C. A., Terborgh, J. W., Silman, M. R., Nunez, P., Neill, D. A., Ceron, C. E., Palacios, W. A. and Aulestia, M. 2002. A comparison of tree species diversity in two upper Amazonian forests. *Ecology*. **83**: 3210-3224.

Putz, F. E. 1983. Liana biomass and leaf area of a "tierra firme" forest in the Rio Negro basin, Venezuela. *Biotropica*. **15:** 185-189.

Putz, F. E. 1991. Silvicultural effects of vines. *In*: Putz, F.E., Mooney, H.A., (Eds.). *The Biology of Vines*, Cambridge University Press, Cambridge, UK. pp. 493-501.

Rastogi, N. and Rastogi, A. 2007. Phytosociological analysis of the restored sal (*Shorea robusta*) plantations and natural sal forest of Tripura. *Indian Journal of Forestry*. **30(4):** 377-385.

Rodgers, W. A., Bennet, S. S. R. and Sawakar, W. B. 1986. Fire and vegetation structure in Sal forests, Dehradun, India. *Tropical Ecology*. **27(1):** 49-61.

Sagar, R. and Singh, J. S. 1999. Species diversity and its measurement. *The Botanica*. **49:** 9-16.

Sahu, P. K., Sagar, R. and Singh, J. S. 2008. Tropical forest structure and diversity in relation to altitude and disturbance in a Biosphere Reserve in central India. *Applied Vegetation Science*. **11:** 461–470.

Schnitzer, S. A. 2005. A mechanistic explanation for global patterns of liana abundance and distribution. *Am. Nat.* **166:** 262-276.

Schnitzer, S. A. and Bongers, F. 2002. The ecology of lianas and their role in forests. *Trends in Ecology and Evolution*. **17:** 223-230.

Schnitzer, S. A. and Bongers, F. 2011. Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. *Ecology Letters*. 1-10.

Schnitzer, S. A., Bongers, F. and Powers, J. 2012. Understanding the increase in lianas in neotropical forests. In: Symposium (12) "Ecology, Evolution and Sustainable use of Tropical Biodiversity", 18-22 June, 2012. Bonito Convention Center, Brazil.

Uniyal, P., Pokhriyal, P., Dasgupta, S., Bhatt, D. and Todaria, N. P. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. *Current Science*. **98(7):** 938-943.

Verma, R. K., Subramani, S. P., Kapoor, K. S. and Kumar, S. 2009. Plant species diversity along an altitudinal gradient in Simbalwara Wildlife Sanctuary, Himachal Pradesh. *Indian J. Forestry*. **32(2):** 195-209.

Whiteford, P. B. 1949. Distribution of woodland plants in relation to succession and colonal growth. *Ecology*. **30:** 199-200.