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RESEARCH ARTICLE

Altitudinal variations of ground species in the southern Aravalli regions of Rajasthan, India

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Abstract

Ground layer species help in sustaining a variety of plants and animals; and maintain a healthy and resilient forest ecosystem by contributing to ecological functioning, structural support, and biodiversity. The western Indian Aravalli range is noted for its vegetation. Studies from these regions indicated that various environmental factors influence plant diversity and its distributions. The present study examines the impacts of altitude on ground species in Rajasthan's southern Aravalli hill ranges. We conducted field investigations year-round in Phulwari Ki Nal wildlife sanctuary, Kumbhalgarh wildlife sanctuary, and Sitamata wildlife sanctuary at different altitudes. A random transect method was used; five $1m^2$ plots were laid at every 250m interval. Species' names and numbers were recorded from sampling plots. Sanctuary-wise species richness, abundance density, and diversity were calculated and related with altitude. The protected areas of Southern Aravalli do not follow an altitude-specific pattern in ground species distribution. Specific lower altitude ranges had the most species richness, abundance density, and diversity. While altitude showed both positive and negative correlations with respect to ground species richness, abundance diversity and density. The study findings help in conserving and preserving ground layer species in the Aravalli regions of Rajasthan.

Keywords

Ground layer; altitude; Aravalli hills; species richness; abundance; density; diversity

Introduction

Ground vegetation is one of the important component of the forest ecosystem (1). This layer has the highest number of species, contributing significantly to the species diversity (2). Despite its small size, the ground layer plays a crucial role in forest ecosystems. It nurtures the ecosystem by exchanging gaseous components within the atmosphere, supports the water and nutrient cycle, increases gross primary production, and sequence carbon dioxide in the soil (3). Ecologists reported the link between ground species distribution along elevation gradients and found that elevation alters the species richness and composition (4–6). However, few studies reported that species richness and composition did not change with elevation (7). A study also found hump-shaped patterns with a high species richness at mid-elevations and a monotonic decrease or increase in species richness from lowest to highest elevations (8). In the western Carpathians, a drastic change in the composition and structure of ground layer species in above the tree line (9). In the forest of central Norway and Abune Yosef mountain range, Northern Ethiopia, plant species increased along the altitudinal gradients (10). Contradiction to that, in the high Alpine zone of central Europe, a decrease in species richness was observed towards higher elevations (11). However, a study done on the *Quercus leucotrichophora* (12) forests of northwest, India did not show any regular trend in the ground vegetation along the elevation gradient of the Himalayas.

The southern Aravalli regions fall under the subtropical, semi-arid climatic condition. Three major distinct seasons were observed, summer (March –June), monsoon (July – September) and winter (October – February) (13). In winter, the lowest temperature was 5°C and during summer the maximum was 45°C (14). The average rainfall in these regions ranges from 725 to 751mm with a maximum of 951mm and a minimum of 517mm (14). The altitude of Phulwari-ki-Nal wildlife sanctuary (PWS) ranges from 300-600m, Kumbhalgarh wildlife sanctuary (KWS) ranges from 300-1300m and Sitamata wildlife sanctuary (SWS) from 280-700m above mean sea level (15). The distribution and overall health of the ground layer species in the Aravalli region are controlled by various environmental conditions. The natural factors, and anthropogenic factors such as deforestation, habitat fragmentation and land use changes have profound impact on ground layer species of Aravalli (16). The present research paper is designed to analyze the relationship between ground species and altitude in the southern Aravalli hills regions of Rajasthan.

Materials and Methods

Study Area

The Aravalli hill range in northern-western India stretches for about 670 kilometres (416.32 miles) in south-westerly direction (Fig. 1). It starts from the state of Gujarat and passes through Rajasthan, and it ends in Delhi (17). Mount Abu's Guru Shikhar, at 1,722 metres, has the highest peak (5,649.61 ft). The Aravalli Range is the oldest geological feature on Earth (18)it origins are in the Proterozoic era . In Southern Aravalli regions of Rajasthan are covered with many protected areas. The southernmost sanctuary is the Phulwari Ki Nal wildlife sanctuary, which has continuous patches of Gujarat polo forest. It is located between 24° 00', and 24° 30' N latitude and 73° 07', and 73° 20' E longitude in the Udaipur district, with a total area of 511.41 km^2, of which 365.92 km^2 is reserved forest and 145.49 km^2 are protected forests (19). The terrain's altitude within the sanctuary ranges from 300 to 900 metres above mean sea level. The sanctuary has a semi-arid climate with an average annual rainfall of 730 mm. It is a largest viable forest tract among Rajasthan's fragmented forest belt (20). Phulwari-ki-Nal forest is a part of the II-dry tropical forest. It sub classified into northern dry mixed deciduous forest (C2) and northern tropical dry deciduous forest (5B) (21). The river and stream courses offer unique microhabitats that support tall evergreen trees and dense undergrowth (22). All species naturally regenerate in large, plentiful amounts.

Kumbhalgarh wildlife sanctuary (23) lies in the north (20° 05' to 23° 03' N latitude and 73° 15' to 73° 45' E longitude) of Phulwari-ki-Nal sanctuary (15). The sanctuary covers areas of the Rajsamand, Udaipur, and Pali districts. The core area of the wildlife sanctuary is 224.890 km^2 (87 sq mi), and the buffer area is 385.638 km^2 (149 sq mi). This sanctuary is covered by the Kumbhalgarh, Sadri, Desuri, and Bokhada hill ranges (17), it acts as a barrier to the Thar Desert, preventing the desert from expanding eastwards (23). The vegetation in this sanctuary is classified as II-dry tropical forest, northern tropical dry deciduous forest (5B), and northern tropical dry mixed deciduous forest (C2) (19). Additionally, the sanctuary features various other sub-forest types, DS1 *Anogeissus pendula* scrub, E2 *Boswellia* forests, E5 *Butea* forests, E8 saline-alkaline scrub savannah, and E9 dry bamboo branches (19).

The Sitamata wildlife sanctuary in Rajasthan's Pratapgarh and Chittaurgarh districts is a protected forest. Its latitude and longitude are from 24°04' to 24°23' N and 74°25' to 74°40' E. Malwa Plateau, Vindhyachal hills, and Aravalli hill ranges meet to provide the sanctuary's undulating environment, (24). Plants and animals from the Aravalli and Vindhyachal ranges are found in this topography (15). The sanctuary is known for its biodiversity, with teak stands, marshes, perennial streams, undulating hillsides, steep gorges, and mixed forests (13). It is the only forest with high-value teak trees. Other trees include salar, tendu, bad, peepal, babool, neem, arinja, siras, churail, kachnar, gulmohar, amaltas, bakayan, ashok, mahua, semal, goondi, and khejadi (16). Forest type is II-dry tropical woods, it divided into southern and northern tropical dry deciduous forests, including southern dry teak-bearing forest (C1) and northern dry mixed deciduous forest (C2) (25). Rivers including the Jakham, Karmoi, and Sitamata flow through the sanctuary. This river network and varying topography generate micro and macro habitats that support many important floral species, highlighting the ecological value of the Sitamata wildlife sanctuary (15).

Field sampling

A field investigation was carried out between 2007 and 2010. The field samples were collected using the vegetation map created by the FES (2007) (26). The samples were taken at various times throughout the year in different altitudinal ranges (Table 1). At the field level, random transects at a length of 1.4 km were laid. At every 250 meter interval, five 1m^2 quadrats (one in the center and the other four in four different directions) were laid in each chosen sampling point. In the sampling points, species names and numbers were recorded. The species were identified using Flora of Rajasthan; the unidentified species were collected, and preserved for identification (27).

Data analysis

The field data were analyzed sanctuary-wise. The species richness, abundance diversity (H) and density/sqm were calculated at the transect levels, the data were plotted using the graph builder available in JMP Pro ver 16.2. The correlation was calculated between the herb and grass (including sedges) species in relation to altitude.

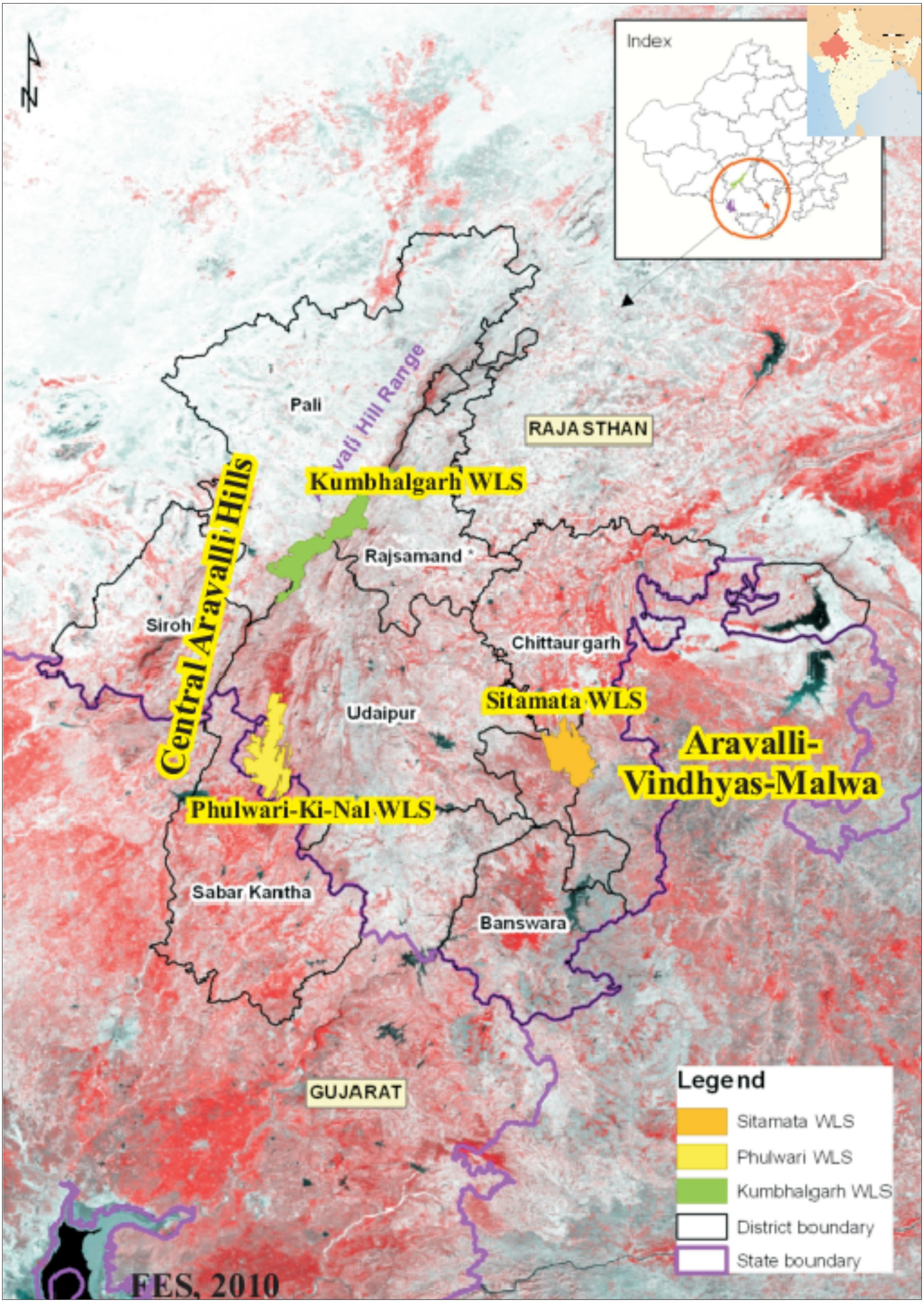


Fig. 1. Location of protected areas in the southern Aravalli regions of Rajasthan.

Table 1. Details on sampled plots in protected areas of the southern Aravalli regions of Rajasthan.

Total	PWS	KWS	SWS
	735	900	840
	Altitude (m)		
300-400	360	220	550
400-500	280	265	195
500-600	95	55	65
600-700	-	120	30
700-800	-	40	-
800-900		70	-
900-1000		70	-
1000-1100	-	60	-

Results and Discussion

The species richness was greater in SWS with a count of 188 species, followed by 163 in KWS and 134 in PWS (Table 2 and Table S1). The highest abundance was seen in SWS (36,464), followed by KWS (29,392) and PWS (17373). SWS also showed greater species diversity (3.98) and density (43/sqm). KWS showed the second most species diversity and density of 3.45 and 33/sqm, respectively. The species diversity of PWS was 3.04 and density was 24/sqm respectively (Table 2).

The herb and grass species richness was highest at 300-400m (78 and 24) at PWS and the lowest at 500-600m (57 and 12) (Table 3). The highest species richness of herb and grass was found at KWS at 300-400m (73 and 31) and lowest at 700-800m; the SWS richness was high at 300-400 and low at 600-700m (Table 3). Herb diversity was higher at 300-400m in SWS (H=3.53) and lower at 600-700m (H=1.91). In the case of grass, diversity was higher at SWS at 300-400m (H=2.6) and lower at SWS at 600-700m (H=0.82). The PWS of the herb and grass diversity was higher at 300-400m and lower at 400-500m. In KWS the highest herb diversity (H=3.09) was recorded at 500-600m; for grass species, the highest diversity was found at 300-400m. In PWS, the abundance of herb species was higher at 400-500m (6,849) and lower at 500-600m (1,454); the abundance of grass species was higher at 300-400m (2,344) and lower at 500-600m (704). In KWS, the abundance of herbs was higher at 300-400m (4103) and lower at 1000-1100m (170); while grass species was higher at 300-400m (7,301), and lower at 700-800m (708). In SWS, herb species abundance was higher at 400-500m (6,371) and lower at 600-700m (177); while grass species were higher at 300-400m (8,012) and lower at 600-700m (106). The herb density/sqm was high at 400-500m of PWS, 300-400m of KWS, and SWS. The grass density/sqm was highest at KWS, with 33.2 individuals in 300-400m and 600-700m. PWS and SWS showed fewer individuals of grasses per sqm (Table 3).

Table 2. Richness, abundance diversity and density of ground species in protected areas in the southern Aravalli regions of Rajasthan.

	PWS	KWS	SWS
Species Richness	134	163	188
Diversity (H)	3.04	3.45	3.98
Abundance	17373	29392	36464
Density/sqm	24	33	43

In the protected regions of PWS, KWS and SWS, the richness of herbs and grasses was high at 300-400m. No significant changes in species richness were recorded with altitude increase in PWS. In KWS and SWS, the richness of species decreased with an increase in altitude. However, at 1000-1100m altitude KWS showed unique habitats with an increased in the species richness (Table 3 and Fig. 2). The diversity of herbs and grasses was decreasing in SWS in response to altitude. In accordance with altitude, abundance of herbs showed an increase and then decreased in PWS, while grass species decreased with increasing altitude. Herb and grass species of KWS do not showed any pattern in accordance with altitude. In SWS, herb species do not followed any pattern in response to altitude but, grass species decreased with increasing altitude. However, mixed responses were observed in altitude in PWS and KWS. The density of herbs and grasses increased towards altitude in PWS and decreased in SWS (except 500-600m) and mixed response in KWS (Table 3 and Fig. 2).

Correlations between altitude and richness, abundance diversity and density were presented in Fig. 2, 3, 4 and 5. In PWS, the correlation between altitude, herb species richness (r:0.154), abundance (r:0.314) and density/sqm (r:0.278), were positively related and diversity (r:-0.181) showed negative relationships. The grass species richness (r: -0.058) and diversity (r:-0.196) were negatively related and density/sqm (r:0.148) and abundance (r:0.181) were positively related. Reverse to the above pattern, in the KWS the diversity (r:0.162) of herb species was positively related while richness (r:-0.153), abundance (r:-0.292) and density/sqm (r:-0.312) were negatively correlated. But in the case of grass species of KWS, richness (r: 0.296) and diversity (r:0.352) were positively related while abundance (r:-0.212) and density (r:-0.224) were negatively correlated. In SWS, diversity (r:0.029) and richness (r:0.041) of herb species showed a positive correlation, while density (r:-0.168) and abundance (r:-0.165) showed a negative correlation. But in the case of grass species diversity, density, abundance and richness (r:-0.124; r:-0.155; r:-0.163; r:-0.157) were negatively correlated.

In PWS, the correlation between altitude, herb species richness, abundance and density are positively related, and diversity showed negative relationships. For grass species, richness and diversity were negatively related, while abundance and density were positively related. This pattern is due to the various ecological conditions affects the diversity and biomass productivity of ground species (28, 29). Plant biomass is also a major influential factor in preserving water, soil, and carbon reserves (29). In the study conducted in the Swiss Alps regions, the understory plants of forests in various altitudes found that species declined with the elevation and fewer species survived at higher altitudes ranges (30). Altitude has affected the physiology and growth of understory plants in the tropical montane forest of Costa Rica (31). The study found that certain ground species were confined in lower eleva-

Table 3. Altitudinal changes of ground species (herb and grass) in protected areas in the southern Aravalli regions of Rajasthan.

	300-400m		400-500m		500-600m		600-700m		700-800m		800-900m		900-1000m		1000-1100m	
	Herb	Grass	Herb	Grass	Herb	Grass	Herb	Grass	Herb	Grass	Herb	Grass	Herb	Grass	Herb	Grass
PWS																
Species Richness	78	24	65	15	57	12	-	-	-	-	-	-	-	-	-	-
Diversity (H)	3.3	1.85	1.47	1.18	2.85	1.58	-	-	-	-	-	-	-	-	-	-
Abun-dance	3948	2344	6849	2074	1454	704	-	-	-	-	-	-	-	-	-	-
Density/	10.9	6.3	24.5	7.4	15.3	7.4	-	-	-	-	-	-	-	-	-	-
KWS																
Species Richness	73	31	67	27	33	14	21	10	20	10	20	11	23	12	22	25
Diversity (H)	2.87	2.12	2.50	1.98	3.09	1.68	2.65	1.37	1.95	1.6	1.95	1.89	2.25	1.49	2.54	2.49
Abun-dance	4103	7301	4075	3990	638	838	776	2654	350	708	350	576	806	1084	170	817
Density/	18.7	33.2	15.3	15	11.6	15.2	6.5	22.1	8.75	17.4	5	8.2	11.5	15.5	3	13.9
SWS																
Species Richness	123	41	93	31	54	18	16	5	-	-	-	-	-	-	-	-
Diversity (H)	3.53	2.6	3.44	2.53	2.98	1.94	1.91	0.82	-	-	-	-	-	-	-	-
Abun-dance	15785	8012	6371	3289	1475	1249	177	106	-	-	-	-	-	-	-	-
Density/	29	14.6	32.6	16.9	23	19.3	6	3.5	-	-	-	-	-	-	-	-

tions and others could grow in greater heights. Research done in the Boreal forests of Norway found that altitude was one of the most crucial factors influencing the distribution of ground layer vegetation with distinct species present at different elevations (32). They also suggested this might be due to altitudinal effects on nutrient availability, soil, and moisture.

In the case of KWS, the diversity of herb species was positively related to the altitude when compared with richness, abundance and density. The density and abundance of grass species were negatively related, while richness and diversity were positively related. The KWS altitude ranges from 300-1100m showed mixed effects without following any pattern. However, species richness, density, abundance and diversity are high in low and mid-hill ranges. Semi-arid Zagros Mountain woods in Iran showed a similar pattern (33). The study found that the annual functional group was more diverse in the lowlands and midlands, whereas the grass functional group was similar across height classes. However, lowland and midland diversity exceeded highland diversity altitude negatively correlated with species biodiversity in the Guancen Mountains, China (34). Herbaceous plant diversity and richness were highest at lower altitudes (<1600m) and lowest at higher elevations (>1800m) in the Zagros–Dalab protected regions (35). Another study found that the annual functional group at high altitudes was less diverse than the perennial functional group in dry, grazed Mediterranean areas (36). This difference was due to the microclimate and richness of perennial plants. In the KWS, ground layer species were more abundant at 1000-1100m. This could be due to reduced human activity, competitive interactions, and beneficial humidity and light at that height (23, 37).

In SWS, the abundance of species decreased with the increase in altitude. The richness and diversity of herbs showed a positive relation while density and abundance showed a negative relation. Richness, density, abundance and diversity were negatively related to grass species. This pattern has been reported in many studies (38, 39). In Sierra Nevada, Mexico, the distribution of species variety and richness displayed an unimodal pattern, with a leaning towards greater values in the lower half of the elevation gradient (40). The correlation of ground species decreased with latitude and increased with altitude was observed among the mountainous forests of the Loess Plateau, China (41). Another study done on the high altitudinal mountainous areas found that altitude gradients have a significant effects on the diversity of ground species (42). The increased record of ground species richness, density and diversity at low altitudes is due to optimum conditions and high moisture (43, 44). At the same time, higher altitude factors like strong wind, intense solar radiation, low fertile soil, soil erosion, lack of moisture, and soil nutrients could be the limiting factors for the optimum conditions for the growth of ground species and responsible for the decrease of ground species in response to altitude (45–47).

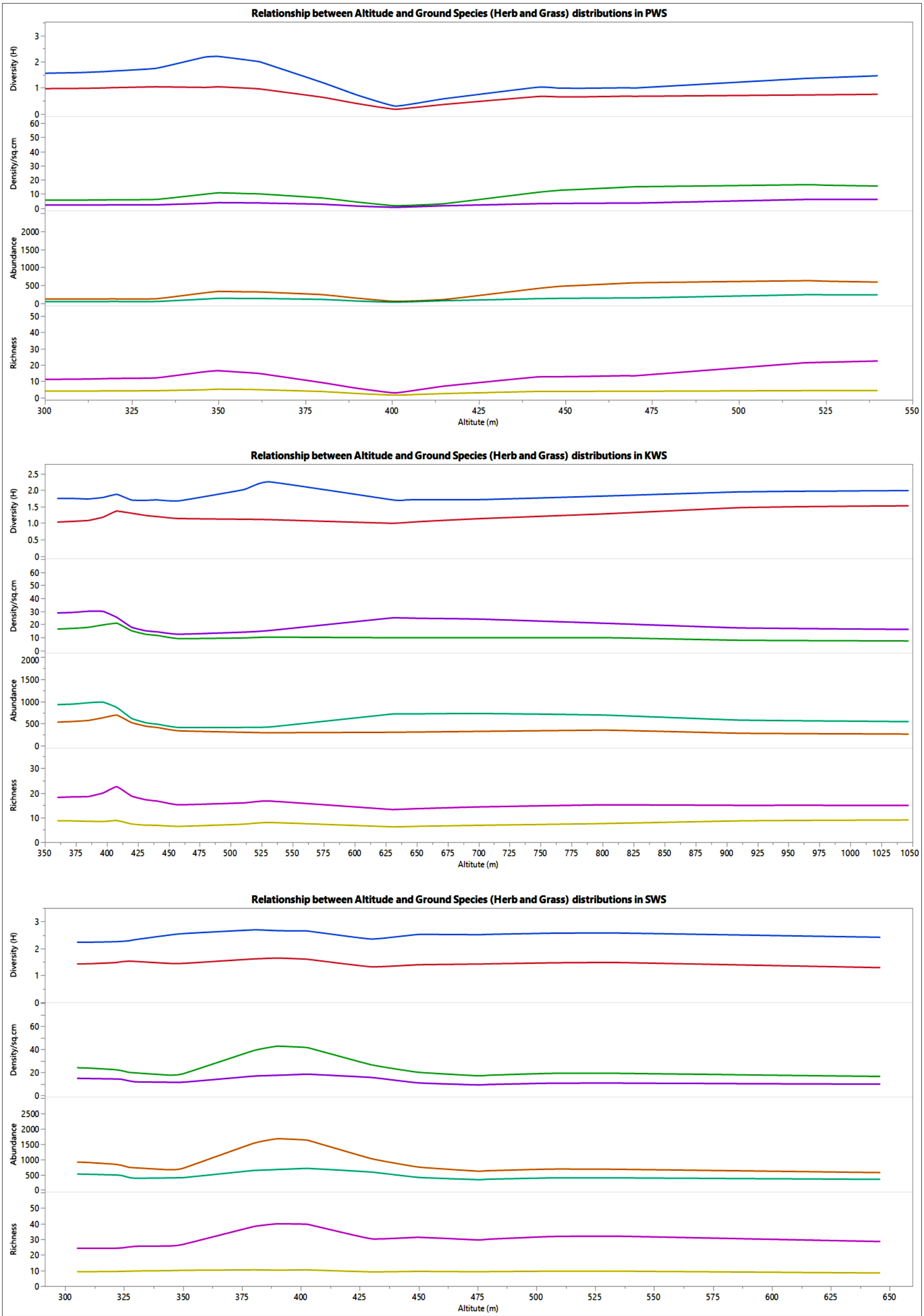
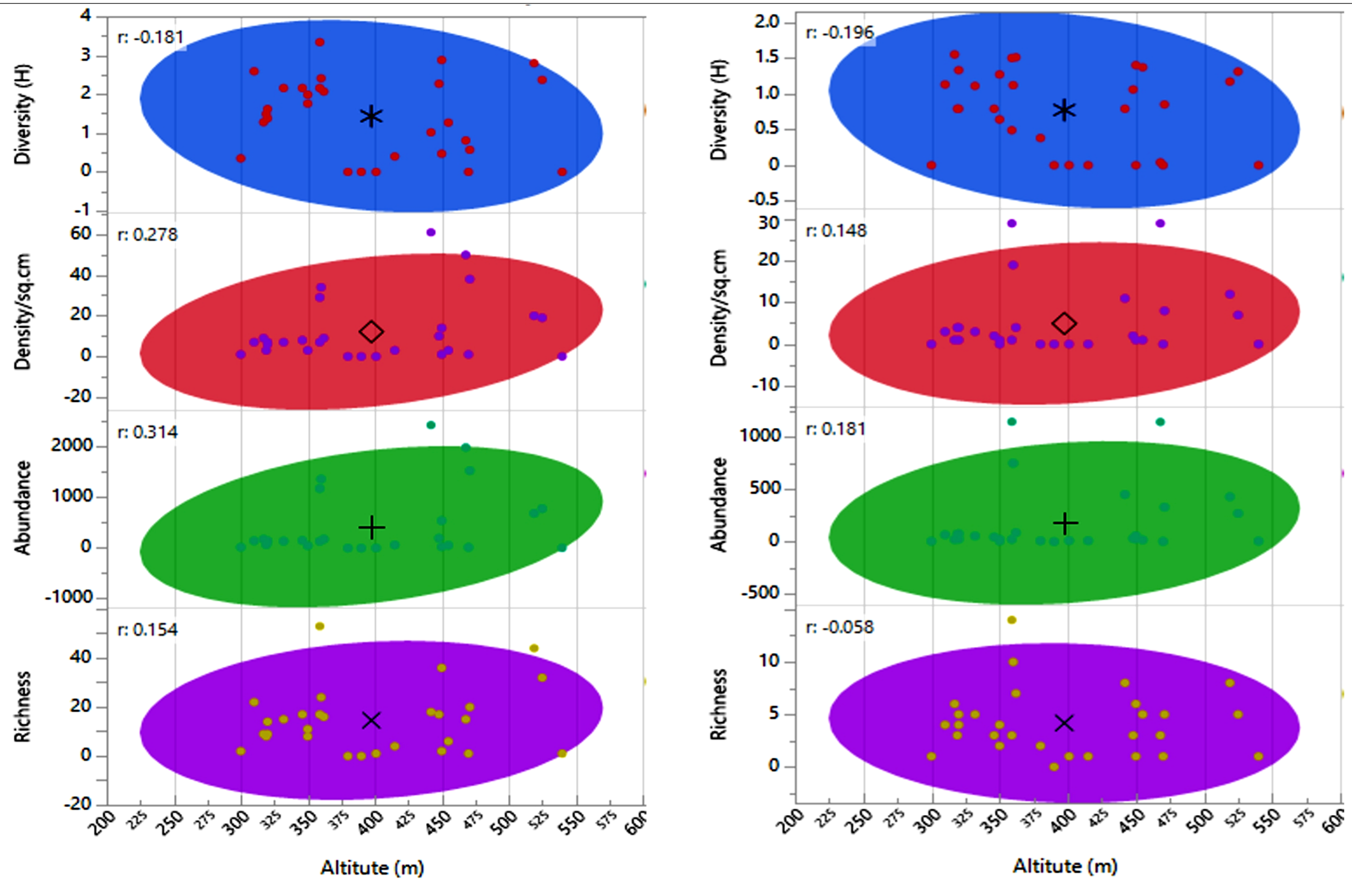
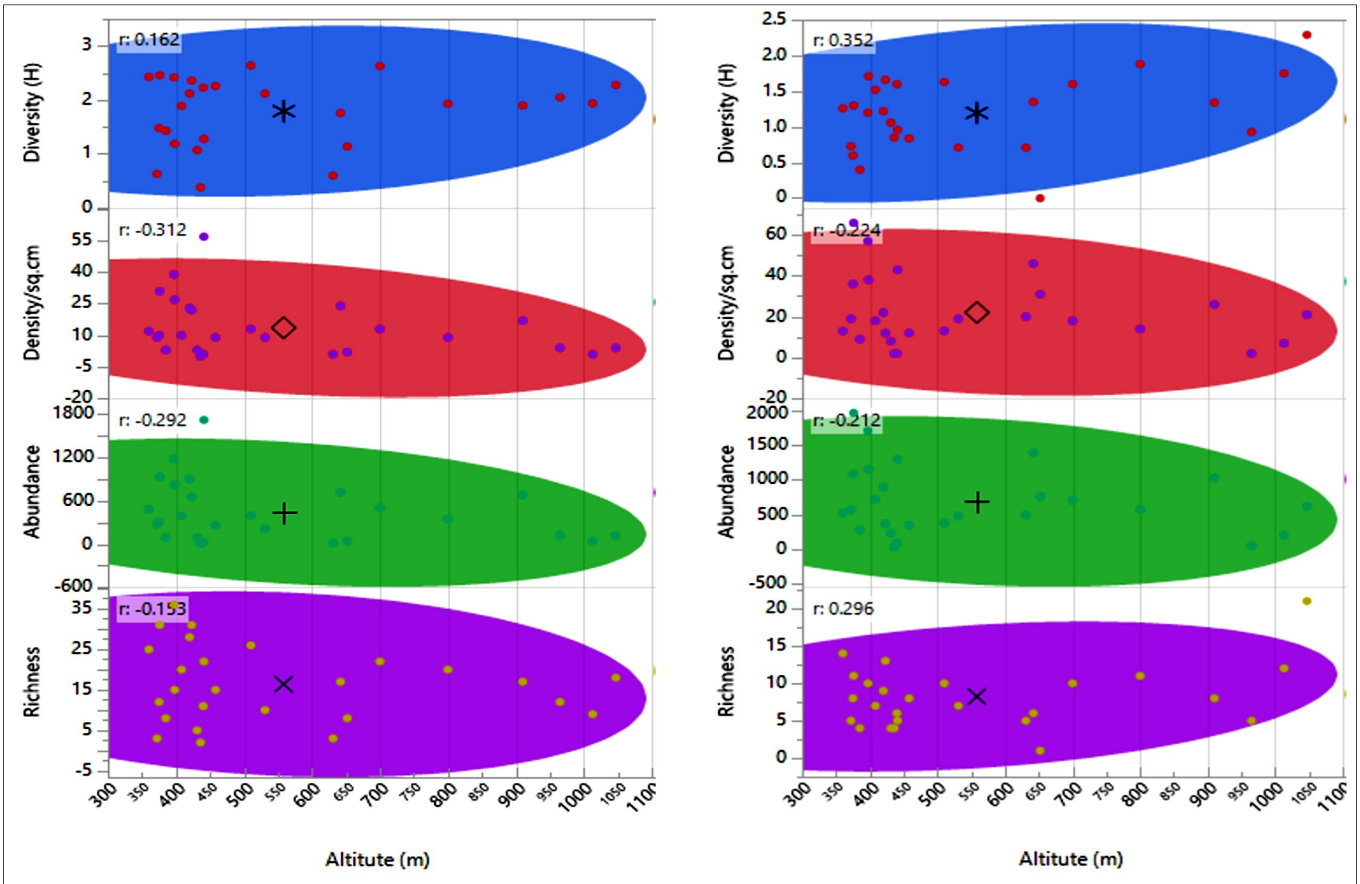


Fig. 2. Relationship between altitude and ground species (herb and grass) distributions in protected areas of the southern Aravalli regions of Rajasthan.



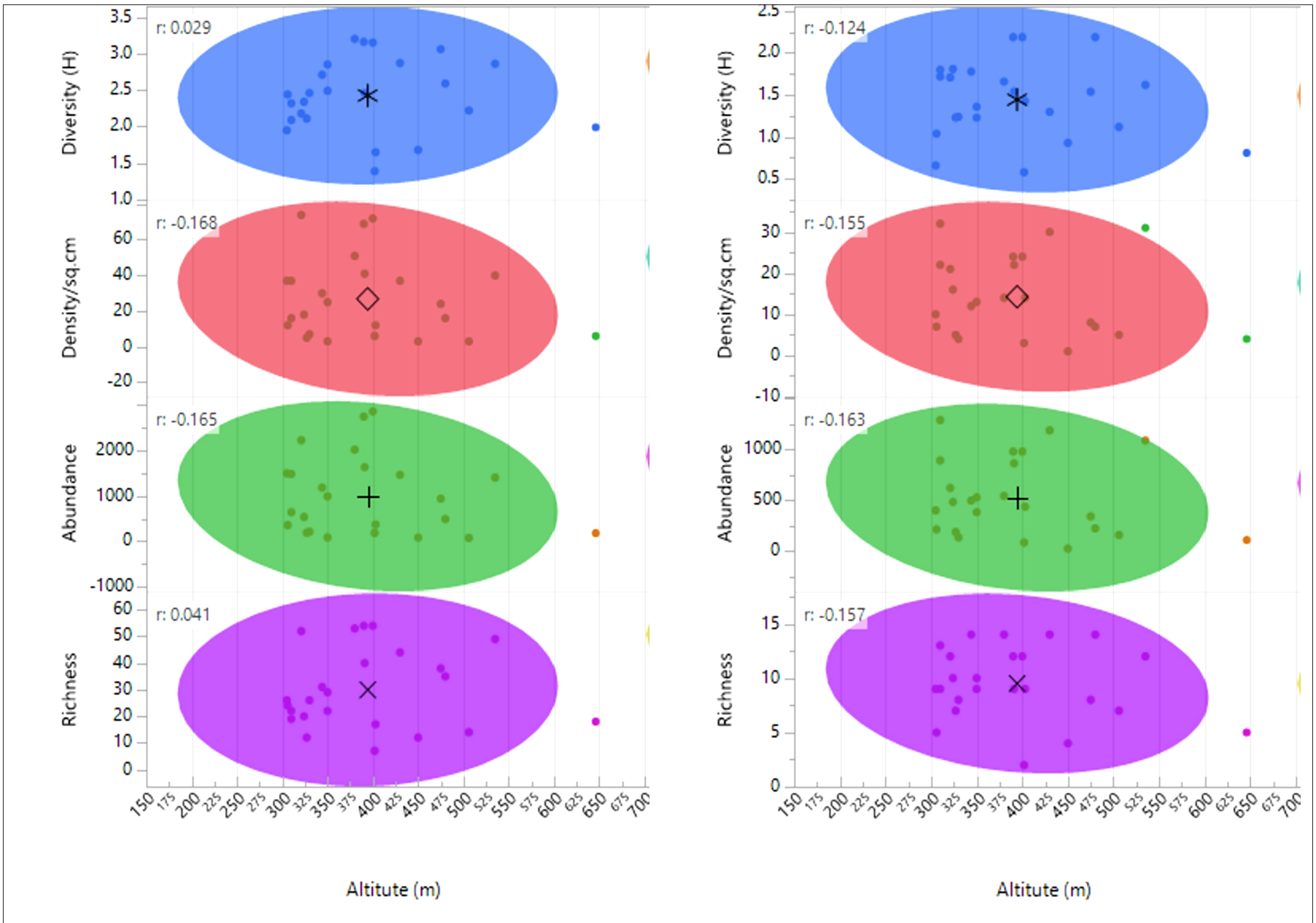
3a. Relationship between altitude and herb species **3b. Relationship between altitude and grass species**

Fig. 3. Correlation between altitude and ground species in the Phulwari Ki Nal wildlife sanctuary, Rajasthan.



4a. Relationship between altitude and herb species **4b. Relationship between altitude and grass species**

Fig. 4. Correlation between altitude and ground species in the Kumbhalgarh wildlife sanctuary, Rajasthan.



5a. Relationship between altitude and herb species　**5b. Relationship between altitude and grass species**

Fig. 5. Correlation between altitude and ground species in the Sitamata wildlife sanctuary, Rajasthan.

Conclusion

The present study was focused on the variation of ground species in different altitudinal ranges. The protected areas of southern Aravalli hills did not follow any specific pattern in ground layer species in accordance with altitude. The highest species richness, abundance, density and diversity were recorded at specific lower altitude ranges. Both positive and negative correlations were observed among the species richness, diversity, abundance and density of ground species in PWS, KWS, and SWS when related to altitude. It indicates that altitude is not a major limiting factor. Studies on ground species influences with other environmental factors would help in a better understanding of ground species dynamics. The species conservation practices should be implemented at the lower altitudes in protected areas of the southern Aravalli hills.

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Authors' contributions

SS participated in formal analysis, visualization and drafted the manuscript. PK participated in data analysis. AK participated in data analysis. SR carried out data collection, data curation, participated in data analysis, did supervision and investigation, participated in reviewing and editing of final draft. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

Supplementary data

Supplementary Table S1: List of ground species and number recorded from different altitudes of the southern Aravalli regions of Rajasthan.

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