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Dr. Nisha Vashishat
Department of Zoology, Punjab Agricultural University, Ludhiana, Punjab, India

Rajwinder Singh
Department of Zoology, Punjab Agricultural University, Ludhiana, Punjab, India

Tejdeep Kaur Kler
Department of Zoology, Punjab Agricultural University, Ludhiana, Punjab, India

Corresponding Author:
Dr. Nisha Vashishat
Department of Zoology, Punjab Agricultural University, Ludhiana, Punjab, India

Comparative avian and macrofaunal diversity of Miyawaki forest, orchard, and grassland ecosystems in Punjab

Nisha Vashishat, Rajwinder Singh and Tejdeep Kaur Kler

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Abstract
Rapid urbanization, deforestation, and climate change have created the need for sustainable afforestation techniques. The experiment was conducted during the months of November to February of the year 2025-26 at different locations of Punjab Agricultural University, Ludhiana to study avian and macrofaunal diversity. Macrofaunal biodiversity was studied and compared at selected sites, a small forest based on the Miyawaki model, a citrus orchard, and a grassland at Punjab Agricultural University, Ludhiana. The citrus orchard showed the highest species richness with 26 avian species, followed by Miyawaki forest (22 species), while the grassland area recorded comparatively lower diversity (15 species) with order Passeriformes as the predominant one (51.72% species). Feeding guild analysis of recorded species revealed that 10 species were omnivorous, nine insectivorous, seven carnivorous, two granivorous, and a single frugivorous species. The overall vegetation structure was the main contributing factor to avian diversity at the study sites. Miyawaki forest has more macrofaunal diversity (five species) as compared to the citrus orchard (three species) and grassland ecosystem (One species). Our study indicates that Miyawaki forest and citrus orchard area sustain higher avian and macrofaunal diversity as compared to the grassland ecosystem due to more availability of food and shelter. Thus, Miyawaki forest may enhance species richness, which can provide niches for avian and macrofaunal development. The present study highlights research gaps and policy implications for the adoption of Miyawaki forest at larger areas, which acts as a natural solution for ecological restoration and higher faunal biodiversity.

Keywords: Avian, faunal diversity, grassland, Miyawaki forest, orchard

Introduction
A forest ecosystem is an area dominated by trees, plants, animals and microorganisms having complex ecological interactions between them that together make up a productive system (Fayle *et al*., 2015) [6]. Forests cover about 31% of land and play a vital role in maintaining ecological balance, mitigating climate change, and supporting life on earth (Beregniak, 2023; Schuh *et al*., 2022) [3, 17]. Forests are known as lungs of the earth and host more than 80% of terrestrial species biodiversity (Kimmins *et al*., 2008) [9]. They regulate water cycles, improve soil characteristics, prevent soil erosion and provide essential resources like food, medicine and livelihoods for millions of people (Isabel, 2020; Watson *et al*., 2018) [8, 24]. Miyawaki afforestation is a method proposed by Professor Akira Miyawaki in the 1980s in Japan to restore indigenous ecosystems and maintain global environments. Miyawaki forests are plantation mixtures of multiple native species, planted closely, having rapid vertical growth, ultra-dense structure, and high biodiversity, which ensures ecological harmony (Roy *et al*., 2025) [16]. This is an innovative approach for reforestation and afforestation and mimic natural forest (Singh and Saini, 2019) [19]. These involve local communities, fostering environmental awareness and are based on the concept of Potential Natural Vegetation (Qi *et al*., 2024) [21]. These are self-sustaining native ecosystems in small urban areas that develop within 20-30 years and grow 10 times faster, 30 times denser and absorb 30 times more carbon than conventional plantations (Verma, 2025) [23]. Miyawaki forests become self-sustaining without human intervention after 2-3 years of post-plantations, which can be planted on a 300-400 sq m area thus, making them ideal for urban area plantations and providing green spaces (Ahirwal & Maiti, 2021; Miyawaki 2004) [2, 11].

These are best for ecological restoration, which has been lost due to urbanization and industrial activities, improve air quality, lower urban heat island effects, carbon and biodiversity gains, having minimal economic yield (Kurian, 2020) [10]. Dense vegetation not only sustains biodiversity but also serves as a natural pollution barrier and can improve environmental quality by lowering particulate matter (PM 2.5 and PM 10) concentrations by 20-30% and noise pollution levels (Nowak *et al*., 2014) [13]. Orchards are agroecosystems which are dominated by citrus species like orange, lemon, guava, and sapota with limited species diversity and managed for farm output and focused on fruit production. They have managed soils with fertilizers, pruning, irrigation and lower structural diversity. Grassland ecosystems are dominated by grass and herbaceous vegetation to managed pastures and less plant diversity and soil biodiversity. Miyawaki forests focus on rapid restoration of native climate resilience biodiversity, whereas orchards emphasize productive sustainability and food security. The establishment of natural forests could take much more time, whereas Miyawaki forest is a technique of creating green cover in a shorter span of time, which also gains importance across the continents. Restoration of forests and urban forests are imperative and need of the hour and understanding biodiversity in these ecosystems helps to guide ecological restoration (Miyawaki, 1999) [11]. They have a strong pollinator and soil protection role with limited woody biomass accumulation. Maintaining forests is very crucial to balance today's human needs and to anticipate necessities of the next generation and preserve the long-term ecosystem to support other living beings and the future. Environmental sustainability should be at the top priority as people live in it and it influences the most to the environment (Beregniak, 2023) [3]. Currently, attention should be focused on implementing policies which may help in conserving forest biodiversity to improve the ecological state of the environment (Aggestan *et al*., 2018) [1]. The present study focused on study of faunal diversity at Miyawaki forest, orchard, and grassland ecosystem at Punjab Agricultural University, Ludhiana.

Materials and Methods

Study area

The experiment was conducted during the months of November to February of the year 2024-25 at different locations of Punjab Agricultural University, Ludhiana to study avian and macrofaunal diversity. Different sites were selected at Punjab Agricultural University, Ludhiana, as site A-Miyawaki forest plantation, site B- Citrus orchard, and site C-Grassland ecosystem. Ludhiana is the most densely populated district of Punjab (India) and has a humid sub-tropical climate with hot summers (mid-March-June), monsoon (July-September) and cool winters (mid-November-early March). The extreme temperatures vary from 45 °C in summer to -5 °C in winter, with 680 mm annual rainfall. Punjab Agricultural University has main co-ordinates as 30.90° N (latitude) and 75.80° E (longitude).

Monitoring of bird diversity

Bird diversity was monitored using the line transect method, a widely accepted technique for assessing avian species richness and diversity in terrestrial habitats. In this method, predetermined transect lines were laid across the study area to cover different habitat types. Observations were conducted by walking slowly and steadily along each transect during peak bird activity hours, preferably in the early morning (6:00 am to 8:00 am) and late evening (5:00 pm to 7:00 pm), to ensure maximum detection. All birds seen or heard were recorded, irrespective of their distance from the observer, to estimate overall species richness. Care was taken to minimize disturbance by maintaining a uniform walking pace and avoiding sudden movements or loud noises.

Each transect was surveyed multiple times during the study period to improve accuracy and reduce sampling bias. The total number of bird species observed across all transects was pooled to prepare a comprehensive inventory of avian diversity in the study area. Both visual sightings and auditory calls were considered for species identification. Birds were identified primarily based on morphological characteristics such as size, plumage colour, beak shape, wing pattern, flight behaviour and habitat preference. Standard field identification was carried out using the reference guide "The Book of Indian Birds" by Salim Ali to ensure correct classification and nomenclature. The numerical distribution of species under each order was calculated and their%age contribution to total diversity was determined using the formula

% age = Number of species in the order/ Total number of species X 100

Field data were systematically recorded, including species name, number of individuals, location, habitat type, and time of observation.

Monitoring of faunal diversity

The rodent population was estimated on the basis of burrow count of different rodent species at different locations. For the toad and squirrel, the specimen was visually searched, photographed, and identified using keys. For earthworms, pits of size 1×1×1 feet were dug with the help of a spade from the periphery around/in selected locations, and the soil dug was collected in a transparent plastic bag, which was further sifted through a wire sieve to count earthworms (Pennock *et al.,* 2008) [15] and identified using suitable keys.

Statistical analysis

Different avian species were analyzed using% ages.

Results and Discussion

Distribution of avifauna

A total of 29 bird species belonging to nine orders were recorded across all selected study locations during the survey period. Among the three habitats, the citrus orchard showed the highest species richness with 26 species, followed by the Miyawaki forest with 22 species, while the grassland area recorded comparatively lower diversity with 15 species (Table 1). The higher diversity in the citrus orchard may be attributed to the availability of food resources, tree cover, nesting sites, and comparatively less disturbance. The Miyawaki forest also supported considerable diversity due to dense plantation and mixed vegetation structure. Therefore, people are taking much interest in this kind of plantation (Qi *et al*., 2026) [22]. In contrast, the grassland habitat, being more open and less structurally complex, supported fewer species. Zeybek (2025) [25] reported that the Miyawaki forestation method offers rapid forest establishment, increased biodiversity, and improved air quality. Schirone *et al*. (2025) [18] also reported increased incidence of urban biodiversity after establishment of Miyawaki Forest in Italy.

Table 1: Avian species observed at the orchard, Miyawaki forest, and grassland areas of Punjab Agricultural University, Ludhiana.

S. No	Bird species				Citrus orchard	Grassland area	Miyawaki forest
	Common Name	Scientific Name	Order	Family			
1.	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	Passeriformes	Cisticolidae	✓	✓	-
2.	Asian Pied Starling	*Sturnus contra* (Linn. 1758)	Passeriformes	Sturnidae	✓	✓	✓ (Kachnar)
3.	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	Passeriformes	Sturnidae	✓	✓	-
4.	Baya Weaver Bird	*Ploceus philippinus* (Linn. 1766)	Passeriformes	Ploceidae	-	-	✓ (Desi Babool, Adusa)
5.	Black Drongo	*Dicrurus macrocercus* (Viellot, 1817)	Passeriformes	Dicruridae	✓	✓	✓ (Ber)
6.	Black Ibis	*Pseudibis papillosa* (Temminck, 1824)	Pelecaniformes	Threskiornithidae	✓	✓	-
7.	Black Kite	*Milvus migrans* (Boddaert, 1783)	Accipitriformes	Accipitridae	✓	-	✓ (Bel)
8.	Black-winged Stilt	*Himantopus Himantopus* (Linn. 1758)	Charadriiformes	Recurvirostridae	✓	-	-
9.	Blue Rock Pigeon	*Columba livia* (Gmelin, 1789)	Columbiformes	Columbidae	✓	✓	✓ (Talhi)
10.	Cattle Egret	*Bubulcus ibis* (Linn.1758)	Pelecaniformes	Ardeidae	✓	✓	-
11.	Common Babbler	*Turdoides caudata* (Dumont, 1823)	Passeriformes	Leiothrichidae	✓	✓	✓ (Har Shingar, Baheda)
12.	Common Hoopoe	*Upupa epops* (Linn.1758)	Bucerotiformes	Upupidae	✓	✓	✓ (Ground area)
13.	Common Myna	*Acridotheres tristis* (Linn.1766)	Passeriformes	Sturnidae	✓	✓	✓ (Pilkan, Suhanjana)
14.	Common Starling	*Sturnus vulgaris* (Linn. 1758)	Passeriformes	Sturnidae	✓	-	-
15.	Common Tailor Bird	*Orthotomus sutorius* (Pennant, 1769)	Passeriformes	Cisticolidae	✓	-	✓ (Amla)
16.	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	Cuculiformes	Cuculidae	✓	-	✓ (Ground area)
17.	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	Galliformes	Phasianidae	✓	-	✓ (Ground area)
18.	House Crow	*Corvus splendens* (Vieillot, 1817)	Passeriformes	Corvidae	✓	✓	✓ (Talhi)
19.	Indian Pea Fowl	*Pavo cristatus* (Linn.1758)	Galliformes	Phasianidae	✓	✓	✓ (Ground area)
20.	Indian Robin	*Saxicoloides fulicata* (Linn.1758)	Passeriformes	Muscicapidae	-	-	✓ (Amla, Tota)
21.	Indian Treepie	*Dendrocitta vagabunda* (Latham, 1790)	Passeriformes	Corvidae	✓	-	✓ (Bel)
22.	Little Brown Dove	*Streptopelia senegalensis* (Linn.1766)	Columbiformes	Columbidae	✓	-	✓ (Suhanjana)
23.	Paddy Field Pipit	*Anthus rufulus* (Vieillot, 1818)	Passeriformes	Motacillidae	✓	✓	-
24.	Purple Sunbird	*Nectarinia asiatica* (Latham, 1790)	Passeriformes	Nectariniidae	✓	-	✓ (Amla, Amaltas, Adusa)
25.	Red-vented Bulbul	*Pycnonotus cafer* (Linn.1766)	Passeriformes	Pycnonotidae	✓	-	✓ (Karonda)
26.	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Charadriiformes	Charadriidae	✓	✓	✓ (Ground area)
27.	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	Psittaciformes	Psittaculidae	✓	-	✓ (Kachnar)
28.	Shikra	*Accipiter badius* (Gmelin, 1788)	Accipitriformes	Accipitridae	-	-	✓ (Jamun)
29.	Spotted Owlet	*Athene brama* (Temminck, 1821)	Strigiformes	Strigidae	✓	✓	✓ (Suhanjana)

Distribution of avifauna based on orders

The order Passeriformes was predominant and comprised 15 species (51.72%) of the total recorded avifauna as Passeriformes (perching birds) represent the largest and most diverse order of birds worldwide (Figure 1). Families such as Sturnidae, Corvidae, Cisticolidae, Muscicapidae and Pycnonotidae contributed significantly to this dominance. The high proportion indicates the suitability of orchard and forest habitats for small perching birds that depend on insects, fruits and grains. Orders such as Pelecaniformes, Accipitriformes, Charadriiformes, Columbiformes and Galliformes each contributed only two species (6.90%), showing moderate representation. These groups include water-associated birds, raptors, waders, pigeons and ground-dwelling birds, indicating habitat heterogeneity and availability of diverse ecological niches. The remaining orders, Bucerotiformes, Cuculiformes, Psittaciformes and Strigiformes were represented by a single species each (3.45%). Their lower representation may be due to specialized habitat requirements or lower population density. The predominance of Passeriformes (51.72%) suggests that the study area supports a healthy population of perching birds, which are key indicators of ecosystem stability. The presence of raptors, ground birds, waders, and nocturnal birds further reflects ecological balance and habitat diversity. According to Bitani *et al.*, (2023) [4] the avian diversity is predominantly affected by the forest structural complexity, tree species and canopy cover which form the main forest characteristics.

Distribution of avifauna based on their feeding guilds

The feeding guild analysis of the recorded species revealed that 10 species were omnivorous, nine insectivorous, seven carnivorous, two granivorous and a single frugivorous species. The dominance of omnivorous and insectivorous birds indicates habitat suitability with abundant insects, grains, fruits and small prey organisms. Carnivorous birds such as the Shikra and Black Kite reflected the presence of a stable food chain within the ecosystem. The occurrence of insectivorous species like Ashy Prinia and Common Hoopoe suggests effective biological pest control potential in orchard and forest habitats. Certain species such as House Crow, Common Myna, Indian Peafowl and Spotted Owlet, were observed in all three habitats, indicating their adaptability and ecological flexibility. In contrast, species like Shikra and Indian Robin were restricted to the Miyawaki forest, possibly due to dense vegetation and better nesting opportunities. The distribution of bird species according to their feeding guilds is largely dependent upon vegetation structure (Shafie *et al*. 2023) [20].

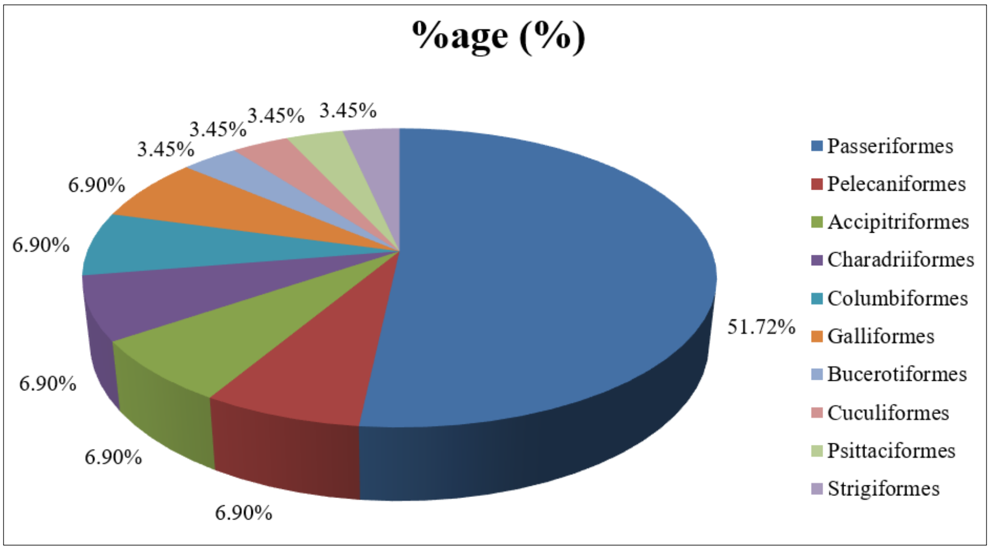

Fig 1: Order-wise distribution (%age) of avifauna

Distributions of faunal diversity

During the survey, three rodent species, one amphibian species and one earthworm species were observed in the study area. Among rodents, rat and squirrel species belonged to the order Rodentia, whereas families Muridae and Sciuridae, respectively. Similarly, recorded earthworm and toad species belonged to the order Opisthopora, Anura and families Lumbricidae and Bufonidae, respectively (Table 2). Miyawaki forest includes the field mouse, lesser bandicoot rat, five-striped palm squirrel, redworm and common Asian toad species. In the citrus orchard, only the field mouse, lesser bandicoot rat and five-striped palm squirrel was recorded, whereas only the five-striped palm squirrel from the grassland ecosystem. It was revealed from the survey that Miyawaki forest has more diversity (five species) as compared to the Citrus orchard (three species) and the grassland ecosystem (One species) in Punjab Agricultural University. This increase in faunal diversity in Miyawaki forest was due to dense plantations, which harbor more insect populations as food, and fallen leaves of trees as residue and porous structure of soil, which provide congenial environmental conditions suitable for development, as compared to the citrus orchard and grassland ecosystem. In a study, Condit *et al*. (2002) [5] described that faunal diversity among different plantations can indicate how biotic and abiotic components change community structure. Similarly, Goveanthan *et al*. (2019) [7] recorded Simpson's index of diversity to be highest for Miyawaki forest (0.1306) as compared to the normal forest (0.1011).

Table 2: Macrofaunal species observed at orchard, Miyawaki forest and grassland areas of Punjab Agricultural University, Ludhiana.

		Miyawaki Forest		
S. No.	**Common name**	**Scientific name**	**Order**	**Family**
1	Field mouse	*Mus booduga* (Gray, 1837)	Rodentia	Muridae
2	Lesser bandicoot rat	*Bandicota bengalensis* (Hardwicke, 1833)	Rodentia	Muridae
3	Five striped palm squirrel	*Funambulus pennantii* (Wroughton, 1905)	Rodentia	Sciuridae
4	Redworm (Earthworm)	*Eisenia fetida* (Savigny, 1826)	Opisthopora	Lumbricidae
5	Common Asian toad	*Duttaphrynus melanostictus* (Schneider, 1799)	Anura	Bufonidae
		Citrus orchard		
1	Field mouse	*M. booduga*	Rodentia	Muridae
2	Lesser bandicoot rat	*B. bengalensis*	Rodentia	Muridae
3	Five striped palm squirrel	*F. pennantii*	Rodentia	Sciuridae
		Grassland		
1	Five striped palm squirrel	*F. pennantii*	Rodentia	Sciuridae

Conclusion

Findings indicated that habitat complexity and vegetation diversity strongly influenced avian and macrofaunal diversity and distribution. The citrus orchard and Miyawaki forest supported higher biodiversity compared to open grassland areas, highlighting the ecological importance of mixed and structured vegetation. These structured habitats fostered greater bird and macrofaunal communities, suggesting that creating complex vegetation can boost biodiversity. Therefore, the study showed that maintaining structured environments, such as forests and orchards, is crucial for sustaining faunal communities, whereas open grasslands supported lower biodiversity.

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Declarations

The authors declare no competing interests.

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