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Floristic diversity and dominance patterns of Sal (*Shorea robusta* Gaertn. f.) forests in North Western Himalayas: implications for conservation and sustainable management

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The floristic composition of Sal forests is paramount for biodiversity and environmental resilience. Monitoring species diversity contributes to conservation and sustainable management. Considering this, the present study was undertaken to assess the floristic composition and diversity of *Shorea robusta*-dominated stands in the Paonta Forest Range of Himachal Pradesh. Sample plots of 0.1 ha were laid out (systematic random sampling) in seven compartments, recording 33 genera with 34 species belonging to 26 families. The results revealed that the flora of compartments catalogued with Lai C_{28} had the maximum (9) tree species, Kukron C_{15} and Rajban C_{10} had the maximum shrub species, and Rajban C_6 and Rajban C_7 had maximum herb species among all the compartments. *S. robusta* was the dominant species, with IVI varying between 126.72 and 156.59 in the compartments. The similarity index of trees in compartments ranged from 0.67 to 1.00. Rajban C_6 and Rajban C_7 had the maximum similarity index. This research focused on documenting the diversity of plants within the Sal Forest of Himachal Pradesh, India, and produced valuable scientific data and a fundamental understanding for the conservation of biodiversity and sustainable management.

KEYWORDS

floristic composition, IVI, phytosociology, diversity indices, reserve forest

1 Introduction

Vegetation is a community of plants that grow together in a region and are distinguished by their species composition or the combination of structural and functional characteristics that define their phenotypic characteristics (Goldsmith et al., 1986). Phytosociological study is crucial for understanding forest ecology and vegetation dynamics because it evaluates plant species, their distribution, abundance, and structural analysis. This method gives important insights into species diversity and richness in forest ecosystems, which are essential for successful management and understanding of ecosystem functioning (Mandal and Joshi, 2014; Dar and Sundarapandian, 2016; Siraj et al., 2017). The extent of change in forest stands is measured using phytosociological characteristics such as density and total basal cover, which are key metrics for analyzing vegetation types (Mishra et al., 2012; Haq et al., 2023).

Each species in a community is structurally and functionally distinct, with varied ecological amplitude and modality. Thus, floristic composition and phytosociological features can be used to compare communities throughout seasons and years (Singh and Joshi, 1979). The species diversity, floristic composition, and vegetation structure are essential for assessing the status of natural forests in any area and developing conservation and management plans. The ecological characteristics of sites, such as species richness, diversity, distribution, and abundance, have a significant impact on forest community composition. Furthermore, species diversity indices are important indicators of the stability and sustainability of forest ecosystems (Sarkar and Devi, 2014; Pandita et al., 2019).

Assessment of species diversity, floristic composition, and vegetation structure is essential for evaluating the status of natural forests and developing appropriate conservation and management policies. The species diversity, floristic composition, and vegetation structure are essential for assessing the status of natural forests in any region (May and Stumpf, 2000). In fact, those ecological features, such as species richness, diversity, distribution, abundance, and regeneration, very often define the composition of forest communities and influence overall ecosystem health significantly (Lindenmayer et al., 2006; Bhat et al., 2020). A forest with high plant diversity generally indicates fertile soil and supports a wider range of animal species, as biodiversity is a key driver of ecosystem function (Noss, 1999). Studies on ecology concentrate on understanding vegetation composition and ecological factors, such as species richness and diversity, due to their importance (Zhang et al., 2013). Studying vegetation structure in a plant ecosystem can reveal age groups and forest regeneration patterns, which determine future species composition and stocking density (Behera et al., 2023). The floristic assessment and the ecological variations occurring within the Sal forest could be helpful to give scientific silvicultural practices or interventions to increase productivity while maintaining the health of the ecosystem (Saikia et al., 2017). Different forest ecosystems have varied floristic composition and environmental variables, such as temperature, resource availability, herbivorous activity, and anthropogenic activities, all impacting species richness and abundance (Poorter et al., 2024).

Shorea robusta Gaertn. f. is a tropical tree endemic to South Asia, ranging from Myanmar in the east to Bangladesh, Nepal, and India in the west, encompassing nearly 12 million hectares of forest (Troup, 1921; Tewari, 1995). It is a huge deciduous timber species that grows in a mono-specific canopy and requires full overhead light from its early establishment. The tree may grow up to 50 m tall (usually 18–32 m), with a straight cylindrical bole and a diameter of 3–5 m (Kayastha, 1985; Chitale and Behera, 2012; Swaminathan and Kochhar, 2019). Sal is highly adaptable to a wide range of climatic conditions and may thrive in deciduous, semi-evergreen, or evergreen forests, depending on the microclimate, geology, and soil characteristics (Kumar and Saikia, 2020c; Mishra et al., 2021). Its geographical range includes the southern Himalayan slopes, lower foothills, plains, riverbanks, and valleys of India, Nepal, Bangladesh, Bhutan, and South China, with coordinates of 75°–95°E longitude and 20°–32°N latitude (Sapkota, 2009). Sal is an ecologically and commercially significant plant widespread throughout South Asia (Sharma et al., 2022). Recognized as an endangered species by the International Union for Conservation of Nature (IUCN), it holds significant socioeconomic value. Sal is commonly used for timber, medicinal purposes, animal feed, fuelwood, dried leaves for cooking and heating, fresh leaves for plate making, edible seeds, and religious ceremonies (Kumar and Saikia, 2021).

In India, forests cover nearly 21.71% of the country's total geographical area (Forest Survey of India, 2021). In tropical India, Sal forest comprises approximately 13.30% of the total forest area (Satya and Nayaka, 2005). It stretches up to Assam, Meghalaya, and Tripura in the east to the foothills of north-west Bengal, Uttar Pradesh, Uttarakhand, and Paonta Sahib in Himachal Pradesh in the Himalayan foothill region. In Sal forests, there are generally four separate layers: *Shorea robusta* and *Terminalia alata* in the top story, *Syzygium cumunii* in the middle story with *Mallotus philippensis* as a co-dominant tree species, and *Ardisia solanacea, Clerodendron viscosum,* and *Lantana camara* as understory associate species in the shrub layer and *Pogostuimon benghalensis* in the herb layer.

Sal forests, which are influenced by microclimate, geology, and soil characteristics, can be deciduous, semi-evergreen, or evergreen in phenological patterns, structure, and composition (Kumar and Saikia, 2020b), resilient to anthropogenic disturbances (Rahman et al., 2009; Sapkota et al., 2010; Behera et al., 2023) and climate change responses (Mishra et al., 2021; Kongkham et al., 2021; Shankar and Garkoti, 2023). In Himachal Pradesh, the Sal Forest is present in the Paonta and Andreta villages of the districts Sirmour and Kangra with a total area of approximately 306.97 km^2 (Sharma et al., 2020). Champion and Seth (1968a) classified the division's forest types as: 3C/C2a Moist Shiwalik Sal Forests, 3C/C2b(i) Moist Bhabar Sal-Bhabhar-Dun Sal Forest, 5b/C1a Dry Shiwalik Sal Forests, and 5b/C2 Northern Dry Mixed Deciduous Forests.

This study was conducted within the framework of sustainable forest management, with an approved silvicultural felling plan in the Paonta Forest Division. It aims to increase forest production, conserve biodiversity, and promote climate resilience. Recognizing the ecological and economic importance of Sal forests, the study hypothesizes a significant research gap by studying inter-compartmental variation in floristic composition, which often goes undetected in large-scale studies. Unlike previous studies conducted over extensive geographical areas, this study emphasizes the significance of site-specific silvicultural planning by accounting for variability driven by site quality, geographical parameters, and human activities. Thus, the current study addresses significant research issues such as how floristic diversity differs between compartments, what phytosociological characteristics and diversity measures (e.g., species richness, Shannon-Wiener index, Simpson's index) define these compartments and how much inter-compartmental differences in dominance exist, which will form the scientific base for developing a set of targeted silvicultural interventions, and which will leverage inter-compartmental variations to ensure sustainable forest management and balanced ecosystem resilience. Therefore, this study was carried out with the following objectives: (1) to analyze inter-compartmental variation in floristic composition and phytosociology and (2) dominance patterns and diversity indices in Sal forest ecosystems in Himachal Pradesh.

2 Materials and methods

2.1 Study area

The study was conducted in different compartments selected/approved under Experimental Silvicultural Green Felling in Reserve Forest (RF) of the Paonta forest range of the forest division in Himachal Pradesh situated between 30^0 22′ 37″ and 30^0 41′ 36″ North latitude and $77^0$7′19″ and $77^0$49′48″ East latitude at elevations ranging from 300 to 400 m above sea level (Table 1; Figure 1). The study area falls under Moist Bhabhar Sal-Bhabhar-Dun Sal Forest [3C/C2b (i)] (Champion and Seth, 1968b). The study area represents a sub-tropical climate with distinct summer, monsoon, and winter seasons.

In the present study, the seven compartments, viz. Rajban $C_{6,7,10}$, Kukron $C_{14,15}$, Gorakhpur C_7, and Lai C_{28}, were selected for Experimental Silvicultural Green Felling using a systematic random sampling to represent variations based on site quality (II and III) and periodic blocks (PB I, II, and III) rotation age of the stands within the Sal Conversion Working Circle. Here, the site quality of all the compartments was II except Rajban C_7 and Lai C_{28}, which falls in site quality III and all have Sal Conversion Working Circle and PB I with Sal overlapping the silvicultural system of management as per working plan for felling of Sal trees in Paonta Forest Division (2019–2020).

The Hon'ble Supreme Court of India approved the Experimental Silvicultural Felling Program for the reserve forest of Sal in Paonta Forest Division (2018–2020), which strictly adheres to CEC guidelines and ensures compliance with the extended working plan.

In the Sal forests of Site Quality II and III, a 40-cm diameter class is reached in 118 years, resulting in a 120-year rotation period and a 30-year regeneration phase. The working circle is split into four periodic blocks (PBs): PB I (mature and over-mature trees with modest regeneration), PB II (almost mature trees with limited regeneration), and PB III (the remaining regions). Yield control is based on the Von Mantel formula. The Sal Working Circles aim to accomplish sustainable forest management by taking into account management objectives, socioeconomic demands, and biodiversity conservation. The National Working Plan Code-2014 has been utilized to provide detailed mapping, sampling intensity, and distribution of working circles and areas selected for felling operation in the Sal Working Circle. This classification was made to direct silvicultural management inside the Sal Conversion Working Circle, ensuring sustainable growth and regeneration of the stands.

Based on the management framework and compartmental classification outlined in the Working Plan, the same compartments were selected for the present study to ensure consistency in site quality and silvicultural treatment. The area-based sampling approach, as specified in the National Working Plan Code-2014, was used with a standardized sampling unit of 0.1 ha. This method was used to conduct a comprehensive assessment of inter-compartmental variation in floristic composition, diversity indices, and dominance patterns throughout Sal forest ecosystems for the current study.

2.2 Vegetation analysis: sampling, designing, data collection, and analysis

Seven compartments were selected for executing the present study. Under each compartment, a sample plot of 0.1 ha (31.62 × 31.62 m^2) was selected for studying structural and functional parameters of tree vegetation. The density of trees was determined by counting trees in each sample plot. The diameter was measured by taking two measurements of stems (major and minor axes) at breast height (1.37 m) with tree calipers, and their mean was calculated as the DBH of a tree. The basal area of each tree in the sample plot was assessed using a tree caliper, and the height was measured with Spiegel Relaskop (Haga Model, 2020). The volume of standing trees was determined using Pressler's (1865) method. In each 0.1 ha of sample plot for shrub characteristics, two subplots of size 5 m × 5 m were laid out. Furthermore, in each shrub plot, two subplots of size 1 m × 1 m were laid out to study the herb-related traits. Standard measurement procedures were followed for taking primary observations (Figure 2). The specimens were prepared and identified at the Department of Forest Products, Dr. YSP University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.

2.2.1 Sample plot size

Trees: 31.62 m × 31.62 m (0.1 ha)
Shrubs: 5 m × 5 m
Herbs: 1 m × 1 m.
Regeneration: 2 m × 2 m
Replications: 4

2.2.2 Density (N ha^{-1})

It measured the total number of individuals per unit area and was calculated as:

$$\text{Density}(\text{D}) = \frac{\text{Total number of individuals}}{\text{Total number of quadrates studied}}$$

2.2.3 Basal area (cm^2)

It measures the cross-sectional area of the stem, and it is obtained by the following relationship with diameter/girth.

$$\text{Basal Area} = \frac{\pi d^2}{4}$$

Where; d = Diameter at breast height (1.37 m)

2.2.4 Frequency (%)

It measures the degree of occurrence of a species in sampling units; thus, it expresses the distribution of various species in the community.

$$\text{Percent frequency}(\%) = \frac{\text{Number of sampling units in which the species occurs}}{\text{Number of sampling units studied}} \times 100$$

2.2.5 Relative density, relative basal area, and relative frequency

These parameters were obtained from percentage frequency, density, and basal area by using the following relationship:

$$\text{Relative density}(\text{RD}) = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals of all species}} \times 100$$

TABLE 1 Soil and topographical characteristics of different compartments of the Sal Working Circle of Paonta Forest Division, Himachal Pradesh.

Sr no	Compartment	Location	Altitude (m asl)	Slope (°)	Relative humidity (%)	Temperature (°C)	Annual rainfall (mm)	Terrain	Aspect	Soil texture	Site quality
1	Rajban C_6	Above Chaudi cultivation, North West of Paonta road, south of Choudi Khali	600–850	5–25	100% (monsoon) to 26% (summer)	25°C (winter) to 45°C (May and June)	1,270 mm and 1,900 mm	Undulating, slightly flat to hilly	Southern	Clayey to clayey loam with adequate drainage	III
2	Rajban C_7	Between Rajban Khali & Dhangwali Khali, south of the blazed block line	650–900	10–30				Relatively flat to hilly	Southern	Clayey loam	III
3	Rajban C_{10}	Between Baggar Khala & Haaldu Khala, south of the block line	700–950	15–35				Gentle to moderate slope	Southern	Clayey loam with good drainage	II
4	Kukron C_{14}	Between compartment 13 & below the sub-compartment cut line	750–1,000	20–40				Hilly area with a gentle mainland slope near Khalas	Southern	Clayey loam to sandy loam	II
5	Kukron C_{15}	Along Jammu Khala, below the block line	800–1,050	15–35				Undulating, relatively flat to hilly with a gentle mainland slope near Khalas	Southern	Clayey loam	II
6	Gorakhpur C_7	Flat plain area	550–750	0–5				Nearly flat terrain	Southern	Clayey loam	II
7	Lai C_{28}	South of Mehrar-Rajban road, west of Khara Ka Khala, East of Satiwala Khala	600–850	5–20				Gentle terrain	Southern	Loam to clayey loam	II

Working Plan (2020).

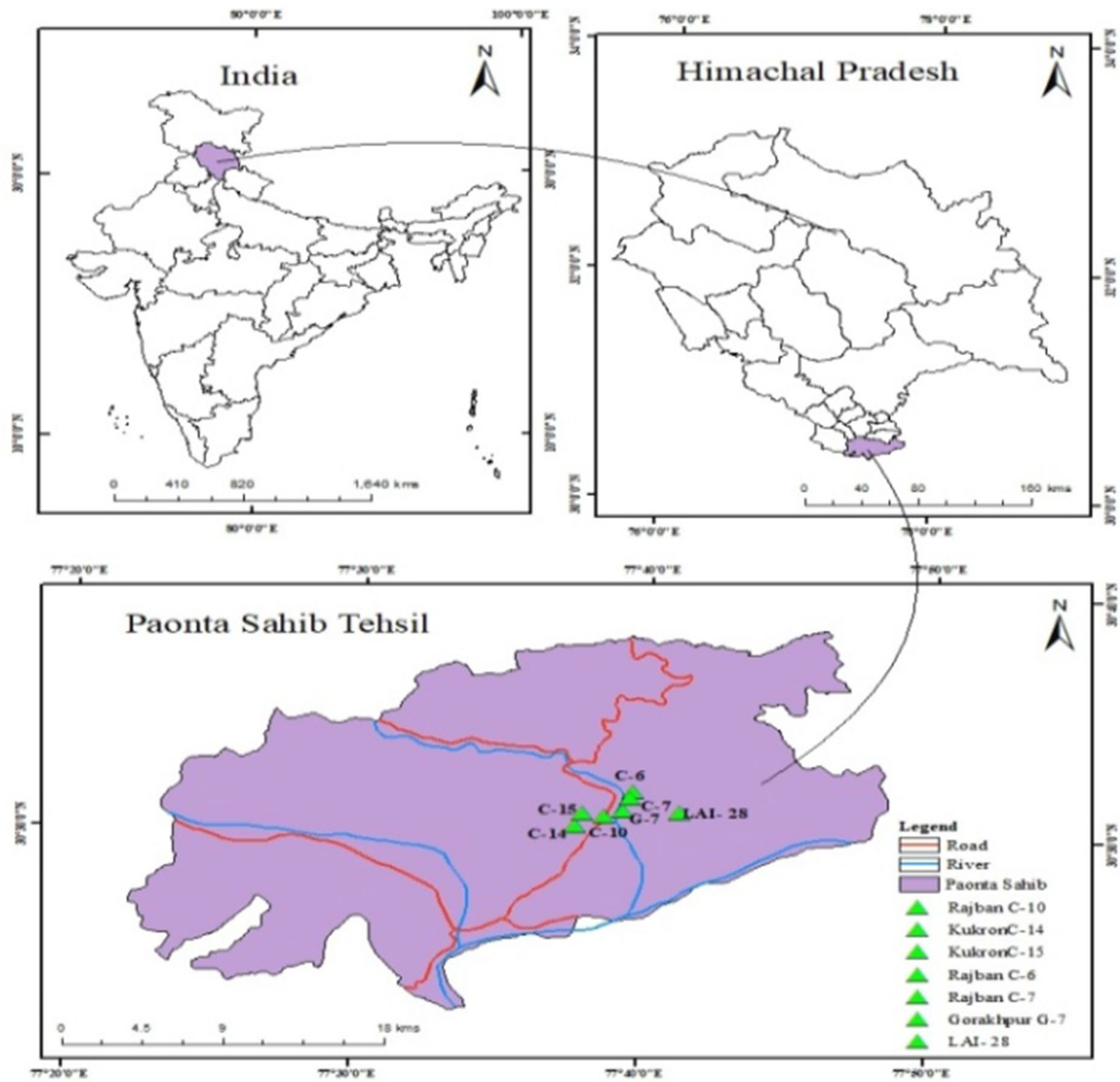

FIGURE 1
Map of the study area of Paonta Sahib Sal Forest.

$$\text{Relative basal area (RBA)} = \frac{\text{Total basal area of individual species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Number of occurrences of individual species}}{\text{Number of occurrences of all species}} \times 100$$

2.2.6 Importance value index (IVI)

IVI is the sum total of relative density, relative basal area, and relative frequency, and was calculated for all herbs, shrubs, and tree species separately for all the compartments.

$$\text{IVI} = \text{Relative basal area (RBA)} + \text{Relative density (RD)} + \text{Relative frequency (RF)}.$$

2.3 Vegetation indices

Community diversity was assessed using non-parametric measures such as diversity indices, and these measures have gradually gained credibility (Magurran, 1988). Simpson diversity index and Simpson concentration of dominance (Simpson, 1949), Margalef index of species richness (Margalef, 1958), the Importance Value Index (IVI) (Phillips, 1959), Shannon–Wiener diversity index (Shannon and Weaver, 1963), Pielou's equitability (Pielou, 1966), and species richness index of Menheink (Whittaker, 1977) were computed for each compartment under study (Table 2).

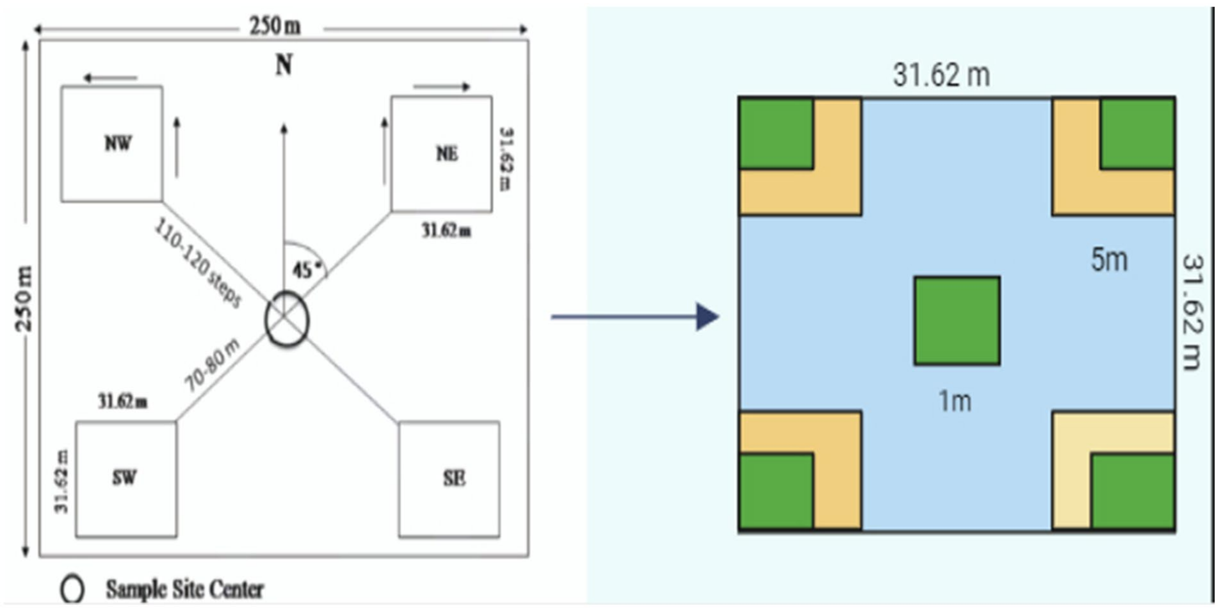

FIGURE 2
Cluster sample plot design (2-stage sampling) for enumerating trees, shrubs, and herbs sampling.

2.4 Similarity index and dissimilarity index

$$\text{Similarity index } (S) = 2C / A + B.$$

Where, A = number of species in community A; B = number of species in community B; C = number of common species in both the communities.

$$\text{Dissimilarity index} = 1\text{-S}$$

2.5 Statistical analysis

The phytosociological data were analyzed using Microsoft Excel 2010. Species diversity matrices were calculated using the software Past 3.1 program (version 3.1; Oyvind Hammer, Natural History Museum, University of Oslo) (Hammer et al., 2001).

3 Results

The floristic assessment of the Sal Working Circle in Paonta Forest Division found diversity of tree, shrub, and herb species. The phytosociological study of *Shorea robusta* and its associate plants examined dominance, structural variation, and diversity patterns. Whereas, similarity and dissimilarity indexes measured species composition dynamics, supporting sustainable management and biodiversity conservation in Paonta Forest Division, Himachal Pradesh.

TABLE 2 Vegetation indices for biodiversity analysis.

Sr. No	Vegetation indices
1	Shannon–Wiener index of diversity (H′) = $-\sum$pi In pi
2	Simpson's concentration of dominance index (Cd) = $\sum pi^2$
3	Simpson's diversity index (D) = 1-Cd
4	Margalef's index of richness (MI) = (S−1)/lnN
5	Pielou's equitability (Ep)= $\frac{H'}{H'_{max}} = \frac{H'}{\ln S}$
6	Menheink's index of species richness (MeI) = $\frac{S}{\sqrt{N}}$

Where, pi = Proportion of individuals of species i in the total sample; Pi^2 = Proportion of individuals of species i in the total sample; S = Total number of species; N = Total number of individuals; H′ = Shannon–Wiener diversity index; H'_{max} = Maximum possible diversity (ln S).

3.1 Species distribution: diversity of trees, shrubs, and herbs

The study of various phytosociological attributes revealed that different compartments of the Sal Working Circle of Paonta Forest Division (Figure 3) constituted 33 genera with 34 species belonging to 26 families. In Rajban C_6, six tree species, 10 shrubs, and 10 herbs were identified. Similarly, Rajban C_7 had six tree species, 10 shrub species, and 10 herb species. Kukron C_{14} contained six tree species, nine shrub species, and nine herb species, whereas Rajban C_{10} comprised 11 shrub species and eight herb species. In addition, seven tree species, 11 shrub species, and eight herb species were documented in Kukron C_{15}; and six tree species, 10 shrub species, and eight herb species were identified in Gorakhpur C_7. Finally, Lai C_{28} included nine tree species, eight shrub species, and nine herb species, respectively.

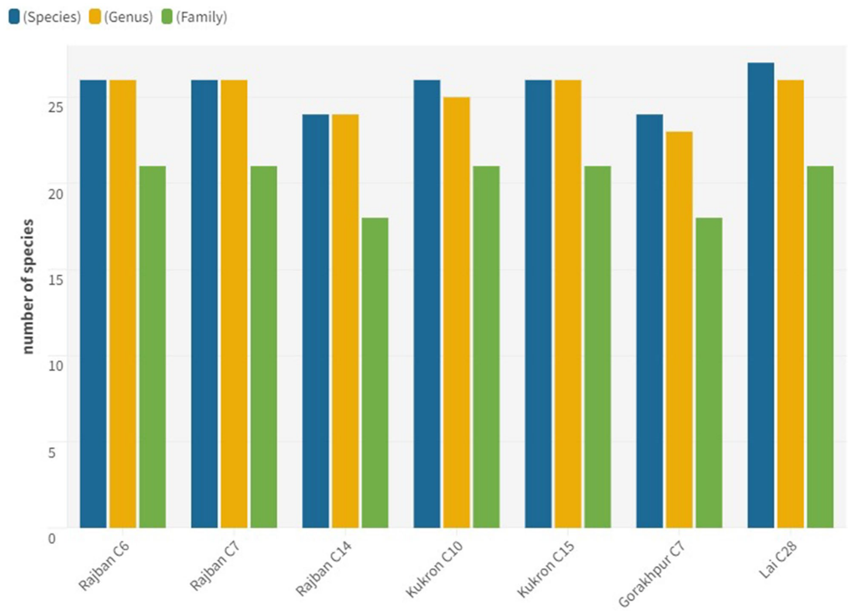

FIGURE 3
Floral distribution of vegetation under different compartments in the Sal Working Circle.

3.2 Phytosociology of the standing crop of *S. robusta* and its associates

The phytosociological study of the standing crop of *S. robusta* and its associates throughout seven compartments (Tables 3–5) revealed that among the tree component, *S. robusta* is consistently dominant among tree species in all the compartments with Importance Value Index varied between 126.72 in Gorakhpur C_7 to 156.59 in Rajban C_{10} (Figure 4). Among shrubs, *Ardisia solanacea* had the highest IVI, ranging from 72.35 in Rajban C_{10} to 109.98 in Gorakhpur C_7 (Figure 5). In the herb layer, *Apluda mutica* was the most prevalent species in most compartments, with an IVI ranging from 55.14 in Rajban C_6 to 86.81 in Kukron C_{15} (Figure 6).

3.3 Plant species diversity of the Sal Working Circle of Paonta Forest Division, Himachal Pradesh

The Shannon Index of diversity (H′) for trees ranged between 1.83 (Lai C_{28}) and 1.44 (Gorakhpur C_7), for shrubs between 2.02 (Kukron C_{14}) and 1.56 (Gorakhpur C_7), and for herbs between 2.28 (Rajban C_6) and 2.02 (Kukron C_{14} and Kukron C_{15}). Simpson Index of diversity (D) for trees ranged between 0.75 (Rajban C_7) and 0.67 (Kukron C_{14}), for shrubs between 0.81 (Kukron C_{14}) and 0.63 (Gorakhpur C_7), and for herbs between 0.89 (Rajban C_6 and Rajban C_7) and 0.86 (Kukron C_{14} and Gorakhpur C_7). Simpson Index of dominance (Cd) for trees ranged between 0.33 (Kukron C_{14}) and 0.23 (Lai C_{28}), for shrubs between 0.37 (Gorakhpur C_7) and 0.19 (Kukron C_{14}), and for herbs between 0.14 (Kukron C_{14} and Kukron C_{15}) and 0.11 (Rajban C_6 and Rajban C_7). Pielou's equitability (Eq) varied between 0.88 (Rajban C_7) and 0.75 (Kukron C_{14}) for trees, between 0.84 (Kukron C_{14} and Lai C_{28}) and 0.68 (Gorakhpur C_7) for shrubs, and between 0.99 (Rajban C_6) and 0.97 (Rajban C_{10}, Kukron C_{14}, Kukron C_{15}, and Lai C_{28}) for herbs. Margalef's Index of richness (MI) ranged for trees between 1.43 (Lai C_{28}) and 0.87 (Rajban C_{10} and Gorakhpur C_7), for shrubs between 1.08 (Kukron C_{15}) and 0.89 (Lai C_{28}), and for herbs between 0.74 (Rajban C_6 and Rajban C_7) and 0.59 (Kukron C_{14}) (Table 6).

3.4 Similarity index and dissimilarity index

The dissimilarity index examined in Table 7 illustrated that across tree species, Rajban C_6 had the least dissimilarity (0.00) with Rajban C_7, C_{10}, and Gorakhpur C_7. Similarly, Rajban C_7 reported minimum dissimilarity with Rajban C_{10} and Gorakhpur C_7. Gorakhpur C_7 and Rajban C_{10} had a minimum dissimilarity index (0.00) with Kukron C_{14}. Maximum dissimilarity was recorded by Lai C_{28} with Rajban C_6, C_7, C_{10}, Gorakhpur C_7, Kukron C_{14}, and C_{15}. In case of shrub species, Rajban C_6 recorded minimum dissimilarity (0.00) with Rajban C_7. Kukron C_{15} had the maximum dissimilarity (0.24) with Rajban C_6 and Rajban C_7. In respect of herb species, Rajban C_6 reported minimum dissimilarity (0.00) with Rajban C_7; however, maximum value was recorded by Kukron C_{15} (0.22), followed by Lai C_{28} with Rajban C_{10}, Kukron C_{15}, and Gorakhpur C_7.

4 Discussion

The pattern of vegetation structure, composition, and diversity in tropical forests is influenced by various environmental factors, such as soil characteristics, microclimate, and disturbance regimes (DRYFLOR et al., 2016). Quantitative assessment of the vegetation layers is essential for evaluating biodiversity and monitoring long-term changes in forest

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TABLE 3 **Phytosociological tree status of the Sal Working Circle of Paonta Forest Division, Himachal Pradesh.**

Phytosociological tree status												
Compartment	Area of forest (area in ha)		*Syzyguim cuminii*	*Cordia dichotoma*	*Mallotus philippensis*	*Cassia fistula*	*Terminalia tomentosa*	*Shorea robusta*	*Callicarpa japonica*	*Ficus Palmata*	*Acacia catechu*	*Eucalyptus sp.*
Rajban C_6	30.96	RD	10.68	12.62	13.59	3.88	11.65	47.57				
		RF	15.79	21.01	15.79	10.53	15.79	21.05				
		RBA	2.08	2.07	1.17	0.6	10.2	83.87				
		IVI	28.55	35.75	30.55	15.01	37.64	152.5				
Rajban C_7	19.87	RD	10.00	18.00	14.00	4.00	13.00	41.00				
		RF	15.79	21.05	15.79	10.53	15.79	21.05				
		RBA	1.82	4.24	4.07	0.7	13.3	75.86				
		IVI	27.61	43.29	33.86	15.23	42.09	137.91				
Kukron C_{14}	30.18	RD	9.02	10.66	13.11	7.38	12.3	47.54				
		RF	16.67	16.67	16.67	11.11	16.67	22.22				
		RBA	1.22	1.5	3.11	0.84	9.75	83.59				
		IVI	26.90	28.83	32.89	19.32	38.72	153.35				
Rajban C_{10}	45.00	RD	10.00	10.00	10.00		9.17	54.17	1.67	5		
		RF	16.67	15.79	15.79		15.79	21.05	5.26	10.53		
		RBA	1.12	3.4	6.46		5.62	81.37	0.56	1.46		
		IVI	26.91	29.19	32.25		30.58	156.59	7.49	16.99		
Kukron C_{15}	70.12	RD	11.76	12.61	5.88		10.92	52.94	2.52	3.36		
		RF	15.79	15.79	10.53		15.79	21.05	10.53	10.53		
		RBA	2.13	5.38	0.86		11.97	77.94	0.8	0.91		
		IVI	29.69	33.77	17.27		38.69	151.94	13.85	14.8		
Gorakhpur C_7	100.00	RD	18.6	7.75	12.4	3.1	8.53	49.61				
		RF	21.05	15.79	15.79	10.53	15.79	21.05				
		RBA	12.22	2.61	5.35	0.96	22.8	56.05				
		IVI	51.88	26.16	33.54	14.59	47.12	126.72				
Lai C_{28}	22.56	RD	9.26	8.33	12.96		3.7	42.59	5.56	3.7	5.56	8.33
		RF	12.5	12.5	12.5		8.33	16.67	8.33	8.33	8.33	12.5
		RBA	2.22	1.72	3.94		4.41	76.7	2.3	1.47	3.29	3.94
		IVI	23.98	22.55	29.41		16.45	135.96	16.19	13.5	17.18	24.77

TABLE 4 Phytosociological shrub status of the Sal Working Circle of Paonta Forest Division, Himachal Pradesh.

Compartment	Area of forest (area in ha)		*Adhatoda vasica*	*Asparagus racemosus*	*Ardisia solanacea*	*Baliospermu mmontanum*	*Carissa carandas*	*Lantana camara*	*Murraya koenigii*	*Rubus ellipticus*	*Solanumin dicum*	*Clerodendron infortunatum*	*Solanum viarum*	*Lonicera japonica*
Rajban C_6	30.96	RD	8.08	3.93	47.38	3.71	8.52	6.55	7.42		3.93	5.9		4.59
		RF	11.43	8.57	14.29	7.86	11.43	10.71	10.56		7.14	10.45		8.57
		RBA	11.93	0.31	24.94	0.57	21.57	18.39	6.84		3.39	8.88		3.24
		IVI	31.44	12.82	86.61	12.14	41.52	35.66	24.26		14.46	24.77		16.39
Rajban C_7	19.87	RD	6.16	3.94	53.2	3.2	6.91	7.14	5.42		1.97	5.91		6.16
		RF	11.59	8.7	14.49	8.7	10.87	11.59	8.7		5.8	10.14		9.42
		RBA	10.8	0.47	25.23	0.51	19.6	23.66	2.96		1.32	6.41		9.06
		IVI	28.55	13.11	92.92	12.39	37.37	42.4	23.9		9.09	22.46		24.64
Kukron C_{14}	30.18	RD	6.86	5.78	53.79	6.86	3.97	7.22	4.69		5.78	5.05		
		RF	9.77	11.28	15.04	9.02	11.28	10.53	12.03		9.02	12.03		
		RBA	7.26	0.45	30.8	0.44	5.27	32.74	8.78		4.18	10.08		
		IVI	23.9	17.51	99.63	16.32	20.52	50.48	25.5		18.97	27.17		
Rajban C_{10}	45.00	RD	7.45	5.1	40.98	4.51	8.82	4.51	11.37	2.75	2.55	3.73	8.24	
		RF	9.68	10.32	12.9	7.74	10.32	8.39	10.32	7.11	5.16	7.74	10.32	
		RBA	7.62	0.83	23.13	0.31	17.13	10.29	20.64	1.34	0.62	2.67	15.41	
		IVI	24.75	16.25	77.01	12.56	36.28	23.18	42.33	11.18	8.33	14.14	33.97	
Kukron C_{15}	70.12	RD	6.86	5.78	53.79	6.86	3.97	7.22	4.69		5.78	5.05		
		RF	9.77	11.28	15.04	9.02	11.28	10.53	12.03		9.02	12.03		
		RBA	7.26	0.45	30.8	0.44	5.27	32.74	8.78		4.18	10.08		
		IVI	23.9	17.51	99.63	16.32	20.52	50.48	25.5		18.97	27.17		
Gorakhpur C_7	100.00	RD	5.2	4.34	58.67		4.62	8.38	5.2	2.6	2.31	5.78	2.89	
		RF	11.76	10.29	14.71		8.82	11.76	11.76	5.88	5.88	11.76	7.35	
		RBA	8.75	0.54	36.6		0.68	19.6	17.6	1.12	1.54	12.32	1.25	
		IVI	25.71	15.17	109.98		14.13	39.74	34.56	9.61	9.74	29.86	11.49	
Lai C_{28}	22.56	RD	6.43	5.66	42.93		7.71	9	10.28	4.11		8.23	5.66	
		RF	13.91	10.43	16.52		6.96	13.91	10.43	6.96		13.91	6.96	
		RBA	14.72	0.5	19.69		0.46	26.71	18.32	1.3		16.99	1.31	
		IVI	35.06	16.59	79.14		15.13	49.62	39.04	12.37		39.13	13.92	

TABLE 5 Phytosociological herb status of the Sal Working Circle of Paonta Forest Division, Himachal Pradesh.

Compartment	Area of forest (area in ha)		*Dicliptera paniculata*	*Digitaria sanguinalis*	*Achranthus bidentata*	*Bidens bipinnata*	*Ageratum conyzoides*	*Apluda mutica*	*Cyperus rotundus*	*Cynodon dactylon*	*Parthenuim hysterophorus*	*Pogostemon benghalensis*
Rajban C_6	30.96	RD	12.96	11.12	9.35	7.86	8.04	14.31	6.56	10.94	10.56	8.37
		RF	9.57	10.43	10.78	10.09	10.43	12.17	7.48	8.87	9.19	10.26
		RBA	21.75	10.38	5.49	3.96	6.34	28.66	3.87	4.73	9.98	5.71
		IVI	44.28	31.81	25.63	21.93	24.82	55.14	17.91	24.54	29.73	24.34
Rajban C_7	19.87	RD	11.63	14.64	10.98	7.75	7.75	13.56	6.89	11.41	8.83	6.57
		RF	8.59	12.16	12.16	8.59	10.73	9.12	7.69	10.55	11.09	10.02
		RBA	14.48	36.58	5.29	3.78	4.34	18.31	2.37	6.02	4.15	4.83
		IVI	34.69	61.95	24.86	20.83	22.82	40.99	16.95	27.99	23.92	21.41
Kukron C_{14}	30.18	RD	15.6	15.6	9.6	8.93	9.68	18.3		4.65	9.15	8.48
		RF	9.39	11.69	13.36	13.57	11.48	12.32		5.43	11.69	11.06
		RBA	27.34	8.22	2.54	9.79	9.84	28.05		0.33	8.51	5.38
		IVI	52.34	35.52	25.5	32.28	31.01	58.68		10.41	29.36	24.92
Rajban C_{10}	45.00	RD	18.97		13.44	9.93	11.13	19.42		5.9	12.32	8.89
		RF	12.03		14.48	14.92	13.14	12.47		6.68	13.59	12.69
		RBA	29.32		3.55	10.45	10.88	29.41		0.45	10.6	5.34
		IVI	60.32		31.47	35.31	35.15	61.3		13.03	36.51	26.93
Kukron C_{15}	70.12	RD	17.65		10.49	10.11	11.61	21.07		6.12	12.56	10.41
		RF	12.42		13.06	13.28	12.42	12.63		8.78	14.99	12.42
		RBA	12.16		2.03	9.39	7.66	53.11		0.48	8.85	6.33
		IVI	42.22		25.58	32.76	31.69	86.81		15.38	36.4	29.16
Gorakhpur C_7	100.00	RD	18.91	14.7	9.01	7.35	9.39		9.39	11.69	11.05	8.5
		RF	13.24	11.52	12.09	11.32	11.52		8.25	9.98	10.56	11.52
		RBA	34.44	16.04	5.55	5.54	8.03		5.09	6.41	11.73	7.18
		IVI	66.59	42.25	26.66	24.21	28.94		22.73	28.08	33.34	27.2
Lai C_{28}	22.56	RD	16.82	14.43	9.99	9.64	9.36	17.38	4.79		9.64	7.95
		RF	10.65	11.05	12.62	13.21	11.65	11.64	6.9		11.83	11.05
		RBA	26.95	7.67	2.73	10.43	27.77	26.95	0.35		9.51	5.06
		IVI	54.42	33.14	25.35	33.29	29.94	56.79	12.04		30.98	24.05

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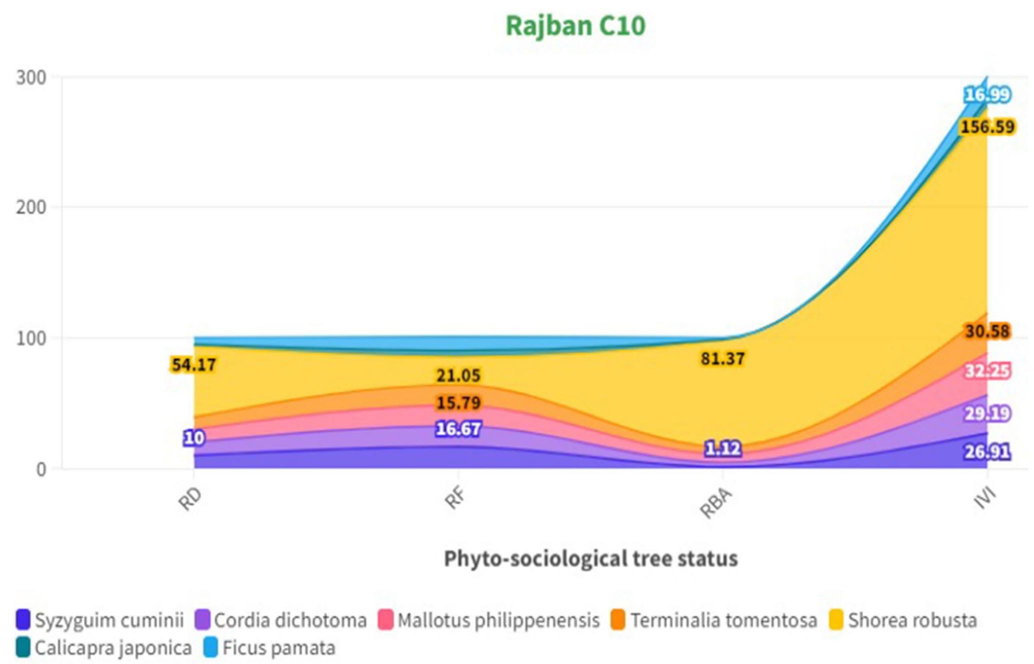

FIGURE 4
Phytosociological status of trees in the Sal Working Circle.

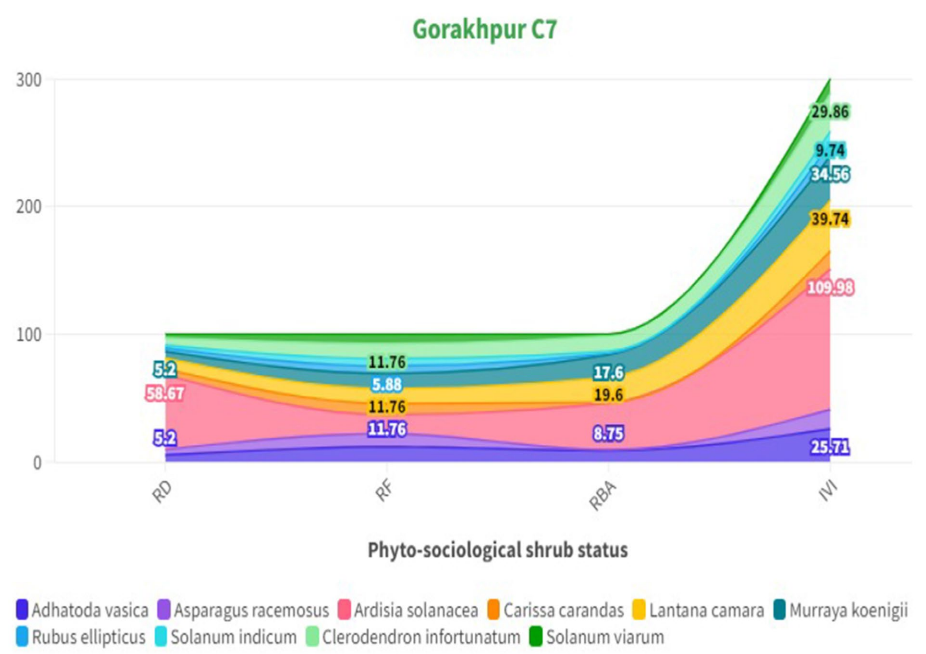

FIGURE 5
Phytosociological status of shrubs in the Sal Working Circle.

ecosystems (Dash et al., 2021). Understanding the variation in floristic composition across different forest compartments is crucial for assessing the overall biodiversity and sustainable management of forest ecosystems. The present study aimed to investigate the comparative floristic composition of trees, shrubs, and herbs across seven compartments within the same forest range, as it was hypothesized that the total inter-compartmental variation in the representation of these vegetation layers would be limited due to the relatively homogeneous microenvironmental conditions (Jucker et al., 2018; Hofhansl et al., 2020).

The site quality classification of the present study indicates a forest site's potential for productivity, where site quality II (Kukron $C_{14,15}$,

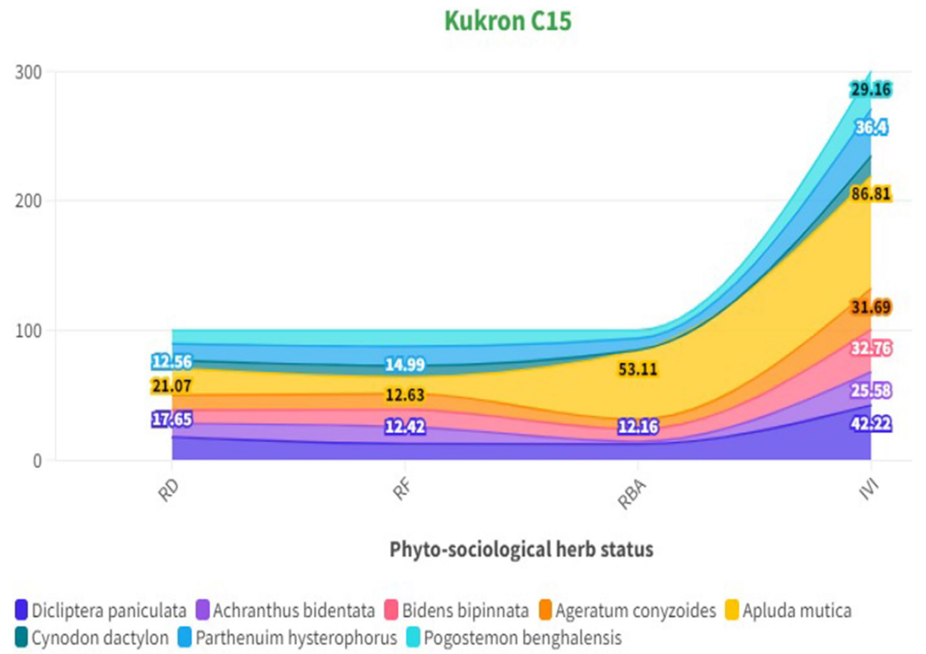

FIGURE 6
Phytosociological status of herbs in the Sal Working Circle.

Gorakhpur C_7, Rajban C_{10}, and Lai C_{28}) represents moderately productive areas where Sal grows well but with some limitations in soil fertility or moisture. Site quality III (Rajban $C_{6,7}$) shows lesser productivity due to inferior soil conditions or limited moisture availability, resulting in slower development of vegetation and regeneration. The present study found limited inter-compartmental variation in the representation of trees, shrubs, and herbs, which may be due to the fact that the different compartments under study were located within the same forest range and thus experienced relatively similar microclimate. In the present study, it was found that most of the species of trees, shrubs, and herbs were common among different compartments, except Lai C_{28}, which may be due to uniformity in habitat and topography and prevailing climatic conditions, and thus implies application of similar sustainable management practices for the compartments under investigations with slight variation for Lai C_{28}. Mishra et al. (1997) opined that species composition varies from site to site mostly due to microenvironmental changes and patterns of distribution, depending both on physico-chemical properties of the environment and biological peculiarities between species.

Floristic composition is important to assess the state of natural forests in any region and formulate conservation and management strategies. The floristic composition of the trees, shrubs, and herbs in the present study is lower than that reported by Divakara (2015) in Sal forests of Jharkhand and by Dutta and Devi (2013) in the Doboka reserve forest of Assam's tropical wet deciduous Sal forest. In the present study, *S. robusta* was found to be dominant in all compartments, followed by *M. philippensis, T. tomentosa, C. dichotoma,* and *S. cuminii,* with the rest of the species displaying a non-frequent population pattern. Similarly, the number of species documented in the current study was found to be lower than that reported by Mandal and Joshi (2014) in different climatic conditions, indicating uniformity within the compartments under consideration in terms of habitat, climate, soil, and geography. They reported *M. philippensis, T. tomentosa, and S. cuminii* as the principal companions of the Sal forest while examining vegetation dynamics and plant diversity in dry deciduous forests of the Doon valley region.

In forest ecosystems, the magnitude of variation is investigated through phytosociological aspects, mainly by relative density, relative frequency, relative basal area, and IVI values, which reflects factors such as species preference, management practices, utilization, and felling patterns that impact forest composition (Shrestha et al., 2010; Sarkar and Devi, 2014). In all the seven compartments examined in the current investigation, *S. robusta* has demonstrated large percentage of RD, RBA, and IVI values. Based on RD and IVI values, it is ascertained that *S. robusta* covers over 50% of these compartments. The most common associates of *S. robusta* in all the compartments are *M. phillippensis, T. tomentosa, C. dichotoma,* and *S. cuminii,* except Lai C_{28}. In Lai C_{28}, besides these associates, *E. globulus*, *B. variegata*, *A. catechu,* and *F. palmata* were also present in insignificant proportions based on their IVI values. In the shrub layer, *A. solanacea* was the most common species (IVI values) occurring in almost all the compartments. While, in the herbaceous layer, *Apluda mutica* was the most dominant associate of *S. robusta,* the analysis of IVI values showed that *S. robusta* was the dominant species in all the compartments (IVI value~150), which is well within the limits of earlier studies (Rawat and Bhainsora, 1999). Tree species with higher IVI values for trees, shrubs, and herbs in the compartments may be due to good regenerative capability, better adaptability, and wide ecological amplitude in the forest stand with greater species diversity, providing more diverse ecosystem services, resilience to disturbances, and supporting greater soil nutrient retention and carbon storage than less diverse compartments (Gamfeldt et al., 2013; Liang et al., 2016; Van Rooyen et al., 2017; Zhang et al., 2017; Liu et al., 2018).

Phytosociological data from these forests were quantitatively analyzed to work out the density, relative density, basal area, and

TABLE 6 Diversity indices of trees, shrubs, and herbs among different compartments in the Sal Working Circle of Paonta Forest Division, Himachal Pradesh.

Diversity indices	Rajban C_6	Rajban C_7	Rajban C_{10}	Kukron C_{14}	Kukron C_{15}	Gorakhpur C_7	Lai C_{28}
Trees							
Simpson concentration of dominance index (Cd)	0.29	0.25	0.28	0.33	0.32	0.31	0.23
Simpson diversity index (D)	0.71	0.75	0.72	0.67	0.68	0.69	0.77
Shannon–Wiener index of diversity (H′)	1.50	1.57	1.53	1.46	1.47	1.44	1.83
Menheink's index of species richness (Mel)	0.37	0.38	0.34	0.40	0.40	0.33	0.55
Margalef index of species richness (MI)	0.90	0.90	0.87	1.05	1.05	0.87	1.43
Pielou's equitability (Ep)	0.84	0.88	0.85	0.75	0.76	0.80	0.83
Shrubs							
Simpson concentration of dominance index (Cd)	0.26	0.31	0.32	0.19	0.21	0.37	0.23
Simpson diversity index (D)	0.74	0.69	0.68	0.81	0.79	0.63	0.77
Shannon–Wiener index of diversity (H′)	1.82	1.69	1.64	2.02	1.97	1.56	1.85
Menheink's index of species richness (Mel)	0.10	0.11	0.12	0.10	0.11	0.12	0.11
Margalef index of species richness (MI)	0.99	1.00	0.93	1.07	1.08	1.02	0.89
Pielou's equitability (Ep)	0.79	0.73	0.75	0.84	0.82	0.68	0.84
Herbs							
Simpson concentration of dominance index (Cd)	0.11	0.11	0.13	0.14	0.14	0.12	0.13
Simpson diversity index (D)	0.89	0.89	0.87	0.86	0.86	0.88	0.87
Shannon–Wiener Index of diversity (H′)	2.28	2.27	2.13	2.02	2.02	2.15	2.13
Menheink's index of species richness (Mel)	0.02	0.02	0.03	0.03	0.02	0.02	0.04
Margalef index of species richness (MI)	0.74	0.74	0.68	0.59	0.60	0.67	0.67
Pielou's equitability (Ep)	0.99	0.98	0.97	0.97	0.97	0.98	0.97

important value index (IVI). In our study, the variation under different compartments can be clearly seen for tree density that ranged between 322 and 250 N ha^{-1} (Rajban C_{10}-322 N ha^{-1} RD = 54.17), having a basal area of 0.37 to 1.19 m^2 ha^{-1} (Gorakhpur C_{7-} RBA = 126.72) with high dominance of *S. robusta* in the overstorey layer. It may be because of less competition for space and light at canopy level in compartments (Lai C_{28}, Rajban C_{10}, and Kukron C_{15}) with higher tree density. The soil and climate in compartments constrain development, resulting in heterogeneity in stand characteristics. The present study reveals similar patterns, with both elevation and slope playing a crucial role in determining species association, community structure, and the dominant species within each community. These variables primarily affect the prevailing microclimate, canopy density, and competition (Khan et al., 2013; Nakhoul et al., 2020). Kumar et al. (2006) also observed a similar range for tree density (380 trees ha^{-1}–260 trees ha^{-1}) in the sub-tropical forest of the Garhwal Himalaya, although the basal area (0.78 to 1.43 m^2 ha^{-1}) was higher in the present study. The highest IVI (150) indicated dominance of *S. robusta*. Additionally, similar patterns were observed in the Doboka reserve forest of Assam's tropical wet deciduous Sal forest. *S. robusta* had the highest IVI (125.30) density, which was found to be higher in the lower girth class, i.e., 30–60 cm (Dutta and Devi, 2013). In the present study, *S. robusta* was found to be extensively dispersed in all compartments, followed by *M. philippensis*, *T. tomentosa*, *C. dichotoma,* and *S. cuminii*, with the rest of the species exhibiting a non-frequent population pattern. In addition, *S. robusta* showed considerably maximum values in all the compartments with the highest IVI (156.59) for Rajban C_{10}. IVI values for shrubs ranged between 8.35 and 27.33. The high value of IVI of Sal trees denoted that they not only play a critical role in the functioning of their ecosystems but also possess a robust capacity to withstand environmental stresses such as deforestation, fire, and illicit cutting (Pandey and Shukla, 2019). The results confirmed that diversity (species richness) for tree species was highest, followed by shrubs and herbs. Results of present phytosociological studies of trees are in line with similar findings by Deka et al. (2012), who suggested that *S. robusta* has contributed approximately 90% of the total stand density (2,559 individual ha^{-1}) of the forest and exhibited the highest IVI (212.67). However, the low basal area recorded in our present study resulted from low stocking among the large size diameter classes (i.e., 60–80 cm) despite the presence of some small diameter class trees. Differences in basal area can be related to altitudinal variances, age structure, forest successional stage, species composition, and disturbance (Gogoi and Sahoo, 2018; Yumnam and Ronald, 2022).

TABLE 7 Index of similarity and dissimilarity of vegetation in compartments of the Sal Working Circle in Paonta Forest Division, Himachal Pradesh.

	Similarity						
Dissimilarity	Rajban C_6	Rajban C_7	Kukron C_{14}	Rajban C_{10}	Kukron C_{15}	Gorakhpur C_7	Lai C_{28}
Trees							
Rajban C_6	–	1.00	1.00	0.77	0.77	1.00	0.67
Rajban C_7	0.00	–	1.00	0.77	0.77	1.00	0.67
Rajban C_{10}	0.00	0.00	–	0.77	0.77	1.00	0.67
Kukron C_{14}	0.23	0.23	0.23	–	1.00	0.77	0.75
Kukron C_{15}	0.23	0.23	0.23	0.00	–	0.77	0.75
Gorakhpur C_7	0.00	0.00	0.00	0.23	0.23	–	0.67
Lai C_{28}	0.33	0.33	0.33	0.25	0.25	0.33	–
Shrubs							
Rajban C_6	–	1.00	0.95	0.86	0.76	0.80	0.84
Rajban C_7	0.00	–	0.95	0.86	0.76	0.80	0.84
Rajban C_{10}	0.05	0.05	–	0.90	0.80	0.84	0.89
Kukron C_{14}	0.14	0.14	0.10	–	0.91	0.95	0.90
Kukron C_{15}	0.24	0.24	0.20	0.09	–	0.86	0.80
Gorakhpur C_7	0.20	0.20	0.16	0.05	0.14	–	0.95
Lai C_{28}	0.16	0.16	0.11	0.10	0.20	0.05	–
Herbs							
Rajban C_6	–	1.00	0.95	0.89	0.89	0.89	0.95
Rajban C_7	0.00	–	0.95	0.89	0.78	0.89	0.95
Rajban C_{10}	0.05	0.05	–	0.94	0.94	0.94	0.89
Kukron C_{14}	0.11	0.11	0.06	–	0.88	0.88	0.82
Kukron C_{15}	0.11	0.22	0.06	0.13	–	0.88	0.82
Gorakhpur C_7	0.11	0.11	0.06	0.13	0.13	–	0.82
Lai C_{28}	0.05	0.05	0.11	0.18	0.18	0.18	–

In all the compartments, relative basal area, density, and frequency of *Ardisia thickets* had the maximum share compared to other shrubs and herbs. This may be attributed to thick monoculture of *A. solanacea* that alters the microenvironment below its understory and inhibit the germination and growth of *S. robusta* and other associate species that results in the exclusion of native plants, probably through a strong decrease in understory light availability (Sharma and Raghubanshi, 2007; Kumar et al., 2022). In our study, the dominance of *A. solanacea,* an invasive plant exotic shrub with IVI (71.31–109.98) (Gorakhpur C_7 = 109.98, followed by Rajban C_6,=86.61 and Rajban C_7 = 92.92), may be due to sparse canopy cover and lack of proper canopy distribution at canopy level and lesser competition for light and space at the understory level. The higher ground layer species richness was most likely due to various abiotic and biotic pressures creating a gap in the overstorey, which helps this exotic species to multiply by vegetative propagation (Pandey and Shukla, 2001). It could be another possible reason for the observed trend and lower shrub and herb diversity in other compartments in the current study. In contrast, species dominance demonstrated an inverse correlation with diversity, with climbers and under shrubs (*Ardisia solanacea*) being more dominant than overstorey species in Gorakhpur C_7, indicating a complex ecosystem structure (Bricca et al., 2023). Furthermore, Koop and Horvitz (2005) studied spatial and temporal variation in the population dynamics of an invasive species, *A. elliptica*, across a range of habitat types to identify contributing factors for its demographic success. Mean population density was highest at the *Ardisia* thicket (358.5 N m^2) and relatively low at the other sites (5.4–47.0 N m^2), while deep shade generated by a continuously dense canopy of adults in the *Ardisia* thicket has suppressed the growth of seedlings and juveniles. However, high water availability has probably resulted in high germination rates of seeds and a dominance of seedlings and small juveniles (Koop, 2003). The invasive potential and population dynamics of *A. elliptica* on native communities may be strongly influenced by light and water availability (Koop, 2004), which resulted in reduced regeneration capacity and seedling development of *S. robusta* in the compartments. All these trends may indicate the influence of different forest management regimes in the compartments under study.

The values in the current study were found to be well within the range of values of The Shannon–Wiener diversity index (H0) for Indian forests, which ranged from 0.83 to 4.10 (Jha and Singh, 1990; Ayyappan and Parthasarathy, 1999; Pandey, 2000). In contrast, Kumar and Saikia (2020b) reported higher values of the Shannon diversity index (2.25 for trees, 2.72 for shrubs, and 2.98 for herbs) than in the present study. However, they are in close proximity to the values reported by Banik et al. (2018) for Sal forests under two forest management regimes (Sal forest and Sal plantation) in Tripura, Northeast India. The range of diversity indices from the present study was lower than those found by Divakara (2015), who evaluated the floristic composition of semi-dense and open forests in two districts of different Sal forests in Jharkhand. The maximum Shannon–Wiener diversity index (H′ = 2.5754, R′ = 2.4071), Simpsons index of diversity (D = 0.8900, D = 0.8596), Margalef richness index (R′ = 4.5806, R′ = 4.5122), and evenness index (E = 0.6677, E = 0.6062) were obtained in Latehar. On the other hand, open and dense forests of Hazaribagh showed the lowest for Shannon–Wiener diversity index (H′ = 1.3825, H′ = 1.1658). However, the lowest Simpsons index of diversity (D = 0.6096), Margalef richness index (R′ = 2.2216), and evenness index (E = O.4100) were found in dense forests of Latehar. Simpson's index value in the present study is lower (0.33) than the value (0.36) of Madhupur National Park (Rahman and Vacik, 2010), Ranchi Sal Forest, Jharkhand, India (Kumar and Saikia, 2020a). Margalef's species richness index was found to have a lower value (1.43). In contrast, the value is lower (0.77) than the Simpson's index value (0.98) of Bhawal National Park and Ranchi Sal Forest, Jharkhand, India. Species (Pielou's) evenness index of the current study is higher (0.88) than that of the Ranchi Sal Forest, Jharkhand, Eastern India (Kumar and Saikia, 2020a).

Several climatic and edaphic factors, including habitat heterogeneity, species composition, forest age, and anthropogenic disturbances, are responsible for differences in diversity and structure of Sal forests along their geographic range (Champion and Seth, 1968a; Gautam and Devoe, 2006a, 2006b). Sal (*Shorea robusta* Gaertn. f.) forests, known for their economic and ecological values, are under immense anthropogenic pressure, particularly in areas near human settlements, due to illicit logging, lopping, and overexploitation for fodder and fuelwood (Lai C_{28} and Gorakhpur C_7). Such disturbances affect species composition, stand structure, and carbon dynamics (Yohannes et al., 2015), resulting in biomass and biodiversity loss (Sapkota et al., 2010; Gautam and Mandal, 2016). Compartments such as Rajban C_6, C_7 had lower tree densities, evidently due to poor site quality, restricted soil depth, reduced canopy cover (Rajban C_6, C_7, and Gorakhpur C_7), and higher disturbance levels viz., lopping for non-timber forest products. The proximity to human activities exacerbates these effects, influencing regeneration and composition (Uprety et al., 2023; Shrestha et al., 2023). The similarities across compartments might be due to their location inside the same forest division and uniform management practices. Variations in species association and community structure, determined by elevation and slope, highlight the involvement of site-specific environmental and anthropogenic activities, highlighting the significance of compartment-level analysis for understanding the dynamics of the Sal-dominated ecosystem.

5 Conclusion

This study gives a detailed insight into the floristic diversity of Sal forests in Himachal Pradesh, presenting valuable insights on the forest's ecological resilience and biodiversity. With 33 genera and 34 species identified, *S. robusta* emerged as the leading species, with IVI values ranging from 126.72 to 156.59. Variations in species diversity across compartments, such as Lai C_{28}, Kukron C_{15}, and Rajban C_6 and C_7, demonstrate the importance of microenvironments and site quality in defining forest composition. The similarity index, which ranges from 0.67 to 1.00, identifies distinct yet interrelated tree communities. This overall uniformity demonstrates that similar sustainable management strategies may be adopted throughout compartments, with small variations for sites such as Lai C_{28}. The existence of a diverse range of species offers important ecosystem services such as carbon sequestration, soil enrichment, and species habitat provision. Understanding and acknowledging the complexities of floristic composition is crucial for effective forest management and conservation. The necessity of protecting native species while avoiding the spread of invasive species such as *A. solanacea* and *L. camara*. The findings of the study will contribute significantly to develop sustainable forest management for the Sal forests of Himachal Pradesh to safeguard *S. robusta*, a high-value wood species and its associates.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AS: Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. DB: Conceptualization, Writing – review & editing. CT: Supervision, Visualization, Writing – review & editing. NK: Software, Writing – review & editing. JS: Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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