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Vegetational Structure, Diversity and Fuel Load in Fire Affected Areas of Tropical Dry Deciduous Forests in Chhattisgarh

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Forest fires are shaping forest vegetation and landscape in many parts of India and cause great loss to the forest ecosystem, diversity of flora and fauna and economic wealth. The study was conducted to analyze the structure and diversity of vegetation in different fire regimes and to assess the fuel load in tropical dry deciduous forest. Delineation and identification of fire prone areas were done on the basis of historical ground fire data in conjunction with satellite remote sensing data provided by NRSA. The composition, structure and diversity of different forest fire zones was conducted by stratified random sampling to measure trees, saplings, seedlings, shrubs, herbs and litter. The regeneration pattern of the different forest fire zones was prepared by graphical population structures. The fuel load for each fire zones was estimated. The duffs litter and wood litter of all fire zones were weighed separately. Along the fire gradients the tree species exhibited highest density of seedlings in low fire zone. The highest density of saplings and trees were present in non-fire zone whereas shrubs and herbs layer showed the highest density in medium fire zone. In this study we found that non-fire zone contained more species as compared to burnt areas. The diversity pattern showed that the medium fire zone showed maximum diversity followed by non-fire zone, whereas low fire zone had minimum Shannon index. The regeneration pattern of tree species in all the fire zones and non-fire zone generally showed five general patterns. In the high fire zone the seedlings were much affected which will result discontinuation of conversion into saplings with the progress of time and ultimately the gap in the regeneration status.

Keywords: Diversity, fuel load, vegetation, regeneration pattern

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INTRODUCTION

Tropical forests cover only 7% of the earth's surface but harbor more than half of the world's species. In India, out of 86% of the tropical forest area, 54% is dry deciduous, 37% moist deciduous and rest is wet evergreen or semi evergreen (Kaul and Sharma 1971) and out of 67.5 million ha of forests, about 55% of the forest cover is being subjected to fires each year (Gubbi 2003). Forest fires cause enormous loss to the forest ecosystem, diversity of flora and fauna, and economic wealth. Majority of these forests burning are surface fires, deliberately linked to human activities and has close relationship to their socio-economic conditions. The shifts in species composition in natural forest occur slowly under normal conditions but catastrophic disturbances like repeated fires can reduce structural and biological complexity in forests. The vegetation and the species composition of a forest are the decisive factors for forest fire. Tree species diversity in the tropics varies dramatically from place to place (Pitman 2002). Much attention has been given to tropical forests due to their species richness, high standing biomass and greater productivity. The study of floristic composition of trees, shrubs, herbs in quantitative terms in fire prone areas helps in

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better understanding of the complex dynamics of ecological changes taking place in space and time, fertility status of forests and habitats of both flora and fauna. The database on occurrence and distribution of floral species provides useful information for prioritizing sites for conservation. The objective of present study was to delineate the fire affected areas and identify different fire regimes in Dry-Deciduous Forests of Bhoramdeo Wildlife Sanctuary and how species structure and diversity respond to the forest fire.

METERIALS AND METHODS

Study Area

This study was carried out at Bhoramdeo Wildlife Sanctuary in Kabirdham district of Chhattisgarh during the year 2009-2010. The study area is located between 22^0 23 to 22^0 00 N latitudes and 80^0 58 to 82^0 34 E longitudes (Figure 1). The entire area of Bhoramdeo Wildlife Sanctuary is located in the Maikla Range of the Satpura hills. The whole part is hilly and is situated at a height of 600 to 900 m from the sea level. Nearly whole of the Sanctuary area is under the Chilphi group formation of Archean age class. In this range granite and cyst basic and ultrabasic rocks are included. The mean monthly annual temperature ranges from 16.5^0 C in December to 40.8^0 C in May. The mean annual maximum and minimum temperature of study area is 43.4^0 C in May and 7.9^0 C in December. The average annual rainfall of study area ranges from 1250-1380 mm.

Methodology

Historical ground fire data in conjunction with satellite remote sensing data was used for delineation and identification of fire affected areas. Based on the frequency and spatial extent of forest fire damage, the fire affected areas were divided into four fire zones *viz.,* high, medium, low and non-fire zones. Under each fire zone the characterization of vegetation and fuel load assessment was done in pre-fire (November-December) and post-fire (June) seasons in order to assess both qualitative and quantitative changes in vegetation. The vegetation was analyzed for its structure in different fire affected zones (i.e., High, Medium, Low and Non-fire zone). The trees and saplings were analyzed by randomly laying five quadrats of size 20 x 20 m. The girth at breast height (i.e., 1.37 m above the ground) of all the trees and saplings in each quadrat was measured and recorded individually. For tree species, the individuals > 31.5 cm GBH are categorized as tree, <31.5 cm but > 10 cm as saplings. In each of these quadrat, a subquadrat of 5 x 5 m size were randomly laid for measuring seedlings and shrubs. The seedlings (<10 cm GBH) and shrubs are measured at the collar height. Similarly, an another quadrat of 1 x 1 m size in 20 x 20 m quadrat was laid for measuring herbs .

Vegetational data was quantitatively analysed for frequency, density and abundance (Curtis and McIntosh, 1950). The relative frequency, relative density and relative basal area values were calculated following Phillips (1959). The sum of relative frequency, relative density and relative basal area values represented as Importance Value Index (IVI) for the various species and for the forest in different fire zones. Diversity parameters for tree, sapling, seedling, shrub and herb layers were determined using basal area values from the Shannon-Weiner information function (Shannon and Weaver, 1963). Concentration of dominance was measured following Simpson's index method (Simpson, 1949). Vegetations were also measured for species richness (Marglef, 1958), equitability (Pielou,1966) and Beta diversity (Whittaker,1962).

To show the regeneration pattern of tree species, the population structures were developed based on different tree girth classes in addition to seedlings and saplings. The total number of individuals belonging to these girth classes was calculated for each species on each site following Saxena and Singh (1984). In addition to seedling (A) and sapling (B) classes, three more size classes (based on G.B.H.) i.e., 31.5-70.0 cm (C); 70.1-110.0 cm (D) and > 110 (E) were arbitrarily established for each tree species. The total numbers of individuals belonging to these size classes were calculated for each species on each stand.

The total fuel load in each fire zone was estimated following Kodandapani *et al* (2008). The fuel load is assessed by a quadrat of 1 x 1 m was laid out within each of 20x20 m quadrat to measure the Duffs (dead grass, leaf litter, organic matter, etc.) and wood litter. The biomass of duffs litter and wood litter were summed to derive total fuel load. The net change in fuel load was assessed by subtracting the fuel load existing in pre and post-fire seasons in each fire zone.

RESULTS AND DISCUSSION

Vegetational Structure

The density of trees across the various forest fire zones ranged from 255 to 630 trees ha^{-1} (Table 1). Maximum density of tree layer was recorded under non-fire zone followed by medium fire, low fire and high fire zones. In the high fire zone and non-fire zone *Shorea robusta* and *Ougeinia oojeinensis* were recognized as predominant plant community. The greater tree population in the non-fire zone was the direct consequence of fire protection. In the tree layer maximum number of tree species (20) were recorded in non-fire zone having maximum tree density (630 individuals ha^{-1}) and basal area (15.71 $m^2 ha^{-1}$) followed by medium fire zone (15 species with 360 individuals ha^{-1} density and 10.21 $m^2 ha^{-1}$ basal area), low fire zone (12 species with 340 individuals ha^{-1} density and 14.54 $m^2 ha^{-1}$ basal area) and high fire zone (10 species with 255 individuals ha^{-1} density and 10.11 $m^2 ha^{-1}$ basal area). Kafle (2004) also reported that protected area (non-fire zone) also supports greater tree population as compared to fire affected areas. This might be happen due to repeated frequency and intensity of high fire disturbances during past whereas in medium and low fire zones, the number further declined as compared to non-fire zone therefore, the non-fire zone supported higher tree density. Kodandapani *et al.* (2008) have also reported the similar trend in his study while comparing the spatial, temporal and ecological characteristics of forest fires in the dry tropical ecosystem in the Western Ghats.

For the sapling layer, maximum number of species (18) with the density of 990 saplings ha^{-1} having 3.18 $m^2 ha^{-1}$

Fig 1. Location mapof the study area

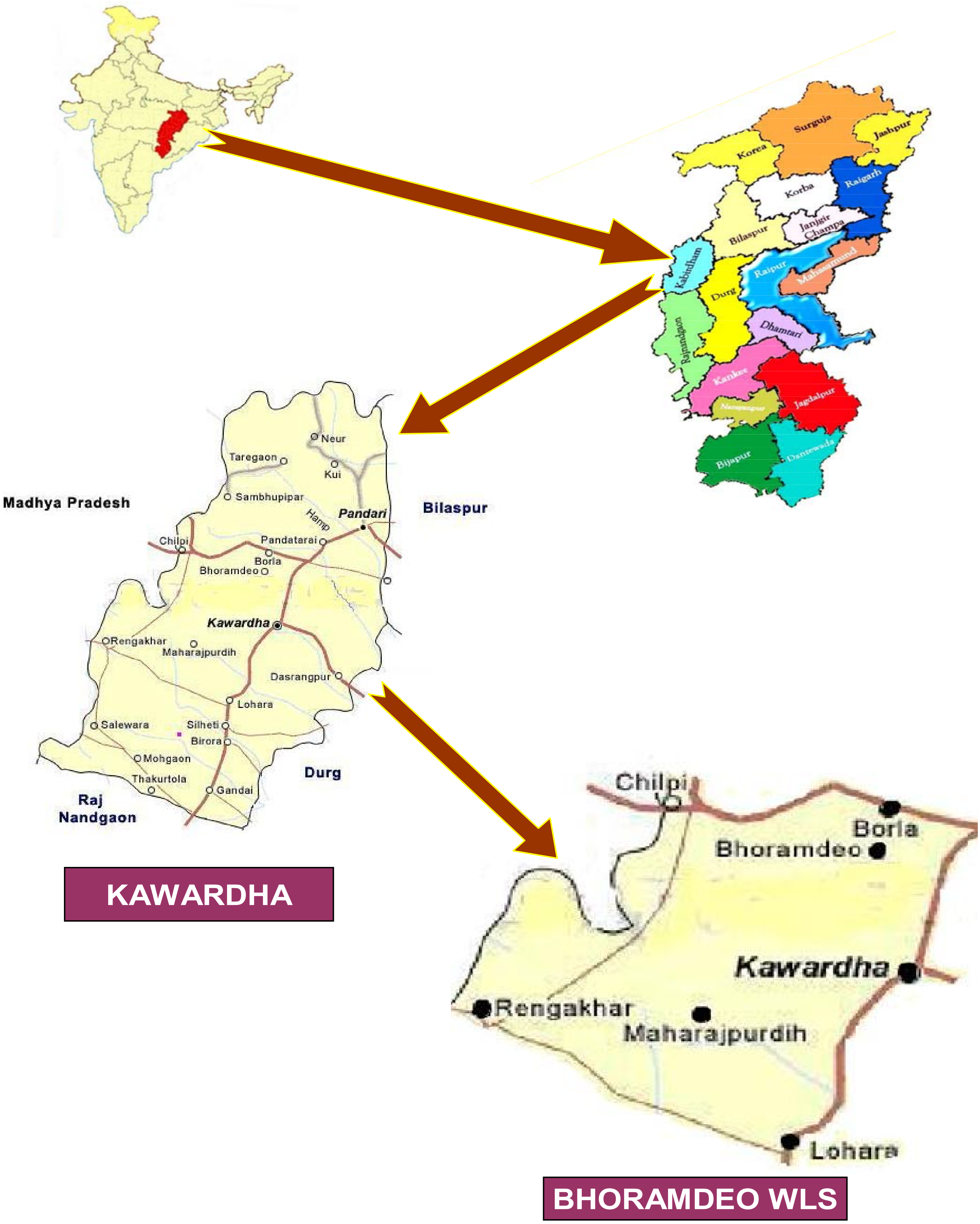

Fig 2. Population structures of major tree species of high fire zone of Bhoramdeo Wildlife Sanctuary.

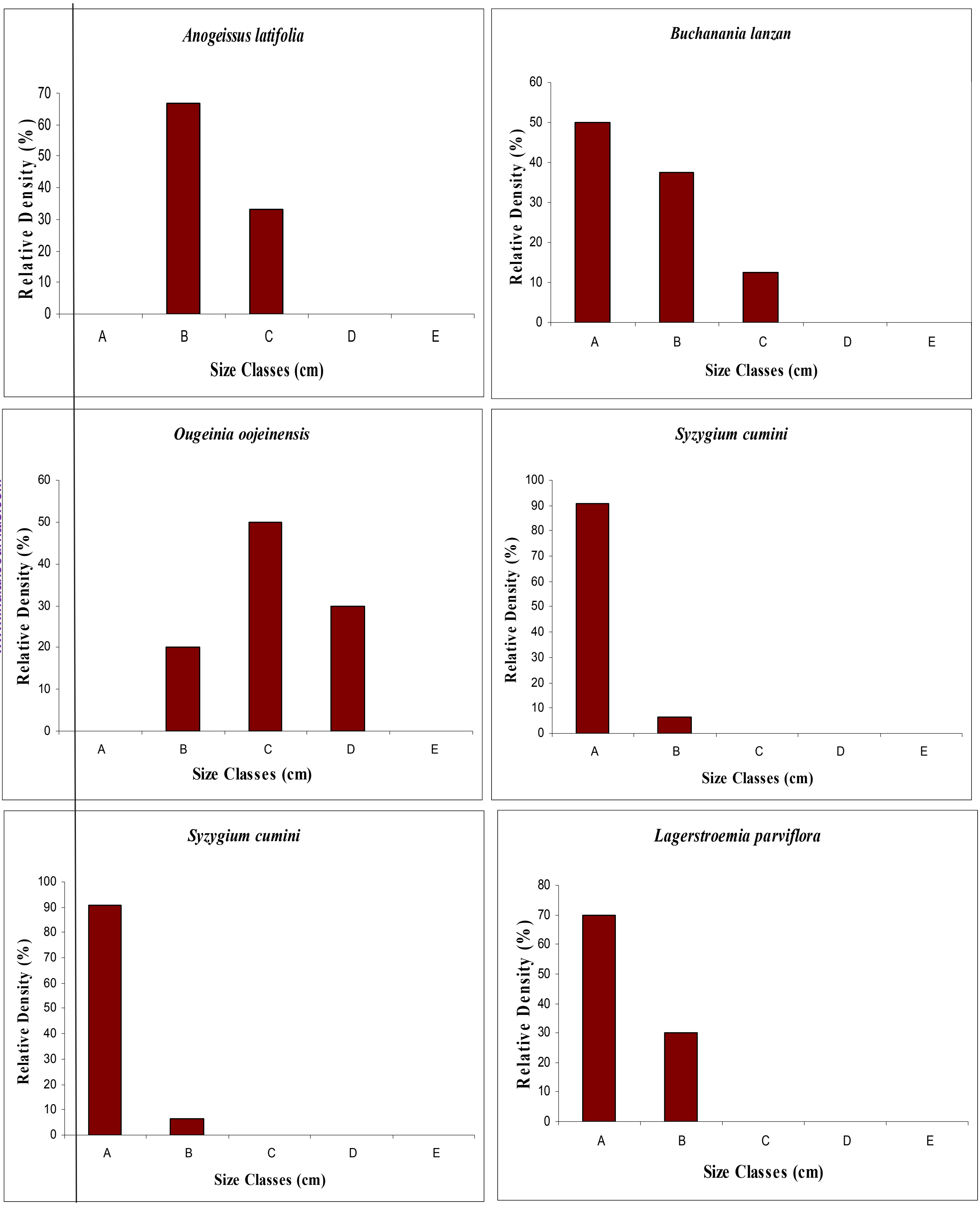

Fig 3. Population structures of major tree species of medium fire zone of Bhoramdeo Wildlife Sanctuary

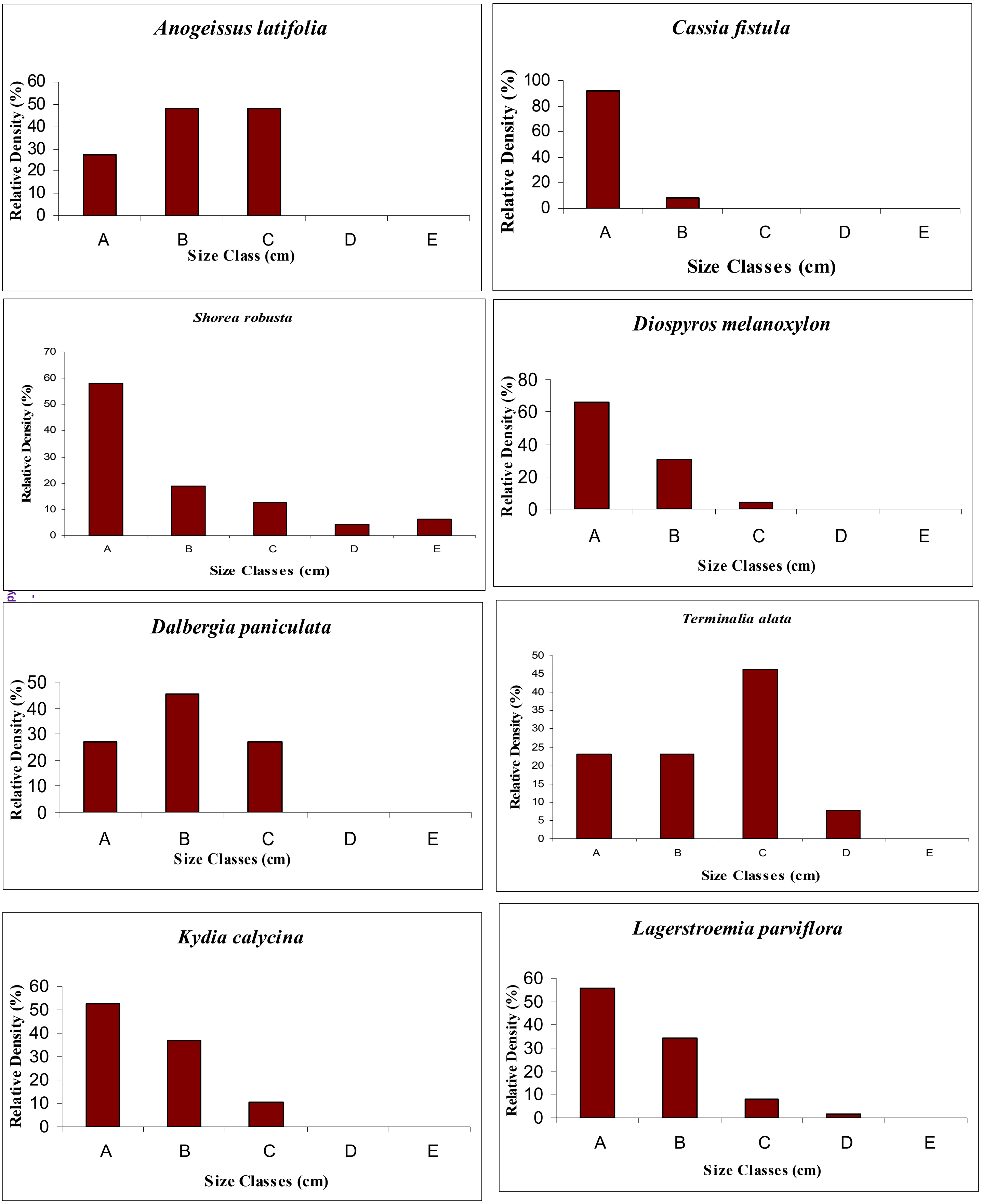

Figure 4. Population structures of major tree species of low fire zone of Bhoramdeo Wildlife Sanctuary.

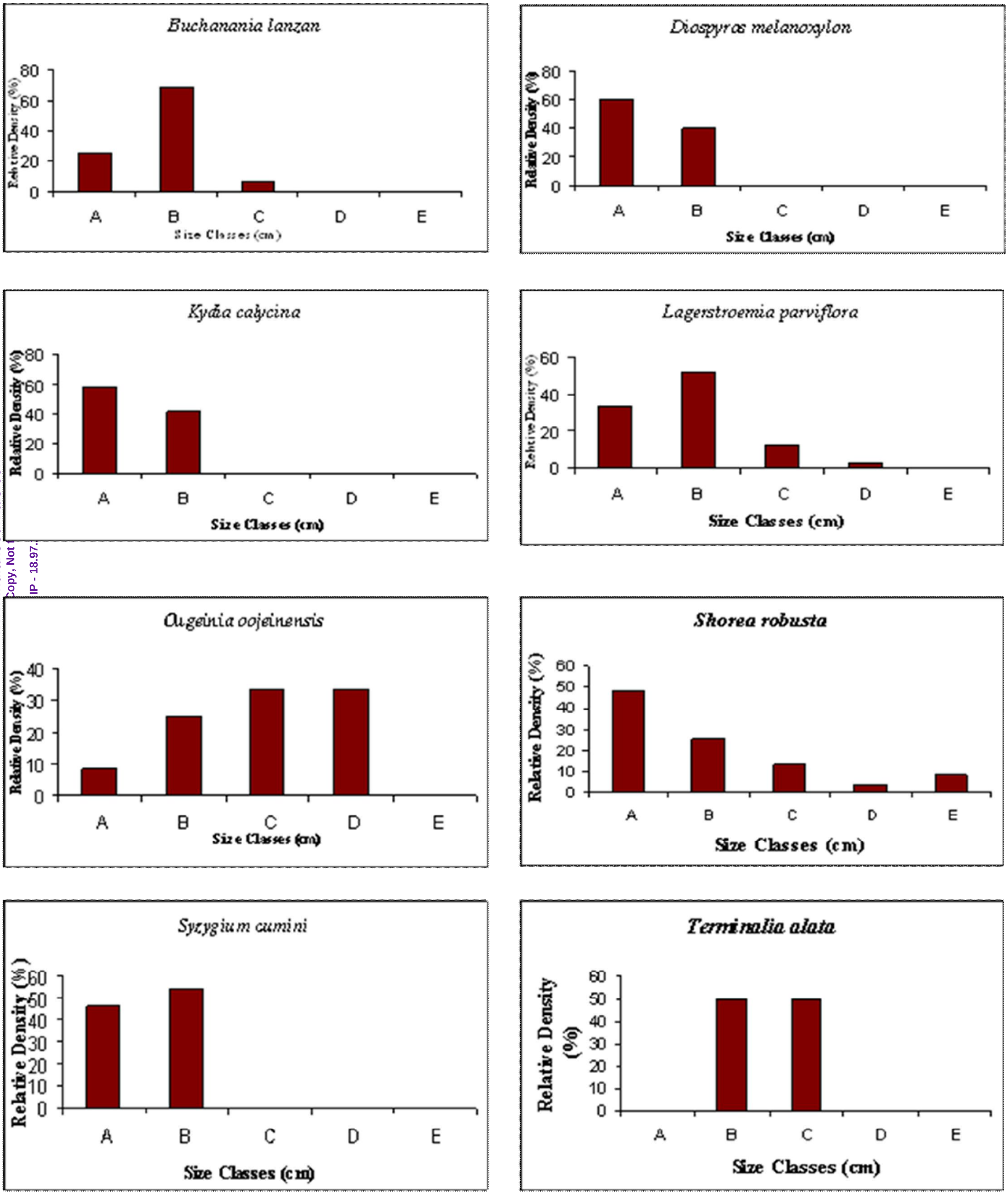

Fig 5. Population structures of major tree species of non-fire zone of Bhoramdeo Wildlife Sanctuary.

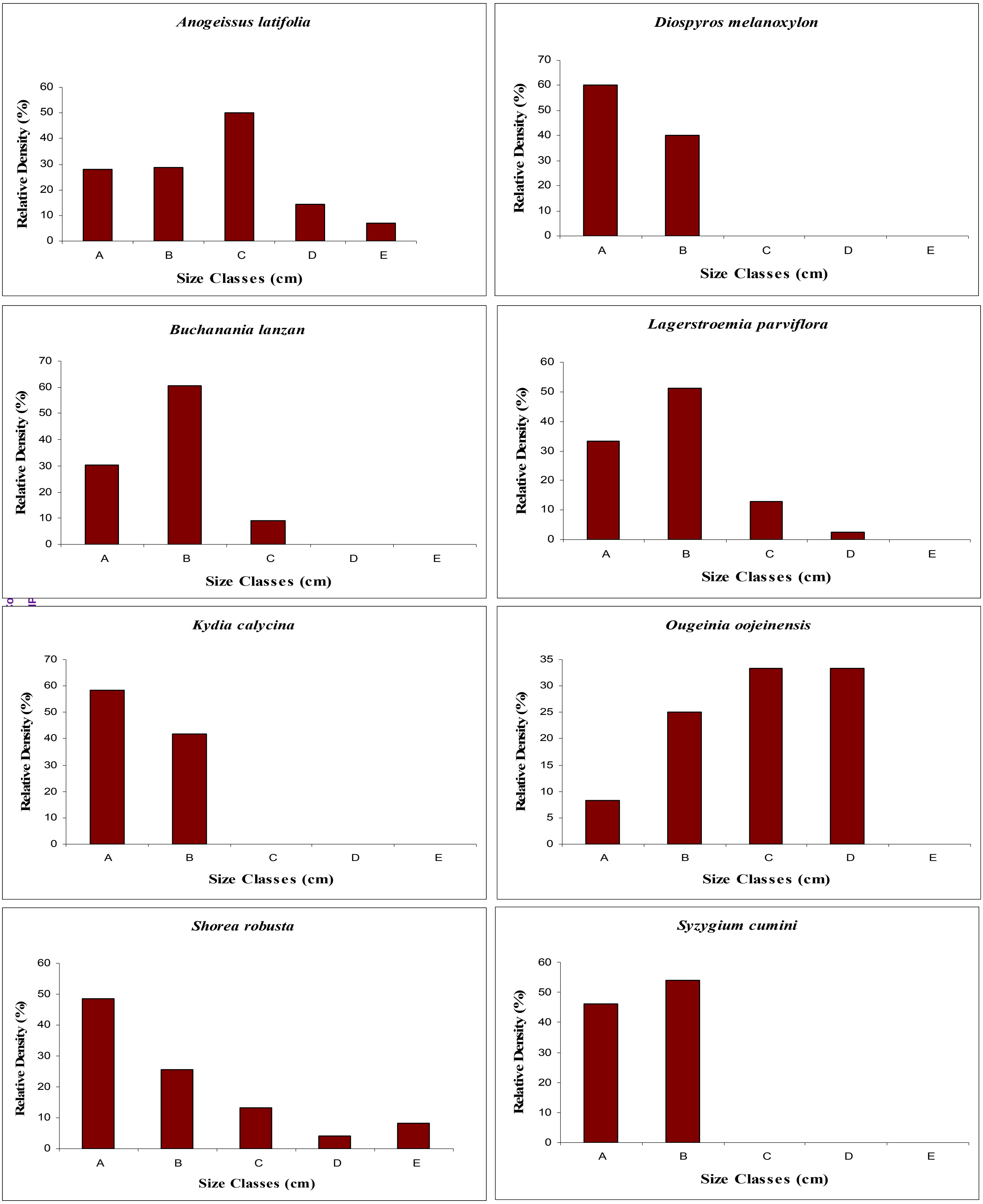

Table 1. Vegetational analysis of tree layer in different fire zones of Bhoramdeo Wildlife Sanctuary

Species	High Fire Zone			Medium Fire Zone			Low Fire Zone			Non Fire Zone		
	D	BA	IVI	D	BA	IVI	D	BA	IVI	D	BA	IVI
Adina cordifolia Hook.f.	15	0.35	19.32	5	0.93	13.29	15	0.25	10.9	5	0.12	3.94
Aegle marmelos Linn.	---	---	---	---	---	---	5	0.21	7.69	---	---	---
Anogeissus latifolia Wall ex Bedd.	10	0.14	15.27	60	0.94	37.01	---	---	---	30	0.77	21.6
Boswellia serrata Roxb. ex Colebr.	---	---	---	25	2.48	39.56	---	---	---	---	---	---
Bridelia retusa (Linn.) Spreng.	5	0.28	9.73	---	---	---	---	---	---	20	0.43	10.7
Buchanania lanzan Spreng.	5	0.06	7.55	15	0.25	12.13	10	0.09	8.35	15	0.16	8.18
Careya arborea Roxb.	---	---	---	10	0.42	12.43	---	---	---	---	---	---
Casearia graveolens Dalz.	---	---	---	25	0.3	18.24	---	---	---	15	0.13	5.6
Cassia fistula Linn.	---	---	---	---	---	---	10	0.31	14.6	10	0.22	7.72
Dalbergia paniculata Roxb.	---	---	---	15	0.24	12.06	---	---	---	---	---	---
Diospyros melanoxylon Roxb.	---	---	---	10	0.12	6.77	---	---	---	---	---	---
Garuga pinnata Roxb.	---	---	---	---	---	---	---	---	---	5	0.08	3.66
Grewia tiliaefolia Vahl.	---	---	---	---	---	---	---	---	---	5	0.04	3.42
Kydia calycina Roxb.	---	---	---	10	0.11	9.4	---	---	---	5	0.18	4.34
Lagerstroemia parviflora Roxb.	---	---	---	30	0.53	21.91	30	0.57	27.1	5	0.04	3.42
Lannea coromandelica (Houtt.) Merr.	15	0.36	19.45	55	2.02	46.17	5	0.05	6.59	25	0.57	19.5
Madhuca longifolia Roxb.	---	---	---	---	---	---	---	---	---	5	0.05	3.48
Mitragyna parviflora (Roxb.) Korth.	---	---	---	---	---	---	---	---	---	15	0.18	8.32
Ougeinia oojeinensis (Roxb.) Hochr.	40	1.42	44.75	65	1.31	44.77	40	1.6	41.8	70	2.09	33.9
Emblica officinalis Gaertn	---	---	---	5	0.14	5.52	5	0.1	6.92	---	---	---
Saccopetalum tomentosum (H F.) Thoms	---	---	---	---	---	---	---	---	---	15	0.21	6.12
Schleichera oleosa (Lour.) Oken	15	0.47	15.51	---	---	---	5	0.09	6.86	5	0.06	3.54
Semecarpus anacardium L.	---	---	---	15	0.15	11.18	15	0.79	14.6	---	---	---
Shorea robusta Gaertn.f.	110	6.14	128.72	---	---	---	185	10.23	144	345	9.64	124.2
Sterculia urens Roxb.	5	0.09	7.86	15	0.27	9.56	---	---	---	5	0.05	3.47
Terminalia alata Heyne ex Roth.	35	0.79	31.58	---	---	---	15	0.25	10.9	20	0.96	16.4
Terminalia chebula Retz.	---	---	---	---	---	---	---	---	---	10	0.34	8.52
Total	255	10.11	**300**	360	10.21	**300**	340	14.54	**300**	630	15.71	**300**

D= Density (individuals ha^{-1}), BA= Basal area $m^2 ha^{-1}$, IVI= Importance Value Index

Table 2. Vegetational analysis of sapling layer in different fire zones of Bhoramdeo Wildlife Sanctuary

Species	High Fire Zone			Medium Fire Zone			Low Fire Zone			Non Fire Zone		
	D	BA	IVI	D	BA	IVI	D	BA	IVI	D	BA	IVI
Adina cordifolia Hook.f.	---	---	---	---	---	---	10	0.03	8.73	---	---	---
Anogeissus latifolia Wall ex Bedd.	20	0.07	25.04	60	0.17	26.35	20	0.04	7.95	70	0.15	19.02
Bombax ceiba Linn.	---	---	---	---	---	---	---	---	---	5	0.03	3.92
Boswellia serrata Roxb. ex Colebr.	---	---	---	5	0.01	4.6	---	---	---	---	---	---
Buchanania lanzan Spreng.	15	0.04	16.21	---	---	---	110	0.31	49.03	100	0.25	27.59
Butea monosperma (Lamk) Taub.	5	0.01	6.15	---	---	---	10	0.01	4.92	---	---	---
Casearia graveolens Dalz.	---	---	---	155	0.33	58.43	10	0.02	8.19	50	0.13	16.59
Cassia fistula Linn.	---	---	---	5	0.005	4	10	0.03	8.83	---	---	---
Dalbergia paniculata Roxb.	---	---	---	25	0.07	17.29	---	---	---	---	---	---
Diospyros melanoxylon Roxb.	55	0.11	36.9	80	0.23	42.36	60	0.1	25.84	75	0.13	18.85
Grewia tiliaefolia Vahl.	5	0.01	6.15	---	---	---	---	---	---	10	0.05	7.39
Kydia calycina Roxb.	---	---	---	35	0.08	19.69	25	0.03	11.15	20	0.04	8.06
Lagerstroemia parviflora Roxb.	15	0.06	21.99	105	0.28	49.77	100	0.24	40.67	60	0.29	19.93
Lannea coromandelica (Houtt.) Merr.	---	---	---	20	0.09	20.18	10	0.05	7.43	10	0.05	5.07
Mitragyna parviflora (Roxb.) Korth.	---	---	---	---	---	---	---	---	---	25	0.09	10.16
Ougeinia oojeinensis (Roxb.) Hochr.	10	0.05	16.15	55	0.18	29.41	15	0.07	11.62	25	0.1	12.97
Emblica officinalis Gaertn	30	0.11	32.37	5	0.03	5.79	20	0.03	9.91	15	0.08	8.99
Saccopetalum tomentosum (H F.) Thoms	---	---	---	---	---	---	---	---	---	10	0.03	6.74
Schleichera oleosa (Lour.) Oken	10	0.02	8.54	---	---	---	5	0.01	4.02	10	0.04	4.71
Semecarpus anacardium L.	---	---	---	15	0.05	11.44	---	---	---	---	---	---
Shorea robusta Gaertn.f.	90	0.29	76.45	---	---	---	185	0.53	68.44	465	1.61	109.72
Sterculia urens Roxb.	20	0.04	20.83	25	0.06	10.68	---	---	---	5	0.03	3.85
Syzygium cumini (Linn.) Skeels.	5	0.01	5.87	---	---	---	35	0.07	12.18	---	---	---
Terminalia alata Heyne ex Roth.	15	0.04	15.72	---	---	---	15	0.04	12.37	20	0.05	10.82
Terminalia chebula Retz.	10	0.01	11.62	---	---	---	10	0.03	8.73	15	0.05	5.61
Total	305	0.86	**300**	590	1.6	**300**	650	1.65	**300**	990	3.18	**300**

D= Density (individuals ha^{-1}), BA= Basal area m^2 ha^{-1}, IVI= Importance Value Index

Table 3. Vegetational analysis of seedling layer in different fire zones of Bhoramdeo Wildlife Sanctuary

Species	High Fire Zone			Medium Fire Zone			Low Fire Zone			Non Fire Zone		
	D	BA	IVI	D	BA	IVI	D	BA	IVI	D	BA	IVI
Anogeissus latifolia Wall ex Bedd.	---	---	---	720	0.143	19.23	400	0.16	16.5	640	0.336	30.46
Buchanania lanzan Spreng.	320	0.036	17.6	---	---	---	640	0.21	20.12	800	0.054	16.57
Casearia graveolens Dalz.	720	0.022	18.8	1440	0.312	49.42	2640	0.61	62.06	1840	0.234	41.43
Cassia fistula Linn.	---	---	---	880	0.156	30.94	---	---	---	80	0.041	6.52
Chloroxylon swietenia D.C.	---	---	---	320	0.077	11.93	---	---	---	---	---	---
Dalbergia paniculata Roxb.	---	---	---	240	0.069	10.74	---	---	---	---	---	---
Diospyros melanoxylon Roxb.	3360	0.198	101.5	2800	0.212	56.29	1440	0.15	29.87	2640	0.209	50.5
Kydia calycina Roxb.	---	---	---	800	0.102	17.68	560	0.11	12.17	---	---	---
Lagerstroemia parviflora Roxb.	560	0.036	20	2720	0.491	75.72	1040	0.31	30.55	80	0.041	6.63
Mitragyna parviflora (Roxb.) Korth.	---	---	---	---	---	---	---	---	---	480	0.068	14.85
Ougeinia oojeinensis (Roxb.) Hochr.	---	---	---	1040	0.25	28.05	80	0.06	6.54	80	0.006	4.64
Emblica officinalis Gaertn	---	---	---	---	---	---	400	0.2	21.34	---	---	---
Saccopetalum tomentosum (H F.) Thoms	---	---	---	---	---	---	---	---	---	80	0.054	7.22
Schleichera oleosa (Lour.) Oken	---	---	---	---	---	---	80	0.05	6	400	0.073	10.78
Shorea robusta Gaertn.f.	4400	0.159	103.6	---	---	---	5600	0.19	65.05	5440	0.62	94.53
Sterculia urens Roxb.	---	---	---	---	---	---	80	0.05	6	---	---	---
Syzygium cumini (Linn.) Skeels.	800	0.041	27.5	---	---	---	480	0.02	10.82	---	---	---
Terminalia alata Heyne ex Roth.	240	0.007	11.01	---	---	---	---	---	---	80	0.064	7.74
Terminalia chebula Retz.	---	---	---	---	---	---	240	0.11	12.99	80	0.064	7.74
Total	10400	0.48	**300**	10960	1.81	**300**	13680	2.25	**300**	12720	1.86	**300**

D= Density (individuals ha^{-1}), BA= Basal area $m^2 ha^{-1}$, IVI= Importance Value Index

basal area were recorded for non-fire zone. High fire zone recorded 14 species with 305 saplings ha^{-1} and 0.86 $m^2 ha^{-1}$ basal area, whereas medium fire zone had only 13 species with 590 saplings ha^{-1} having 1.60 $m^2 ha^{-1}$ basal area. The low fire zone recorded 17 species with 650 saplings ha^{-1} and 1.65 $m^2 ha^{-1}$ basal area. *S. robusta* was recognized as predominant plant communities in all fire zones accept the medium fire zone (Table 2). The sapling layer showed higher density under non-fire zone whereas drastic reductions of individual were found under low, medium and high fire zones. This was due to the heavy reduction of susceptible species. This may results extinction of such fire susceptible species in the future. West *et al.* (1981) also reported that population is on way to extinction if such trend continues.

Low and Non-fire zone recorded similar number of seedling species (7) but the density was slightly higher (13680 seedlings ha^{-1}) in low fire zone as compared to non-fire zone (12720 seedlings ha^{-1}). The basal area also showed the similar trend. High fire zone recorded the lowest density of 10400 seedlings ha^{-1}, whereas the medium fire zone showed a slight increase in species number (9) and density (10960 seedlings ha^{-1}) as compared to high fire zone. *S. robusta* and *Diospyros melanoxylon* having higher density under high fire and non-fire zones. In medium fire zone the highest density was recorded by *D. melanoxylon* and *Lagerstroemia parviflora*, whereas in the low fire zone the highest

Table 4. Vegetational analysis of shrub layer in different fire zones of Bhoramdeo Wildlife Sanctuary

Species	High Fire Zone			Medium Fire Zone			Low Fire Zone			Non Fire Zone		
	D	BA	IVI	D	BA	IVI	D	BA	IVI	D	BA	IVI
Bauhinia racemosa Lam.	240	0.02	28.6	---	---	---	160	0.01	25.74	---	---	---
Bauhinia vahlii (W.) A.	400	0.02	36.71	320	0.01	26.97	160	0.01	17.77	---	---	---
Butea superba Roxb. ex Willd.	240	0.17	54.01	240	0.09	36.55	240	0.27	69.09	80	0.337	51.73
Carissa spinarum D.C.	160	0.02	18.4	240	0.1	38.68	80	0.17	36.95	---	---	---
Dioscaria spp Roxb.	240	0.003	18.73	---	---	---	---	---	---	---	---	---
Embelia robusta Roxb.	80	0.003	11.18	400	0.01	31.45	160	0.02	26.74	240	0.054	40.6
Mallotus phillippinensis Muell.	80	0.03	15.78	160	0.046	25.99	---	---	---	---	---	---
Mimusops hexandra Roxb.	---	---	---	---	---	---	400	0.02	39.41	400	0.013	65.43
Spatholobus roxburgii Benth.	80	0.007	11.83	---	---	---	---	---	---	160	0.01	29.6
Ventilago cayculata Tul.	320	0.08	49.2	480	0.06	41.24	640	0.18	84.29	160	0.55	81.53
Zizyphus xylopyra (Retz.)Willd.	240	0.22	55.51	640	0.31	99.11	---	---	---	80	0.108	31.11
Total	2080	0.591	**300**	2480	0.65	**300**	1840	0.67	**300**	1120	1.11	**300**

D= Density (individuals ha^{-1}), BA= Basal area $m^2 ha^{-1}$, IVI= Importance Value Index

density was noticed in *Shorea robusta* and *Casearia graveolens* (Table 3). Joshi (1990) observed higher values of seedling density on burned sites as compared to unburnt stand. The low fire zone supported highest number of seedlings ha^{-1} as compared to other fire zones. This result can be correlated to the effects of fire on juvenile die back. Several juvenile escaped from fire did not undergo stem die back, they exhibit height and growth patterns similar to unburnt seedlings (Saha 2002). According to Kodandapani (2001) fire enhances the productivity of ecosystems by releasing chemicals and nutrients locked up in old herbages this results to regeneration of seedlings benefited from forest fire.

In contrast to tree layer the number of shrub species was maximum in the high fire zone (10) and minimum in the non-fire zone (6). The medium and low fire zone recorded similar number of species (7). Maximum density of shrub layer (2480 shrubs ha^{-1}) was recorded in the medium fire zone and minimum (1120 shrubs ha^{-1}) in the non-fire zone. The high and low fire zones showed 2080 individuals ha^{-1} and 1840 shrubs 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 4). Natural regeneration potential for 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. 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. Similar results were also reported by Rodgers *et al.* (1986).

In the herbaceous layer, medium fire zone supported maximum number of species (10) as well as the density (668000 herbs ha^{-1}) whereas minimum numbers of species (5) were recorded in high fire zone. The lowest density (112000 herbs ha^{-1}) of herbaceous vegetation was recorded in the non-fire zone. *Apluda mutica, Ischaemum pilosum, Corchorus aequitans* and *Desmodium pulchellum* recorded highest density under high, medium, low and non-fire zones, respectively (Table 5). The quantity of humus deposition was optimum under medium fire zone this helps for herbs to easily uptake of nutrients from the soil. Danielle *et al.* (2005) reported that the humus characteristics significantly explained the distribution of under story species. The medium fire zone supported higher values of density of herb species while it has drastically reduced in high and non-fire zone. In the non-fire affected zone, the herb density was also reduced due to competition for moisture, nutrients, light and for space. Azizi *et al.* (2006) stated that the fire mainly affect the undergrowth and young trees. Kumar and Thakur (2008) have also reported the lesser density and basal area of fire affected sites as compared to non-fire areas.

Table 5. Density of herb layer in different fire zones of Bhoramdeo Wildlife Sanctuary

Species	High Fire Zone	Medium Fire Zone	Low Fire Zone	Non Fire Zone
Achyranthus aspera	---	8000	---	---
Apluda mutica	70000	---	---	---
Biophytum reinnardtii	---	40000	---	---
Cassia tora	---	60000	---	---
Clebrookia oppositifolia	30000	20000	12000	---
Convolvulus arvensis	---	---	---	10000
Conyza japonica	30000	---	---	---
Corchorus aequitans	4000	18000	50000	14000
Coriandrum setium	---	74000	10000	6000
Crotolaria calycina	---	---	---	28000
Desmodium pulchellum	---	---	---	30000
Eragrotis tenella	---	118000	---	---
Ischaemum pilosum	---	242000	---	---
Paspalidium flavidum	2000	---	26000	---
Peristnphe paniculate	---	74000	---	---
Perotis hordeiformis	---	---	10000	---
Sida cardata	---	---	8000	---
Themeda arundinaceae	---	14000	22000	---
Xanthium strumarium	---	---	---	24000
Total	136000	668000	138000	112000

D=Density (individuals ha^{-1}), A= Abundance, F= Frequency

Table 6: Diversity pattern of different vegetational layers of different fire zones of Bhoramdeo Wildlife Sanctuary

Different Fire Zone	Different Layers	Shannon Index (H')	Simpson's Index (Cd)	Species richness (d)	Equitability (e)	Beta Diversity (βd)
High Fire Zone	Tree layer	2.57	0.24	1.62	1.11	2.7
	Sapling Layer	3.22	0.14	2.27	1.22	1.78
	Seedling Layer	2.10	0.29	0.64	1.08	2.71
	Shrub Layer	3.13	0.12	1.17	1.36	1.10
	Herb Layer	1.69	0.36	0.33	1.05	3.8
Medium Fire Zone	Tree layer	3.49	0.10	2.37	1.28	1.8
	Sapling Layer	3.09	0.14	1.88	1.20	1.92
	Seedling Layer	2.80	0.17	0.86	1.27	2.11
	Shrub Layer	2.67	0.16	0.76	1.37	1.57
	Herb Layer	2.71	0.20	0.67	1.17	1.90
Low Fire Zone	Tree layer	2.40	0.32	1.88	0.96	2.25
	Sapling Layer	3.26	0.15	2.47	1.15	1.47
	Seedling Layer	2.70	0.22	1.26	1.05	1.46
	Shrub Layer	2.50	0.20	0.79	1.28	1.57
	Herb Layer	2.50	0.21	0.50	1.28	2.71
Non-Fire Zone	Tree layer	2.68	0.32	2.94	0.89	1.35
	Sapling Layer	2.88	0.25	2.46	0.99	1.38
	Seedling Layer	2.47	0.25	1.26	0.96	1.46
	Shrub Layer	2.35	0.22	0.71	1.31	1.83
	Herb Layer	2.39	0.20	0.43	1.33	3.16

Table 7. Quantification and variation of fuel load in forest fire affected zones during pre-fire and post-fire season

Forest floor Biomass					
	Pre-fire				
	Particulars	**High fire zone**	**Medium fire zone**	**Low fire zone**	**Non-fire zone**
	Duffs litter (t ha^{-1})	10.4	8.95	9.07	8.2
	Wood litter (t ha^{-1})	1.55	3.8	3.49	3.85
	Total (t ha^{-1})	**11.95**	**12.75**	**12.56**	**12.05**
	Post-fire				
	Particulars	**High fire zone**	**Medium fire zone**	**Low fire zone**	**Non-fire zone**
	Duffs litter (t ha^{-1})	3.38	4.0	4.05	4.12
	Wood litter (t ha^{-1})	1.47	1.63	1.87	1.65
	Total (t ha^{-1})	**4.85**	**5.63**	**5.92**	**5.77**
Net change (t ha^{-1})	Duffs litter (t ha^{-1})	7.02	4.95	5.02	4.08
	Wood litter (t ha^{-1})	0.08	2.17	1.62	2.2
	Total (t ha^{-1})	**7.1**	**7.12**	**6.64**	**6.28**

Diversity Pattern

In the tree layer, results of diversity parameters revealed that Shannon index value in different forest fire zones ranged from 2.40 to 3.49, equitability from 0.89 to 1.28, species richness from 1.62 to 2.94, concentration of dominance 0.10 to 0.32 and beta diversity 1.35 to 2.7 under the tree layer vegetation (Table 6). The medium fire zone showed maximum diversity (H'=3.49) followed by non-fire zone. Low fire zone had minimum Shannon index (H'= 2.40). This shows that medium fire supports the diversity as also reported by Kafle (2006). Our data are comparable with the several studies which ranged from 1.9 to 4.0 (Reddy *et al.* 2008). Diversity parameters in the tropical dry forest communities of the Vindhayan region (Jha and Singh 1990) had ranges of 0.68 to 2.02 (Shannon index), 0.75 to 1.75 (equitability), 1.62 to 7.77 (Simpson's index) and 0.13 to 4.33 (beta diversity). Prasad and Pandey (1992) in Sal and teak forests of Madhya Pradesh found species diversity varying from 0.32 to 3.76 and concentration of dominance from 0.07 to 0.63 at different habitation in Madhya Pradesh.

The diversity parameters in the sapling layer showed that the value of Shannon index in different fire zones varied from 2.88 to 3.26, equitability 0.99 to 1.22, species richness 1.88 to 2.47, concentration of dominance 0.14 to 0.25 and beta diversity 1.38 to 1.92 under the sapling layer. The pattern was more or less similar to the tree layer (Table 6).

Shannon index for seedling layer were ranged from 2.10 to 2.70, equitability 0.96 to 1.27, species richness 0.64 to 1.26, concentration of dominance 0.17 to 0.29 and beta diversity 1.46 to 2.71 (Table 6). This result also supports the findings made by Naidu and Sribasuki (1994) that young plants are more badly affected by fires than mature one. The lesser diversity in the frequent fire occurring dry deciduous forest leading to nonspecific forests, frequent fires could also lead to stands where most trees are even aged (Kodandapani 2001). Kafle (2006) reported that the protected area supported greater number of ground flora species. However, the burnt area contained higher species diversity and evenness indices than the protected area intotal.

In shrub layer 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 (Table 6). 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 diversity parameters in the herb layer showed that the value of Shannon index in different fire zones varied from 1.69 to 2.71, equitability 1.05 to 1.33, species richness 0.33 to 0.67, concentration of dominance 0.20 to 0.36 and beta diversity 1.9 to 3.8 under the herb layer (Table 6). Concerning the species richness, a high number of species results with in higher community stability or rather resilience (Guo, 2001). This wide diversity takes the advantage of heterogeneity and increases their diversity. The level of heterogeneity created, obliviously would depend on the height and architecture of the woody species (Sagar *et al.*2008). The fire affected areas supports more herbaceous vegetation as compared to non-fire area because of reduction in competition for space and resources. Keith *et al.* (2010) have reported the similar results and stated that the herb species increase in number immediately after fire because of a general reduction in the tree cover that brings more light to the soil.

Regeneration Pattern

In high fire zone the proportion of seedling size class (A) was dominant (Figure 2). The older tree size class (D) and (E) are represented negligible or nil. The proportion of seedling size class (A) to higher class (D) decreased gradually (e.g., *Buchanania lanzan, S. robusta*). The medium fire zone represented that seedling size class (A) was higher followed by sapling size class (B) and young tree size class (C) exemplified by *Cassia fistula, D. melanoxylon, K. calycina* and *L. parviflora.* The older tree size class (D) and (E) are negligible or nil in case of most of the species (Figure 3). In low fire zone *S. robusta* represented by all the size classes (Figure 4).

The size class (C), (D) and class (E) were either negligible or absent as exemplified by *B. lanzan, L. parviflora, D. melanoxylon, S. cumini* and *T. alata*), whereas in *O. oojeinensis* showed the ascending pattern of population structure. In the non-fire zone two species showed all the size classes of population structure (i.e. *A. latifolia* and *S. robusta*) (Fig 5).

The hump in the middle size classes may indicate comparatively fast growth or less mortality in individuals. Once they successfully crosses the sapling layer and attained the first tree size class as exemplified by *O. oojeinensis* and *T. alata* in high fire zone, *A. latifolia* and *O. oojeinensis* in medium fire zone, *B. lanzan* and *L. parviflora* in low fire zone and *A. latifolia, L. parviflora* and *B. lanzan* non-fire zone. According to West *et al.* (1981) such types of patterns indicate the heavy exploitation of older individuals and greater mortality among young individuals. On the basis of the population structures of different tree species in different stands following five general patterns are recognizable.

Generally greater population of individuals in seedling size class (A) as compared to sapling size class (B) and slightly higher percentage of individuals in third and fourth size classes and some times decline or increase the higher size class (E) as exemplified by *S. robusta*. This situation might have resulted from rapid conversion of seedlings into saplings and that of saplings into trees in the past but the rate has been showed down at present. This species can be referred as a fair reproducer.

The concentration of individuals in intermediate size classes with generally absence or negligible representation of individuals both towards higher and lower size classes (e.g., *A. latifolia*, *T. alata*). According to Saxena and Singh (1984), Bargali *et al.* (1987) the population is on the way to extinction if such a trend continues. Knight (1975) referred to the species showing such population structure as infrequent reproducer.

A greater population of individuals in lower size classes compared to larger classes as exemplified by *L. parviflora*. The structure represents frequent reproduction according to Knight (1975).

A lesser population of individuals in lower size classes compared to larger size classes as exemplified by *O. oojeinensis*. This species has produced abundant population in the past with better conversion rate from one size class to another but at present the seedlings are not comings up frequently, though the species might have produced the seeds but, the environment is not supporting their proper establishment.

D. melanoxylon, K. calycina, S. cumini and *C. fistula* were represented by mainly two size classes i.e. seedling and sapling. These species are facing much pressure and unable to grow towards the higher size classes. If this situation will exhibit for longer time these species may be washed out.

Fuel load

In high fire zone total duffs litter was recorded 10.4 t ha^{-1} during pre-fire season and 3.38 t ha^{-1} during post-fire season (Table 7). Similarly, the total wood litter was1.55 t ha^{-1} and 1.47 t ha^{-1} during pre and post-fire season. The total change recorded by duffs litter was 7.02 t ha^{-1} and by wood litter was 0.08 t ha^{-1} separately. High fire zone showed total net change (duffs litter and wood litter) was 7.1 t ha^{-1}. Total fuel load (duffs litter and wood litter) in medium fire zone was 12.75 t ha^{-1} during pre-fire seasons and 5.63 t ha^{-1} during post-fire seasons. The duffs litter and wood litter recorded highest in pre-fire season. The maximum change between pre-fire and post-fire season was found higher by duffs litter (4.95 t ha^{-1}), while lower by wood litter (2.17 t ha^{-1}). Medium fire zone showed total net change (duffs litter + wood litter) was 7.12 t ha^{-1}. In low fire zone the total duffs litter deposition was 9.07 t ha^{-1} during pre-fire whereas 4.05 t ha^{-1} during post-fire season. Similarly, for wood it was 3.49 t ha^{-1} and 1.87 t ha^{-1} during pre and post-fire season, respectively. The total fuel load was 12.56 t ha^{-1} and 5.92 t ha^{-1} for pre and post-fire season, respectively. In this zone the total net change was 6.64 t ha^{-1}. The duffs litter in non-fire zone was 8.2 t ha^{-1} and 4.12 t ha^{-1} for pre and post-fire season, while the wood litter was 3.85 t ha^{-1} and 1.65 t ha^{-1} for pre and post-fire season. Total fuel load was recorded 12.05 t ha^{-1} during pre-fire and 5.77 t ha^{-1} during the post-fire season. The total net change was 6.28 t ha^{-1}. The total fuel load in different fire zones during pre fire seasons followed the order: medium fire zone > low fire zone > non-fire zone > high fire zone. The total fuel load during post-fire seasons was in the following order: low fire zone > non-fire zone > medium fire zone > High fire zone.

The highest fuel load during pre-fire season was reported in medium fire zone and minimum in high fire zone, whereas these values are maximum in low fire zone and minimum in high fire zone after post fire season. The duffs litter constitutes more shared of the total fuel load and woody litter constitutes least shared of the total fuel load (Kodandapani *et al.* 2008). Fire takes an advantage of these fine leaf and woody litter to spread more intensively in the forest. More importantly not only litter, the other environmental factors like temperature, topography, wind velocity, direction and relative humidity, etc. plays an important role in spread of forest fires.

Under non-fire zone the duffs litter was 8.2 t ha^{-1} and 4.12 t ha^{-1} for pre and post-fire season and the wood litter weighed 3.85 t ha^{-1} and 1.65 t ha^{-1} for pre and post-fire season. The net change recorded was 6.28 t ha^{-1} during post fire season. Increase in litterfall with increasing fine woody fuels, would seem to be a biological phenomenon in stands in early stages of stand development, where crown development, branch shedding and canopy closure occur at a relatively rapid rate compared to latter stages of stand development (Oliver and Larson ,1996). The trend in leaf litter (serving as fuel) accumulation is similar to that in the monsoonal forests of the Western Ghats, Australia and East Africa (Murali and Sukumar, 1993).

In this study we found that the protected area contained more species as compared to the burnt area. This suggests that forest fire protection decreased the killing or damaging of trees, 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 plants are more badly affected by fire than mature ones. The conversion rate of seedlings into sapling and trees is less in high zone as compared to non-fire zone. It shows that these sites are facing the stress caused by the fire or other anthropogenic disturbances. The dry tropical forests are being reduces in area in Indian conditions, losing the species and becoming least diverse for which serious measures are needed to preserve, conserve and sustain whatever intact forest is left. In Indian conditions where the forest cover is about 20.60 % and much of it is under the pressures. In such conditions, a strategy is required to conserve whatever remains and restore areas where it is possible, rather than spending time and resources on selecting new biodiversity rich areas so that the alarming trend of disappearance of species rich communities is halted.

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