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Phytosociological Patterns Along a Soil Nutrient Gradient in Sacred Groves of Haryana

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Key words: Sacred Groves; semi-arid; Important Value Index (IVI); phytodiversity; soil nutrients; vegetation composition.

Ključne besede: Sveti gaji; pol aridno; Indeks pomembnosti vrste (IVI); fitodiverziteta; hranila v tleh; sestava vegetacije.

Abstract

Sacred groves (SGs) are patches of natural vegetation traditionally protected by local communities for religious, cultural, or spiritual reasons. This study evaluated the phytodiversity and soil nutrient profile of four SGs in semi-arid Western Haryana, outside the protected area network. Quadrat sampling recorded floristic composition, species richness, dominance, evenness, and Shannon–Wiener diversity index (H'). Soil parameters included pH, electrical conductivity (EC), bulk density (BD), nitrogen (N), phosphorus (P), potassium (K), and organic carbon (OC). Tree, shrub, and herb density was highest in Bidola SG, while basal area was greater in Sultanpur (19.77 m^2/ha) and Dhingsara (15.51 m^2/ha) than in Makrana Johra (7.69) and Bidola (4.49). Dominant species were *Acacia tortilis* (Bidola), *Salvadora oleoides* (Sultanpur), and invasive *Prosopis juliflora* (Dhingsara). H' ranged 0.61–3.26 for trees, 0.05–0.58 for shrubs, 0.39–0.88 for herbs, and 0.32–4.59 for climbers. Soils showed highest EC, N, P, K, and OC in Makrana Johra, maximum BD in Dhingsara, and highest pH in Bidola. Findings highlight that SGs of Western Haryana sustain notable biodiversity and soil fertility, but agricultural expansion threatens their integrity, requiring urgent conservation and community–scientist collaboration.

Izvleček

Sveti gaji (SG) so zaplate naravne vegetacije, ki jih varuje lokalna skupnost za verske, kulturne in duhovne namene. V naši raziskavi smo ovrednotili fitodiverziteto in hranila v tleh v štirih SG v polsušnem delu Zahodnega Hayrana izven omrežja zavarovanihl območij. Z vzorčenjem kvadratov smo ugotovili floristično sestavo, vrstno pestrost, dominanco, enakomernost in Shannon–Wiener diverzitetni indeks (H'). Preučevani talni parametri vključujejo pH, električno prevodnost (EC), gostoto tal (BD), dušik (N), fosfor (P), kalij (K) in organski ogljik (OC). Gostota dreves, grmov in zelišč je bila največja v SG Bidola, bazalna površina je bila največja v SG Sultanpur (19,77 m^2/ha) in Dhingsara (15,51 m^2/ha) kot v SG Makrana Johra (7,69) in Bidola (4,49). Dominantne vrste so bile *Acacia tortilis* (Bidola), *Salvadora oleoides* (Sultanpur) in invazivna *Prosopis juliflora* (Dhingsara). H' je bil med 0,61–3,26 za drevesa, 0,05–0,58 za grme, 0,39–0,88 za zelišča in 0,32–4,59 za plezalke. Največji EC, N, P, K in OC v tleh so bili v Makrana Johra, največji BD v Dhingsara in najvišji pH v Bidola. Rezultati so pokazali, da najdemo v SG v območju Zahodni Hayrana visoko biodiverziteto in rodovitna tla, vendar je zaradi širjenja kmetijstva ogrožena njihova celovitost, zato je nujno potrebno varovanje in sodelovanje skupnosti in raziskovalcev.

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Introduction

Sacred groves (SGs) are small forest patches protected by local communities for religious or cultural reasons, often dedicated to deities or spirits, where activities like tree cutting or hunting are traditionally forbidden. These are revered and protected across cultures and continents for centuries, embodying a unique blend of biodiversity conservation, cultural heritage, and spiritual significance. They have been acknowledged by the International Union for the Conservation of Nature as Indigenous and Community Conserved Areas (ICCAs) (IUCN 2009). Usually located around a centre of devotion, the SGs are run by local people e.g., indigenous organizations or local communities who are the guardians of the surrounding forest (Dudley et al., 2010). SGs' conferred biodiversity protection can thus help to supplement efforts at biodiversity conservation in formally identified protected areas more usually under government or NGO management (Klepeis et al., 2016).

SGs have been reported in diverse regions such as West Africa (Nigeria, Ghana), Southeast Asia (Thailand, Cambodia), and Japan (Shinto forests), in addition to their widespread presence across India. This highlights the global significance of sacred groves as both biodiversity hotspots and cultural landmarks. Sacred groves have often been preserved due to their role in maintaining plant diversity and cultural heritage (Gokhale, 2007; Kufuor & Omari, 2015). Sacred groves in India are most concentrated in regions such as the Western Ghats (Southern zone), the Northeast (e.g., Meghalaya), the Himalayas (North), and Rajasthan (West). This information provides a better understanding of the regional significance of sacred groves across the country (Bawa et al., 2004; Das & Ratha, 2013).

The SGs provide several advantages for nature conservation, such as the preservation of up to 85% of native species richness as refuges for rare and endemic species (Rösch et al., 2015). Other than this, local people can preserve their biodiversity for a long time because of cultural value that lasts for generations (Manna & Roy, 2021). They are also home to variety of medicinal plants (Ma et al., 2022), act as wildlife corridors or buffer zones for protected areas (Ishii et al., 2010), seed dispersal and pollination (Rajasri et al., 2017), erosion control and water resources (Ma et al., 2022).

Some SGs represent remnants of ancient, continuous forests (Scull et al., 2017), whereas others appear to be regenerated forests (Bhagwat et al., 2014). People are diverse and dynamic, and their religions and practices affect management of SGs (Dove et al., 2011). Such as the most widespread historical sites of Eurasian steppes are 'kurgans' (ancient burial mounds) which embody important historical, spiritual, cultural, and conservational values (Deák et al., 2019). Thus, SGs represent how humans and environment interact dynamically and are essential for preserving cultural values along with ecological assets across cultures and regions. Other than this, firewood, medicinal or ceremonial plants, and nontimber forest products including fruits and seeds can be found in SGs. They also host prayer, ceremonial, and ancestor worship (Lynch et al., 2018). Stewards of SGs can maintain high habitat quality, limit chronic and acute forest disturbance and facilitate passive restoration (Bhagwat et al., 2014). In India, SGs hold profound ecological and socio-cultural importance, often serving as repositories of traditional knowledge and biological diversity. These groves can range in size from small areas with a few trees to extensive hectares of greenery preserved due to their association with specific deity.

The present study focused on sacred groves (SGs) in Western Haryana, a semi-arid region in northern India with a sub-tropical climate, where forest cover is limited to only 3.53% of the total geographical area (ISFR, 2021). Although SGs are traditionally regarded as well-protected ecosystems, those in this region are increasingly vulnerable to anthropogenic pressures such as urbanization, land-use changes, overharvesting, pollution from religious activities, and expansion of villages into grove areas. The absence of tribal communities, who historically played a key role in safeguarding these groves, has further intensified these threats. Compounding the issue is a decline in traditional conservation practices and cultural values, leading to erosion of local stewardship over these ecologically valuable sites.

Despite their cultural and ecological significance, there is a lack of comprehensive prior ecological assessments. To address this critical gap, a preliminary survey was conducted to create an inventory of sacred groves across the region. Study sites were selected based on their ecological uniqueness, cultural relevance, and accessibility, with the objective of generating data that could inform targeted conservation strategies and support the long-term sustainability of these threatened ecosystems. Hence, the current study was conducted to investigate a total of four SGs from the four different forest ranges of western Haryana for a comprehensive ecological assessment to understand the phytodiversity and soil nutrient profile dynamics.

Materials and methods

Study site

A preliminary survey was conducted across Western Haryana to create an inventory of SGs, marking the first systematic documentation of these ecosystems in the region. Based on the preliminary survey across Western Haryana, four SGs—Bidola, Makrana Johra, Sultanpur, and Dhingsara—were randomly selected, one from each of the Tosham (Bhiwani), Behal (Bhiwani), Hansi (Hisar), and Fatehabad forest ranges, respectively, for in-depth ecological study (Figure 1). This selection method ensured a representative spatial distribution, enabling the generation of region-specific ecological insights while facilitating thorough field investigations.

The study focused on sacred groves in the semi-arid region of Western Haryana, characterized by undulating sandy plains and bagar. The Thar Desert, which is situated in close vicinity, significantly influences the semiarid and dry climate of the region. The monsoon season is the one in which most of the annual rainfall in the research region is received. The map of study site and the climograph, are shown in Figure 1 and Figure 2.

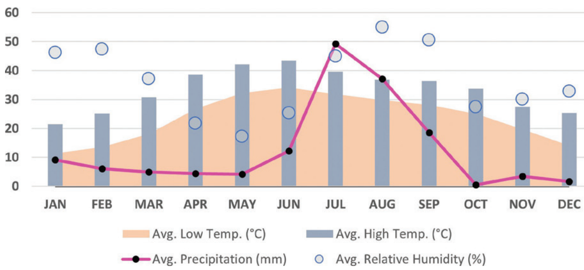

Figure 2: Climograph of the selected districts of Western Haryana showing mean average temperature, precipitation, and humidity (www.worldweatheronline.com).

Slika 2: Klimogram izbranih območij Zahodnega Hayrana s povrečno temperaturo, padavinami in vlažnostjo (www.worldweatheronline.com).

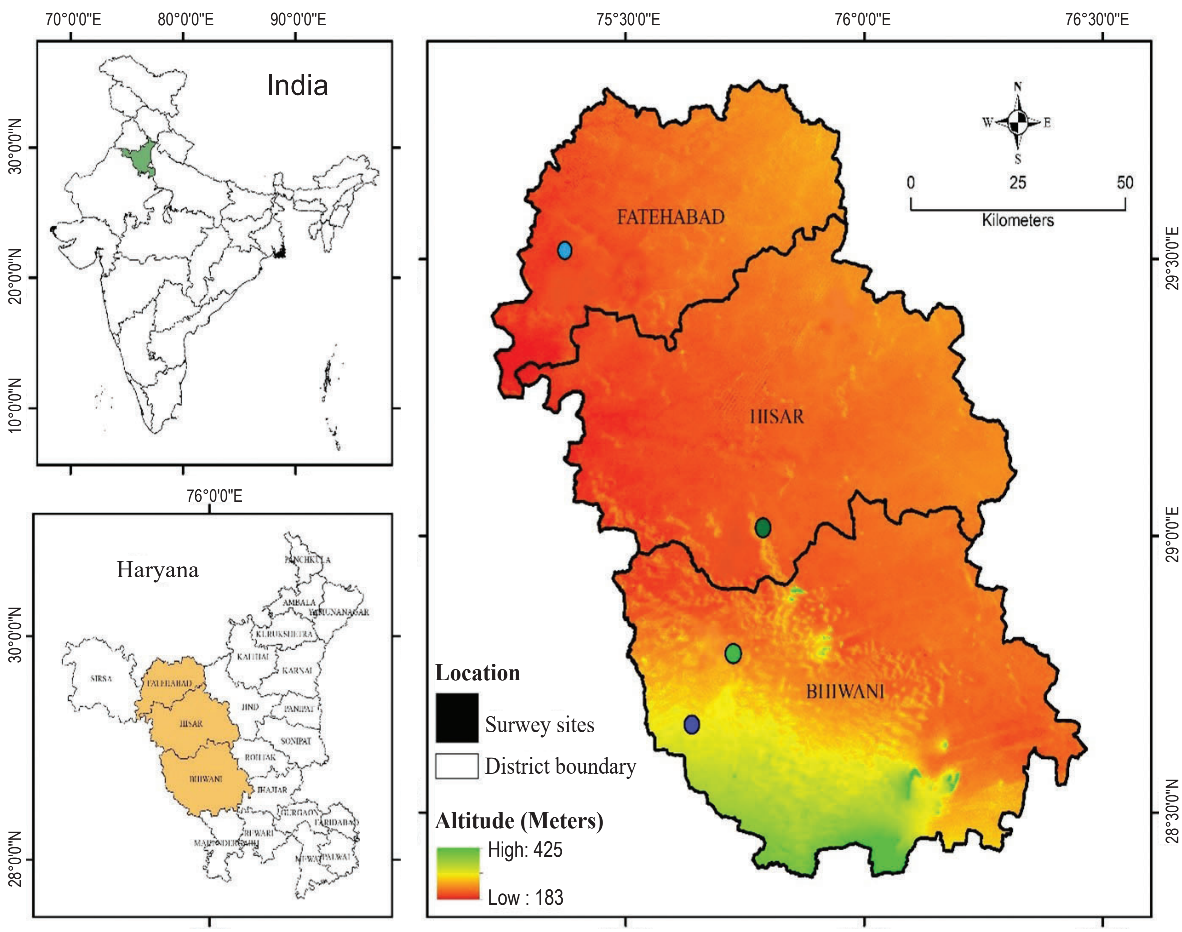

Figure 1: Map showing the location of Haryana in India and the SGs selected for the present study.

Slika 1: Zemljevid z lokacijo območja Hayrana v Indiji in izbrani SG v razsikavi.

Sampling of vegetation and data analysis

For the evaluation of distribution and quantification of phytodiversity, in-depth analyses were required in the study area, so several field visits were performed in the selected SGs. The study specifically utilized the widely recognized and important random quadrate sampling method (Hill, 2005). A total of 60 quadrats were plotted in the selected SGs i.e., 15 quadrats on each SG. Enumeration of trees and climbers was done in the quadrats of size 20×20 m whereas for shrubs and herbs, quadrats of size 5×5m and 1×1 m were used respectively (Cottam & Curtis, 1956). To measure the Circumference at Breast Height during sampling, the tree species girth was noted at 1.37 meters from the ground using measuring tape. For shrubs and climbers, the circumferences were taken at 5 cm from the ground. Whereas the diameter of the herbs was measured just above the ground using Vernier callipers.

Subsequently, the vegetational data was analysed using the phytosociological parameters viz., density (D), frequency (F), abundance (A) and basal area (B.A.) following Misra (1968). The relative values of F, D, and B.A. were calculated after that to obtain the IVI (Important Value Index) value for the encountered plant species following Phillips (1959) and Curtis (1959), using the formula: $Important\ Value\ Index\ (IVI) = RF\% + RD\% + RDo\%$.

Other than this, to understand the distribution pattern of plant species, Abundance to Frequency ratio (A/F) was estimated following Cottam and Curtis (1956) for each species viz., regular (less than 0.025), random (0.025 to 0.05) and contiguous (more than 0.05). The frequency class distribution pattern was also obtained for the selected SGs to understand the nature (Homogenous or heterogenous) of plant communities occurring in them (Raunkiaer, 1918). Other than this, values of different vegetation indices were calculated for the diversity analysis of the four SGs. For this diversity index (Shannon & Wiener, 1963), dominance index (Simpson, 1949), index of evenness (Pielou, 1966) for species equitability and index for species richness (Margelef, 1958) were deliberated.

The soil samples were collected in the 4 SGs from each quadrat, taken at a depth of 0–30 cm. After removing any big stones, the soil samples were brought to the lab where they were first air dried and sieved (pore size – 2 mm). Using a conductivity meter, the electrical conductivity (EC) and soil pH of a saturated soil paste extract were measured (Rhoades 1996; Thomas 1996). Organic Carbon (OC) content of the soil samples was determined following Nelson & Sommers (1996). Soil Nitrogen content (N), Phosphorus content (P), and Potassium content (K) were analysed according to Jackson (1973), Olsen et al. (1954), and Pratt (1965), respectively.

Statistical analysis

Tukey *post-hoc* analysis was performed on the soil data and a box plot was formed using R program (R 4.4.1). Additionally, the two-tailed Carl-Pearson Coefficient was computed between the various floristic and soil parameters that were determined during the investigation and a heatmap was generated to facilitate comprehension of the correlation using R program (R 4.4.1).

Results and Discussion

Phytodiversity

A total of 130 plant species were documented in this study, comprising 21 trees, 12 shrubs, 86 herbs, and 11 climbers, classified across 31 families. The Sultanpur SG exhibited the highest diversity of tree species (13), followed by Makrana Johra (11), Bidola (9), and Dhingsara (8). In terms of herbaceous species, Sultanpur SG also demonstrated the greatest richness, with 47 species recorded, while Makrana Johra SG led in the diversity of shrub (12) and climber species (8). These findings suggest a substantial degree of plant diversity within the region, attributable to the interplay of topographic, edaphic, and physiographic conditions.

The analysis revealed an uneven distribution of species across the encountered families, where approximately half of the species belonged to merely five families, with the remaining species distributed among 26 families. Notably, a significant number of families were represented by only a single species (Figure 3). The family Poaceae was identified as the most dominant, followed in succession by Apocynaceae, Fabaceae, Malvaceae, among others. The predominance of Poaceae aligns with findings by Dhiman et al. (2024) in the lower altitudinal ranges of Morni Hills, Haryana, and in the SG of Midnapore (West Bengal) as reported by Sen and Bhakat (2020), along with Harikesh et al. (2020) in the community forests of Haryana and Garg et al. (2020) in the semi-arid forests of Aravali Hills.

Species-family richness analysis (Figure 3) indicated that Poaceae, Amaranthaceae, and Fabaceae were the most species-rich families in Bidola, Makrana Johra, and Dhingsara SG. Conversely, Sultanpur exhibited a maximum number of species within the Asteraceae family, followed by Amaranthaceae and Fabaceae. The dominance of Asteraceae has been corroborated in studies by Rashid et al. (2021), Dhiman et al. (2021), and Waheed

et al. (2022), while Amaranthaceae's prominence was highlighted by Prakash et al. (2022). This is because of the prevailing disturbances in these ecosystems as the endurance of Asteraceae family to tropical disturbance regimes places plant species belonging to this in an advantageous position to potentially dominate the disturbed ecosystems, also supported by Neto et al. (2017) and Arora et al., (2024).

The Poaceae family is arguably the most successful group of plants, characterized by their widespread presence in angiosperm habitats, ecological dominance, and notable species diversity. Their success can be attributed to several factors: their remarkable ability to colonize and persist in various environments, their effective long-distance dispersal mechanisms, and their ecological adaptability. Additionally, they exhibit tolerance to disturbances and have the capacity to modify ecosystems through processes such as fire and mammalian herbivory (Linder et al., 2017).

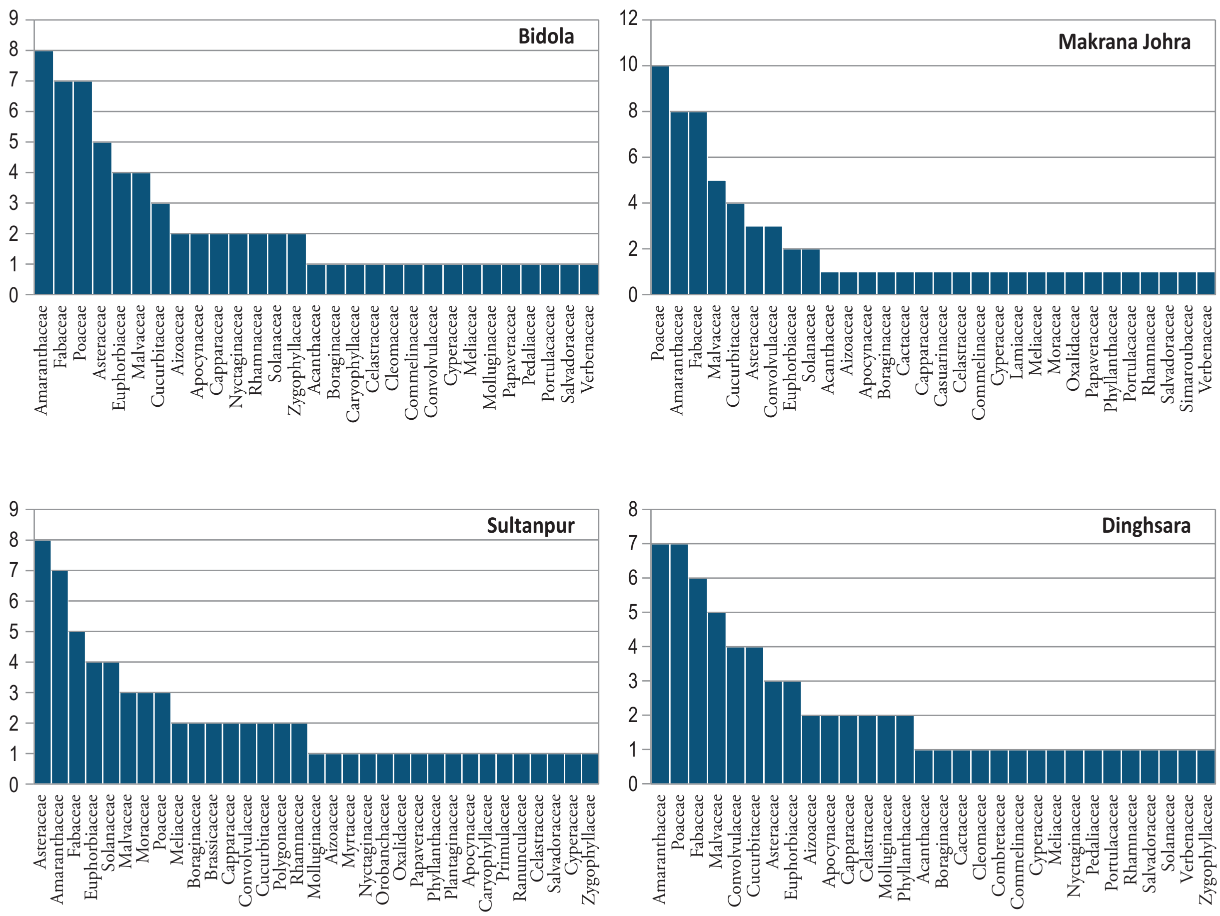

Figure 3: Proportion of families covering encountered plant species during the present study (left) and graphs comparing the species-family richness in the four SGs (right).

Slika 3: Delež družin rastlinskih vrst v raziskavi (levo) in grafi s primerjavo bogstva družin v štirih SG (desno).

The prevalence of Fabaceae plants, following Poaceae, is characterized by their symbiotic nodulated roots and rhizobacteria, which contribute to the enrichment of soil with biologically accessible nitrogen through N_2 fixation in the SGs (Singh et al., 2019; Joshi & Garkoti, 2020). Processes such as direct nutrient fixation, the deposition of organic matter from litter fall, root exudation, and rhizosphere aeration foster the activity of mutualistic aerobic microorganisms, thereby enhancing nutrient cycling and expanding the soil nutrient pool (Tang et al., 2018). Nutrient-rich soils facilitate the germination of seeds and saplings, while taxa that are unable to generate their own nutrient islands beneath their canopies rely on nutrients from other nutrient-fixing plants (Joshi & Garkoti, 2020).

The highest frequency of *Acacia tortilis* was recorded in Bidola, Makrana Johra, and Dhingsara within the tree stratum, while *Acacia nilotica* was predominantly observed in Sultanpur SG. This variation highlights their distinct niche preferences and ability to establish a presence across different geographic areas. While Bidola, Makrana Johra, and Dhingsara are situated in drier, higher elevations with sandy to loamy soils and lower moisture availability, Sultanpur is situated in a relatively low-lying area with finer alluvial soils and significantly higher soil moisture. The distribution and dominance of tree species are probably influenced by these site-specific differences in edaphic and microclimatic circumstances. Conversely, *Capparis decidua* exhibited the greatest frequency in Bidola, Sultanpur, and Dhingsara among shrubs, whereas *Abutilon indicum* was found most frequently in Makrana Johra (Table 1–4). These genera are prevalent in semi-arid zones and have been documented in numerous studies, such as those by Habib et al. (2016), Harikesh et al. (2020), Norman et al. (2024), Adoum (2024), and Arshad et al. (2024).

Additionally, the species distribution curve for the selected sacred groves (SGs) was analyzed using frequency classes (Raunkiaer 1918; McIntosh 1962). According to Raunkiaer's law, species within a community can be classified as either common or rare. Any deviation from the typical J-shaped trajectory of a normal frequency distribution suggests an ecosystem disturbance. Raunkiaer's normal species occurrence ratio (A > B > C >= D < E) indicates a homogeneous plant community when the frequency aligns with the J-shaped curve. The analysis demonstrates that the sacred groves of Bidola and Dhingsara conformed to Raunkiaer's law, exhibiting a J-shaped species distribution curve indicative of a homogeneous plant community. In contrast, Makrana Johra and Sultanpur did not follow this pattern, suggesting greater heterogeneity (Figure 4). This observation is supported by Deil et al. (2021), who noted that in their study of the SGs in NW-Morocco, the proximity of sacred sites to intensively used agricultural landscapes in lowland areas correlates with a diminished conservation propensity, thereby indicating ecosystem disturbance.

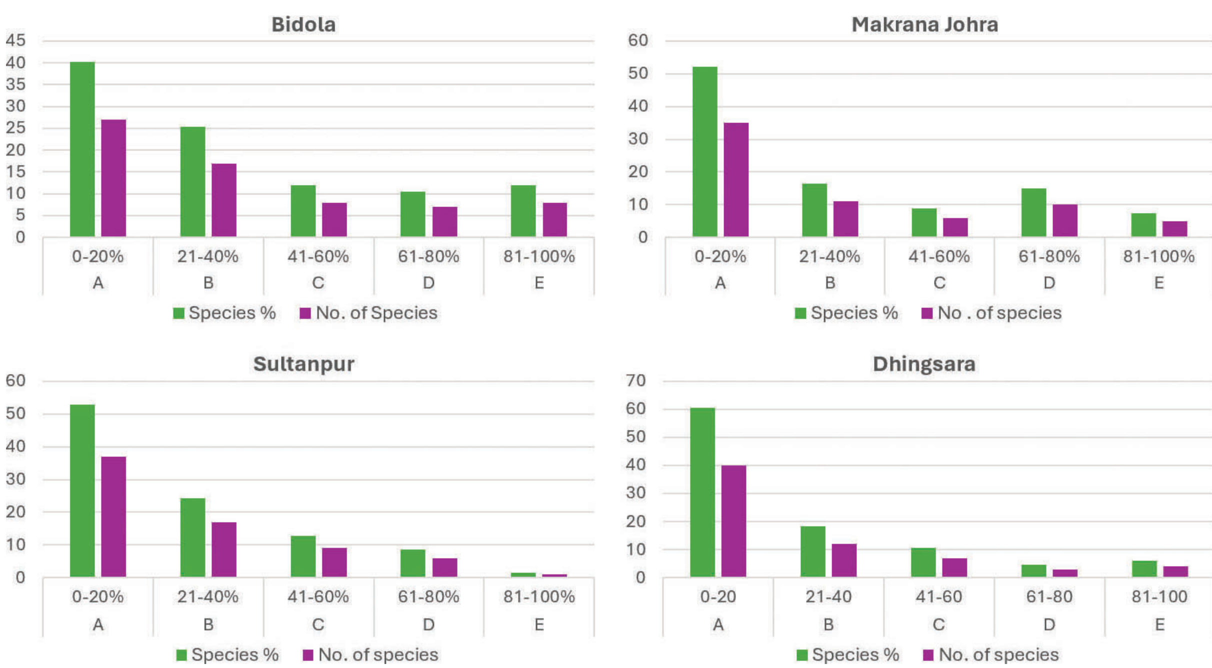

Figure 4: Frequency class distribution of plant species across the selected SGs.
Slika 4: Porazdelitev frekvenčnih razredov rastlinskih vrst v izbranih SG.

In the four surveyed study groups (SGs), a considerable variation in species density was observed among trees, shrubs, herbs, and climbers (Figure 5). Notably, Bidola SG demonstrated the highest density across trees, shrubs, and herbs, while Makrana Johra exhibited the greatest stand density for climbers (Tables 1–4, Figure 5). The individual density of tree species ranged from 5 to 432 individuals per hectare (Ind./ha), 5 to 296.7 Ind./ha, 3.33 to 185 Ind./ha, and 3.33 to 743.33 Ind./ha in Bidola, Makrana Johra, Sultanpur, and Dhingsara SGs, respectively. Both Bidola and Dhingsara displayed higher tree densities (1115 Ind./ha and 881.67 Ind./ha, respectively) compared to Makrana Johra and Sultanpur SGs (503.3 Ind./ha and 533.3 Ind./ha, respectively). A higher tree density in Bidola indicates better habitat quality, while reduced densities in other SGs suggest ecological stress or degradation due to the influence of human pressures, such as lopping, trampling, and scraping, also supported by Aakash et al. (2019).

In addition to the aforementioned analyses, abundance-to-frequency (A/F) values were calculated for each species across the four study groups (SGs). The present investigation revealed that all plant species conformed to a contiguous distribution pattern, as indicated by an A/F ratio surpassing 0.05. This contiguous distribution of plant species is frequently observed in natural forest ecosystems and has been documented in numerous studies (Kittur et al., 2014; Dhiman et al., 2020; Kumar & Verma, 2024).

Basal area (B.A.) analysis indicated that Sultanpur and Dhingsara exhibit significantly higher tree B.A. values (19.772 m^2/ha and 15.507 m^2/ha, respectively) compared to Bidola and Makrana Johra SG, which recorded a notably lower B.A. of 7.693 m^2/ha (495). The elevated B.A. observed in Sultanpur can be attributed to the presence of tree species characterized by substantial girth classes, including *Salvadora oleoides*, *Ficus benghalensis*, and *Ficus religiosa*, among others. These findings are comparable to those reported by Meena et al. (2016), who observed a B.A. of 26.74 m^2/ha in a similar semi-arid forest ecosystem in Delhi, indicating comparable vegetation structure and dominance of large-canopy species. Similarly, Yatar et al. (2024) documented a B.A. of 16.47 m^2/ha in a semi-arid landscape of Thailand, highlighting the influence of regional climatic conditions and species composition on basal area. The similarity in B.A. values across these studies suggests that structural parameters in semi-arid tree-dominated ecosystems are influenced by common ecological factors such as species traits, anthropogenic pressures, and edaphic conditions.

The Importance Value Index (IVI) is pivotal for understanding the ecological significance of various species, as a high IVI value indicates a species' dominance within a community (Kashian et al., 2003). This metric serves to quantify the degree of dominance and assess the role and functionality of a species within the plant community structure. In the study area of Bidola, *Acacia tortilis* emerged as the most prevalent tree species, recording an IVI of 89.096. Conversely, in Makrana Johra and Sultanpur, *Salvadora oleoides* dominated with IVI values of 132.39 and 98.991, respectively. Additionally, *Prosopis juliflora* was identified as the most prevalent tree species in Dhingsara SG, with an IVI of 124.94.

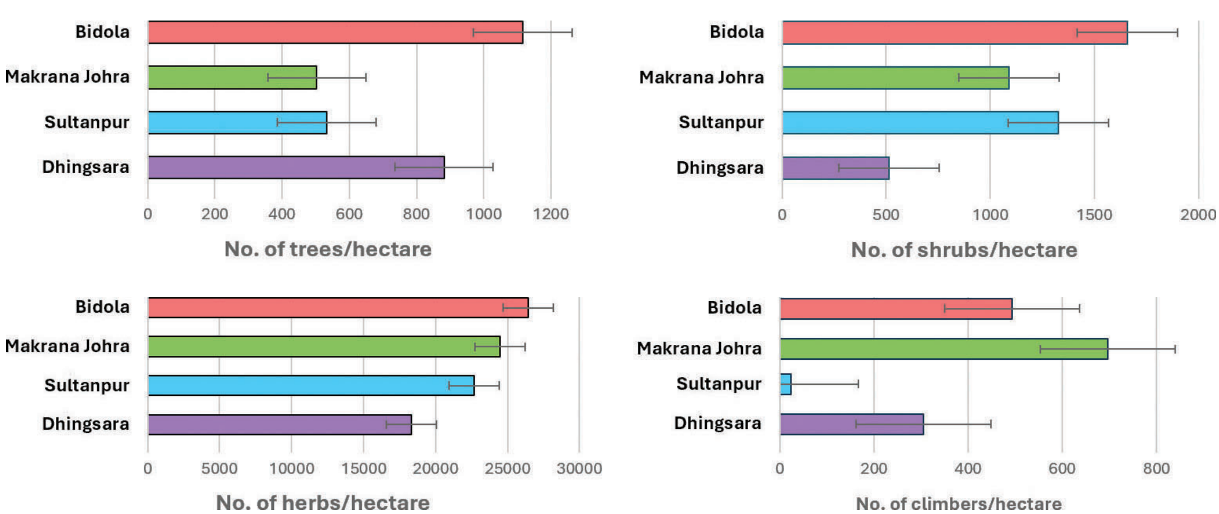

Figure 5: Stand density (per hectare) of trees, shrubs, herbs and climbers in the four SGs.
Slika 5: Gostota sestojev (na hektar) dreves, grmov, zelišč in plezalk v štirih SG.

Among shrub species, *Capparis decidua* was prominent across Bidola (131.46), Makrana Johra (105.76), and Dhingsara (135.65), showcasing the highest IVI values. In contrast, *Parthenium hysterophorus* attained the highest IVI in Sultanpur SG, with a value of 96.392. When examining herbaceous plants, *Peristrophe bicalyculata* was the most prevalent in Bidola (44.834), Makrana Johra (95.544), and Dhingsara (97.599), whereas *Polygonum aviculare* contributed to the dominance in Sultanpur SG with an IVI of 27.269. Furthermore, *Cucumis callosus* exhibited the highest IVI in Bidola (126.08), Makrana Johra (129.65), and Dhingsara (175.72), while *Momordica dioca* recorded a notable dominance as the climber species in Sultanpur SG, with an IVI of 209.45 (see Table 1–4).

Diversity Indices

The selected study sites demonstrated a significant diversity of plant species, as evidenced by the H' values for the identified vegetation in various study groups (SGs), which ranged from 1.26 to 1.935 for trees, 1.625 to 1.971 for shrubs, and 2.625 to 3.262 for herbaceous plants. Consequently, Sultanpur exhibited the highest level of species diversity. According to Kent & Coker (1992), the H' value typically ranges between 1.5 and 3.5, seldom exceeding 4.5. An H' index greater than 3.0 is categorized as high; values between 2.0 and 3.0 are considered medium; those ranging from 1.0 to 2.0 are classified as low; and values below 1.0 are designated as extremely low. Diverse ecosystems are also characterized by a broad spectrum of species

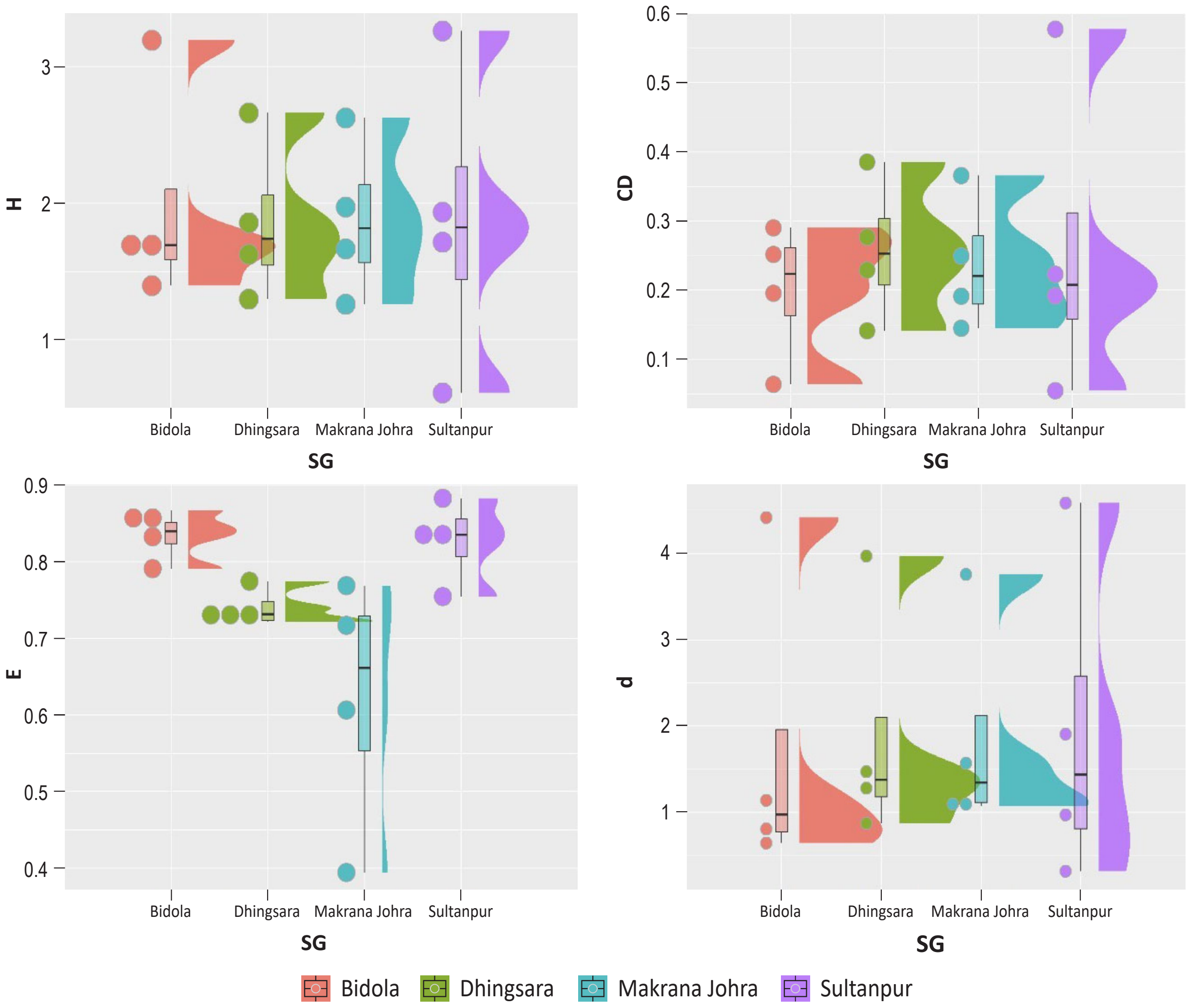

Figure 6: Raincloud plots representing the values of diversity indices i.e., Shannon Weiner diversity index (H'), Simpson's concentration of dominance (CD), Pielou index of evenness (E) and Margalef index of species richness (d) in the four SGs.

Slika 6: Grafi diverzitetnih indeksov, Shannon Weiner diverzitetni indeks (H'), Simpsonova koncentracija dominance (CD), Pielouev indeks enakomernosti (E) in Margalefov indkes vrstnega bogastva (d) v štirih SG.

populations, each possessing a variety of functional traits that contribute to the sustainability of ecosystem services throughout their lifespans (Himanshi et al., 2021).

Furthermore, Dhingsara SG exhibited the highest mean species dominance (0.142–0.385), suggesting a relatively uneven distribution of a few dominant species compared to other groves in the study. These values are higher than those reported by Dhiman et al. (2020) (0.085–0.252), indicating a potential shift in community structure, possibly due to site-specific disturbances or microclimatic factors. Nevertheless, the values still fall within the broader range observed across subtropical Indian forests (0.03–0.92; Malik & Bhatt, 2016; Singh et al., 2016; Saikia et al., 2017), suggesting that the groves retain natural heterogeneity despite anthropogenic pressures. A lower dominance value typically implies higher diversity, and this was reflected in other groves such as Sultanpur, which also showed greater evenness.

Evenness values, a measure of how evenly individuals are distributed among species, were highest in Sultanpur SG (0.755–0.883). These values are comparable to or slightly higher than those reported in other natural forests – for instance, Sarkar (2016) (0.73–0.85), Dhiman et al. (2020) (0.835–0.944), and Sherafu et al. (2024) (0.87). This high evenness suggests a stable and resilient community structure in Sultanpur SG, where no single species is overly dominant. In contrast, managed or degraded forests often show lower evenness due to dominance by a few stress-tolerant species. Thus, the observed evenness values reaffirm the ecological integrity and conservation value of these groves.

Sultanpur exhibited the highest species richness (0.317 to 4.586) among the selected sacred groves (SGs) in our study. But the Margalef Index values observed are lower than those reported in several other SG studies. For instance, in the sacred groves of Mahendergarh district, Haryana, Margalef Index values ranged between 5.78 and 8.61, indicating higher species richness (Choudhary et al., 2015). In contrast, our findings align more closely with those from community forests in southwest Haryana, where Harikesh et al. (2022) reported Margalef Index values ranging from 0.740 to 3.0146, suggesting comparable species richness under similar semi-arid conditions. The relatively lower species richness in our sites may be due to semi-arid conditions and anthropogenic pressures. However, species-rich groves like Sultanpur enhance regeneration, stabilize microclimate, and improve resilience. These findings underscore the ecological importance of SGs and the need for conservation strategies suited to semi-arid landscapes.

Soil Nutrient Profile

The selected SGs exhibited a substantial variation in soil nutrient profile, including pH, BD, EC, N, P, K and OC (Tukey *post-hoc* analysis—$p < 0.05$). The value of soil pH varied from 6 to 6.72, EC – 0.14 to 0.326 dS/m, BD – 1.29 to 1.65 g/cm^3, OC – 0.53 to 0.91%, N – 172.1 to 222.5 mg/g and P – 13.25 to 18.8 mg/g and K – 115.2 to 139 mg/g (Figure 7). The soil sample analysis revealed that Makrana Johra contained comparatively high levels

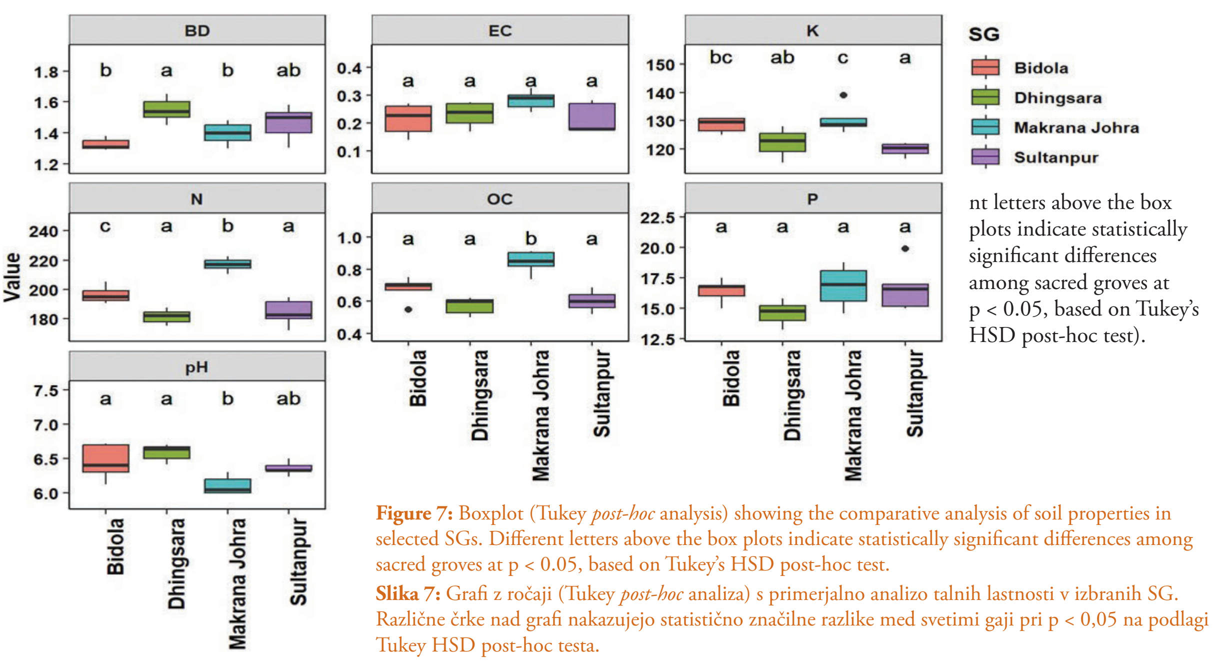

Figure 7: Boxplot (Tukey *post-hoc* analysis) showing the comparative analysis of soil properties in selected SGs. Different letters above the box plots indicate statistically significant differences among sacred groves at $p < 0.05$, based on Tukey's HSD post-hoc test.

Slika 7: Grafi z ročaji (Tukey *post-hoc* analiza) s primerjalno analizo talnih lastnosti v izbranih SG. Različne črke nad grafi nakazujejo statistično značilne razlike med svetimi gaji pri $p < 0,05$ na podlagi Tukey HSD post-hoc testa.

of EC, N, P, K and OC. In contrast, Dhingsara SG exhibited elevated pH and soil BD (Figure 7). Whereas Bidola showed least amount of BD and EC. Minimum value of soil pH was observed in Makrana Johra SG. While Dhingsara SG had least amount of N, P, K and OC, as shown in Figure 7. Soil pH affects nutrient uptake as well as plant growth. It measures the acidity and alkalinity of soil samples along with controlling availability of numerous plant nutrients (Singh et al., 2023).

Additionally, the two-tailed Carl-Pearson Coefficient was computed between the various floristic and soil parameters that were determined during the investigation. A heatmap was generated to facilitate comprehension of the correlation using R (Figure 8). The value of species dominance (CD) was negatively correlated with all these parameters, whereas a positive correlation was observed between Frequency (F), Density (D), Abundance (A), Shannon diversity value (H'), Margalef species richness (d), and electrical conductivity (EC). The value of soil Nitrogen (N) was also positively correlated with soil Organic Carbon (OC), Potassium (K), CD, Phosphorus (P), and EC, while it was negatively correlated with species evenness (E), pH, and bulk density (BD). A very small but positive correlation was observed between H' and K. Akindele et al., (2021) also observed H' to be positively correlated with K but available P, N contents, pH and OC were not correlated with any of the biodiversity variables. The positive correlation between H' and EC is also supported by Malik and Haq (2022). But the negative correlation of H' with OC and N, contrasts with Malik and Haq (2022) who observed it to be positive.

Previous research has demonstrated that SGs, akin to forest fragments, exhibit high biodiversity and contribute significantly to ecosystem functions such as carbon sequestration (Parthasarathy & Naveen Babu, 2021), nutrient-rich soils (Dar et al., 2019b), improved water quality (Oliveira et al., 2017), groundwater recharge (Iftikhar Hussain et al., 2019), pathogen resistance (Quijas et al., 2010), and control of invasive species (Mace et al., 2019). Our findings support this view, as groves like Sultanpur showed notably high species richness, greater basal area values, and the presence of large-girthed native species such as *Salvadora oleoides* and *Ficus benghalensis*, indicating their ecological maturity and carbon storage

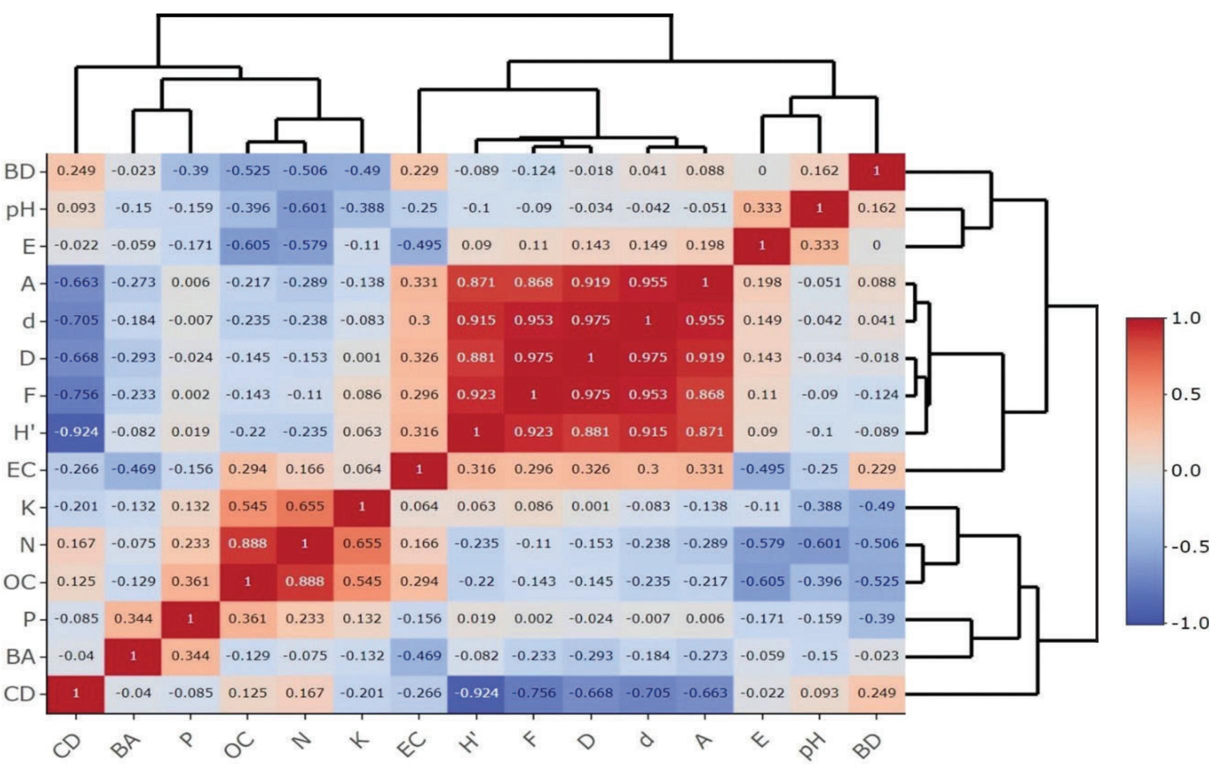

Figure 8: Correlation of the selected parameters (floristic and edaphic) in the study. F = Frequency; D = Density; A = Abundance, BA = Basal Area; H' = Shannon Wiener Index; CD = Simpson Index; E = Pielou Index, d = Margalef index, EC = Electrical conductivity, BD = Bulk density, N = Soil Nitrogen content, P = Soil Phosphorus content, K = Soil Potassium content, OC = Soil Organic Carbon.

Slika 8: Korelacija med izbranimi parametri (florističnimi in talnimi) v raziskavi. F = frekvenca; D = gostota; A = abundanca, BA = bazalna površina; H' = Shannon Wienerjev indeks; CD = Simpsonov indeks; E = Pielouev indeks, d = Margalefov indeks, EC = električna prevodnost, BD = gostota tal, N = vsebnost dušika v tleh, P = vsebnost fosforja v tleh, K = vsebnost kalija v tleh, OC = vsebnost organskega ogljika v tleh.

potential. Additionally, the recorded diversity includes several native, medicinal, and potentially rare or regionally significant species, highlighting the groves' role as in-situ conservation sites. A decline in floral diversity and species richness, as observed in degraded groves like Makrana Johra, can compromise ecosystem stability and services (Edrisi et al., 2020). Therefore, integrating scientific documentation of such sites with government-led conservation strategies and enhancing public awareness of their ecological and cultural significance is essential for long-term sustainability.

Conclusions

The lack of data on sacred groves (SGs) across various study sites significantly hampers our understanding of their biodiversity-protecting benefits. The findings of the current study reveal that sacred groves in semi-arid Haryana possess rich floristic diversity, with species occupying varied ecological niches and exhibiting wide ecological amplitude, enabling deeper insights into ecosystem dynamics beyond what forest cover alone can provide. However, these ecosystems are vulnerable to biotic disturbances and the impacts of global climate change. Haryana's sacred groves face significant challenges, including habitat fragmentation, declining conservation practices, loss of local knowledge and inadequate management. They are threatened by encroachment, lack of legal protection, and youth disconnection from cultural traditions.

To ensure their viability, future conservation efforts must include awareness campaigns, legal protections, and biodiversity registers, with active community involvement in decision-making and management. While some sacred groves (SGs) are already under legal protection—either as deemed forests, community-managed lands, or recognized conservation sites—these provisions are often fragmented and inconsistently enforced. In many regions, the current legal status does not adequately prevent encroachment, resource exploitation, or ecological degradation. Moreover, a notable number of sacred groves across the country remain undocumented or lack formal recognition, further increasing their vulnerability. Therefore, it is crucial to initiate systematic identification and documentation of these groves and consider their designation as conservation reserves or community reserves under the Wildlife (Protection) Act, 1972 (Amended 2022). This enhanced legal status would offer structured protection while fostering community stewardship, supporting awareness initiatives, and promoting a conservation model that harmonizes ecological integrity with the preservation of cultural and spiritual values.

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Declarations

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Data availability

This material is the authors' own original work, which has not been previously published elsewhere and has no conflict of interest. The data generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Appendix

Table 1: Analytical characteristics of plant species encountered in Bidola SG.
Tabela 1: Značilnosti rastlinskih vrst zabeleženih v Bidola SG.

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
	Trees						
1	*Acacia nilotica*	5	10	2	0.2	0.158	7.19
2	*Acacia tortilis*	432.5	100	17.3	0.173	0.845	89.1
3	*Azadirachta indica*	5	10	2	0.2	0.025	4.31
4	*Balenites aegyptiaca*	17.5	10	7	0.7	0.034	5.58
5	*Dalbergia sissoo*	5	10	2	0.2	0.195	7.99
6	*Prosopis cineraria*	132.5	50	10.6	0.212	1.796	67.08
7	*Prosopis juliflora*	367.5	30	49	1.633	0.869	60.65
8	*Salvadora oleoides*	130	40	13	0.325	0.361	32.41
9	*Ziziphus jujuba*	20	30	2.667	0.089	0.212	16.33
	Total	**1115**		**105.6**		**4.495**	**300**
	Shrubs						
1	*Abutilon indicum*	332.5	60	22.17	0.369	0.0103	36.90
2	*Calotropis procera*	187.5	60	12.5	0.208	0.00172	26.62
3	*Capparis decidua*	350	90	15.56	0.173	0.49046	131.46
4	*Capparis sepiaria*	32.5	20	6.5	0.325	0.01268	9.23
5	*Maytenus emarginata*	82.5	70	4.714	0.067	0.00369	23.14
6	*Parthenium hysterophorus*	500	40	50	1.25	0.01043	42.03
7	*Ziziphus nummularia*	172.5	60	11.5	0.192	0.02906	30.61
	Total	**1657.5**		**122.9**		**0.55833**	**300**
	Herbs						
1	*Achyranthes aspera*	837.5	100	33.5	0.335	0.01478	20.52625
2	*Alternanthera sessilis*	70	20	14	0.7	0.00025	1.56365
3	*Alysicarpus vaginalis*	177.5	20	35.5	1.775	0.00197	3.35079
4	*Amaranthus palmeri*	17.5	20	3.5	0.175	0.00108	2.03256
5	*Amaranthus roxburghianus*	175	30	23.33	0.778	0.00168	3.65783
6	*Argemone maxicana*	35	20	7	0.35	0.00042	1.56828
7	*Boerhavia diffusa*	412.5	90	18.33	0.204	0.00226	8.31589
8	*Boerhavia erecta*	50	20	10	0.5	0.00018	1.43202
9	*Cenchrus ciliaris*	350	40	35	0.875	0.00105	4.36089
10	*Chenopodium album*	12.5	10	5	0.5	0.00014	0.70905
11	*Chenopodium murale*	585	80	29.25	0.366	0.00073	7.18756
12	*Cleome viscosa*	5	10	2	0.2	0.00014	0.68078
13	*Commelina benghalensis*	622.5	90	27.67	0.307	0.0054	11.63029
14	*Corchorus aestuans*	82.5	20	16.5	0.825	0.00164	2.72751
15	*Corchorus olitorius*	65	30	8.667	0.289	0.00119	2.84946
16	*Croton bonplandianus*	350	30	46.67	1.556	0.00146	4.14083
17	*Cyanthillium cinereum*	277.5	70	15.86	0.227	0.00712	10.61259
18	*Cynodon dactylon*	8160	100	326.4	3.264	0.00453	39.89737
19	*Cyperus rotundus*	1125	40	112.5	2.813	0.00069	6.99343
20	*Dactyloctenium aegyptium*	752.5	50	60.2	1.204	0.00072	6.16265
21	*Digera muricata*	180	40	18	0.45	0.00008	2.94068
22	*Digitaris ciliaris*	52.5	10	21	2.1	0.00005	0.78755
23	*Eragrostis tenella*	1697.5	90	75.44	0.838	0.00083	12.01151
24	*Euphorbia granulata*	412.5	50	33	0.66	0.00004	4.33453

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
25	*Euphorbia hirta*	232.5	30	31	1.033	0.00028	2.74984
26	*Euphorbia prostata*	70	20	14	0.7	0.00093	2.10997
27	*Evolvulus alsinoides*	105	20	21	1.05	0.00002	1.51082
28	*Heliotropium strigosum*	102.5	20	20.5	1.025	0.00005	1.5255
29	*Indigofera linnaei*	47.5	20	9.5	0.475	0.00015	1.39849
30	*Launaea nudicaulis*	17.5	20	3.5	0.175	0.00005	1.20505
31	*Mollugo nudicaulis*	12.5	10	5	0.5	0.00001	0.60461
32	*Pedalium murex*	57.5	10	23	2.3	0.00157	2.02758
33	*Peristrophe bicalyculata*	2985	70	170.6	2.437	0.03687	44.72128
34	*Physalis minima*	30	20	6	0.3	0.00014	1.32448
35	*Poa annua*	427.5	50	34.2	0.684	0.00207	6.02199
36	*Portulaca pilosa*	105	20	21	1.05	0.00029	1.72774
37	*Pupalia lappacia*	712.5	80	35.63	0.445	0.01222	16.89938
38	*Setaria viridis*	3810	90	169.3	1.881	0.00121	20.28098
39	*Sida cordifolia*	125	30	16.67	0.556	0.00044	2.4731
40	*Spergula arvensis*	250	20	50	2.5	0.00042	2.37884
41	*Trianthema portulacastrum*	10	10	4	0.4	0.00002	0.60322
42	*Tribulus terrestris*	60	30	8	0.267	0.00007	1.93079
43	*Verbena officinalis*	185	30	24.67	0.822	0.00009	2.41811
44	*Verbesina encelioides*	267.5	40	26.75	0.669	0.00956	10.88685
45	*Withania somnifera*	10	10	4	0.4	0.00026	0.79604
46	*Xanthium strumarium*	312.5	50	25	0.5	0.00779	10.18392
47	*Zaleya pentandra*	85	40	8.5	0.213	0.00153	3.74747
	Total	**26525**		**1710.1**		**0.12447**	**300**
	Climbers						
1	*Cucumis callosus*	145	70	8.286	0.118	0.00101	137.4887
2	*Momordica charantia*	55	40	5.5	0.138	0.00005	35.26089
3	*Mukia maderspatana*	207.5	80	10.38	0.13	0.00019	99.35883
4	*Pergularia daemia*	25	20	5	0.25	0.00018	27.89157
	Total	**432.5**		**29.166**		**0.00143**	**300**

Abbreviations:
F = Frequency, D = Density, A = Abundance, BA = Basal Area, A/F = Abundance to Frequency ratio, IVI = Importance Value Index.

Table 2: Analytical characteristics of plant species encountered in Makrana Johra SG.
Tabela 2: Značilnosti rastlinskih vrst zabeleženih v Makrana Johra SG.

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
	Trees						
1	*Acacia nilotica*	5	6.67	3	0.45	0.274	7.4994
2	*Acacia senegal*	8.33	13.3	2.5	0.19	0.738	17.137
3	*Acacia tortilis*	296.7	100	11.867	0.12	1.474	122.22
4	*Anogeissus pendula*	3.33	6.67	2	0.3	0.174	5.8668
5	*Azadirachta indica*	5	6.67	3	0.45	0.0223	4.2244
6	*Pongamia pinnata*	3.33	6.67	2	0.3	0.00008	3.6046
7	*Prosopis cineraria*	3.33	6.67	2	0.3	0.265	7.0532
8	*Salvadora oleoides*	178.3	80	8.9167	0.11	4.744	132.39
	Total	**503.3**		**35.283**		**7.693**	**300**

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
	Shrubs						
1	*Abutilon indicum*	255	80	12.75	0.16	0.005	42.82
2	*Calotropis procera*	103.3	73.3	5.6364	0.08	0.005	27.328
3	*Capparis decidua*	155	66.7	9.3	0.14	1.086	105.76
4	*Capparis sepiaria*	10	6.67	6	0.9	0.128	11.453
5	*Grewia tenax*	3.333	6.67	2	0.3	0.007	2.3968
6	*Gymnosporia senegalensis*	23.33	26.7	3.5	0.13	0.119	16.814
7	*Maytenus emarginata*	71.67	53.3	5.375	0.1	0.011	20.057
8	*Opuntia dillenii*	15	6.67	9	1.35	0.048	6.2927
9	*Parthenium hysterophorus*	408.3	46.7	35	0.75	0.024	50.285
10	*Phyllanthus reticulatus*	20	20	4	0.2	0.00074	6.651
11	*Solanum incanum*	11.67	20	2.3333	0.12	0.00057	5.8734
12	*Ziziphus nummularia*	11.67	13.3	3.5	0.26	0.00032	4.2688
	Total	**1088**		**98.395**		**1.436**	**300**
	Herbs						
1	*Achyranthes aspera*	518.3	86.7	23.923	0.27593	0.0043	11.09814
2	*Aerva javanica*	68.33	20	13.667	0.68335	0.0019	2.89221
3	*Alternanthera sessilis*	71.67	13.3	21.5	1.61654	0.0002	1.38994
4	*Amaranthus spinosus*	51.67	26.7	7.75	0.29026	0.0043	4.78379
5	*Boerhavia diffusa*	260	80	13	0.16250	0.0018	8.04561
6	*Chenopodium album*	11.67	6.67	7	1.04948	0.0002	0.67410
7	*Cleome viscosa*	3.333	6.67	2	0.29985	0.0001	0.54906
8	*Commelina benghalensis*	656.7	80	32.833	0.41041	0.0050	11.64586
9	*Corchorus olitorius*	356.7	73.3	19.455	0.26542	0.0050	9.88787
10	*Croton bonplandianus*	38.33	13.3	11.5	0.86466	0.0003	1.30901
11	*Cynodon dactylon*	9065	100	362.6	3.62600	0.0055	47.59270
12	*Cyperus rotundus*	165	26.7	24.75	0.92697	0.0001	2.71134
13	*Dactyloctenium aegyptium*	281.7	26.7	42.25	1.58240	0.0011	3.79964
14	*Digera muricata*	30	13.3	9	0.67669	0.0014	1.94341
15	*Digitaria ciliaris*	256.7	33.3	30.8	0.92492	0.0003	3.69364
16	*Eragrostis tenella*	1123	53.3	84.25	1.58068	0.0002	8.61657
17	*Erigeron bonariensis*	20	20	4	0.20000	0.0001	1.60290
18	*Euphorbia granulata*	105	20	21	1.05000	0.0000	1.91009
19	*Euphorbia hirta*	48.33	13.3	14.5	1.09023	0.0002	1.27070
20	*Evolvulus alsinoides*	11.67	6.67	7	1.04948	0.0002	0.68625
21	*Evolvulus nummularius*	35	6.67	21	3.14843	0.0000	0.64220
22	*Glinus lotoides*	541.7	20	108.33	5.41650	0.0016	4.65364
23	*Heliotropium strigosum*	55	13.3	16.5	1.24060	0.0001	1.26424
24	*Indigofera linnaei*	50	26.7	7.5	0.28090	0.0001	2.24357
25	*Mollugo nudicaulis*	63.33	33.3	7.6	0.22823	0.0003	2.88887
26	*Pedalium murex*	6.667	13.3	2	0.15038	0.0003	1.19237
27	*Peristrophe bicalycualta*	4153	100	166.13	1.66130	0.1165	95.08587
28	*Perotis indica*	448.3	33.3	53.8	1.61562	0.0002	4.40616
29	*Phyllanthus fraternus*	63.33	46.7	5.4286	0.11624	0.0003	3.86710
30	*Poa annua*	333.3	53.3	25	0.46904	0.0016	6.29142
31	*Portulaca pilosa*	56.67	20	11.333	0.56665	0.0002	1.79981
32	*Pupalia lappacia*	433.3	80	21.667	0.27084	0.0018	8.78697
33	*Setaria viridis*	5037	80	251.83	3.14788	0.0026	27.96850
34	*Sida cordifolia*	10	13.3	3	0.22556	0.0001	1.06030
35	*Trianthema portulacastrum*	6.667	6.67	4	0.59970	0.00002	0.53182
36	*Tribulus terrestris*	105	40	10.5	0.26250	0.0004	3.60216

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
37	*Triumfetta rhomboidea*	6.667	13.3	2	0.15038	0.0001	1.07693
38	*Verbesina encelioides*	11.67	6.67	7	1.04948	0.0022	1.85880
39	*Xanthium strumarium*	18.33	13.3	5.5	0.41353	0.0042	3.60920
40	*Zaleya pentandra*	6.667	13.3	2	0.15038	0.0001	1.06709
	Total	**24584.7**		**1484.897**		**0.1646**	**300**
	Climbers						
1	*Citrullus colocynthis*	6.667	13.3	2	0.15038	0.0001	2.150
2	*Coccinia grandis*	76.67	40	7.6667	0.19167	0.0005	7.859
3	*Cucumis callosus*	191.7	93.3	8.2143	0.08804	0.0068	8.309
4	*Ipomoea pes-tigridis*	165	46.7	14.143	0.30285	0.0008	14.447
5	*Ipomoea triloba*	3.333	6.67	2	0.29985	0.0000	2.300
6	*Mukia maderspatana*	95	66.7	5.7	0.08546	0.0002	5.786
7	*Pergularia daemia*	53.33	33.3	6.4	0.19219	0.0003	6.593
	Total	**591.7**		**46.124**		**0.0088**	**300**

Abbreviations:
F = Frequency, D = Density, A = Abundance, BA = Basal Area, A/F = Abundance to Frequency ratio, IVI = Importance Value Index.

Table 3: Analytical characteristics of plant species encountered in Sultanpur SG.
Tabela 3: Značilnosti rastlinskih vrst zabeleženih v Sultanpur SG.

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
	Trees						
1	*Acacia nilotica*	120	80	6	0.075	1.52866	50.57
2	*Acacia tortilis*	185	73.333	10.1	0.138	0.30968	54.898
3	*Azadirachta indica*	3.33	6.6667	2	0.3	0.00006	2.3202
4	*Ficus beghalensis*	3.33	6.6667	2	0.3	0.76699	6.199
5	*Ficus religiosa*	3.33	13.333	1	0.075	0.64173	7.2604
6	*Melia azedarach*	6.67	13.333	2	0.15	0.0104	4.6925
7	*Mimosa hamata*	11.67	6.6667	7	1.05	0.01338	3.9501
8	*Morus alba*	10	33.333	1.2	0.036	0.0005	10.352
9	*Prosopis cineraria*	55	33.333	6.6	0.198	0.44841	21.055
10	*Prosopis juliflora*	100	60	6.67	0.111	0.20382	35.035
11	*Salvadora oleoides*	28.33	53.333	2.13	0.04	15.8416	98.991
12	*Syzygium cumini*	3.33	6.6667	2	0.3	0.00679	2.3543
13	*Ziziphus jujuba*	3.33	6.6667	2	0.3	0.00042	2.3221
	Total	**533.3**		**50.7**		**19.7725**	**300**
	Shrubs						
1	*Abutilon indicum*	105	46.667	9	0.193	0.01554	34.855
2	*Calotropis procera*	121.7	46.667	10.4	0.223	0.00139	25.132
3	*Capparis decidua*	113.3	66.667	6.8	0.102	0.07721	89.714
4	*Capparis sepiaria*	30	26.667	4.5	0.169	0.01074	19.106
5	*Maytenus emarginata*	10	6.6667	6	0.9	0.00049	3.2597
6	*Parthenium hysterophorus*	823.3	66.667	49.4	0.741	0.01693	96.392
7	*Phyllanthus reticulatus*	73.33	13.333	22	1.65	0.00218	11.471
8	*Ziziphus nummularia*	51.67	40	5.17	0.129	0.0044	20.069
	Total	**1328**		**113**		**0.129**	**300**
	Herbs						
1	*Achyranthes aspera*	455	73.333	24.8	0.338	0.0326	26.339
2	*Aerva javanica*	105	26.667	15.8	0.591	0.00085	3.1068
3	*Alternanthera sessilis*	210	13.333	63	4.725	0.00085	2.4833

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
4	*Amaranthus viridis*	15	13.333	4.5	0.338	0.00003	1.164
5	*Anagallis arvensis*	96.67	13.333	29	2.175	0.00005	1.5344
6	*Argemone maxicana*	125	40	12.5	0.313	0.00375	5.9076
7	*Arnebia hispidissima*	3.333	6.6667	2	0.3	0.00031	0.7283
8	*Boerhavia diffusa*	236.7	20	47.3	2.367	0.00214	3.8685
9	*Cenchrus ciliaris*	166.7	20	33.3	1.667	0.00026	2.5006
10	*Centaurea sp*	248.3	40	24.8	0.621	0.0006	4.6741
11	*Chenopodium album*	195	20	39	1.95	0.0003	2.6476
12	*Chenopodium murale*	381.7	40	38.2	0.954	0.00394	7.1473
13	*Convolvulus arvensis*	363.3	53.333	27.3	0.511	0.00489	8.6822
14	*Coronopus didymus*	1548	33.333	186	5.574	0.02425	23.201
15	*Croton bonplandianus*	380	66.667	22.8	0.342	0.00503	9.9146
16	*Cyanthillium cinereum*	111.7	40	11.2	0.279	0.00029	3.8966
17	*Cynodon dactylon*	4088	100	164	1.635	0.00209	27.301
18	*Cyperus rotundus*	483.3	26.667	72.5	2.719	0.00098	4.8464
19	*Datura innoxia*	61.67	13.333	18.5	1.388	0.00104	1.938
20	*Eclipta alba*	91.67	6.6667	55	8.25	0.00033	1.1303
21	*Erigeron canadensis*	188.3	20	37.7	1.883	0.00128	3.1721
22	*Euphorbia dracunculoides*	18.33	6.6667	11	1.65	0.00015	0.7079
23	*Euphorbia granulata*	518.3	60	34.6	0.576	0.00086	7.6311
24	*Euphorbia prostrata*	148.3	13.333	44.5	3.338	0.00029	1.8965
25	*Evolvulus nummularius*	308.3	6.6667	185	27.75	0.00006	1.9332
26	*Fagonia indica*	6.667	6.6667	4	0.6	0.00009	0.6205
27	*Glinus lotoides*	1695	46.667	145	3.113	0.01602	20.288
28	*Gnaphalium purpureum*	158.3	40	15.8	0.396	0.00107	4.5426
29	*Heliotropium strigosum*	113.3	13.333	34	2.55	0.00047	1.8482
30	*Launaea nudicaulis*	121.7	46.667	10.4	0.223	0.00141	5.1151
31	*Malvastrum coromandelianum*	141.7	6.6667	85	12.75	0.00092	1.6861
32	Orobanche aegyptiaca	6.667	6.6667	4	0.6	0.00008	0.6173
33	*Oxalis corniculata*	168.3	6.6667	101	15.15	0.00101	1.8513
34	*Paspalidium dilatatum*	65	6.6667	39	5.85	0.00015	0.9104
35	*Polygonum aviculare*	4282	40	428	10.7	0.00915	27.269
36	*Pupalia lappacea*	6.667	6.6667	4	0.6	0.0001	0.6286
37	*Ranunculus sceleratus*	3480	33.333	418	12.53	0.02525	32.274
38	*Rumex dentatus*	258.3	20	51.7	2.583	0.00224	4.0205
39	*Sida cordifolia*	25	6.6667	15	2.25	0.00094	1.1832
40	*Sissymbrium irio*	651.7	53.333	48.9	0.916	0.00048	7.467
41	*Solanum nigrum*	3.333	6.6667	2	0.3	0.00046	0.8171
42	*Solanum virginianum*	88.33	20	17.7	0.883	0.00828	6.6828
43	*Sonchus oleraceus*	3.333	6.6667	2	0.3	0.00006	0.5908
44	*Spergula arvensis*	233.3	26.667	35	1.313	0.00022	3.313
45	*Vernonica anagallis-aquatica*	378.3	6.6667	227	34.05	0.0026	3.675
46	*Withania somnifera*	85	20	17	0.85	0.01593	10.979
47	*Zaleya pentandra*	176.7	33.333	21.2	0.636	0.00317	5.2682
	Total	**22697**		**2929**		**0.17731**	**300**
	Climbers						
1	*Citrullus colocynthis*	8.333	6.6667	5	0.75	0.00005	90.886
2	*Momordica dioica*	15	13.333	4.5	0.338	0.00019	209.45
	Total	**23.333**		**9.5**		**0.00024**	**300**

Abbreviations:
F = Frequency, D = Density, A = Abundance, BA = Basal Area, A/F = Abundance to Frequency ratio, IVI = Importance Value Index.

Table 4: Analytical characteristics of plant species encountered in Dhingsara SG.
Tabela 4: Značilnosti rastlinskih vrst zabeleženih v Dhingsara SG.

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
	Trees						
1	*Ailanthus excelsa*	11.667	13.33	3.5	0.26	0.703	10.735
2	*Acacia leucophloea*	10	6.667	6	0.9	0.686	7.9981
3	*Acacia nilotica*	21.667	46.67	1.857	0.04	0.748	24.354
4	*Acacia tortilis*	58.333	53.33	4.375	0.08	1.875	38.222
5	*Azadirachta indica*	6.6667	20	1.333	0.07	0.599	11.937
6	*Casuarina equisetifolia*	3.3333	6.667	2	0.3	0.357	5.1201
7	*Dalbergia sissoo*	3.3333	6.667	2	0.3	0.363	5.1599
8	*Ficus religiosa*	6.6667	13.33	2	0.15	1.802	17.254
9	*Prosopis cineraria*	3.3333	13.33	1	0.08	0.25	6.8664
10	*Prosopis juliflora*	743.33	60	49.56	0.83	2.891	124.94
11	*Salvadora oleoides*	13.333	33.33	1.6	0.05	5.226	47.409
	Total	**881.67**		**75.22**		**15.507**	**300**
	Shrubs						
1	*Abutilon indicum*	61.667	40	6.167	0.15	0.00359	32.573
2	*Calotropis procera*	6.6667	13.33	2	0.15	0.00089	8.0534
3	*Capparis decidua*	118.33	60	7.889	0.13	0.24119	135.65
4	*Grewia tenax*	3.3333	6.667	2	0.3	0.00767	6.5329
5	*Maytenus emarginata*	21.667	20	4.333	0.22	0.00138	14.363
6	*Opuntia dillenii*	23.333	6.667	14	2.1	0.01189	11.88
7	*Parthenium hysterophorus*	248.33	26.67	37.25	1.4	0.01951	67.891
8	*Phyllanthus reticulatus*	28.333	26.67	4.25	0.16	0.00009	18.436
9	*Ziziphus nummularia*	3.3333	6.667	2	0.3	0.00215	4.6186
	Total	**515**		**79.89**		**0.28836**	**300**
	Herbs						
1	*Achyranthes aspera*	548.33	73.33	29.91	0.41	0.00256	11.194
2	*Aerva javanica*	46.667	33.33	5.6	0.17	0.00317	5.5104
3	*Alternanthera pungens*	5	6.667	3	0.45	0.00007	0.6483
4	*Alternanthera sessilis*	41.667	6.667	25	3.75	0.00024	0.9805
5	*Anisomeles indica*	16.667	13.33	5	0.38	0.00026	1.4229
6	*Argemone maxicana*	5	6.667	3	0.45	0.00021	0.7525
7	*Cenchrus biflorus*	118.33	26.67	17.75	0.67	0.00114	3.7877
8	*Cenchrus ciliarias*	41.667	6.667	25	3.75	0.00006	0.8407
9	*Chenopodium album*	75	33.33	9	0.27	0.00022	3.4147
10	*Chenopodium murale*	60	13.33	18	1.35	0.00005	1.5024
11	*Commelina benghalensis*	435	33.33	52.2	1.57	0.01063	13.312
12	*Convolvulus prostratus*	16.667	13.33	5	0.38	0.00003	1.2536
13	*Corchorus aestuans*	15	13.33	4.5	0.34	0.00012	1.3111
14	*Croton bonplandianus*	601.67	73.33	32.82	0.45	0.01054	17.568
15	*Cynodon dactylon*	5651.7	100	226.1	2.26	0.00321	41.852
16	*Cyperus rotundus*	88.333	13.33	26.5	1.99	0.00043	1.9458
17	*Dactyloctenium aegyptium*	1153.3	86.67	53.23	0.61	0.00419	16.882
18	*Digera muricata*	523.33	80	26.17	0.33	0.00119	10.584
19	*Digitaria ciliaris*	465	53.33	34.88	0.65	0.00053	7.4898
20	*Echinochloa crus-galli*	251.67	40	25.17	0.63	0.00705	10.158
21	*Eragrostis tenella*	731.67	53.33	54.88	1.03	0.0003	8.7709
22	*Erigeron bonariensis*	18.333	6.667	11	1.65	0.00007	0.7235

S. N.	Name of Plant species	D	F	A	A/F	BA	IVI
23	*Euphorbia granualata*	240	26.67	36	1.35	0.00002	3.6018
24	*Heliotropium strigosum*	23.333	13.33	7	0.53	0.00013	1.3665
25	*Indigofera linnaei*	16.667	6.667	10	1.5	0.00008	0.7168
26	*Oxalis corniculata*	38.333	6.667	23	3.45	0.00001	0.7808
27	*Paspalidium flavidum*	21.667	6.667	13	1.95	0.00003	0.7065
28	*Peristrophe bicalyculata*	6293.3	86.67	290.5	3.35	0.07328	97.599
29	*Physalis minima*	46.667	20	9.333	0.47	0.00253	3.8854
30	*Poa annua*	16.667	6.667	10	1.5	0.0001	0.7331
31	*Portulaca pilosa*	5	6.667	3	0.45	0.00001	0.6049
32	*Pupalia lappacea*	190	40	19	0.48	0.00108	5.271
33	*Setaria viridis*	130	20	26	1.3	0.00009	2.4867
34	*Sida cordifolia*	196.67	46.67	16.86	0.36	0.00434	8.3613
35	*Solanum xanthocarpum*	36.667	13.33	11	0.83	0.00131	2.3375
36	*Tephrosia purpurea*	68.333	20	13.67	0.68	0.00018	2.2165
37	*Trianthema portulacastrum*	15	20	3	0.15	0.00022	1.9576
38	*Triumfetta rhomboidea*	31.667	20	6.333	0.32	0.00075	2.4473
39	*Verbesina encelioides*	11.667	6.667	7	1.05	0.00077	1.22
40	*Xanthium strumarium*	8.3333	20	1.667	0.08	0.00007	1.8015
	Total	**18300**		**1200**		**0.13128**	**300**
	Climbers						
1	*Citrullus colocynthis*	10	13.33	3	0.23	0.00044	44.47
2	*Cucumis callosus*	223.33	93.33	9.571	0.1	0.00064	175.72
3	*Ipomoea pes-tigridis*	26.667	20	5.333	0.27	0.00012	29.301
4	*Merremia aegyptia*	8.3333	13.33	2.5	0.19	0.00006	15.207
5	*Momordica diocia*	13.333	6.667	8	1.2	0.00003	10.231
6	*Mukia maderspatana*	23.333	26.67	3.5	0.13	0.00003	25.075
	Total	**305**		**31.9**		**0.00132**	**300**

Abbreviations:
F = Frequency, D = Density, A = Abundance, BA = Basal Area, A/F = Abundance to Frequency ratio, IVI = Importance Value Index.