

Sacred Groves as Refuges for Summer Migratory Birds: Diversity, Abundance, Conservation Status and Land Use/Land Cover Dynamics in the Mangar-Bani Forest, Aravalli Landscape, India

Deepak Rai

Kurukshetra University

Anju anju

zoo1921anju@kuk.ac.in

Kurukshetra University

Research Article

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Abstract

Avifaunal richness and abundance are valuable indicators of ecosystem quality and stability. Heterogeneous habitats support greater diversity by providing a wider range of ecological niches and resources. The dense forest cover and unique climate of Mangar-Bani Forest provide important habitat and stopover sites for resident and migratory birds. The present study was conducted in the Mangar-Bani Forest, Aravalli Landscape, from October 2023 to September 2025, to document the richness, abundance, feeding guilds, and conservation status of summer migratory birds, using line-cum point method. A total of 1167 individual sightings from 19 species, 11 families, and four orders, and shifts in habitats were recorded. The richest order was Passeriformes (42.1%), and insectivorous birds dominated the feeding guild. Family Cuculidae exhibited the highest Relative Diversity Index (RDi) (31.5%). Species richness peaked in July 2025, with 19 species and 153 sightings ($H' = 2.09$, $D = 0.80$, and $E = 0.46$). According to the State of India's Birds (2023), one was identified as a high conservation priority. European Roller was listed in CMS Appendix I, and White-eyed Buzzard was listed under Schedule I of the Indian Wildlife Protection Act. LULC analysis revealed substantial changes in vegetation cover and built-up areas, highlighting habitat changes. Therefore, the study provides first comprehensive baseline assessment of summer migrants and highlights the importance of long-term ecological monitoring and habitat conservation for sustaining migratory avifauna in the Aravalli Landscape.

Introduction

India is renowned for its rich avifaunal diversity, which is attributed to the wide variety of habitats available, including forests, wetlands, grasslands, and agricultural zones, which provide foraging, breeding, and migratory habitats for various species. Birds are valuable ecological indicators owing to their sensitivity to environmental change. Their community structure is linked to variations in habitat quality and ecosystem services, such as insect regulation, pest management, pollination, and seed dispersal which aid ecosystem integrity [1].

Forest ecosystems provide important supportive resources for migratory birds, including shelter, food, and nesting habitats. Migratory birds seasonally move between breeding and non-breeding grounds, which are driven by environmental fluctuations, availability of resources, and reproductive requirements. These migrations create intricate patterns of connectivity between distant geographic locations that are vital for species survival, population stability, and gene flow between populations [2]. However, habitat loss and fragmentation, together with increasing anthropogenic disturbances, such as deforestation, urbanization, agricultural expansion, and climate change, can severely disrupt migratory connectivity, transform natural habitats, and contribute to the decline of migratory bird species, particularly along major global flyways [3–5].

Although several studies have documented resident and winter migratory avifauna in northern India, comparable studies focusing on summer migratory birds in the Aravalli Landscape remain limited.

Addressing these knowledge gaps is critical for conservation priorities and baseline information for long-term monitoring. Thus, the objectives of the present study were to examine species diversity, relative frequency, and feeding guild composition; assess seasonal variation in species richness and community structure; and evaluate conservation status using global (IUCN, 2026) and regional (State of India's Birds, 2023) data, along with IUCN population trends.

To complement the avifaunal survey, Google Earth imagery and ArcGIS tools were used to assess the changes in habitat within the study area through an analysis of land use/land cover (LULC) dynamics within the period of 2017 to 2025. The study analysed the spatiotemporal variations in LULC patterns over the last 9 years in the study area and revealed increased vegetation cover with expanding built-up areas, reflecting both conservation efforts and ongoing anthropogenic impacts. It also highlights the importance of implementing sustainable conservation approaches to minimise habitat degradation and support the long-term persistence of migratory avifauna. These results would complement our understanding of the ecological value of Aravallis landscape and prove useful for future conservation and management plans for migratory birds in the region.

Materials And Methods

Study Area

The present study was carried out in the Mangar-Bani Forest located in Faridabad district, Haryana, India, in the northern part of the Aravalli Range, which is one of the oldest mountain ranges in the world. The Aravalli Range extends across Haryana, Delhi, Rajasthan, and Gujarat and acts as a natural barrier restricting the further eastward expansion of the Thar Desert. The Mangar-Bani Forest covers an area of 17.13 km² and is characterized by tropical dry deciduous forests, open grasslands, agricultural fields, rocky outcrops, scrublands, and seasonal water bodies. The climate of the region is semi-arid, with an average annual rainfall of approximately 444 mm. The average minimum temperature is approximately 7°C in January, and the average maximum temperature is 40–41°C in May and June. *Acacia senegal*, *Ziziphus nummularia*, and *Anogeissus pendula* dominate the vegetation, with a heterogeneous habitat that supports a wide range of fauna, including mammals (Golden jackals, leopards, nilgai, and Indian hare), reptiles, amphibians, and a wide variety of insects, thereby providing a suitable environment for both resident and migratory avifauna [6].

Methodology

Comprehensive field surveys were conducted from October 2023 to September 2025 to evaluate summer migrant avifaunal diversity, conservation, and feeding guilds. Bird sampling was carried out using a line transect during which all birds seen or heard, including those flying overhead, were recorded. Due to the variations in the physiography of Mangar and the predominance of foot trails, the study area was systematically divided into five transects. The locations of these transects were selected to cover all habitats and were spatially separated to minimize the possibility of overlap in bird observations. Each

month, bird surveys were conducted over five consecutive days for five transects, during which one fixed transect was surveyed once per day. Consequently, each transect was surveyed once per month, resulting in 24 visits per transect and a total of 120 (24×5) visits across the study area for both waterbirds and terrestrial birds. An average of 5–6 hours was spent on each transect per visit, for an estimated total observation effort of approximately 600–720 hours over the entire study period.

All surveys were conducted on foot at peak hours of bird activity (7:00–11:00 h in the summer and 10:00–14:00 h in the winter), was observed using binoculars and a Nikon COOLPIX P900 camera. Species identification was confirmed using standard field guides [7]. Following Praveen and Jayapal [8], a checklist of recorded avian species was prepared, based on common name, scientific name, genus, order, and family. Conservation status and population trends were assigned according to the IUCN Red list [9], and Conservation priority categories were based on the State of India's Birds [10]. The occurrence frequency was used to calculate the local abundance status of each summer migrant bird. Species were categorized based on their sighting frequency as abundant (10–12 times), common (7–9 times), fairly common (4–6 times), and rare (1–3 times), based on observations made during the summer months over the two-year survey period. The LULC (land use/land cover) dynamics in the study area were assessed using Google Earth satellite imagery from 2017, 2020, 2023, and 2025. ArcGIS software was employed to digitize the satellite imagery and prepare a LULC map to examine the relationships between changes in LULC and the distribution of recorded avifauna.

Data analysis

Species-wise abundance data were used to compute the Shannon, Simpson, Dominance, and Evenness indices using the PAST software version 5.2.2 [11].

Relative Diversity Index (RDi)

It was estimated following Torre-Cuadros et al. [12].

$$RDi = n / N \times 100$$

where “n” represents the number of bird species within a family, and “N” represents the total species richness.

Relative Abundance

It was calculated as

$$\text{Relative abundance} = n / N \times 100$$

where “n” represents the number of individuals of a particular species, and “N” denotes the total number of individuals recorded.

Dominance Index (D)

It was calculated as

$$D = \sum (n_i/N)^2$$

Higher values indicate dominance by a few species, reflecting lower diversity.

Simpson's Diversity Index (1-D)

Diversity considering both richness and evenness was calculated as

$$1-D = 1 - \sum (n_i/N)^2$$

Higher values indicate greater species diversity.

Shannon-Wiener Diversity Index (H')

Measures species richness and evenness

$$H' = - \sum [P_i * \ln P_i]$$

where “Pi” represents the proportion of individuals of a species within the sample and “ln(Pi)” indicates its natural logarithmic value; and higher value means more diversity

([13].

Evenness Index (E)

Indicates the degree of uniformity in species distribution, where values approaching 1 signify similar abundance.

$$E = H'/\ln S$$

where “H” represents Shannon–Wiener's diversity index and “S” denotes species richness [14].

The data were graphically represented using RAWGraphs 2.0. A species accumulation curve was generated by plotting the cumulative number of species recorded against the sampling months. To evaluate whether the sampling effort was sufficient, a sample-based rarefaction curve with extrapolation was constructed using iNEXT software. This approach illustrates how species richness and the number of individuals increase with sampling effort and provides an estimate of the expected total species richness, thereby confirming the adequacy of the survey effort.

Results

For the entire study period, a total of 1167 individual sightings of 19 summer migratory birds were recorded, representing 17 genera, 11 families, and 4 orders. Passeriformes emerged as the most

dominant taxon (42.10% of species richness comprising 7 families) among the recorded orders, followed by Cuculiformes and Coraciiformes (31.57% and 21.05%, respectively), and Accipitriformes (5.26%), represented by a single family (Fig. 2). Among the families, Cuculidae exhibited the highest RDI of 31.57 (Fig. 3). Based on dietary preference, Insectivorous species predominated (84%), followed by omnivorous (11%), and carnivorous (5%). Among the 19 recorded species, six species were categorized as abundant, namely Eurasian Golden Oriole, Pied Cuckoo, Asian Koel, Common Hawk-cuckoo, Small Green Bee-eater and Blue-tailed Bee-eater; two species were classified as common, such as Indian Paradise Flycatcher and Indian Pitta; four species were classified as fairly common, including Western Crowned Warbler, Crested Bunting, Grey-bellied Cuckoo and Blue-cheeked Bee-eater and whereas seven species were rare, namely Asian-brown Flycatcher, Green Warbler, Black-headed Cuckooshrike, White-eyed Buzzard, Indian Cuckoo, Sirkeer Malkoha and European Roller.

Species richness exhibited seasonal fluctuations, reaching a maximum of 19 species in July 2025, which implies that it is nearly completely sampled. Reduced species richness over the winter months was associated with a decreased abundance of summer migrants, and a sharp rise in species richness in April was associated with seasonal arrival patterns. The monthly species accumulation curve showed an initial low level of species richness, followed by a steady increase, and ultimately levelling off at an asymptote. Such a pattern suggests that sampling efforts were adequate and that most of the species were sampled efficiently (Fig. 4). Seasonal variation in monthly diversity indices was observed, with the highest value for Shannon diversity in July 2025 (2.09), corresponding to the highest Simpson diversity (0.80) and the lowest dominance (0.19). In contrast, winter months exhibited higher dominance and lower diversity. Species distribution was variable across months as reflected in evenness indices, which were the highest in October 2024 (0.98) and the lowest in August 2024 (0.92) (Fig. 5).

The rank-abundance distribution exhibited a distinct dominance in a few species, with Small Green Bee-eater being the predominant species, followed by Blue-tailed Bee-eater, Jacobin Cuckoo, and Eurasian Golden Oriole. The least abundant species were White-eyed Buzzard, Indian Cuckoo, and Sirkeer Malkoha (Fig. 6). The relationship between sampling effort and species richness was assessed as a sample-based rarefaction curve with extrapolation, which was generated to estimate sampling completeness. The rarefaction curve with 95% confidence intervals indicated that early samples yielded a greater number of new species. In contrast, the rate of species accumulation gradually declined with continued sampling, approaching an asymptote (Fig. 7). The rate of species accumulation, by contrast, slowly decreased as sampling continued, tending to an asymptote.

All recorded species were categorized as of least concern under the IUCN Red List. Nonetheless, there were mixed trends in the population: 15 species had a stable trend, three species had a downward trend, and one showed an increasing population trend. According to the regional conservation assessment, (SolB, 2023), Sirkeer Malkoha was categorized as a high-priority species, four as moderate priority, and 13 as low priority, whereas one species lacked sufficient data (Fig. 8). Under the Indian Wildlife Protection Act (IWPA, 2022), one species, the White-eyed Buzzard, was listed under Schedule I, and the

remaining species were listed under Schedule II. Additionally, the European Roller is listed in Appendix I of the Convention on the Conservation of Migratory Species (CMS).

The analysis of LULC in the Mangar-Bani Forest revealed substantial changes from 2017 to 2025 (Tables 2 & 3). There was a dramatic rise in the area of vegetation cover from 5,041,579.30 m² in 2017 to 14,040,667.29 m² during 2025, which may reflect significant additional forested area. The agricultural land area exhibited fluctuations, rising from 1,978,925.65 m² in 2017 to 2,013,926.25 m² in 2023, followed by a decrease to 1,980,174.03 m² in 2025, indicating a slow rate of land-use conversion. The area of built-up built up area in 2025 is 2,142,744.72 m², an increase from 904,753.38 m² in 2017, indicating the continued anthropogenic pressure on the landscape. Open land decreased markedly from 30,908,941.70 m² in 2017 to 21,976,132.56 m² in 2025, corresponding with the increase in vegetation cover. Water bodies also expanded from 282,356.80 m² to 462,788.33 m², representing an increase of 180,431.53 m² over time. Overall, the LULC analysis demonstrates substantial changes in habitat composition within the study area over the period (Fig. 9).

Table 1
LULC (Land use/ Land cover of the Mangar-Bani Forest and its fringe area

Land use/land cover types	2017	2020	2023	2025
	Area (m2)	Area (m2)	Area (m2)	Area (m2)
Water Bodies	282356.8	184263.23	325740.39	462788.33
Vegetation	5041579.3	3094769.07	11061952.44	14040667.29
Agricultural Field	3435455.13	4194775.49	4940734.81	1980174.03
Buildup Area	904753.38	1248752.94	1902289.23	2142744.72
Open Land	30908941.7	31895064.33	22391515.43	21976132.56

Table 2
LULC changes of the Mangar-Bani Forest and its fringe area

Land use/land cover types	2017–2020	2020–2023	2023–2025	2017–2025
Water Bodies	-98093.57	141477.16	137047.94	180431.53
Vegetation	-1946810.23	7967183.37	2978714.85	8999087.99
Agricultural Field	759320.36	745959.32	-2960560.78	1455281.1
Buildup Area	343999.56	653536.29	240455.49	1237991.34
Open Land	986122.63	-9503548.9	-415382.87	-8932809.14

Discussion

The present study documented 19 summer migratory bird species belonging to four orders and eleven families, highlighting the ecological significance of the community-protected Mangar-Bani Forest as a seasonal refuge within the northern Aravalli Landscape. Other comparable studies from different areas of Haryana have reported varying numbers and migration statuses of summer migrants. Goyal and Rai [15] documented 12 summer migratory bird species in Chhilchhila Wildlife Sanctuary. Four summer migratory bird species were recorded in Kalesar National Park by Rai and Vats [16], while an earlier preliminary survey of the Mangar-Bani Forest recorded 12 species of summer migrants [17]. Such variations indicate that the migratory status of several species may differ across regions depending on habitat conditions and local environmental factors. The family Cuculidae exhibited the highest species richness ($RDi = 31.57\%$), with Indian Cuckoo, Common Hawk-Cuckoo, Grey-bellied Cuckoo, Jacobin Cuckoo, and Western Koel being frequently recorded in woodland and semi-forested habitats. The patterns of arrival and departure of migratory birds were species-specific in the study area. The majority of summer migrants started to appear between March and April, and reached peak during July-September, indicating temporal change in habitat suitability and occupancy patterns. Certain species show either earlier or delayed arrival than records, which can be attributed to changes in temperature, precipitation regimes, and phenological shifts in food availability, all of which are affecting migration, distributions, and resource availability and, consequently, changing migratory patterns [18, 19]. The Small-green Bee-eater and Common Hawk-Cuckoo were recorded throughout the year; however, their abundance was found to be higher during summer, with only one or two individuals being observed in winter. Species like White-eyed Buzzard, Asian Brown Flycatcher, and Green Warbler were recorded only briefly, indicating them as passage migrants. Sirkeer Malkoha was observed only during the second year of the study period, whereas Crested Bunting, which is traditionally considered a winter migrant in Birds of Haryana Kalsi [20], was found during summer in the present study. Peaks in bird abundance occur in July because monsoon-associated increases in primary productivity are commonly linked with high insect availability, vegetation complexity, and breeding habitat availability, creating favourable ecological conditions supporting migratory assemblages [21]. Blue-tailed Bee-eater, Jacobin Cuckoo, and Eurasian Golden Oriole, these dominant species played a significant role in shaping the community composition and structure of the forest ecosystem. The asymptotic pattern observed in species accumulation and rarefaction analyses further suggests adequate sampling and reliable estimation of migratory diversity. A high proportion of insectivorous species suggests a high insect abundance and diversity, especially in summer when temperatures and humidity are favourable for insect development, creating pulses in resources that enable energetically costly behaviours like breeding and migration. Partly similar relationships between insect prey availability and migratory bird abundance have been reported from tropical and subtropical ecosystems, and insectivorous migrants often follow the seasonal peaks in insect resources [22, 23]. Moving animals often coordinate their activities with changing food availability across seasons to maximize energy intake and achieve high reproductive success [24, 25].

The land use and land cover (LULC) analysis revealed significant landscape changes between 2017 and 2025. The marked decline in open areas (along with the corresponding increase in vegetation cover) indicates habitat restoration and natural vegetation regeneration, but a growth in built-up areas indicates

increasing developmental pressure on the Mangar-Bani landscape. These changes reflect increased structural habitat complexity, enabling more nesting substrate, greater foraging opportunities and shelter for migratory birds, and offer a means of continuing the trend of improved habitat quality and landscape connection. Anthropogenic impacts such as cattle grazing, collection of firewood, infrastructure development, mining, forest fires, and plastic pollution continue to threaten migratory birds of the Aravalli landscape. They interrupt feeding and roosting habitats, affect food availability, and negatively influence habitat quality, making landscapes less ideal for migratory birds as seasonal habitat. This suggests a need to prioritise conservation of habitat heterogeneity, community-based management of protection, restoring degraded habitats, and long-term habitat monitoring programmes for effective sustainable habitat conservation of migratory birds in the Aravalli Landscape.

Conclusions

The present study documented 19 summer migrants across four orders and eleven families, with the most prevalent being the Passeriformes order, the Cuculidae family, and the insectivorous feeding guild. The rarefaction curve with extrapolation as well as the species accumulation curve were confirmed to be adequate with the sample points. The study also highlights significant land use changes, with increased vegetation and built-up areas alongside a decline in agricultural and open land. These landscape changes illustrate the need to prioritize ecological restoration alongside land-use planning to ensure appropriate habitats for migratory birds. Overall, the findings of the present study highlight the ecological importance of the Mangar-Bani Forest as a seasonal habitat for migratory birds. Conservation strategies that need to be implemented for maintaining migratory bird populations in the region include habitat protection, reducing anthropogenic disturbances, and keeping habitats connected.

Declarations

Conflict of Interest:

The authors declare no conflict of interest regarding this work.

Ethics Approval and Consent to Participate:

This work does not contain any studies involving human and animal subjects.

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Author Contribution

A designed the study. B collected the data from the field and wrote the rough draft of the manuscript. A and B finalized the manuscript.

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Data Availability:

The data has been included within the manuscript.

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Figures

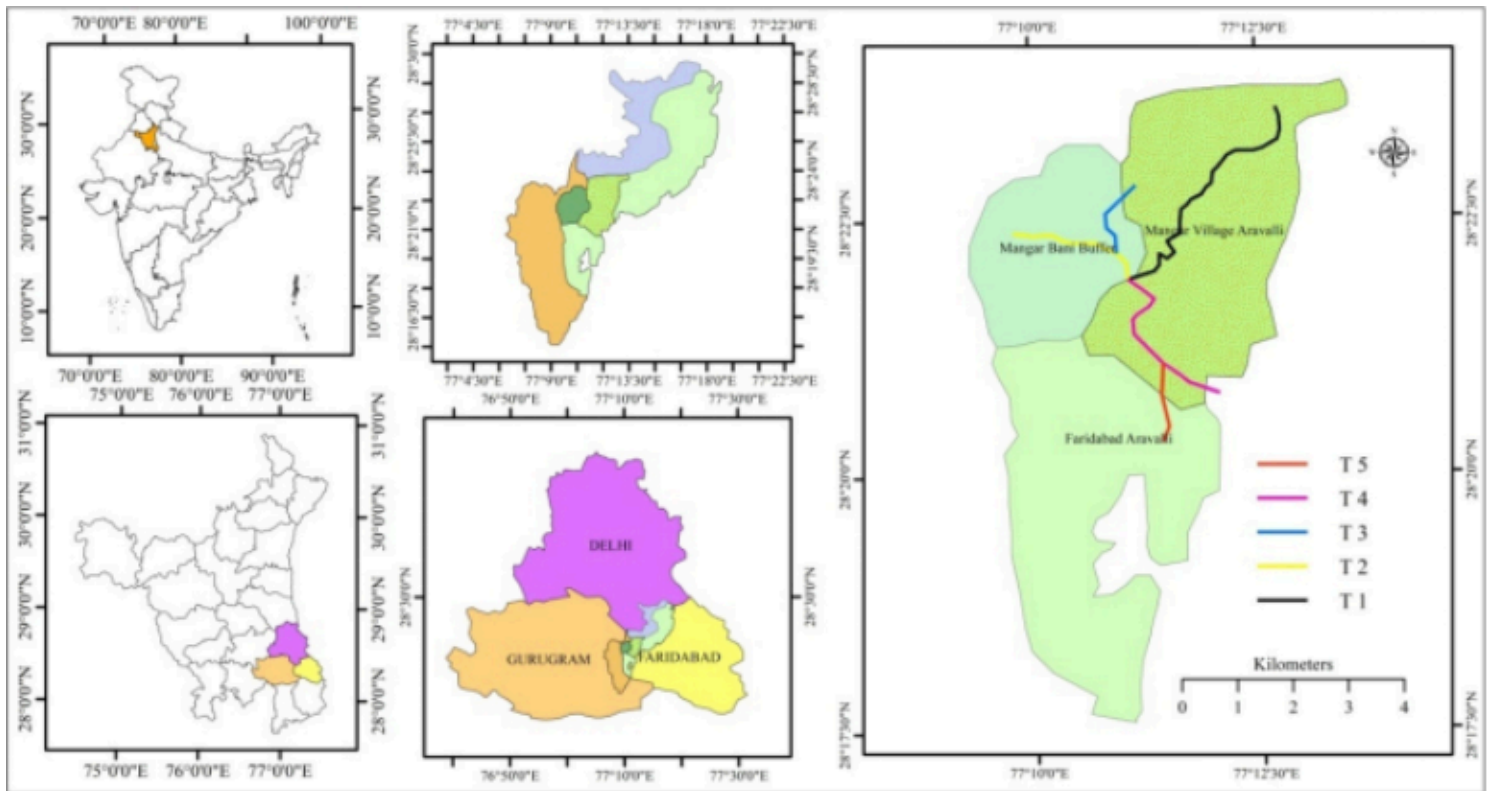


Figure 1

Map of study area showing the locations of different transects in the Mangar-Bani Forest, Aravalli Landscape, Haryana, India.

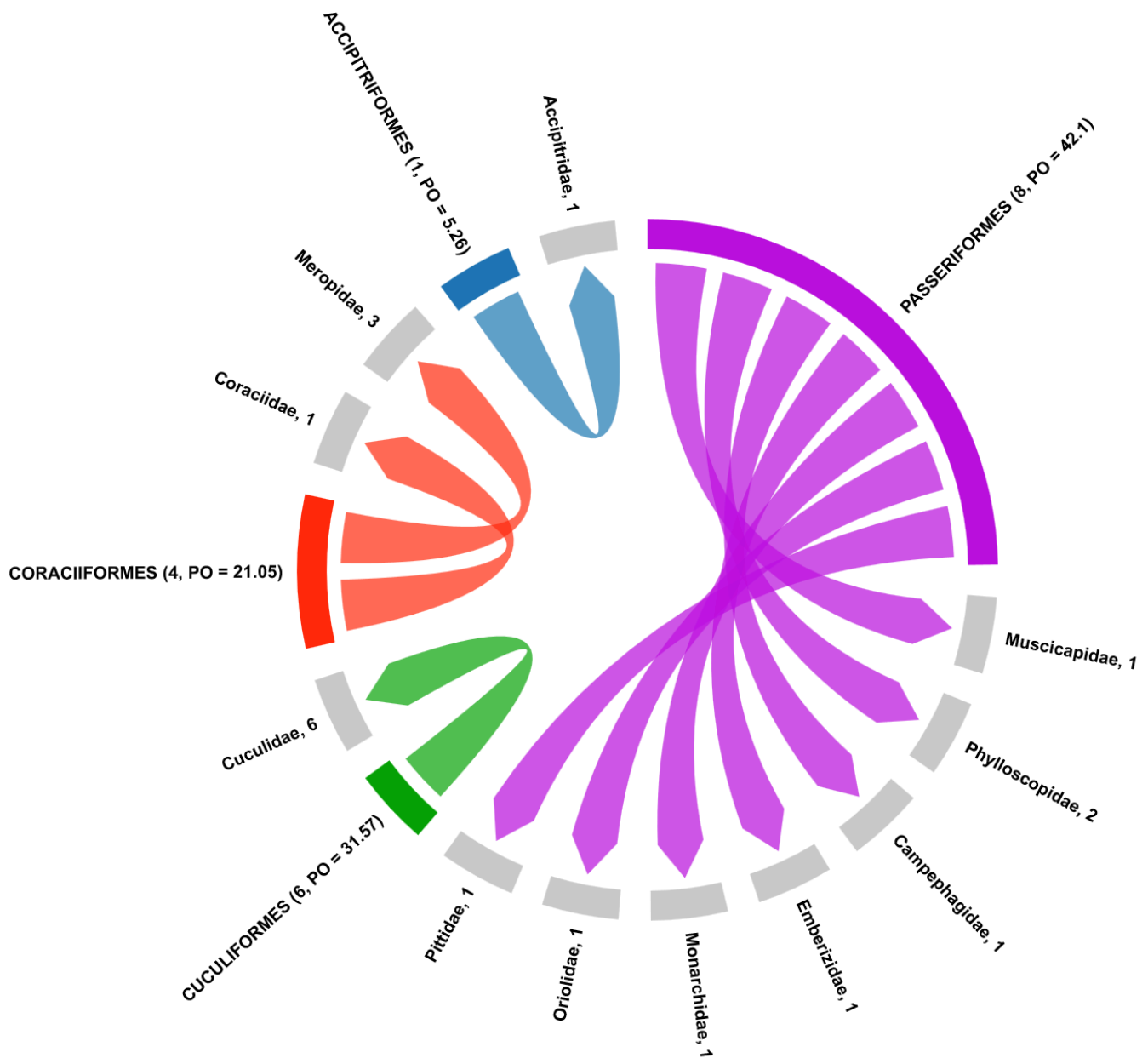


Figure 2

Order-wise family composition of summer migratory birds in the Aravalli Landscape, Haryana, India.



Figure 3

Family-wise avian species richness and Relative Diversity Index (RDi) recorded from the Aravalli Landscape, Haryana, India.

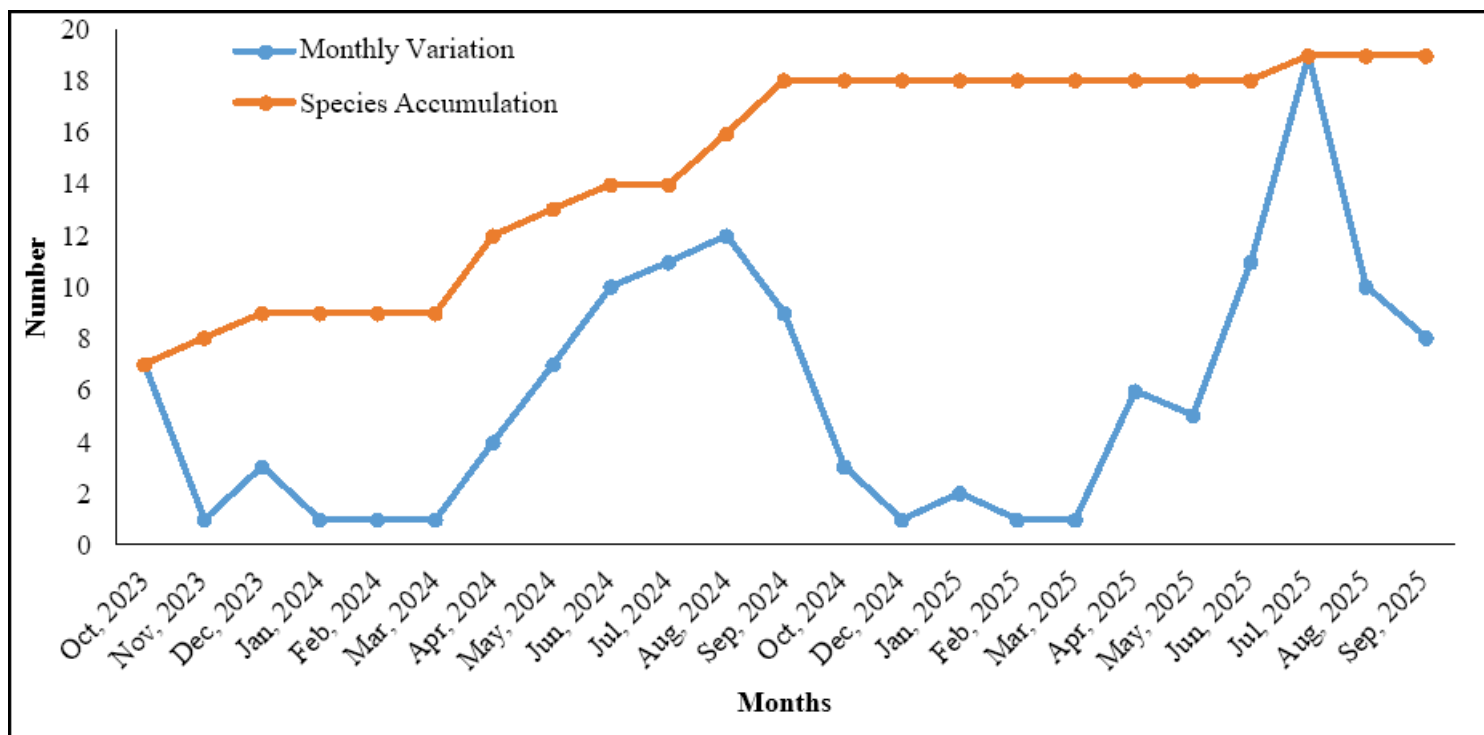


Figure 4

Species accumulation in the species richness and monthly variation observed from Aravalli Landscape, Haryana, India.

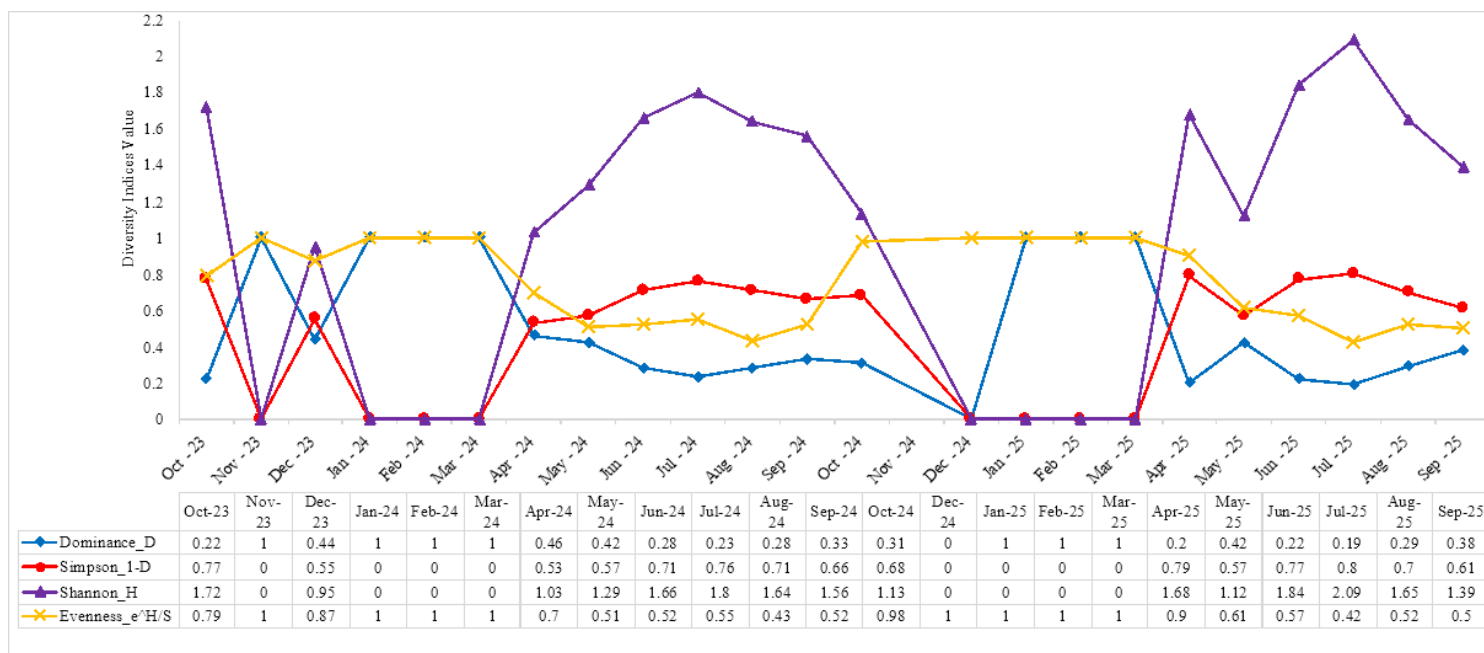


Figure 5

Month-wise variations in species diversity indices during Oct 2023 to Sep 2025 from Aravalli Landscape, Haryana, India.

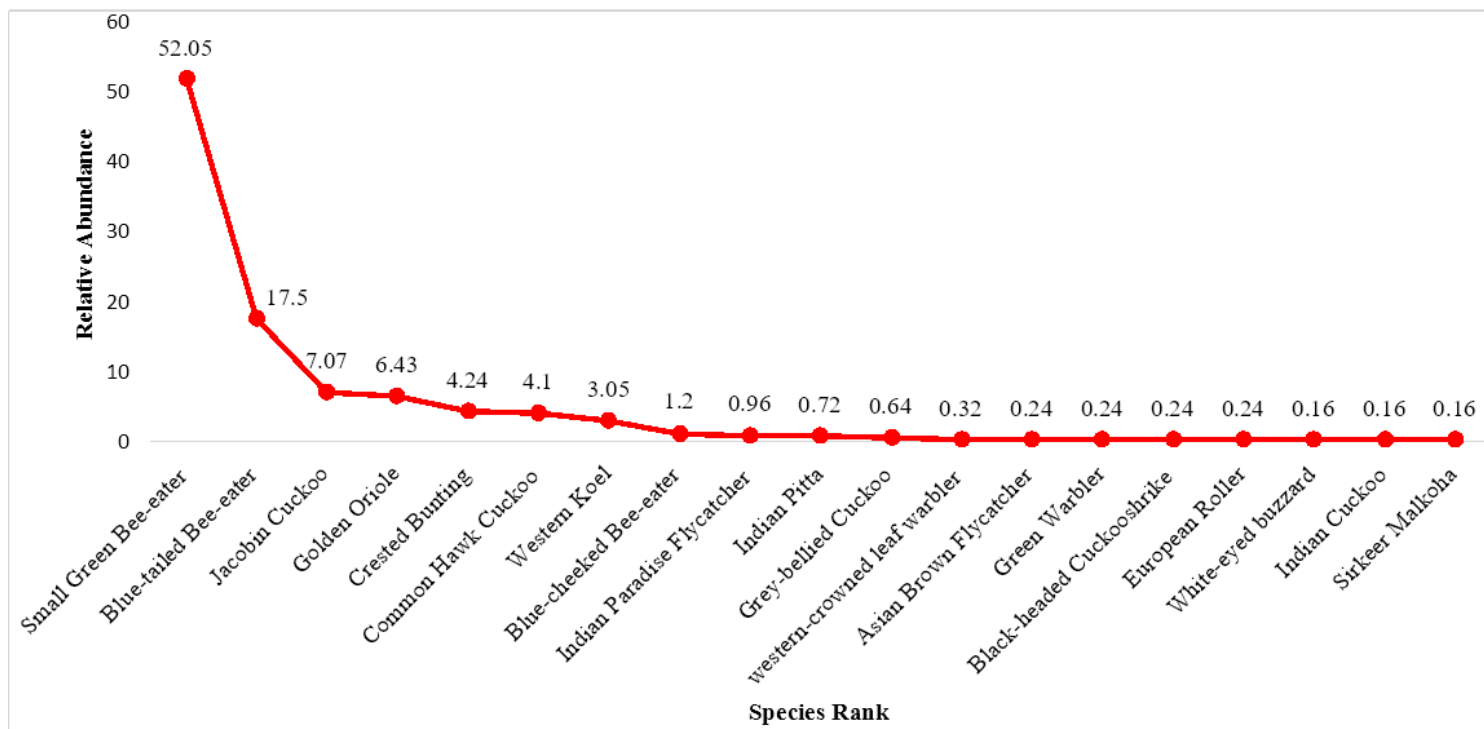


Figure 6

Relative rank abundance distribution of summer migratory birds recorded in the study area.

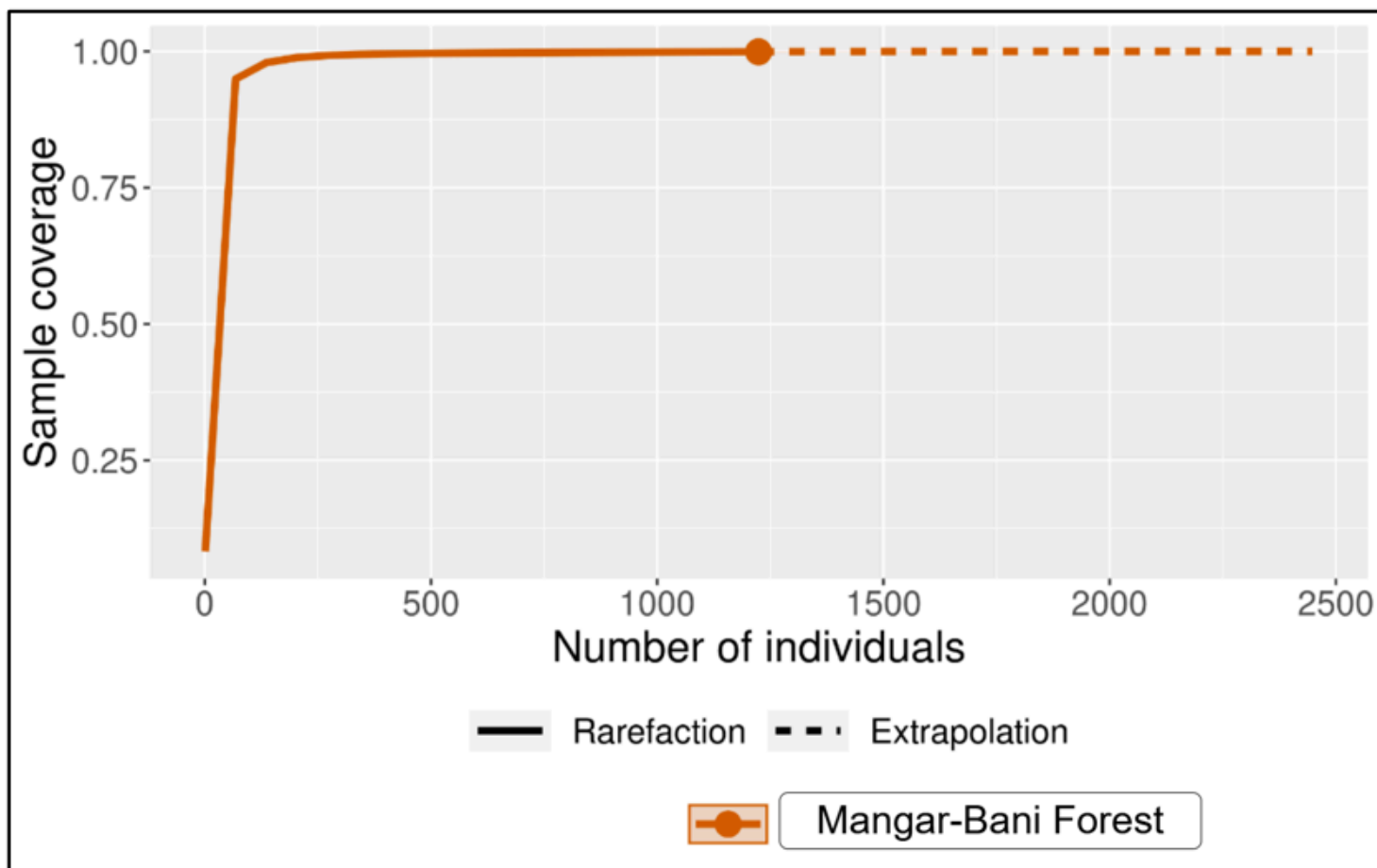


Figure 7

Assessment of Sampling Completeness using Sample Rarefaction Curve with Extrapolation.

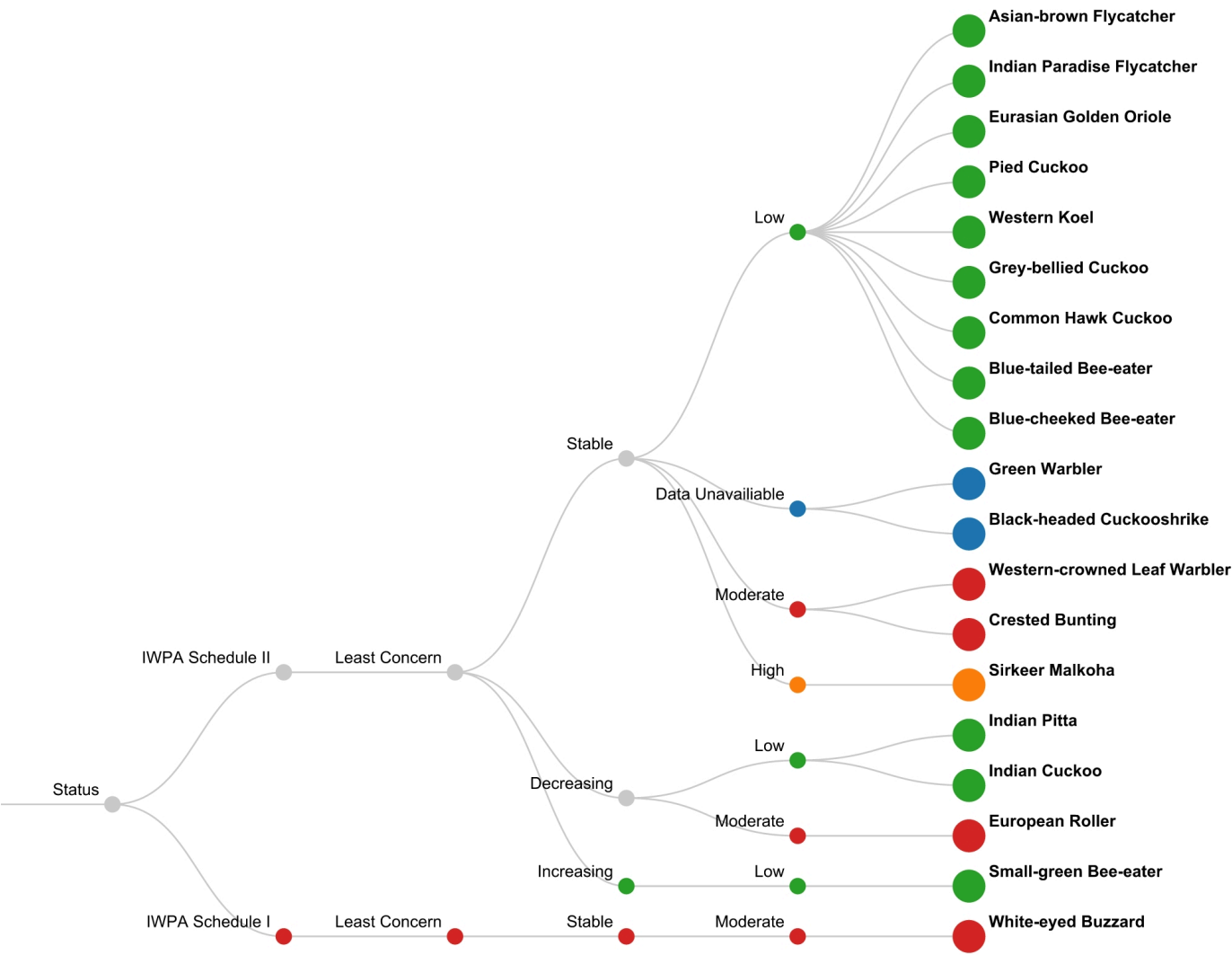


Figure 8

Linear dendrogram of IUCN conservation status, Population Trend, and SoIB (2023), the recorded species from Aravalli Landscape, Haryana, India.

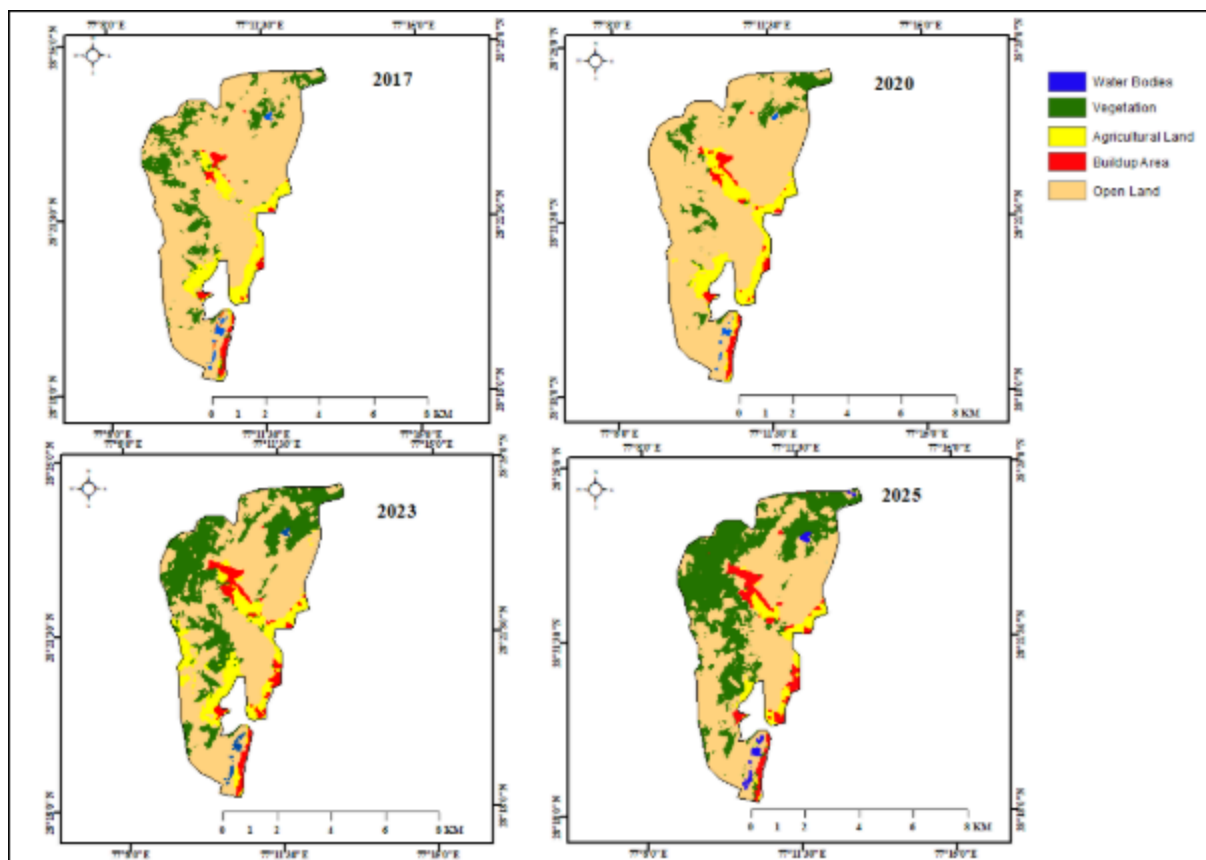


Figure 9

Land use/land cover changes in the Mangar-Bani Forest and its fringe area (source: Google Earth images, 2017, 2020, 2023, and 2025)