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Pattern of distribution of angiosperm plant richness along latitudinal and longitudinal gradients of India

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Abstract

We analyzed a national database on plant richness with 7761 species from 15,565 nested quadrants to offer the maiden and indicative plant richness pattern of India across its latitudinal and longitudinal gradient. We observed two peaks in the species richness curves along both latitudinal and longitudinal gradients, due to harbouring of higher species richness in the Western Ghats and the Himalayan hot spots. The bands at 10°–11°N latitude and 76°–77°E longitude accommodate maximum of 703 and 864 number of plant species respectively, which could be explained due to cumulative contribution of (i) the Western Ghats, Eastern Ghats, Lakshadweep and Andaman and Nicobar islands along latitudinal; and (ii) the Western Ghats, central India and the Western Himalaya along longitudinal gradients. On dissection of the relationship between plant richness to environment (i.e., geographic area, topography and vegetation types) using Generalized Additive Model (GAM), we observed varied explanations for latitude and longitude. While geographic area and topography explained (98.8% deviance) to the species richness pattern across longitude, all three explained (99% deviance) to the distribution pattern along latitude. We also found that the species richness and vegetation types are positively correlated. Environmental heterogeneity, especially geographic area, topography and disturbance explain the distribution pattern of plant richness in India. Knowing the spatial pattern of plant richness could help in formulating large-scale conservation measures for India. It is hoped that the study would attract larger readership, particularly the Indian bio-geographers.

Keywords Diversity · Generalized additive model · Geographic area · Topography · Himalaya · Western Ghats

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Introduction

One of the clearest patterns in biodiversity distribution is its heterogeneous spatial distribution. The plant diversity distribution is not always random, often they demonstrate distinctive spatial patterns (Rosenzweig 1995). According to Darwin's naturalization theory, two processes generally regulate community assemblages i.e., environmental filtering and biological competition. Environmental filtering generally promotes clustering of species with similar traits, leading to phylogenetic convergence and dispersion within communities. On the other hand, competition may limit the clustering of species with similar traits due to niche partitioning, thereby leading to phylogenetic divergence of species within communities (Campbell and Mandrak 2017). Environmental filtering and competition may act simultaneously in regulating species distribution at large spatial scales (Zhang et al. 2016). Precipitation is an important environmental factor and its spatial and temporal variation may lead to substantial alterations in community composition and structure (Adler et al. 2007). Topography is associated with plant distribution patterns and speciation processes that promote habitat diversity and niche partitioning for speciation (Trigas et al. 2013), enabling species coexistence. Topography offers micro-refugia to some species in altered environmental condition (Ashcroft et al. 2012). On the other hand, topography may create gene-flow barriers among divergent populations, resulting in reproductive isolation and local differentiation (Gillespie and Roderick 2014). Human disturbance may alter microhabitats (environmental factors) through habitat heterogeneity and soil chemistry dynamics, leading to changes in plant diversity (Williams et al. 2005). The plant richness ultimately depends on whatever proximate factors are found to affect processes of speciation, extinction, immigration, and emigration. Many ecologists suggest that this ecological pattern is likely to have generated by several contributory mechanisms (Gaston and Blackburn 2000; Rahbek et al. 2007).

The latitudinal diversity pattern has been studied across many geographic regions. The *geographical area* hypothesis asserts that the tropics are the largest biome and tropical areas can support more species than temperate and alpine areas (Terborgh 1973). The *climate stability* hypothesis suggests that a constant environment can allow species to specialize on predictable resources, allowing them to have narrower niches and facilitating speciation. The *historical perturbation* hypothesis proposes that the low species richness of higher latitudes is a consequence of an insufficient time period available for species to colonize or recolonize areas because of historical perturbations such as glaciations (Gaston and Blackburn 2000). The *species energy* hypothesis suggests that the amount of available energy sets limits to the richness of the system; thus, increased solar energy (with an abundance of water) at low latitudes causes increased net primary productivity (or photosynthesis) and diversity. *Biotic* hypotheses claim ecological species interactions such as competition, predation, mutualism, and parasitism are stronger in the tropics and these interactions promote species coexistence and specialization of species, leading to greater speciation and diversity in the tropics. Behera and Kushwaha (2007) have provided the species richness and endemic pattern along altitudinal gradient in Eastern Himalaya. Also the vegetation distribution pattern along altitudinal gradient was established earlier (Behera et al. 2001; Roy and Behera 2005). However, the plant richness pattern across India`s latitudinal and longitudinal gradient is not studied before due to unavailability of comprehensive and systematic dataset, and coordinated effort.

India is known for its rich heritage of biological diversity, has so far documented 45,500 species of plants in its ten bio-geographic regions that represents 11% of the known plant species of the World (Rao 1997). Besides, it is recognized as one of the eight Vavilovian centres of origin and diversity of crop plants, having more than 300 wild ancestors and close relatives of cultivated plants, which are still evolving under natural conditions. India ranks among the top ten species-rich nations and shows high endemism. India has four global biodiversity hot spots (Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaland). The varied edaphic, climatic and topographic conditions and years of geological stability have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, deserts, and coastal and marine ecosystem. Roy et al. (2015) have provided the forest vegetation type map of India using satellite images and field verification with 100 classes consisting of natural, semi-natural and managed formations grouped under 10 broad categories. The tree-dominant systems include mixed, gregarious, locale-specific, degraded formations, plantations and woodlands; followed by scrublands, grasslands and managed ecosystems.

Longitudinal gradients are related to maritime/continental moisture and temperature gradients particularly along the east and west margins of continents (Chou 2003). Although, the longitudinal pattern of biological diversity may not be as striking as the latitudinal pattern (since the later is associated with large climatic differences from the poles to the equator), there are climatic gradients associated with coastal to interior areas, such as precipitation and temperature, which may result in a pattern of biological diversity along a longitudinal gradient (Morse et al. 1993), in addition to phytogeography. Qian (1999) illustrated longitudinal patterns in the vegetation zones in North America along the east west continental margins. O'Brien (1988, 1993) argued that the woody plant species richness tends to increase from west to east across southern Africa in longitudinal fashion; consistent with the increasing dominance of woody plants as vegetation shifts from desert to evergreen forest. Karrenberg et al. (2003) examined the woody vegetation within the active zone of the near-natural Tagliamento, NE-Italy using CCA and found that the woody vegetation was mainly structured by the longitudinal gradient incorporating air temperature and altitude. Behera et al. (2016) have analysed the plant species distribution pattern along the longest longitudinal gradient of India. They observed that the number of vegetation types, plant species, genera and families increased towards eastern longitude, along with the trees, lianas and shrubs across 3^0 latitudinal bands (25°–27°N latitude).

Plant alpha diversity reaches maxima in equatorial forests. For example, a single hectare of Amazonian forest can support more than 280 tree species (Valencia et al. 1994). A 0.52-km^2 plot in Borneo and a 0.25-km^2 plot in Ecuador support 1175 and 1104 tree species, respectively (LaFrankie 1996). In contrast, a 4.2×106 km^2 of temperate forests that cover Europe, North America and Asia support just 1166 tree species (Latham and Ricklefs 1993). Behera et al. (2005) recorded 764 plant species by laying 122 quadrates of 0.04 ha in Subansiri region of Indian Himalaya. Behera and Kushwaha (2007) recorded 336 plant species that belong to 185 genera and 78 families from 8 quadrates of 0.04 ha each in 200 m elevation steps between 200 m and 2200 m in Eastern Himalaya, India. 154 sample plots were laid in Kargil district in Ladakh Himalaya by Matin et al. (2012) with 30, 44, 80 plots of 0.04 ha each in agroforest, moist alpine scrubs and moist alpine pastures that recorded 226, 189 and 79 species respectively. In another study Matin et al. (2017), recorded 284 plant species from 446 quadrates of 0.04 ha in Gangetic plains of Uttar Pradesh, India; where forests are scanty due to conversion to agricultural lands. Sharma et al. (2019) conducted a field survey that included 224 plots of 20 m × 20 m quadrat for trees, 448 plots of 5 m × 5 m quadrat for shrubs, 1120 plots of 1 m × 1 m for herbs; and recorded 150,391 individuals belonging to 664 species, 367 genera and 131 families.

India's biogeography with the Thar Desert in the northwest and the Himalayas in the north is ruled by monsoon climate, which has distinct regional variations in the Himalayas, coastal regions, the Western and Eastern Ghats and the central Indian tropical convergence zone (Mani 1974). At the confluence of three major bio-geographic realms (viz., the Indo Malayan, the Eurasian, and the Afro-tropical), India accommodates diverse vegetation and plant species. The richness and diversity of flora of India spread over 10 biogeographic regions representing three basic biomes and two natural relams as identified by Udvardy (1975) are recognised within the territory of Indian republic. These are Himalayan highlands, Thar Desert, Malabar rain forest, Indo-Ganges monsoon forest, Coromondal, Mahanadian, Bengalian rain forest, Lakshadeep islands, Andamans and Nicobar Islands.

Database on plant richness

A comprehensive and well-distributed dataset is the key to such a study. The Indian Space Research Organisation (ISRO) under the department of Space, Government of India has carried out a national level project on 'Biodiversity characterisation at landscape level using remote sensing and GIS' wherein a vegetation type map generation and field sampling was done (Roy et al. 2012, 2015). Stratified random sampling was done with respect to India using 15,565 nested quadrates (each of 0.04 ha size) wherein trees and lianas were accounted at 20×20 m^2 area, shrubs were accounted at two 5×5 m^2 nested area, and herbs were accounted at five 1×1 m^2 area (Roy et al. 2012). Lianas include mostly creepers, climbers and orchids among others. Details of the field sampling protocol are provided in the project manual (Anon. 2008). Field sampling intensity was maintained between 0.002 and 0.005% for all 100 vegetation types. Global positioning system (GPS) receivers were utilized for locating field sample plots, gathering location attributes of plant species.

Generalized additive modelling offers an objective way to predict abundance according to the known ecology of species over broad geographic areas. Generalised additive model (GAM) fits a non-parametric and nonlinear relation between species and the environment (Yee and Mitchell 1991). GAM can quantify complex species-environment relationships. Model testing and sensitivity analysis can also help identify influential environmental variables and their corresponding range of influence. Here, we tried to establish the relationship of species richness to their environmental heterogeneity on a spatial domain.

Methodology

We analysed the species count from the national database (*bis.iirs.gov.in*), and brought out their life form wise distribution at each quadrant. We counted their total number at every 1° grid and further at latitudinal (6°–35°N) and longitudinal (68°–98°E) bands to bring out their distribution pattern for the Indian landmass. The cumulative number of species per grid was plotted for each 1° bands at northern latitudinal and eastern longitudinal gradient to depict the plant richness distribution pattern. Although many species distribution models are employed to study relationships between species richness and the environment, we selected the generalised additive model (GAM) for its efficiency in fitting complex species richness pattern (Hastie and Tibshirani 1990). GAM is flexible in choosing smoothing functions and in controlling over-fitting through generalised cross validation (GCV). GCV applies appropriate smoothness to maximise the models' parsimony. Regression lines for plant richness along latitudinal (06°–35°E) and longitudinal (68°–98°N) gradients of Indian landmass were calculated at 95% confidence limit using GAM.

The relationships with geographic area, vegetation area, vegetation type and physiognomy (represented by terrain ruggedness) were analyzed per grid, and accounted to the latitudinal and longitudinal bands, using ArcGIS 10. The 1° grid map was prepared using 'Fishnet' function. The geographic area for each 1° grid was derived using zonal statistics of spatial analyst tool. We utilised 'vegetation type map of India' with 100 vegetation classes to compile information on vegetation type and their area (Roy et al. 2015). We utilised elevation map from the Global Multi-resolution Terrain Elevation Data 2010 (GMTED 2010; Danielson and Gesch 2011) database at an approximate 250 m resolution to derive the terrain ruggedness index (RI) by calculating the differences of mean elevation values of adjacent cells relative to the central cell (Riley et al. 2000). The RI serves here as an index of topography. The mean of terrain ruggedness index was assigned for each 1° grid along the latitudinal and longitudinal gradients. The correlation between the four candidate variables (i.e., ruggedness index, geographic area, vegetation area and vegetation type) were tested and variables with > 0.80 correlation level were considered separately to avoid overestimation problem. The multicollinearity was tested through hierarchal clustering analysis using the package 'corrplot' in RStudio (Wei and Simko 2016). GAM was fitted with a Poisson error distribution with a 'log' link function for species count data and cubic spline smoother, using the package 'mgcv' in RStudio (Wood 2016). The deviance explained was used to predict importance of each variable and their combined effects on species richness. Variable combinations those were statistically significant at $p < 0.01$ level or higher were discussed.

We also derived the vegetation area statistics as per the vegetation type mapping carried out by Roy et al. (2015) at 1° latitudinal and longitudinal bands; and attempted to plot the species richness with vegetation types at each 1° grids to realize how the two are correlated.

Results

Plant richness pattern at 1° latitudinal and longitudinal gradients

A total of 3,13,076 (individual) plants comprising of 7761 species were sampled across Indian forest vegetation using 15,565 nested quadrates. At quadrant level, the maximum number of trees, shrubs, herbs and lianas were accounted to 46, 37, 25 and 12 respectively (Fig. 1). Trees dominated the central India, Western and Eastern Ghats, while shrubs dominated the central India, and Western Ghats (Fig. 1a and b). Herbs dominated Western Ghats and Western Himalaya, whereas lianas found abundantly distributed in Eastern Ghats, central India and western Himalaya (Fig. 1c and d). The maximum number of total plant species at each quadrate and at each 1° grid were calculated as 59 and 623 respectively (Fig. 2a and b).

A maximum of 703 and 527 species of which 192 and 172 trees, 160 and 143 shrubs, 321 and 194 herbs were found at 10°–11°N and 27°–28°N latitudinal bands (Fig. 3a). However, maximum number of 32 and 26 liana species was found at 11°–12°N and 26°–27°N latitudinal bands. The contribution of species at 6°–8°N latitudinal bands are solely accounted by Nicobar Islands (Fig. 3a). At 28°–35°N latitudinal bands, the species richness contribution is reported only from Western Himalaya wherein the herbal contribution

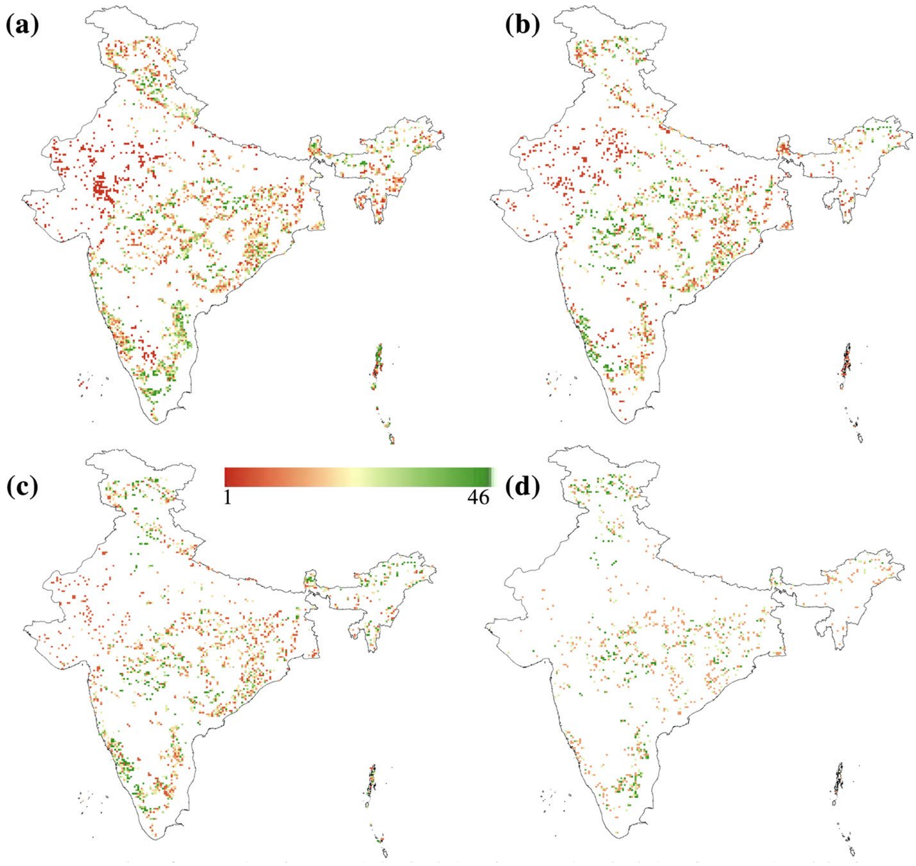

Fig. 1 Number of **a** tree (maximum, 46), **b** shrub (maximum, 37), **c** herb (maximum, 25) and **d** Liana (maximum, 12) species in each quadrate of 0.04 ha in India

dominates. A maximum of 864 and 719 species of which 455 and 381 herbs were reported at 76°–77°E and 77°–78°E longitudinal bands (Fig. 3b). The maximum number of 245 and 231 tree species were found at 74°–75°E and 92°–93°E; 222 and 167 shrub species were found at 76°–77°E and 74°–75°E, 39 and 34 liana species were found at 92°–93°E and 77°–78°E longitudinal bands. The contribution of species richness at 68°–69°E longitudinal band are solely from the Kachchh peninsula of western Gujarat state; and beyond 89° longitudinal bands, the species contribution is reported from north-east Indian states of Eastern Himalaya only (Fig. 3b).

The bands at 10–11°N latitude and 76–77°E longitude accommodate maximum of 703 and 864 number of plant species (Fig. 3). This could be explained due to cumulative effect of (i) the Western Ghats, Eastern Ghats, Lakshadweep and Andaman and Nicobar islands along latitude (Fig. 4a); (ii) the Western Ghats, central India and the Western Himalaya along longitude; wherein herbs are dominant (Fig. 4b). The latitudinal pattern of species richness of India is contributed by Nicobar islands; cumulative of Lakshadweep islands, the Western Ghats, the Eastern Ghats, the Andamans islands (the highest); cumulative of Eastern Ghats and central India; cumulative of Kachchh peninsula, central India, the

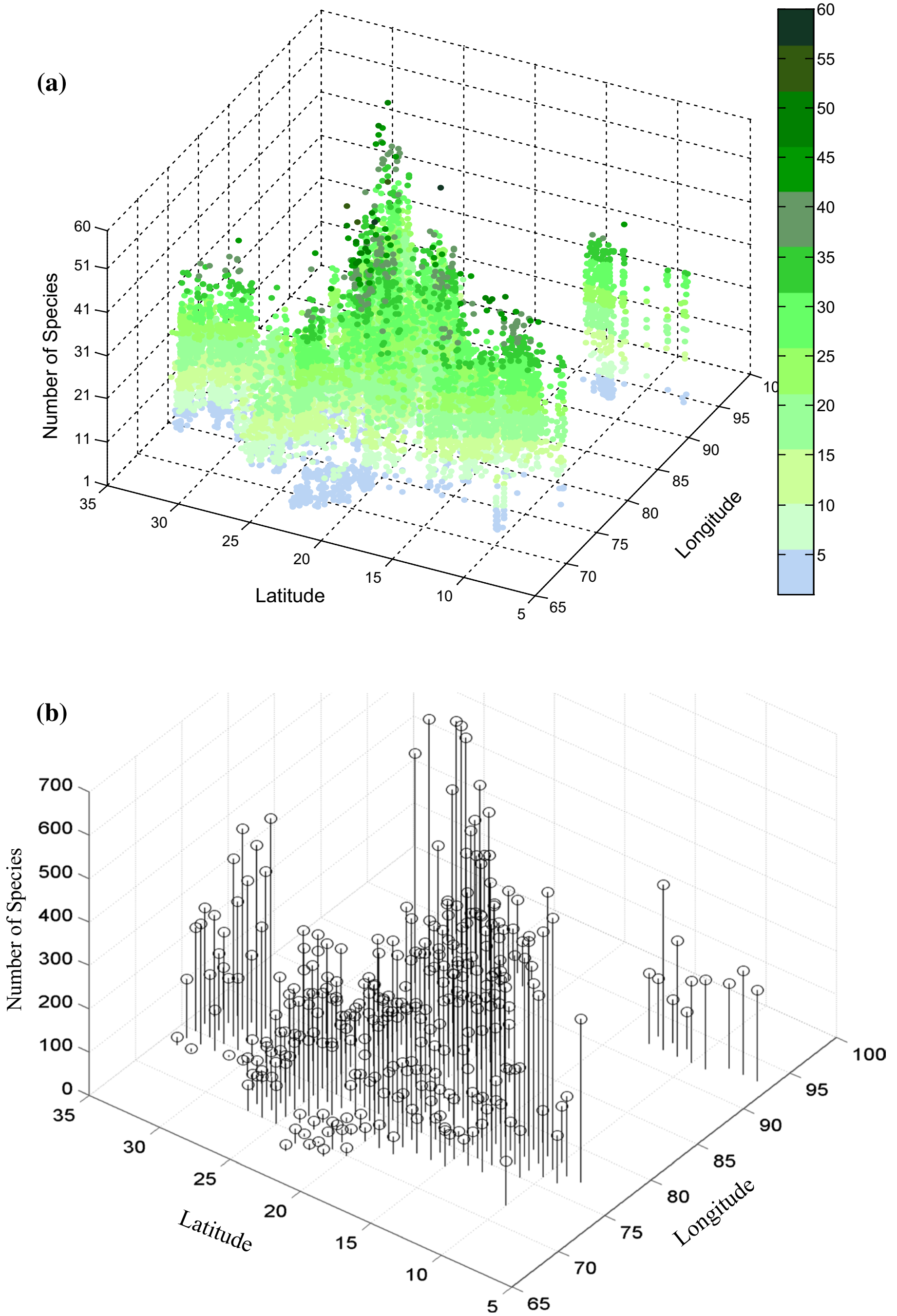

Fig. 2 **a** Number of total plant species (maximum 59) at each quadrat of 0.04 ha, shown in 3-D space across latitudinal and longitudinal extent of India. **b** Number of total plant species (maximum 623) at each 1° grid, shown in 3-D space across latitudidinal and longitudinal extent of India

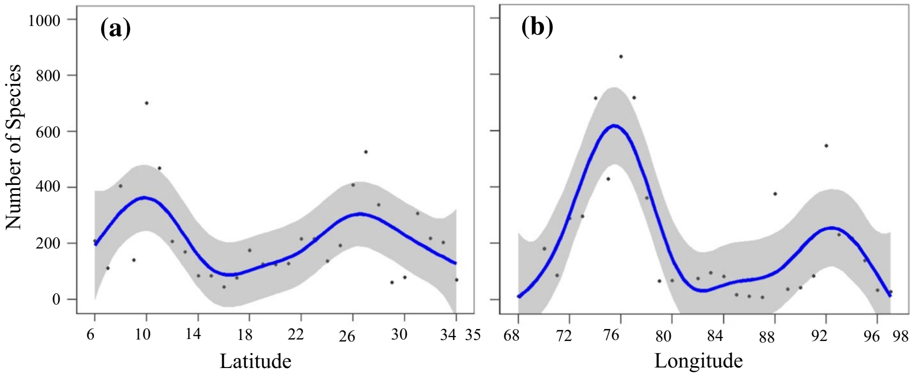

Fig. 3 Regression lines for plant richness along **a** latitudinal (06°–35°E) and **b** longitudinal (68°–98°N) extent of Indian landmass; calculated at 1° grid resolution, and derived using Generalised Additive Model (GAM). Points represent sample locations, dark/blue lines represent species richness pattern and grey areas indicate 95% confidence limit

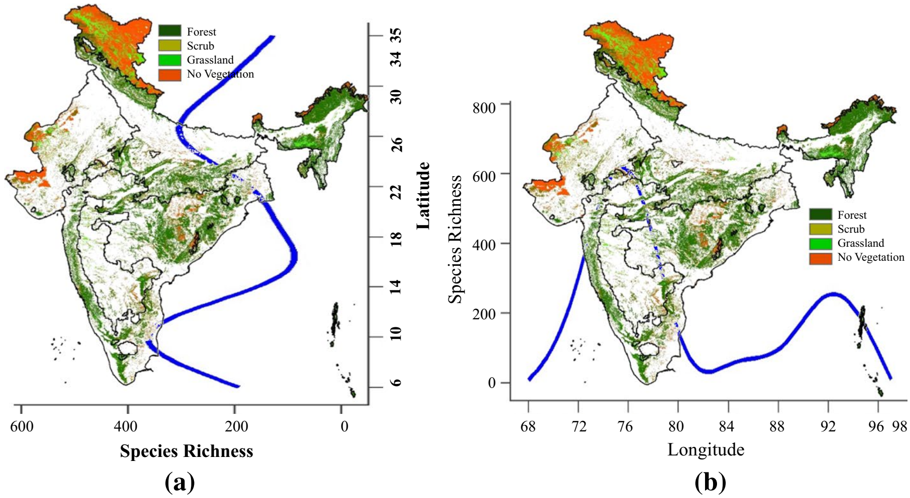

Fig. 4 **a** Plant richness curve along the latitudinal (06°–35°E) extent in India (drapped over Vegetation type map of India, modified from Roy et al. 2015); calculated at 1° grid resolution and, derived using generalised additive model (GAM). **b** Plant richness curve along the longitudinal (68°–98°N) extent in India (drapped over Vegetation type map of India, modified from Roy et al. 2015); calculated at 1° grid resolution and, derived using generalised additive model (GAM)

Sunderban mangroves and the Indo-Burma Hot spots; cumulative of Western Desertic flora, lower Shiwalik Himalaya, Indo-Gangetic plains and Eastern Himalaya; upper Shiwalik Himalaya; and Western Himalaya from lower to higher latitudes (Fig. 4a). The longitudinal pattern of species richness of India is contributed by Kachchh peninsula; Western Desertic flora; cumulative of Western Himalaya, upper Shiwalik Himalaya, central India and the Western Ghats (the highest); cumulative of lower Shiwalik Himalaya, lower Indo-Gangetic plains, eastern India and the Sunderban mangroves; the Sikkim Himalaya;

cumulative of Eastern Himalaya and the Indo-Burma Hot spots, from western to eastern longitudes representing various crests and troughs in the curve (Fig. 5b).

Regression of species richness with environmental heterogeneity variables

Independent influence of variables was found less significant in defining species richness along the latitudinal gradient. Ruggedness index and geographic area are found to explain 28.5% and 39.5% deviance, respectively. Comparatively, the influence of each variable was more prominent on species richness along the longitudinal gradient. Vegetation type is found to describe maximum species richness by an independent variable (76.2% explained deviance) along the longitude (Table 1). Ruggedness index and geographic area explained deviance of 71.7% and 68.4% in longitudinal pattern of species richness, respectively. Vegetation area described 54.1% deviance in species richness along longitudinal gradient, the lowest among the four variables. Although, independent effect of each variable was less significant in explaining species richness along latitude, the explanatory ability substantially improved when two or more variables were combined. Ruggedness index and geographic area could explain 63.2% ($R^2=0.28$), the maximum deviance explained by any two variables (49.7 ± 12.9%; $R^2=0.11 \pm 0.24$). The deviance explained by ruggedness index, geographic area and vegetation type was 96.7%, the maximum deviance explained by combinations of any three variables (76.8 ± 19.9%). The best model with combinations of all four variables could explain 99% deviance in species richness. Along longitude, the combined influence of any two or more variables were highly significant (≥ 90% explained deviance); and the best combination was contributed from terrain ruggedness, geographic area and vegetation area, which described 98.8% deviance in species richness, i.e., the maximum explanation by any variable combination for longitudinal species richness (Table 1).

The grid with maximum number of vegetation types (17) accommodated 609 numbers of species while the grid with maximum number of species (623) accommodated 12 vegetation types (Fig. 5a). Most of the grids in central India and Western Ghats

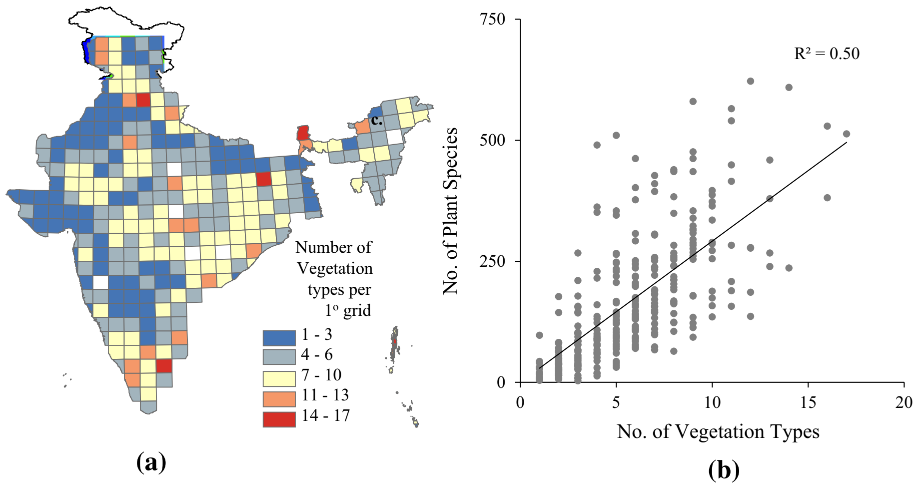

Fig. 5 Number of **a** vegetation types (counted from Roy et al. 2015), and **b** vegetation types versus plant species; per 1° grid of India

Table 1 Regression analysis between species richness (SR) and variable combinations statistically significant at $p < 0.001$, derived using generalized additive model; comparisons made for latitude and longitude at 1° grid; 's' indicates cubic spline smooth function; 'ns' represents non-significant ($R^2 < 0.10$) relationships

Models	a. Latitude		b. Longitude	
	Adjusted R^2	Deviance explained (%)	Adjusted R^2	Deviance explained (%)
SR ~ s(RI) + s(GA) + s(VA) + s(FT)	0.97	99	ns	ns
SR ~ s(RI) + s(GA) + s(FT)	0.94	96.7	0.92	97.8
SR ~ s(GA) + s(VA) + s(FT)	0.69	88	0.94	97.9
SR ~ s(RI) + s(GA) + s(VA) + s(FT)	0.37	76.8	0.96	98.8
SR ~ s(RI) + s(GA)	0.27	63.2	0.75	89.6
SR ~ s(VA) + s(FT)	0.35	58.1	0.91	91
SR ~ s(RI) + s(FT)	0.28	57.9	0.82	91.3
SR ~ s(RI) + s(VA)	0.11	49.7	0.84	89.9
SR ~ s(GA)	0.10	39.5	0.57	68.4
SR ~ s(RI)	0.11	28.5	0.59	71.7
SR ~ s(VA)	ns	ns	0.28	54.1
SR ~ s(FT)	ns	ns	0.69	76.2

RI ruggedness index, *GA* geographic area, *VA* vegetation area, *VT* vegetation type

accommodate medium number of vegetation types as per the satellite based classification given by Roy et al. (2015). It can be seen that the number of species increases proportionally with increase in number of vegetation types per 1° grid (Fig. 5b). We found that the number of vegetation types is positively correlated (with $R^2 = 0.5$) with the number of vegetation types at 1° grid levels in Indian landmass (Fig. 5b), which is quite expected as per ecological framework.

Discussion and conclusions

100 forest vegetation classes of India prepared using Indian Remote Sensing (IRS) satellite data geo-tagged to 7761 species from 15,565 field plots generated a database on vegetation, plant diversity including life-forms; that allowed through this study to bring out the maiden latitudinal and longitudinal pattern of plant species distribution of India. The plant species richness database has been organised in form of a web portal (bis.iirs.gov.in). Though the sampling asymptoteness was accomplished using species-area curves at vegetation type level for India (Roy et al. 2012), the 1° band-wise sampling asymptoteness was also ensured in this study. The patterns and curves obtained in this study provide the maiden trend and early indications for India. Jamir and Pandey (2003) have noted 395 species, 250 genera, and 108 families comprising pteridophytes, gymnosperms and angiosperms in the sacred groves of the Jaintia Hills, in northeast India. The peninsular Indian evergreen forests are rich in woody plant species when compared with the drier vegetation (Daniels et al. 1992).

Explanation of environmental heterogeneity to plant richness distribution pattern

The species richness along latitude is not significantly explained by any one independent variable, whereas the importance of each variable greatly influences species richness along longitude. The increase in moisture, increase in disturbance due to dense population, land use pattern, industrialisation, intensive agriculture from west to east provide plausible explanation for significant effects of each variable. Increase in GA leads to increase in VA availability, and increase in VA and RI provides more space for different species at multiple habitat conditions with favourable climate (moisture availability), driving species richness from west to east. The extreme heat condition in west may hold strong consequences on its poor species diversity.

The mountain ecosystems particularly the Himalayas and the Western Ghats contribute prominently in geographic range, biophysical and socio-cultural variety and uniqueness. The extent of species endemism in vascular plants along elevation gradient ranges 13 per ha in the Himalayan mountain ecosystems (Behera et al. 2002). Human involvements, including progressive activities and widespread poverty are leading to changes in forest conversion to agricultural land in the Gangetic plain (Behera et al. 2014). Similarly, in Western Ghats, selective logging, and conversion to agriculture etc., has contributed to the biodiversity decline (Ray et al. 2016). Of late, mass tourism, unsustainable land use practices, excessive subsistence dependence on forests, etc., are major challenges (Ashok et al. 2017).

Latitudinal and longitudinal pattern of plant richness

Relatively higher and comparable species richness was observed for the Western Ghats and the Eastern Himalaya respectively for both the latitudinal and longitudinal curves with respect to mapped vegetation area and total geographic area of the country (Table 1). This effect may be attributed to the effect of topography, which promotes habitat diversity and niche partitioning leading to species coexistence (Trigas et al. 2013). In the mid-regions of both the latitudinal and longitudinal curves, relatively more pessimistic scenario was noticed with respect to the total geographic area of the country than the mapped vegetation area (Fig. 4). This may be attributed to human disturbance causing microhabitats alteration (environmental factors) through habitat heterogeneity leading to decline in plant diversity (Williams et al. 2005). Hence, the study explains that the plant richness ultimately depends on the proximate factors that affect processes of speciation, extinction and migration. Conversely, the longitudinal pattern of plant richness seen here could be broadly explained by presence of Western Ghats and the Himalayas; and the islands. They are associated with coastal and mountainous areas with precipitation and temperature alternations, which may result in a pattern of biological diversity along a longitudinal gradient, in addition to phytogeography (Morse et al. 1993). This also corroborates with the findings of Behera et al. (2016), who observed that the number of vegetation types, plant species, genera and families increased towards eastern longitude, along with the trees, lianas and shrubs across 3° latitudinal bands (25°N–27°N) in India.

We feel the species-energy, historical-perturbation, climate-stability and biotic hypothesis may explain to the highest contribution of species richness by the Western Ghats in the lower and western part of the latitudinal and longitudinal gradient. Similarly, the climate-stability, species-energy and biotic hypothesis may explain the second highest contribution of species richness by the Himalayas in the upper and eastern part of the latitudinal and longitudinal pattern of species richness. Additionally, the disturbance might be playing determining role in the species distribution pattern that may be inferred from the analysis with respect to geographic and vegetation area in the mid-region that needs to be further evaluated and confirmed (Table 1). The longitudinal pattern of species richness can be broadly attributed to topography, as observed by Karrenberg et al. (2003) while examining the woody vegetation within the active zone of the near-natural Tagliamento, NE-Italy.

This study presents the maiden (though, indicative) plant richness pattern of India across its latitudinal and longitudinal gradient, which could be further modified with addition of more sampled data. The Western Ghats and the Himalayan regions with higher species richness depict the maxima in the latitudinal and longitudinal pattern of plant richness of India. The environmental heterogeneity particularly geographic area, topography and disturbance explain the distribution pattern. The pattern may slightly be modified if overlapping bands are considered to obtain the plant richness distribution pattern. The proportionately stratified random sampling allowed presenting the national latitudinal and longitudinal pattern of angiospermic plant species distribution for understanding of biogeography. The life-form distribution pattern would provide basis for future monitoring, as the shrub and herbs are expected to respond faster to higher temperature than trees in the warming tropics. Knowing the spatial pattern of plant diversity is critically important for large-scale conservation programs and it is hoped that the study will attract readership of the World bio-geographers, and Indian in particular.

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