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Species diversity and community structure in sal (*Shorea robusta*) forests of two different rainfall regimes in West Bengal, India

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Abstract Knowledge on the structure and composition of the plant communities has enormous significance in conservation and management of forests. The present study aimed to assess the community attributes, viz., structure, composition and diversity in the moist and dry sal (*Shorea robusta*) forests in the West Bengal province of India and compare them with the other sal forests of India. The phytosociological data from these forests were quantitatively analysed to work out the species richness, diversity, evenness, dominance, importance value, stand density and the basal area. The analysis showed that plant richness and diversity in moist sal forests of northern West Bengal are higher than the dry sal forests of south-west Bengal; a total of 134 tree (cbh ≥30 cm), 113 shrub and 230 herb species were recorded in the moist sal forest compared to 35 tree, 41 shrub and 96 herb species in dry sal forest. Papilionaceae was observed to be the dominant family. Dry sal forests had higher tree dominance (0.81) and stand density (1,006 stems ha^{-1}) but lower basal area (19.62 m^2ha^{-1}) while moist sal forest had lower tree dominance (0.18) and stand density (438 stems ha^{-1}) but higher basal area (56.52 m^2ha^{-1}). Tree species richness and stem density across girth classes in both the types decreased from the smallest to largest trees, while the occurrence rate of species increased with increase in girth class. A *t*-test showed significant differences in species richness, basal area and the stand density at 95% confidence level ($p = <0.05$) in the two forest types. The CCA indicated very low overall match (canonical correlation value = 0.40) between the two sets of variables from moist and dry sal types. The differences in these forests could be attributed to the distinct variations in climatic conditions- mainly the rainfall, disturbance regimes and the management practices.

Keywords Diversity · Dominance · Rainfall · Sal forest · Species occurrence

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Introduction

Sal (*Shorea robusta*) is one of the most important timber trees in India. Sal forest is widely distributed in tropical India and covers approx. 13.30 per cent of the total forest area of the country (Satya and Nayaka 2005). As per Champion and Seth (1968), it is one of the dominant tree species in the tropical moist as well as dry deciduous forests in India. The leaf phenology of sal has been debated in past due to its evergreen versus deciduous paradox (Troup 1921). Sal has been described by several workers as a deciduous species (Cooke 1958; Kirtikar and Basu 1975; Tiwari 1995), semi-deciduous species (Bor 1953), an evergreen species (Krishnaswamy and Mathauda 1954; Singh and Singh 1992; Borchert 2000), and deciduous or borderline between evergreen and deciduous (Joshi 1980). Sal occurs generally as gregarious formation and tends to form pure stands to mixed forests in the Himalayan foothills and central India (Troup 1921). In the Himalayan foothills, it extends from Kangra area of Himachal Pradesh to Assam valley (including Meghalaya and Tripura provinces) in the eastern Himalaya through Uttarakhand, Uttar Pradesh, Nepal, Bihar and northern West Bengal (Satya and Nayaka 2005) up to approx. 1,000 m elevation. Sal forests have been under selective logging for the timber over time.

To meet the timber demand of an ever-increasing population over the past few decades, large natural habitats of sal were converted into agricultural, industrial or urban landscapes, leading to habitat fragmentation and loss of the biodiversity (Jacquemyn et al. 2003). The structure and composition of forests are strongly related to the climate and topography (Schall and Pinaka 1978; Wright 1983; Currie 1991). However, the knowledge on the structure, composition or dynamics of tropical forests is still inadequate (Hubbell and Foster 1992). Phytosociological analysis helps in understanding the structure and composition of plant communities (Braun-Blanquet 1965). Quantitative inventories also help in the identification of economically useful species as well as the species of special concern, i.e. rare, endangered, endemic, threatened or vulnerable species (Keel et al. 1993) and thus have enormous implications in the conservation and management of tropical forests (Campbell 1994). Various workers have studied Indian sal forests (Gupta and Shukla 1991; Singh et al. 1995). Uma Shankar et al. (1998a) compared the natural sal forest of Darjeeling Himalaya with regard to habitat alteration, species loss and the ecosystem recovery related to *taungya* plantation. Changes in the diversity and the community pattern in relation to the degree of disturbance were studied by Pandey and Shukla (1999). Uma Shankar (2001) studied phytosociological attributes in a sal-dominated lowland forest of eastern Himalaya. In a recent study using remote sensing, GIS and field investigations, IIRS (2007) reported high biological richness in moist and low biological richness in dry sal forests. It also indicted lower forest fragmentation in moist sal compared to dry sal forest, thereby indicating an inverse relationship between the forest fragmentation and biological richness.

Sal forests in West Bengal can be differentiated into two extreme types- the dry and the moist sal (Troup 1921). Champion and Seth (1968) have classified moist sal forests as *Northern Tropical Moist Deciduous Forest* (3C) and dry sal forests as *Northern Tropical Dry Deciduous Forest* (5B). Moist sal areas are confined to the Sub-Himalayan West Bengal in Darjeeling and Jalpaiguri districts with deep, moist, nutrient-rich terai soil, whereas dry sal forests are restricted to the south-western West Bengal in the districts of West Medinipur, Bankura, Purulia, Bardhaman and Birbhum with dry, denuded or hard ground shallow lateritic soil (Chakravarty and Chakravarty 1957). In dry type, the commonest companions of the sal are *Buchanania lanzan*, *Diospyros tomentosa* and *D. melanoxylon*. The average stand height of the moist sal in northern West Bengal is $\sim$35 m while the same in dry sal forest of south-western Bengal is $\sim$20 m. The moist type is characterized by higher rainfall combined with relatively lower temperature and considerably higher humidity. The moist sal is associated with various evergreen species.

Both the categories of forests are fire climaxes. The moist sal, if protected from fire, will succeed to evergreen forest beneath whose canopy sal seedlings fail to regenerate (Champion and Seth 1968). Moist sal, therefore, has an understorey of evergreens, which includes canopy species juveniles, while dry sal does not. Cattle grazing and an increased human-induced fire frequency have led to vast areas appearing to meet the dry sal criterion through extinction of evergreens, though these usually persist in swales and along rivers. As stated earlier, the climatic, anthropogenic factors as well as management practices seem to regulate the species diversity and community structure in these forests. During one of our earlier studies spanning over entire West Bengal province, we noticed considerable physiognomic differences in the moist and dry sal forests. So far, no study has been carried out on the diversity and community structure in these two climatically distinct sal forests. We, therefore, undertook the present study to analyze the structure, composition, pattern of distribution and the diversity in two sal forests of West Bengal and compare them with the other sal forests in India.

Study area

The West Bengal province (21°45′–27°16′N and 85°55′–89°56′E), covers a geographical area of 88,752 km^2 in India (Fig. 1). With 2.70 per cent of the country's geographical area, the province supports 7.81 per cent of the India's population and holds highest average population density record of 904 persons per km^2 in the country. The rising population density sounds an alarm as it tends to make more demand on the limited forest and other natural resources of the State. The State is bounded in the north by Sikkim province and the Bhutan, in the east by Assam province and the Bangladesh, in the south by Bay of Bengal, in the west by Jharkhand and Orissa provinces and in the northwest by Bihar province and the Nepal. The State is a unique biogeographic area from biodiversity point of view as it stretches between the Bay of Bengal in the south and high Himalayas in the north i.e. from mean sea level to 3,685 m elevation (sea to snow). The state is endowed with the impressive littoral forests of the Sunderbans (largest mangrove formation in India), moist deciduous forests of the Himalayan foothills, to temperate forests and alpine grasslands in the north.

Climate in West Bengal varies from moist tropical in the southeast and the Sub-Himalayan Northern West Bengal to dry tropical in the south-west, and from sub-tropical to temperate in the mountains of north. Annual rainfall varies from 1,400 mm in south-west to 2,800 mm in the north. The temperature ranges from sub-zero in the north during the winter to about 45°C in the south during summer. The average annual rainfall (India Meteorological Department 25-year mean) is 2,739 mm in the northern West Bengal and 1,439 mm in the Gangetic West Bengal (including south-western area). In a recent study, Samanta et al. (2011) worked out the annual rainfall distribution pattern in West Bengal using data from Climatic Research Unit of East Anglia, U.K. and India Meteorological Department (IMD) for 1901–2002 period. They concluded that northern Bengal receives an annual rainfall of 2,600–2,800 mm while south-western Bengal receives 1,400–1,600 mm annual rainfall. Thus, the northern and the south-western sal forests have considerably different rainfall, temperature and edaphic conditions and this contrast in climatic conditions is attributed to the development of the moist and dry sal forests.

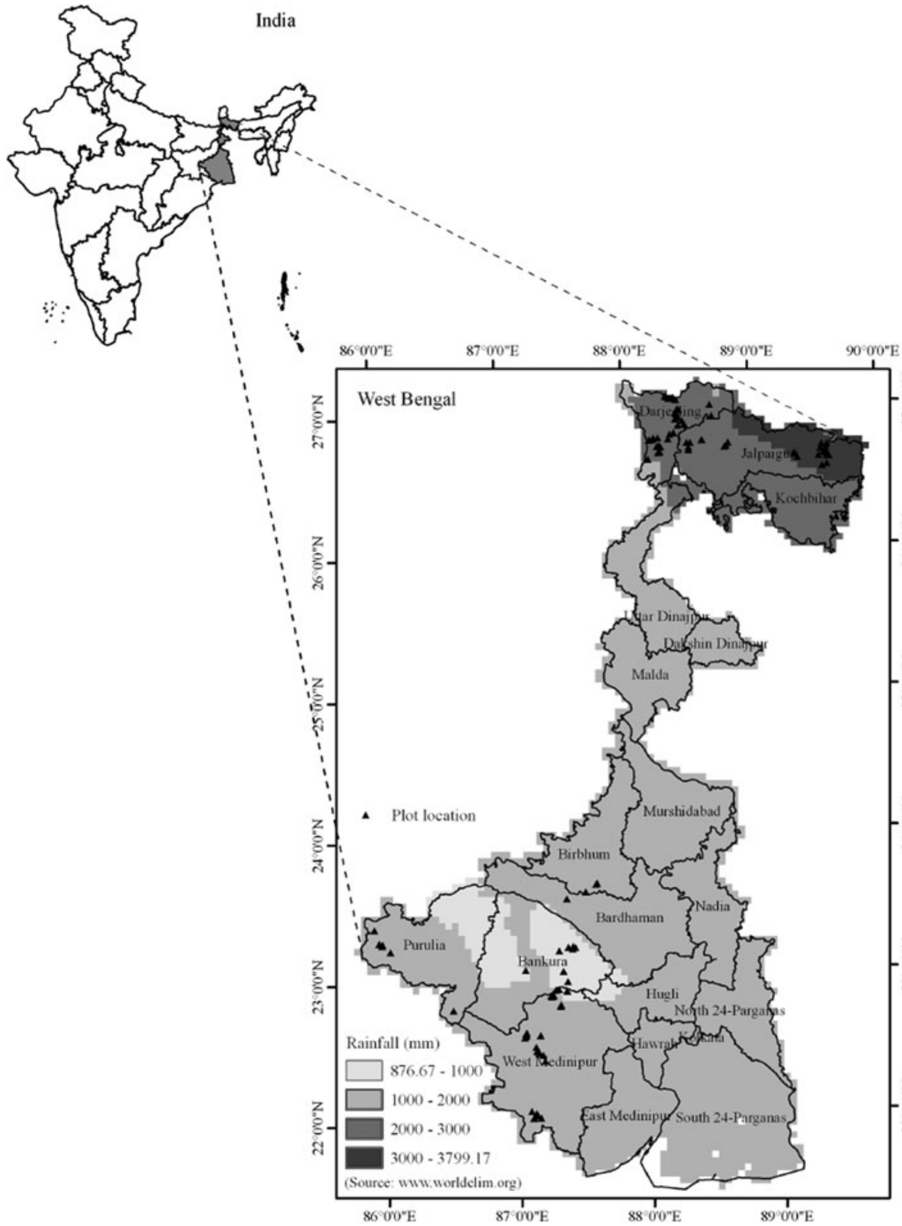

Fig. 1 Location of the study area in India

The Province can be divided into five broad agro-ecological zones, viz., the Darjeeling Himalayas, Sub-Himalayan West Bengal, the Central Alluvial Tract, the Laterite Tract, and the Coast. The forests of the state are mainly concentrated in three regions; the north, the south and the south-west. The moist sal forests are found on the lowest slopes of outer Himalayas from around 1,000 m in the hills to plains of 'duar'. Word 'terai' is used for similar land in Sub-Himalayan Indo-Gangetic region in northern India. The south-western part of the state is an extension of the Chotanagpur Plateau with dry sal forests in West Bengal, Jharkhand and the adjoining Bihar. The biodiversity of the state is under severe threat due to an ever-increasing demand for fodder, medicinal plants, land for agriculture, industry, settlements and the hydroelectric projects. Excessive extraction of forest produces, over-grazing and the man-made forest fires are also responsible for forest degradation and depletion (IIRS 2007). No natural fires are reported from the area.

Methods

The stratified random sampling approach was followed for phytosociological survey in the present study. Sampling was done in all the strata i.e. trees, shrubs and herbs. The size of the quadrat for sampling of trees, shrubs and herbs was determined by species-area-curve method (Misra 1968; Mueller-Dombois and Ellenberg 1974). A 20 × 20 m quadrat for trees (≥30 cm cbh), two 5 × 5 m quadrats for shrubs and four 1 × 1 m quadrats for herbs were laid (Fig. 2) at each sample site. In each quadrat, the circumference at breast height (cbh) of all the trees with ≥30 cm was measured. Trees with <30 cm cbh were taken as shrubs. The individuals of shrub species were noted in the two 5 × 5 m quadrats. For herbs, the number of species in the four 1 × 1 m quadrats was recorded. A total of 80 and 70 plots were randomly laid in the moist and dry sal forests, respectively. The plant species were identified using regional flora and herbarium collection in the Central National Herbarium, Kolkata. The field data were quantitatively analysed for abundance, density and frequency (Curtis and McIntosh 1950). The importance value index (IVI) (Curtis 1959) for the tree species was also worked out. Species diversity of each site was determined using Shannon–Weaver Index (1949):

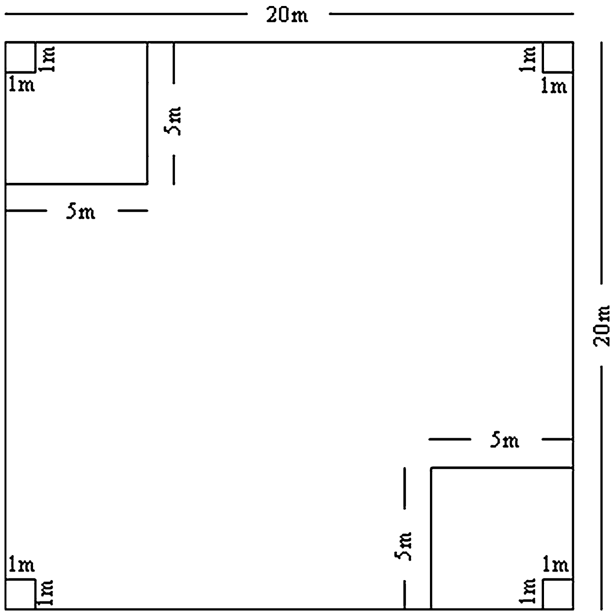

Fig. 2 The sampling design

$$H = -\sum [(n_i/N)\log_n(n_i/N)] \quad (1)$$

where, n_i is the total number of individuals of species i and N is the total number of individuals of all species in that stand; log implies to natural log.

The concentration of dominance (Cd), known as Simpson index, was measured according to Simpson (1949):

$$\text{Index of dominance } (Cd) = \sum \left({}^{n_i}\!/_{N^2}\right) \quad (2)$$

The equitability or evenness (e) refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou (1966) as:

$$\text{Equitability } (e) = {}^{\bar{H}}\!/_{\log S} \quad (3)$$

where $\bar{H}$ = Shannon–Weaver index and S = number of species.

A t-test was run using independent variables viz., species richness, basal area and stand density from two sal forest types. The canonical correspondence analysis (CCA) was also carried out to work out the differences in the two sal forests using same parameters.

Results

The study revealed interesting information on the diversity and community structure in moist and dry sal forests of West Bengal.

Species richness, diversity, evenness and dominance

Dry sal forest showed poor representation of trees, shrubs and herbs compared to moist sal forests. In dry sal forest 35 tree, 41 shrub and 96 herb species were encountered, while 134 tree, 113 shrub and 230 herb species were recorded in moist sal forests. Shannon–Weaver index of diversity also showed higher values in moist sal than in dry sal forests. Higher tree diversity (3.10) was observed in moist sal forests. In both the forests, herb diversity was found to be higher than trees and shrubs. The same pattern was noticed in evenness index. The trees in the moist sal forest showed higher evenness (0.59) than in dry sal forest (0.17). The dominance of trees in both the forests was higher for trees than for shrubs and herbs. Tree species had highest dominance (0.81) in dry sal forests (Table 1).

Taxonomic diversity

The 134 tree species, found in moist sal forest, belonged to 44 families and 82 genera. Meliaceae was the dominant family (14 spp.), followed by Mimosaceae (9 spp.) and Euphorbiaceae (9 spp.). In addition to that, 113 species of shrubs belonging to 88 genera and 39 families, and 230 species of herbs representing 170 genera and 56 families were recorded in the moist sal forest. Among the tree species, Combretaceae was found to be the dominant family representing 4 species, followed by Flacourtiaceae (3 spp.) and Anacardiaceae (3 spp.). Among the shrubs, the dominant families were Euphorbiaceae (6 spp.), Rubiaceae (5 spp.) and Combretaceae (3 spp.). Asteraceae (7 spp.), Papilionaceae (7 spp.) and Acanthaceae (6 spp.) were found to be the dominant families among herbs in dry sal forests. Papilionaceae with 15 species and Asteraceae with 23 species were the dominant families representing shrubs and herbs, respectively in the moist sal forest.

Table 1 Summary of the species inventory in moist and dry sal forests

Variable	Moist sal			Dry sal		
	Tree	Shrub	Herb	Tree	Shrub	Herb
Species richness (No. of spp.)	134	113	230	35	41	96
Number of genera	82	88	170	31	38	83
Number of families	44	39	56	19	18	38
Basal area (m^2/ha)	56.52	–	–	19.62	–	–
Stand density (stems/ha)	438	–	–	1,006	–	–
Shannon–Weaver's index	3.10	3.08	4.36	0.62	2.80	3.40
Simpson's index	0.18	0.12	0.03	0.81	0.10	0.07
Pileou's index	0.59	0.65	0.80	0.17	0.75	0.74

The co-dominant shrub families were Euphorbiaceae (10 spp.) and Rubiaceae (10 spp.) and for herbs it were Poaceae (18 spp.) and Papilionaceae (14 spp.). In dry sal forests, 35 tree species representing 31 genera and 19 families, 41 species of shrubs belonging to 38 genera and 18 families and 96 herb species representing 83 genera and 38 families were recorded.

Density, basal area and importance value

The stand density (stems ha^{-1}) was observed to be higher in dry sal (1,006) compared to moist sal forests (438) but the trees were represented by higher basal area in moist sal (56.52 m^2ha^{-1}) than in the dry sal forests (19.62 m^2ha^{-1}). The *S. robusta* had highest IVI (150.31), followed by *Schima wallichii* (18.44) and *Terminalia bellirica* (10.12) in moist sal forests. In dry sal forest the *S. robusta* had an IVI value of 221.78. Other associates were *Buchanania lanzan* (10.85) and *Madhuca longifolia* var. *latifolia* (10.31). *Clerodendrum viscosum* (43.47), *Coffea benghalensis* (28.24) and *Eupatorium odoratum* (20.44) were the dominant shrub species in moist sal while *Holarrhena pubescens* (48.21), *Flacourtia indica* (23.74) and *Combretum decandrum* (16.42) were dominants in dry sal forest. Among the herbs, *Oplismenus burmanii* (15.19), *Peperomia pellucida* (9.22) and *Clerodendrum viscosum* (8.45) were found to be the dominant species in moist sal. *Hemidesmus indicus* (22.42) and *Oxalis corniculata* (9.46) were the dominant species in dry sal forest (Fig. 3).

Stand density and forest structure

Tree species richness and stem density across girth classes in both the forest types decreased from the smallest to largest trees, while the occurrence rate of species increased with tree size class (Table 2). The same trend was observed by Mani and Parthasarathy (2006) in tropical dry evergreen forests of peninsular India. The species occurrence rate of almost all the girth classes was higher in moist sal than in dry sal. In the 150–180 and 210–240 cm girth classes, the species occurrence rate was found to be slightly higher in dry sal forests. Tree size class distribution of both the categories of forests followed a reverse J-pattern (Fig. 4). In dry sal forest, the mean tree density in the lower girth classes i.e. 30–60 and 60–90 cm was found to be higher than the moist sal forests. In the lowest girth class, i.e. 30–60 cm, the stem density in dry sal was almost five times more than the moist sal forests, indicating disturbance. The mean basal area (12.07 m^2ha^{-1}) contribution

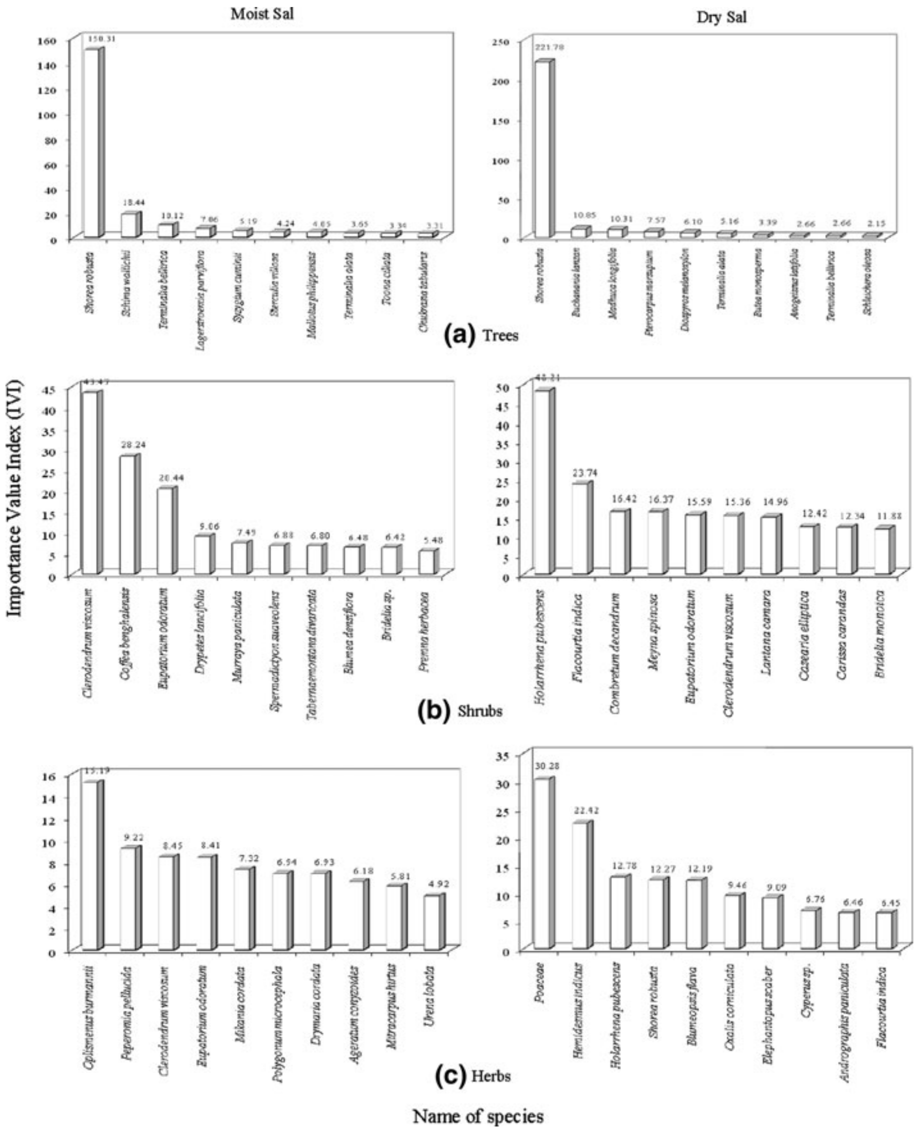

Fig. 3 Ten dominant species of trees, shrubs and herbs in moist and dry sal forests

in the lowest girth class was higher than the other girth classes in dry sal, whereas in moist sal, the mean basal area was found to be highest (10.44 m^2ha^{-1}) in the middle girth class i.e. 210–240 cm. Except for the lower girth classes, mean basal area in all the intermediate and higher girth classes was represented by higher values in moist sal than dry sal forests. The *t*-test showed that species richness, basal area and stand density differ significantly at 95% confidence level in both the forest types ($p = <0.05$). The canonical correspondence analysis (CCA) indicated very low overall match (canonical correlation value = 0.40) between two sets of variables from moist and dry sal types. Figure 5 shows the canonical correlation between two sets of variables from moist and dry sal forests.

Table 2 Mean tree species richness and density (ha^{-1}), occurrence rate of species in moist and dry sal forests

Girth class (cm)	Moist sal			Dry sal		
	Mean species richness ± SD (ha^{-1})	Mean stem density ± SD (ha^{-1})	Species occurrence rate (species richness/stem density)	Mean species richness ± SD (ha^{-1})	Mean stem density ± SD (ha^{-1})	Species occurrence rate (species richness/stem density)
30–60	94.53 ± 3.26	181.25 ± 7.94	0.52	66.67 ± 1.68	883.80 ± 17.24	0.08
60–90	41.80 ± 1.61	67.97 ± 3.59	0.61	27.78 ± 1.37	95.83 ± 4.97	0.29
90–120	25.00 ± 1.11	38.28 ± 1.66	0.65	7.87 ± 0.89	15.28 ± 1.76	0.52
120–150	23.44 ± 0.97	32.81 ± 1.52	0.71	4.17 ± 0.80	7.41 ± 1.46	0.56
150–180	21.88 ± 0.86	33.20 ± 1.54	0.66	1.85 ± 0.33	2.78 ± 0.50	0.67
180–210	16.41 ± 0.65	28.52 ± 1.83	0.58	0.46 ± 0.14	–	–
210–240	17.19 ± 0.73	26.17 ± 1.17	0.66	0.46 ± 0.14	0.46 ± 0.14	1.00
240–270	10.94 ± 0.61	15.23 ± 0.94	0.72	–	–	–
270–300	6.64 ± 0.57	7.81 ± 0.71	0.85	–	–	-
300–330	3.13 ± 0.33	4.30 ± 0.46	0.73	–	–	–
>330	2.34 ± 0.29	2.34 ± 0.34	1.00	0.46 ± 0.14	0.46 ± 0.14	1.00

Discussion and conclusions

The study indicated that there are considerable differences between moist and dry sal forests of West Bengal in terms of diversity, composition, and the stand structure. The differences could be attributed chiefly to variations in the climatic conditions (especially the rainfall), biotic interference and the management practices. According to Beard (1955), the annual rainfall and edaphic factors are responsible for the differences in forest structure among various tropical forest formations. As mentioned earlier, the sal forest in northern West Bengal is markedly different from the sal forest in south-western West Bengal and its counterparts in central Himalaya and elsewhere in India. The proportion of sal in the moist forest in northern West Bengal is lesser than other sal forests in India. Being evergreen is a characteristic feature of northern West Bengal sal forest. Although foliage is markedly thin during summer; simultaneous leaf flushing never renders the canopy totally leafless during summer. The floristic composition indicates the presence of many evergreen species in moist sal forest of north Bengal. The dry sal forests, on the other hand, experience a long dry spell when leaves are shed and thus the forest floor becomes dry and hot during summer. It is the duration of dry period, rainfall and the humidity that influences the floristic composition in both the forest types. This was also observed in the dry deciduous forests of Western Ghats by Sukumar et al. (1992), Murali et al. (1996) and Uma Shankar et al. (1998b).

The present study highlights that the moist sal is fairly rich in species number in all the strata (trees, shrubs and herbs). The number of tree species in moist sal (134) is four times more than that of dry sal forests (35) of south-west Bengal. The overall species richness in moist sal forest in northern West Bengal is even greater than the sal forests in central Himalaya (Singh and Singh 1992) and central India (Jha and Singh 1990; Prasad and Pandey 1992) and deciduous forests of the Western Ghats (Sukumar et al. 1992; Murali et al. 1996; Sukumar et al. 1998; Sundarapandian and Swamy 1997; Uma Shankar et al. 1998a; Ghate et al. 1998) and Eastern Ghats (Reddy et al. 2007; Sahu et al. 2007).

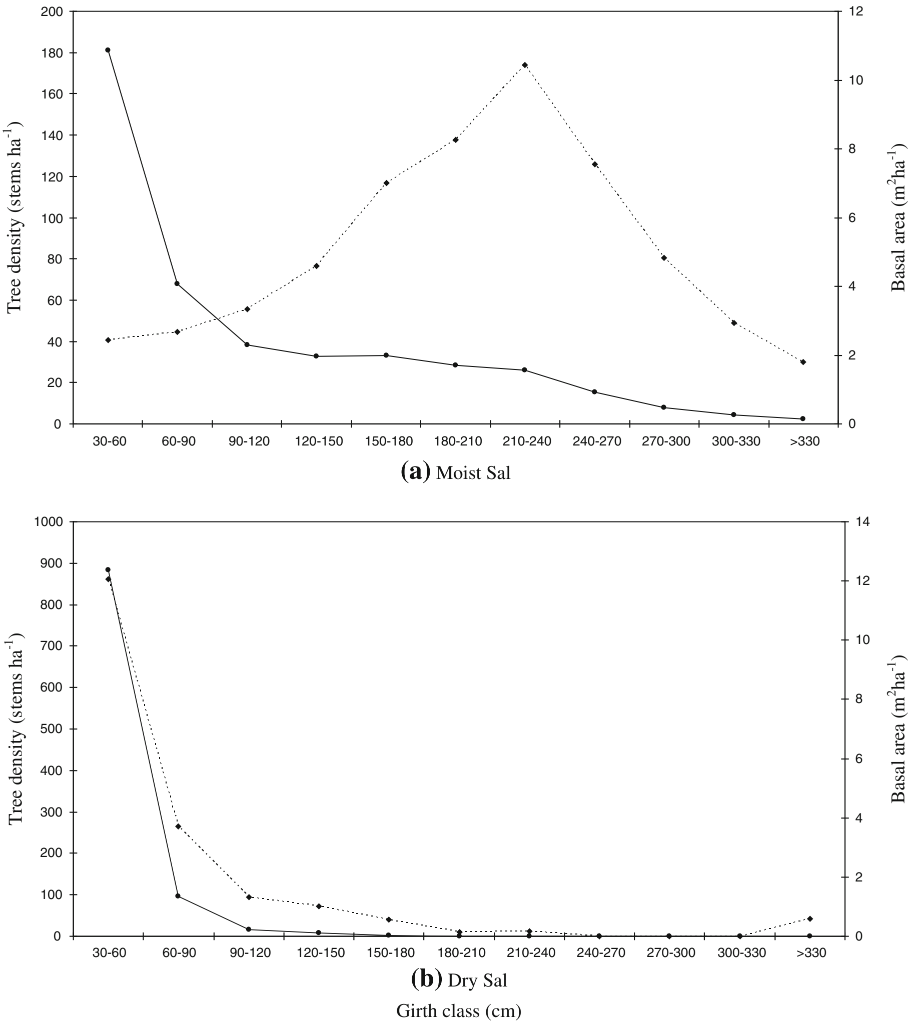

Fig. 4 Stand structure based on the tree density (*solid line*) and basal area (*dotted line*) in moist and dry sal forests

Supplementary Table S1 facilitates comparison of the moist and dry ends of the ecological gradient with the sal dominated deciduous forests of India. Shannon–Weaver's index of diversity was also found to be higher in moist than in the dry sal forests. The index value of 3.10 for trees was slightly lower than the sal dominated forests (3.59) in the eastern Himalayan lowlands of the Mahananda Sanctuary, Darjeeling (Uma Shankar 2001). But it was found to be on the higher side of values (1.98–3.53) recorded for the old sal plantations in Gorakhpur (Pandey and Shukla 1999). Species diversity is an important attribute of a natural community that influences functioning of an ecosystem (Hengeveld 1996). High species content per unit area is largely due to the presence of synusiae in the forest (Richards 1996). Greater diversity leads to higher community stability (MacArthur 1955).

The neotropical deciduous forests are dominated by the family Leguminosae followed by Bignoniaceae (Gentry 1995), whereas Leguminosae is the prominent family in Indian

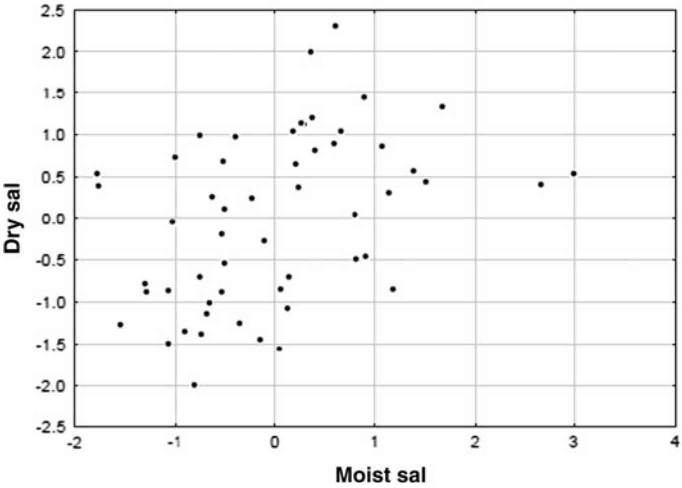

Fig. 5 Canonical correlation between two sets of variables from moist and dry sal forests

deciduous forests (Sukumar et al. 1992; Murali et al. 1996; Uma Shankar et al. 1998a). In the present study also the Papilionaceae was found to be the dominant family in both moist and the dry sal forests, followed by Euphorbiaceae, Asteraceae and the Rubiaceae. So far as tree species are concerned, the dominant family is Meliaceae followed by Euphorbiaceae, Mimosaceae and Lauraceae in the moist sal forests. Almost same trend was observed in sal dominated forests of Mahananda Sanctuary, Darjeeling by Uma Shankar (2001), where Euphorbiaceae stands first followed by Lauraceae and Meliaceae. The moist sal forest was characterized by the presence of more tree species (134 species) compared to 76 species in the sal forests of Mahananda Sanctuary (Uma Shankar 2001). In the dry sal forest of south-west Bengal, 35 tree species were recorded. In Siwalik sal forest of central Himalaya, Singh and Singh (1992) recorded only 13 tree species- 5 in the outgrowth sal forest and 8 in the coppice sal forests. In 24 stands of Gorakhpur old sal plantations 29 tree species were found and most of them were shrub form (Pandey and Shukla 1999) indicating high disturbance.

A basal area of 56.52 m^2 ha^{-1} in moist sal is higher than the one observed by Uma Shankar (2001) in sal-dominated forest in the eastern Himalayan lowland (26.3 m^2ha^{-1}). The basal area in dry sal forests (19.62 m^2ha^{-1}) falls within the range compiled for the dry tropical forests by Murphy and Lugo (1986). The stand density (stems ha^{-1}) was observed to be higher in dry sal forests (1,006) than in moist sal forest (438). The stand density of 438 stems ha^{-1} in the moist sal forest in the present study is close to 484 stems ha^{-1} recorded for sal forests in Himalayan lowland by Uma Shankar (2001). Pande (1999) recorded high stand density in the sal forests of central Himalaya, which is more than the dry sal forests (1,006 stems ha^{-1}) of studied by us. Understanding the forest structure is a pre-requisite to describe various ecological processes and also to model the functioning and dynamics of forest (Elouard et al. 1997). The tree density in different size classes showed a reverse J-shaped pattern in both moist and dry sal forests, which suggests that it is climax or stable forest (Mishra et al. 2005). High tree density in lower girth class could be attributed to the repeated disturbance, rapid colonization and turnover of gaps in the forest (Whitmore 1975).

Sal forest in the northern West Bengal are mostly restricted to the protected areas viz., Mahananda Wildlife Sanctuary, Gorumara National Park, Jaldapara Wildlife Sanctuary, Buxa Wildlife Sanctuary, Buxa National Park, Buxa Tiger Reserve and several reserve forests. The Wildlife (Protection) Act 1972 of India prohibits any kind of extraction from protected areas and thus, moist sal is better protected than dry sal. This together with high rainfall is responsible for the significant difference in the plant diversity and the community structure in the two sal forests in West Bengal. Vast tracts of forests in the Himalayan lowland as well as in the south-western part have been cleared in past for agriculture, human settlements and other developmental activities. Besides, sizeable forested land has also been diverted for tea plantation in the early part of 20th century and forest plantations through *taungya*. The ever-increasing anthropogenic pressure continues to degrade the natural forest patches both in northern and south-western West Bengal in spite of the stringent forest laws and rigorous conservation and the management policy. The analysis reveals that the moist sal forest is extremely important ecosystem by virtue of high species diversity. The same in the dry sal forest is low due to drier climate and high disturbance. As evident from the present study, the dry sal forests in West Bengal need protection for recovery. In fact, some of the patches, which are adequately protected, have shown good regeneration.

Both temperature and the rainfall in eastern Himalaya including the study area are projected to undergo considerable upward change under B2 and A2 climate change scenarios, and sal forests are expected to undergo significant changes (Ravindranath et al. 2006). As per the projection, the dry sal forest in the eastern part of central India including south-west part of the West Bengal would receive an increased mean annual rainfall of 348.3 mm by 2085 (B2 scenario) from current mean annual rainfall of 1,435 mm. An increase of 2.7°C in the mean annual temperature from current mean annual temperature of 24.6°C is expected during same period. A similar scenario of increased rainfall and temperature is projected for entire eastern Himalayan region of India including sub-Himalayan moist sal forest of northern West Bengal. A warmer and wetter climate is also expected to result in increased net primary production by an average of 30.3 per cent by 2035 and by 56.2 per cent by 2085 over India (A1B scenario) and the eastern Himalaya is expected to have higher productivity than average of India (Gopalalkrishnan et al. 2011). Such a climate would also enhance biodiversity in both types of sal forests in the study area.

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