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Avian Diversity in Agroforestry Landscapes of Kolar District of Karnataka A Rapid Farmer's Field Survey Assessment Outcomes

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AN ABSTRACT

Agroforestry is increasingly recognised as a land-use system capable of reconciling agricultural production with biodiversity conservation. Yet, quantitative information on avian diversity in farmer-managed agroforestry landscapes remains scarce in semi-arid India. This paper reports a rapid assessment of avian diversity in farmer-managed agroforestry plots in Kolar district, Karnataka, undertaken between January and July 2026 as an adjunct to farmer-onboarding surveys for an Afforestation, Reforestation and Revegetation (ARR) carbon project. Birds were recorded opportunistically (ad libitum) across 79 plots in 21 villages of Malur and Bangarapet taluks in the Eastern Dry Agro-Climatic Zone. A total of 32 confirmed species belonging to 22 families were documented. Thirty species (93.8%) are categorised as Least Concern and two (6.2%), the Painted Stork (Mycteria leucocephala) and the Black-headed Ibis (Threskiornis melanocephalus), as Near Threatened on the IUCN Red List. Ardeidae was the most species-rich family (five species), followed by Muscicapidae (three species). Open farmland and scrub generalists (14 species, 43.8%) and wetland-associated species (13 species, 40.6%) dominated the assemblage, and insectivores (12 species) formed the largest feeding guild. Black Drongo (Dicrurus macrocercus) and Green Bee-eater (Merops orientalis) were the most frequently detected species, with occurrence frequencies of 58.3% and 41.7%, respectively. Both Near Threatened species were associated with farm ponds and irrigation channels rather than tree-crop plots, indicating that retained water bodies materially enhance the conservation value of the agroforestry mosaic. Canopy-dependent species were under-represented (15.6%), consistent with the young age and open structure of most planted agroforestry blocks. The findings demonstrate that farmer-managed agroforestry delivers incidental biodiversity co-benefits, supporting a functional, generalist-dominated bird community rich in insectivores capable of natural pest suppression. However, the opportunistic survey design and absence of individual counts mean the present data constitute a qualitative baseline only, insufficient for abundance-based indices or trend detection. The results provide an evidence base for claiming biodiversity co-benefits within the project's Monitoring, Reporting and Verification framework and highlight the need to integrate standardised bird monitoring protocols, prioritise retention of farm ponds and irrigation channels as discrete habitat assets, and establish long-term seasonal surveys to track changes in species composition as plantations mature. Converting the present checklist into a quantitative monitoring dataset would require modest additions to existing field routines, namely fixed-duration counts at a subset of plots, recording of individual numbers, and repetition across seasons to satisfy co-benefit standards such as the Climate, Community and Biodiversity Standards administered by Verra.

Keywords: *Avian Diversity-Agroforestry-Kolar-Eastern Dry Zone-Carbon Project-Biodiversity Co-Benefits-MRV-Farmer-Managed Landscapes-IUCN Red List-Feeding Guilds-Farm Ponds-Near Threatened Species*

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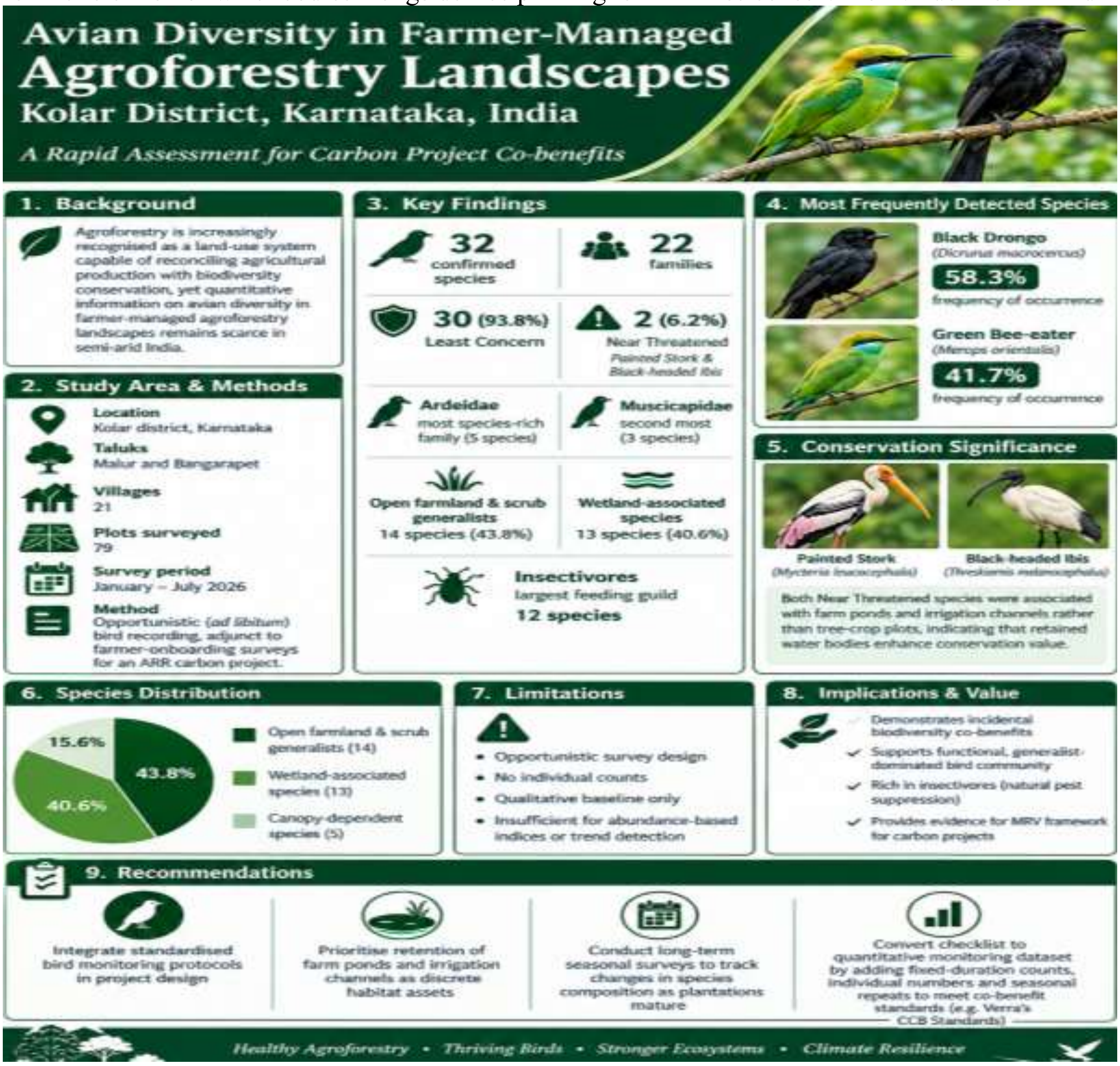
I-INTRODUCTION

A rapid ecological survey conducted in 2026 documented avian diversity across farmer-managed agroforestry plots in the Kolar district of Karnataka, India. Researchers identified 32 bird species, predominantly featuring insectivores and generalists that provide essential ecosystem services like natural pest suppression. While most recorded birds are common, the presence of Near Threatened species highlights the vital role of farm ponds and irrigation channels in supporting biodiversity within agricultural mosaics. The findings serve as a qualitative baseline to help validate carbon project co-benefits under international environmental standards. To improve future assessments, the report suggests adopting standardised monitoring protocols as the young tree plantations reach canopy maturity. These results advocate for the retention of water bodies alongside tree planting to maximise conservation value in semi-arid landscapes.



Conversion of natural habitat to cropland, expansion of settlements and intensification of agricultural practice are among the principal drivers of biodiversity loss worldwide (Tscharntke et al., 2005). Within this context, agroforestry, the deliberate integration of woody perennials with crops and, in some systems, livestock, has attracted attention as a production system that can sustain yields while maintaining habitat features that many wild species require (Jose, 2009). Trees on farms also store carbon in biomass and soil, and a substantial share of the world's agricultural land already carries measurable tree cover, making agroforestry a recognised mitigation pathway (Nair, Kumar & Nair, 2009; Zomer et al., 2016).

Birds are widely used as indicators of ecological condition because they occupy a range of trophic positions, respond quickly to changes in vegetation structure and land management, and are comparatively easy to detect and identify in the field (Şekercioğlu, 2006). They also deliver ecosystem services of direct relevance to farmers, including control of insect pests, pollination and seed dispersal (Whelan, Wenny & Marquis, 2008). Bird assemblages therefore offer a practical means of tracking the ecological consequences of land-use decisions within working agricultural landscapes.

India supports more than 1,300 bird species across forest, wetland, grassland and agricultural biomes (Grimmett, Inskipp & Inskipp, 2011), and Karnataka, with its varied agro-climatic zones, holds a well-documented and diverse avifauna (Praveen, Jayapal & Pittie, 2016). Kolar district, in the state's Eastern Dry Agro-Climatic Zone, is characterised by tree-based farming in which mango, tamarind, neem, casuarina, Melia dubia, coconut and other species are grown alongside annual crops, producing a fine-grained mosaic of orchards, field borders, scrub and small water bodies. Despite the extent of these systems, quantitative information on the birds they support remains scarce.

The present study addresses this gap by documenting the bird species encountered in farmer-managed agroforestry plots during field surveys conducted for an ARR carbon project. Its specific objectives were to (i) compile a verified checklist of bird species in the surveyed agroforestry landscapes; (ii) describe the taxonomic, habitat and feeding-guild composition of the assemblage; (iii) quantify the frequency of occurrence of species; and (iv) evaluate the implications of the findings for biodiversity co-benefit reporting within the project's MRV framework.

II-KEY INSIGHTS FROM THE LITERATURE REVIEW

A review of the published literature on birds in agroforestry and agricultural landscapes yields five insights that frame the interpretation of the present study.

2.1 Agroforestry supports richer bird communities than open cropland

Comparative studies across the tropics consistently show that tree-integrated farming systems hold more bird species than annual monocultures, largely because vertical vegetation layers create additional foraging niches, nesting sites and refuges from predators and weather (Harvey & González Villalobos, 2007; Bhagwat et al., 2008). At the same time, agroforest assemblages are typically modified relative to natural forest: they are enriched in generalists and open-country species and depleted in forest specialists. Agroforestry is thus best understood as a complement to, rather than a substitute for, protected natural habitat.

2.2 Structural heterogeneity, not tree cover alone, drives diversity

Species richness in farmed landscapes correlates with the diversity of habitat elements present, including hedgerows, scattered trees, orchards, fallows and water bodies, more strongly than with any single element (Tscharntke et al., 2005). Indian studies from agricultural mosaics in West Bengal and Haryana report that mixed landscapes with tree cover, crop fields and water bodies support 60 to 120 species, dominated by insectivores and omnivores (Hossain & Aditya, 2016; Kumar & Sahu, 2020).

2.3 Small agricultural wetlands are disproportionately important

Farm ponds, irrigation tanks and channels embedded within cropland function as stepping-stone wetlands for large waterbirds, including storks, ibises and herons, and can sustain populations of species of conservation concern even in intensively farmed regions (Sundar & Kittur, 2013). This has particular relevance in semi-arid Karnataka, where traditional tank systems have historically supported wetland birds.

2.4 Birds provide ecosystem services that benefit farmers

Insectivorous birds suppress crop pests, frugivores disperse tree seeds, and nectarivores contribute to pollination, and the loss of these functional groups has measurable economic and ecological consequences (Şekercioğlu et al., 2004; Whelan, Wenny & Marquis, 2008; Şekercioğlu, 2012). Documenting feeding guilds is therefore a useful step towards valuing the services that bird assemblages provide in agroforestry systems.

2.5 Biodiversity monitoring is increasingly expected in carbon projects

Carbon standards that award co-benefit labels, such as the Climate, Community and Biodiversity (CCB) Standards administered by Verra, require projects to demonstrate net positive biodiversity outcomes using credible baseline and monitoring data (Verra, 2017). Simple, repeatable bird surveys built on established census techniques (Bibby et al., 2000) can satisfy this requirement at low cost when embedded in routine project field activity.

III-MATERIALS AND METHODS

3.1 Study Area

Kolar district lies in south-eastern Karnataka on the Deccan Plateau, between 12°46′ and 13°58′ N latitude and 77°21′ and 78°35′ E longitude, and borders Andhra Pradesh and Tamil Nadu. It comprises five taluks: Kolar, Bangarpet, Malur, Mulbagal and Srinivaspura (Census of India, 2011). The district falls within the Eastern Dry Agro-Climatic Zone and has a semi-arid climate, undulating terrain and predominantly rainfed agriculture supplemented by borewell irrigation. Mean annual rainfall is approximately 740 mm, received mainly during the south-west and north-east monsoons (KSNDMC, 2026). The surveyed plots were located in Kasaba and Tekal hoblis of Malur taluk and Kasaba hobli of Bangarapet taluk (Figure 1).

Figure 1. Location of Kolar district, Karnataka, showing the taluks in which surveys were conducted.

3.2 Sampling Design

Bird observations were made between January and July 2026 during farmer-onboarding visits for an ARR agroforestry carbon project. Because the primary purpose of each visit was the agroforestry survey, a structured transect or fixed-radius point-count design was not feasible. An opportunistic (ad libitum) approach was therefore adopted, in which all birds seen or heard during the visit to each farmer's plot were recorded without fixed time or distance limits (Hossain & Aditya, 2016). Survey effort was organised in two phases. Phase 1 (February 2026) covered 79 plots totalling 74.6 acres in 21 villages of Malur and Bangarapet taluks over five field days (Table 1). Phase 2 (through July 2026) comprised 12 visits to plots in the same landscape, during which species presence was recorded on a per-visit basis.

Table 1. Survey effort during Phase 1 (Malur and Bangarapet taluks, February 2026).

Date	Location	Village visits	Plots visited	Area covered (acres)
02 Feb 2026	Kasaba Hobli, Malur	4	15	17.95
03 Feb 2026	Kasaba Hobli, Malur	6	19	18.03
04 Feb 2026	Tekal Hobli, Malur	5	12	15.47
05 Feb 2026	Kasaba Hobli, Bangarapet	10	18	23.19
13 Feb 2026	Kasaba Hobli, Malur	5	15	22.15

Date	Location	Village visits	Plots visited	Area covered (acres)
Total		**30 (21 unique villages)**	**79**	**74.64**

Note: Village visits are counted per field day; several villages were visited on more than one day.

3.3 Bird Recording and Identification

Birds were recorded through direct visual observation, vocalisations and photographic documentation with a digital camera. Identification followed Grimmett, Inskipp and Inskipp (2011) and Ali and Ripley (1987), and photographs were used to cross-verify records where necessary. Nomenclature and taxonomic sequence follow the checklist of the birds of Karnataka (Praveen, Jayapal & Pittie, 2016). Conservation status was assigned according to the IUCN Red List (IUCN, 2026). Records that could not be resolved to species were retained as 'sp.' entries and excluded from richness counts.

3.4 Data Analysis

The compiled checklist was used to characterise species richness, family composition, habitat association and feeding guild. Each species was assigned to one of three broad habitat associations (wetland or water-associated; open farmland or scrub; tree or orchard canopy) and to a feeding guild based on its predominant diet as described in standard references (Ali & Ripley, 1987; Grimmett, Inskipp & Inskipp, 2011). For Phase 2, frequency of occurrence (FO) was calculated for each species as:

$$FO\ (\%) = (\text{number of visits in which the species was recorded} \div \text{total number of visits}) \times 100$$

Because individual counts were not recorded, abundance-based diversity indices such as the Shannon–Wiener index could not be computed (Magurran, 2004); the analysis is therefore restricted to presence-based measures.

IV-RESULTS

4.1 Species Richness and Composition

Bird surveys across the study landscapes yielded the species inventory presented in Table 2. Two additional records from Phase 2, an unidentified egret (Ardeidae) and an unidentified kingfisher (Alcedinidae), were excluded from the species-richness tally, as they likely correspond to taxa already confirmed during Phase 1. Of the documented species, 23 were recorded exclusively in Phase 1, three only in Phase 2, and six occurred in both phases. Representative photographic documentation is provided in Figure 4. Common open-country and edge-tolerant species included the Indian Roller (Coracias benghalensis) (a), Black Drongo (Dicrurus macrocercus) (b), and Green Bee-eater (Merops orientalis) (c). Species associated with orchards and scrub habitats comprised the Red-whiskered Bulbul (Pycnonotus jocosus) (d), Common Myna (Acridotheres tristis) (e), Common Kingfisher (Alcedo atthis) (f), and Large Grey Babbler (Argya malcolmi) (g). Wetland-associated taxa, including Near Threatened species, were also recorded: Black-headed Ibis (Threskiornis melanocephalus), Painted Stork (Mycteria leucocephala) (j)—observed alongside Little Cormorant (Microcarbo niger) and an egret at a farm pond (h)—and Rose-ringed Parakeet (Psittacula krameri) (i). Additional photographic records include the Spotted Dove (Spilopelia chinensis) (k) and a Little Cormorant (Microcarbo niger).

(a) Indian Roller (Coracias benghalensis)

(b) Black Drongo (Dicrurus macrocercus)

(c) Green Bee-eater (Merops orientalis)

(d) Red-whiskered Bulbul (Pycnonotus jocosus)

(e) Common Myna (Acridotheres tristis)

(f) Kingfisher sp. (Alcedo atthis)

(g) Large Grey Babbler (Argya malcolmi)

(h) Black-headed Ibis (Threskiornis melanocephalus)

(i) Rose-ringed Parakeet (Psittacula krameri)

(j) Painted Stork (*Mycteria leucocephala)*

(k) Spotted Dove (*Spilopelia chinensis)*

(l) Little Cormorant (*Microcarbo niger)*

Figure 2. Representative bird species photographed during the surveys.

4.2 Species Checklist

Table 2. Checklist of bird species recorded in agroforestry landscapes of Kolar district.

Sl. No.	Common name	Scientific name	Family	IUCN status	Phase
1	Painted Stork	*Mycteria leucocephala*	Ciconiidae	NT	1
2	Little Cormorant	*Microcarbo niger*	Phalacrocoracidae	LC	1, 2
3	Grey Heron	*Ardea cinerea*	Ardeidae	LC	1
4	Little Egret	*Egretta garzetta*	Ardeidae	LC	1
5	Cattle Egret	*Bubulcus ibis*	Ardeidae	LC	1
6	Intermediate Egret	*Ardea intermedia*	Ardeidae	LC	1
7	Indian Pond Heron	*Ardeola grayii*	Ardeidae	LC	1

Sl. No.	Common name	Scientific name	Family	IUCN status	Phase
8	Black-headed Ibis	*Threskiornis melanocephalus*	Threskiornithidae	NT	2
9	Black-winged Stilt	*Himantopus himantopus*	Recurvirostridae	LC	1
10	Red-wattled Lapwing	*Vanellus indicus*	Charadriidae	LC	1
11	White-throated Kingfisher	*Halcyon smyrnensis*	Alcedinidae	LC	1
12	Common Kingfisher	*Alcedo atthis*	Alcedinidae	LC	1
13	Eurasian Hoopoe	*Upupa epops*	Upupidae	LC	1
14	Indian Roller	*Coracias benghalensis*	Coraciidae	LC	1, 2
15	Green Bee-eater	*Merops orientalis*	Meropidae	LC	2
16	Spotted Dove	*Spilopelia chinensis*	Columbidae	LC	2
17	Rose-ringed Parakeet	*Psittacula krameri*	Psittaculidae	LC	1, 2
18	Black Drongo	*Dicrurus macrocercus*	Dicruridae	LC	1, 2
19	House Crow	*Corvus splendens*	Corvidae	LC	2
20	Common Myna	*Acridotheres tristis*	Sturnidae	LC	1, 2
21	Rosy Starling	*Pastor roseus*	Sturnidae	LC	1
22	Red-whiskered Bulbul	*Pycnonotus jocosus*	Pycnonotidae	LC	1
23	Bulbul sp. (cf. Red-vented Bulbul)	*Pycnonotus cf. cafer*	Pycnonotidae	LC	2
24	Large Grey Babbler	*Argya malcolmi*	Leiothrichidae	LC	2
25	Wire-tailed Swallow	*Hirundo smithii*	Hirundinidae	LC	1
26	White-browed Wagtail	*Motacilla maderaspatensis*	Motacillidae	LC	1
27	Pied Bushchat	*Saxicola caprata*	Muscicapidae	LC	1, 2
28	Siberian Stonechat	*Saxicola maurus*	Muscicapidae	LC	1
29	European Stonechat*	*Saxicola rubicola*	Muscicapidae	LC	1
30	Purple-rumped Sunbird	*Leptocoma zeylonica*	Nectariniidae	LC	1
31	Purple Sunbird	*Cinnyris asiaticus*	Nectariniidae	LC	1
32	Indian Peafowl	*Pavo cristatus*	Phasianidae	LC	1

*Note: NT = Near Threatened; LC = Least Concern (IUCN, 2026). *Record of European Stonechat (Saxicola rubicola) requires photographic confirmation, as the species is rarely reported from peninsular India and is readily confused with Siberian Stonechat.*

4.3 Family-wise Distribution

Ardeidae was the most species-rich family with five species (Grey Heron, Little Egret, Cattle Egret, Intermediate Egret and Indian Pond Heron), followed by Muscicapidae with three (Pied Bushchat, Siberian Stonechat and the stonechat record noted above). Alcedinidae, Sturnidae, Pycnonotidae and Nectariniidae were each represented by two species, and the remaining 16 families by a single species each (Figure 3).

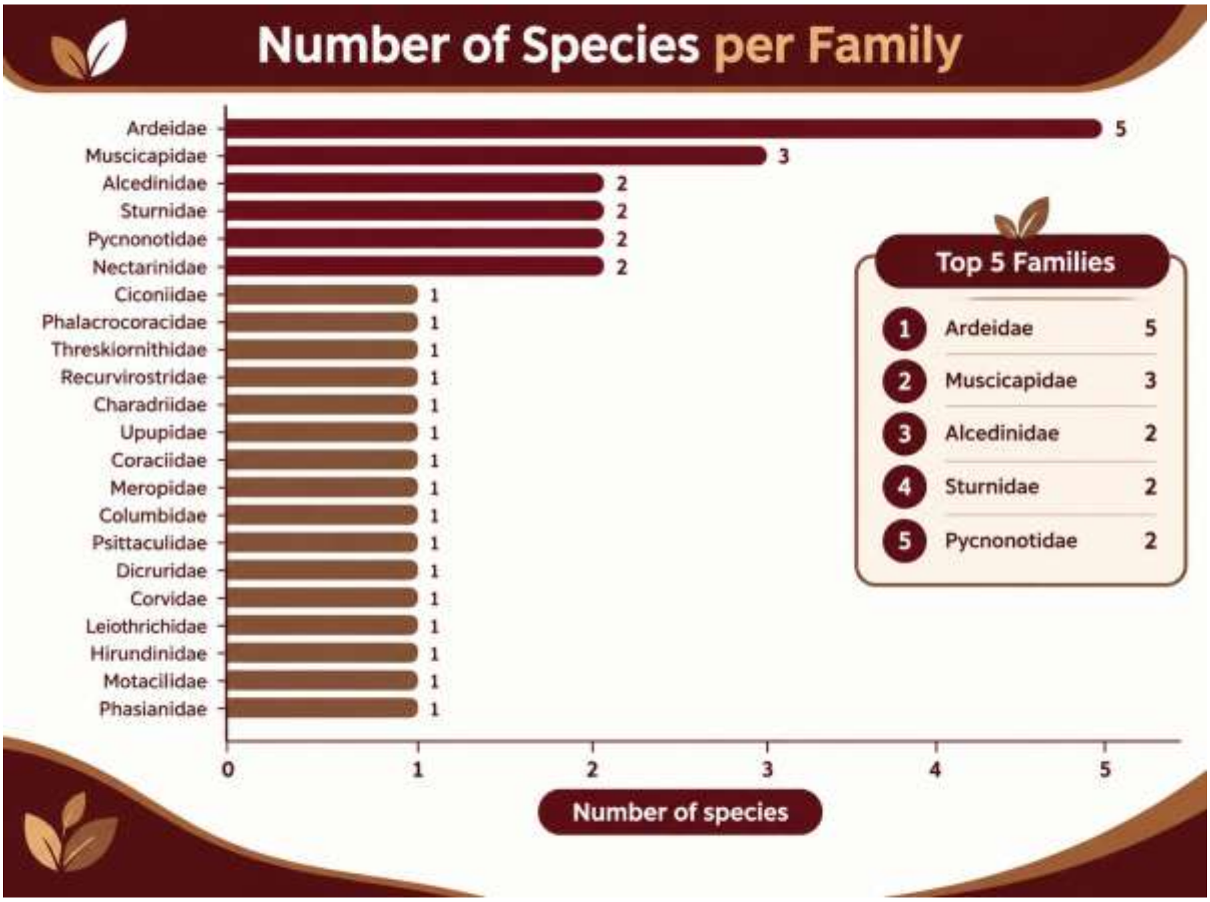


Figure 3. Number of species recorded per family.

4.4 Frequency of Occurrence

Frequency of occurrence was computed for the 12 Phase 2 visits (Table 3; Figure 4). Black Drongo was recorded on seven visits (58.3%) and Green Bee-eater on five (41.7%). Kingfishers were noted on three visits (25.0%), and Indian Roller and bulbuls on two each (16.7%). The remaining nine taxa, including the Near Threatened Black-headed Ibis, were each recorded on a single visit (8.3%).

Table 3. Frequency of occurrence of bird taxa during Phase 2 (n = 12 visits).

Taxon	Visits recorded (of 12)	FO (%)
Black Drongo	7	58.3
Green Bee-eater	5	41.7
Kingfisher sp.	3	25.0
Indian Roller	2	16.7
Bulbul sp.	2	16.7
Egret sp.	1	8.3
Black-headed Ibis	1	8.3
Little Cormorant	1	8.3
Large Grey Babbler	1	8.3
Rose-ringed Parakeet	1	8.3
Spotted Dove	1	8.3
Common Myna	1	8.3
House Crow	1	8.3
Pied Bushchat	1	8.3

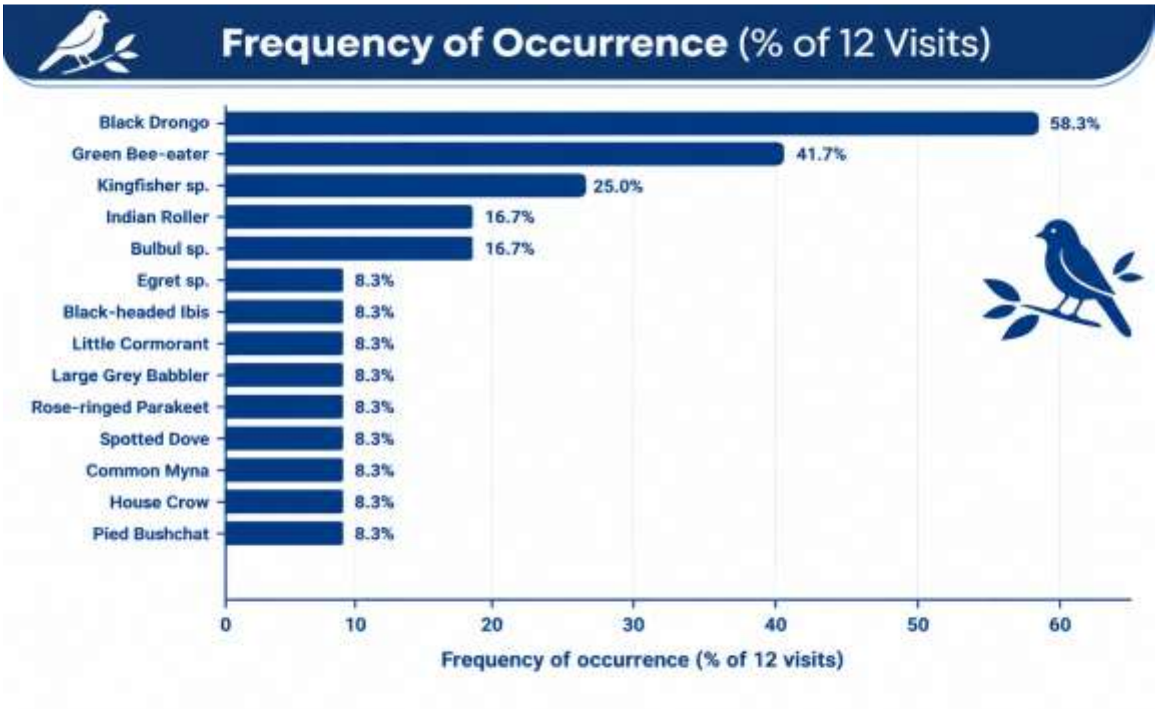


Figure 4. Frequency of occurrence of bird taxa during Phase 2 visits.

4.5 Habitat Association and Feeding Guild Composition

Assignment of the 32 species to broad habitat associations (Table 4) shows that open farmland and scrub species were the largest group (14 species, 43.8%), closely followed by wetland or water-associated species (13 species, 40.6%), with tree or orchard canopy species forming a smaller component (5 species, 15.6%) (Table 5; Figure 5a). By feeding guild, insectivores were the most numerous (12 species, 37.5%), followed by wading piscivores and invertivores (8 species, 25.0%), omnivores (4 species), kingfisher-type piscivores, frugivore-insectivores and nectarivores (2 species each), and a single granivore and frugivore-granivore species (Figure 5b).

Table 4. Habitat association and feeding guild of recorded species.

Sl. No.	Common name	Scientific name	Habitat association	Feeding guild
1	Painted Stork	*Mycteria leucocephala*	Wetland / water-associated	Wading piscivore / invertivore
2	Little Cormorant	*Microcarbo niger*	Wetland / water-associated	Wading piscivore / invertivore
3	Grey Heron	*Ardea cinerea*	Wetland / water-associated	Wading piscivore / invertivore
4	Little Egret	*Egretta garzetta*	Wetland / water-associated	Wading piscivore / invertivore
5	Cattle Egret	*Bubulcus ibis*	Wetland / water-associated	Insectivore
6	Intermediate Egret	*Ardea intermedia*	Wetland / water-associated	Wading piscivore / invertivore
7	Indian Pond Heron	*Ardeola grayii*	Wetland / water-associated	Wading piscivore / invertivore
8	Black-headed Ibis	*Threskiornis melanocephalus*	Wetland / water-associated	Wading piscivore / invertivore

Sl. No.	Common name	Scientific name	Habitat association	Feeding guild
9	Black-winged Stilt	*Himantopus himantopus*	Wetland / water-associated	Wading piscivore / invertivore
10	Red-wattled Lapwing	*Vanellus indicus*	Wetland / water-associated	Insectivore
11	White-throated Kingfisher	*Halcyon smyrnensis*	Wetland / water-associated	Piscivore / invertivore
12	Common Kingfisher	*Alcedo atthis*	Wetland / water-associated	Piscivore / invertivore
13	Eurasian Hoopoe	*Upupa epops*	Open farmland / scrub	Insectivore
14	Indian Roller	*Coracias benghalensis*	Open farmland / scrub	Insectivore
15	Green Bee-eater	*Merops orientalis*	Open farmland / scrub	Insectivore
16	Spotted Dove	*Spilopelia chinensis*	Open farmland / scrub	Granivore
17	Rose-ringed Parakeet	*Psittacula krameri*	Tree / orchard canopy	Frugivore / granivore
18	Black Drongo	*Dicrurus macrocercus*	Open farmland / scrub	Insectivore
19	House Crow	*Corvus splendens*	Open farmland / scrub	Omnivore
20	Common Myna	*Acridotheres tristis*	Open farmland / scrub	Omnivore
21	Rosy Starling	*Pastor roseus*	Open farmland / scrub	Omnivore
22	Red-whiskered Bulbul	*Pycnonotus jocosus*	Tree / orchard canopy	Frugivore / insectivore
23	Bulbul sp. (cf. Red-vented Bulbul)	*Pycnonotus cf. cafer*	Tree / orchard canopy	Frugivore / insectivore
24	Large Grey Babbler	*Argya malcolmi*	Open farmland / scrub	Insectivore
25	Wire-tailed Swallow	*Hirundo smithii*	Open farmland / scrub	Insectivore
26	White-browed Wagtail	*Motacilla maderaspatensis*	Wetland / water-associated	Insectivore
27	Pied Bushchat	*Saxicola caprata*	Open farmland / scrub	Insectivore
28	Siberian Stonechat	*Saxicola maurus*	Open farmland / scrub	Insectivore
29	European Stonechat*	*Saxicola rubicola*	Open farmland / scrub	Insectivore
30	Purple-rumped Sunbird	*Leptocoma zeylonica*	Tree / orchard canopy	Nectarivore
31	Purple Sunbird	*Cinnyris asiaticus*	Tree / orchard canopy	Nectarivore

Sl. No.	Common name	Scientific name	Habitat association	Feeding guild
32	Indian Peafowl	*Pavo cristatus*	Open farmland / scrub	Omnivore

Table 5. Number and proportion of species by habitat association.

Habitat association	Number of species	Percentage
Open farmland / scrub	14	43.8%
Wetland / water-associated	13	40.6%
Tree / orchard canopy	5	15.6%
Total	**32**	**100%**

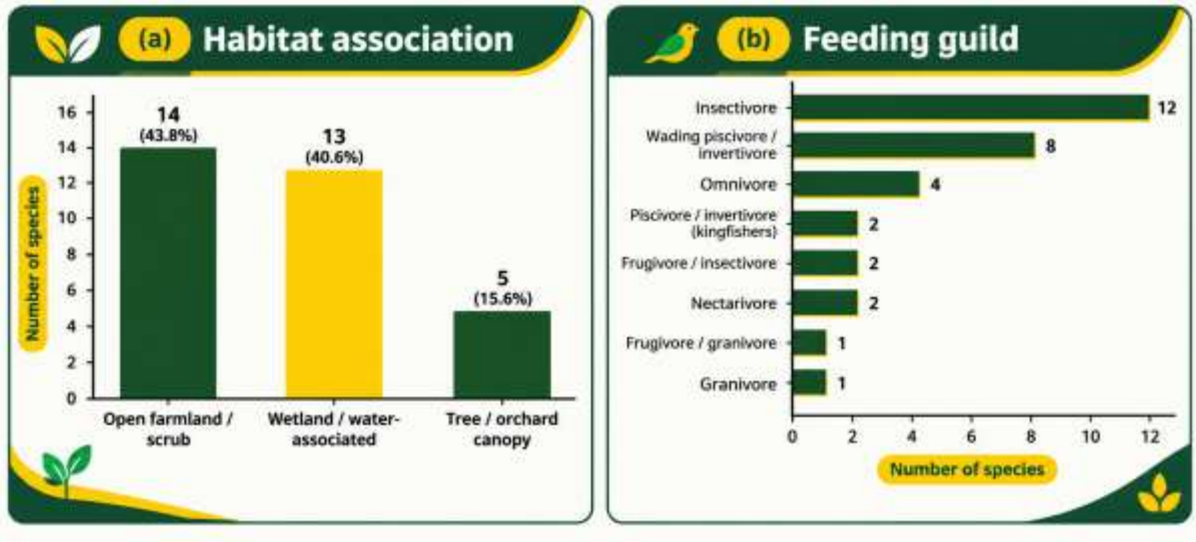


Figure 5. Distribution of recorded species by (a) habitat association and (b) feeding guild.

4.6 Conservation Status

Of the 32 confirmed species, 30 (93.8%) are categorised as Least Concern and two (6.2%), Painted Stork (Mycteria leucocephala) and Black-headed Ibis (Threskiornis melanocephalus), as Near Threatened on the IUCN Red List (IUCN, 2026) (Figure 6). Both were recorded at farm ponds and irrigation-linked wetlands adjoining the surveyed plots.

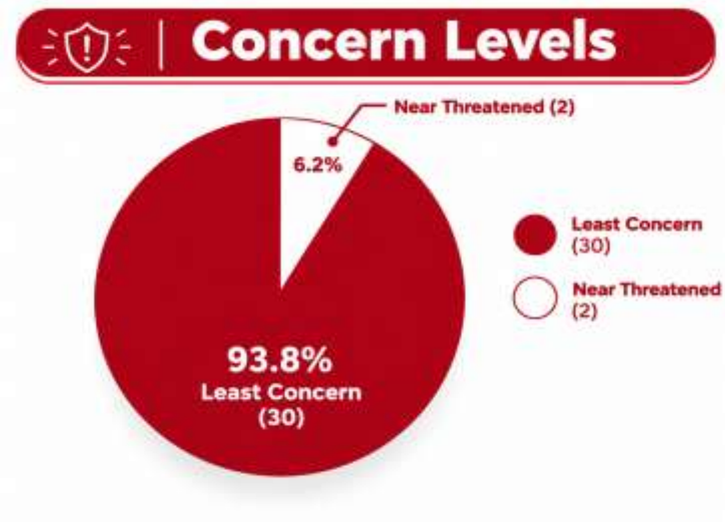


Figure 6. IUCN Red List status of recorded species.

V-ANALYSIS OF KEY RESULT AREAS

The results are examined below under five key result areas (KRAs) that correspond to the study objectives and to the co-benefit indicators most relevant to the carbon project.

KRA 1: Species richness relative to survey effort

Thirty-two species from 22 families were recorded in roughly 17 field visits with no dedicated birding effort. Systematic surveys of comparable dry-zone landscapes in Karnataka have reported considerably higher totals; for example, Basavarajappa (2006) documented an extensive avifauna across the maidan agro-ecosystems, and Khan, Nautiyal and Venkatesha (2019) recorded a rich assemblage in semi-arid Chitradurga district. The ratio of families to species (22:32, or 0.69) is high, indicating that most families were represented by a single species. This pattern is characteristic of a short inventory that has captured the common and conspicuous members of many lineages but has not yet accumulated the rarer congeners that longer surveys reveal (Magurran, 2004). The richness figure should therefore be read as a lower bound.

KRA 2: Community dominance and evenness

Frequency-of-occurrence data reveal a strongly uneven community. Two species, Black Drongo and Green Bee-eater, together accounted for 12 of the 28 visit-level detections in Phase 2 (42.9%), whereas nine taxa were recorded only once. Both dominant species are perch-hunting aerial insectivores that exploit field edges, fence lines and scattered trees, precisely the structures that agroforestry borders provide. Dominance by edge-tolerant generalists is a consistent feature of human-modified agricultural mosaics across India (Kumar & Sahu, 2020) and signals a landscape in which open-country habitat is abundant but structurally complex canopy habitat is limited.

KRA 3: Habitat association and the role of water bodies

Wetland-associated species constituted 40.6% of the checklist, a proportion that is high for a landscape sampled primarily in tree-crop plots. This reflects the density of farm ponds, borewell-fed channels and traditional tanks within the survey area, which act as small wetland patches embedded in cropland (Sundar & Kittur, 2013). Both Near Threatened species, and all eight wading piscivores, were associated with these features rather than with the tree component. In contrast, canopy-dependent species accounted for only 15.6% of the checklist, consistent with the young age and open structure of most planted agroforestry blocks.

KRA 4: Functional composition and ecosystem services

Insectivores dominated the assemblage (37.5%), with a further 25.0% comprising wading species that consume aquatic invertebrates and small vertebrates. The prominence of insectivorous species such as Black Drongo, Green Bee-eater, Indian Roller and the chats indicates a functional capacity for natural pest suppression in the crop matrix (Whelan, Wenny & Marquis, 2008; Şekercioğlu, 2012). The presence of two sunbird species and two frugivorous bulbuls, although few, indicates that pollination and seed-dispersal functions are present and may strengthen as planted trees mature and flower.

KRA 5: Conservation significance

The proportion of threatened or near-threatened species (6.2%) is modest but noteworthy for a working agricultural landscape. Painted Stork and Black-headed Ibis are both large colonial waterbirds whose global populations are declining owing to wetland loss and disturbance (IUCN, 2026). Their use of farm ponds in Kolar demonstrates that the conservation value of the project area extends beyond carbon stocks and that the water bodies retained within farms constitute a discrete, reportable co-benefit.

VI-INFERENCES FROM THE ANALYSIS

Four principal inferences follow from the analysis of the key result areas.

1. **Farmer-managed agroforestry in Kolar sustains a functional, if generalist-dominated, bird community.** The recorded assemblage is rich in insectivores and open-country species, consistent with the literature on tropical agroforests as species-rich but modified habitats (Harvey & González Villalobos, 2007; Bhagwat et al., 2008). The system delivers biodiversity co-benefits, but its value lies in supporting common species and ecosystem functions rather than forest specialists.
2. **Water bodies, not tree cover, currently confer the highest conservation value.** Both Near Threatened species and two-fifths of all species depend on farm ponds and irrigation features. Conservation planning within the project should therefore treat retained water bodies as habitat assets of equal standing with planted trees.

3. **Canopy-dependent species are under-represented, indicating scope for gain as plantations mature.** The low share of tree or orchard canopy species (15.6%) is consistent with young, open plantations. As Melia dubia, mango, jackfruit and coconut borders develop, an increase in canopy frugivores, nectarivores and cavity-nesters can reasonably be expected, providing a measurable trajectory for co-benefit reporting.
4. **The present data constitute a qualitative baseline, not a quantitative one.** Because the survey was opportunistic and individual counts were not recorded, the results cannot support abundance-based indices, statistical comparison between plot types, or detection of change over time. Establishing a standardised protocol is the necessary next step (Bibby et al., 2000).

6.1 Limitations

The findings should be interpreted with the following limitations in mind. Sampling effort was uneven between phases, was concentrated in February and did not cover the post-monsoon peak of migrant arrivals. Detection was biased towards conspicuous and vocal species, and habitat and guild assignments were made at a coarse level. One record (European Stonechat) awaits confirmation, and two photographic records (a stork in flight and a pigeon) could not be assigned with confidence and were excluded from the checklist. These limitations affect the completeness of the inventory but not the validity of the species confirmed.

VII-DISCUSSION

The species total obtained here is lower than that reported by dedicated surveys in similar Karnataka landscapes (Basavarajappa, 2006; Khan, Nautiyal & Venkatesha, 2019), a difference attributable primarily to survey design and duration rather than to an impoverished community (Kumar & Sahu, 2020). Nevertheless, the composition of the assemblage aligns closely with patterns described for Indian agricultural mosaics, in which insectivorous and omnivorous generalists predominate and waterbirds contribute substantially wherever water bodies persist (Hossain & Aditya, 2016; Kumar & Sahu, 2020).

The most significant management insight is the interaction between the wetland and agroforestry components of the landscape. The Near Threatened species were not using the tree-crop plots themselves but the ponds and channels adjacent to them. This finding echoes landscape-scale work in north India showing that agricultural wetlands maintained for irrigation can sustain large waterbird populations (Sundar & Kittur, 2013), and it implies that the biodiversity outcomes of the carbon project are contingent on farmers continuing to retain rather than fill or drain these features.

For the ARR project, the results provide an evidence base for claiming incidental biodiversity co-benefits and a starting point for the type of baseline documentation expected under co-benefit standards (Verra, 2017). Converting the present checklist into a quantitative monitoring dataset would require only modest additions to existing field routines, namely fixed-duration counts at a subset of plots, recording of individual numbers, and repetition across seasons.

VIII-CONCLUSIONS

1. **Agroforestry Supports Functional Avian Communities**: Farmer-managed agroforestry in Kolar sustains a functional bird community dominated by generalists and open-country species, consistent with tropical agroforest patterns documented in the literature.
2. **Water Bodies Drive Conservation Value More Than Tree Cover**: Both Near-Threatened species (Painted Stork and Black-headed Ibis) were associated with farm ponds and irrigation channels rather than tree-crop plots, indicating that retained water bodies materially enhance conservation value.
3. **Generalist and Open-Country Species Dominate the Assemblage**: Open farmland and scrub generalists comprised 43.8% of recorded species (14 species), reflecting a landscape where open-country habitat is abundant but structurally complex canopy habitat remains limited.
4. **Wetland-Associated Species Constitute 40.6% of Recorded Diversity**: Thirteen wetland or water-associated species were documented, a high proportion for a landscape sampled primarily in tree-crop plots, reflecting the density of farm ponds and traditional tanks within the survey area.
5. **Insectivores Form the Largest Feeding Guild at 37.5%**: Twelve insectivorous species were recorded, indicating functional capacity for natural pest suppression in the crop matrix and delivery of ecosystem services directly relevant to farmers.
6. **Two Near-Threatened Species Documented in Farm Landscapes**: The Painted Stork (Mycteria leucocephala) and Black-headed Ibis (Threskiornis melanocephalus), both categorised as Near Threatened on the IUCN Red List, were recorded, representing 6.2% of the confirmed species.
7. **Black Drongo and Green Bee-eater Are Most Frequently Detected**: Black Drongo (58.3% frequency of occurrence) and Green Bee-eater (41.7%) were the most commonly detected species during Phase 2 visits, both being perch-hunting aerial insectivores that exploit field edges and scattered trees .

8. **Canopy-Dependent Species Are Under-Represented at 15.6%**: Only five species (15.6%) were associated with tree or orchard canopy, consistent with the young age and open structure of most planted agroforestry blocks in the survey area .
9. **Current Data Provide Qualitative Baseline Only**: Because the survey employed an opportunistic (ad libitum) approach without individual counts, the results cannot support abundance-based indices, statistical comparison between plot types, or detection of change over time .
10. **Farmer-Managed Landscapes Deliver Incidental Biodiversity Co-Benefits**: The findings demonstrate that farmer-managed agroforestry delivers incidental biodiversity co-benefits, providing an evidence base for claiming such benefits within the ARR carbon project framework .
11. **Structural Heterogeneity Enhances Species Richness**: The high family-to-species ratio (22:32, or 0.69) indicates that most families were represented by a single species, characteristic of a short inventory capturing common and conspicuous members across diverse lineages .
12. **Young Plantations Limit Forest Specialist Presence**: The low representation of canopy-dependent species and absence of forest specialists reflects the early successional stage of planted agroforestry blocks, with scope for gains as plantations mature .

IX-RECOMMENDATIONS

1. **Integrate Standardised Bird Monitoring into MRV Framework:** Embed simple, repeatable bird surveys built on established census techniques into the project's Monitoring, Reporting and Verification framework to satisfy co-benefit documentation requirements at low cost.
2. **Prioritise Retention and Protection of Farm Ponds and Irrigation Channels:** Treat retained water bodies as habitat assets of equal standing with planted trees in conservation planning, as they currently confer the highest conservation value in the landscape.
3. **Develop Quantitative Baseline with Fixed-Duration Count Protocols:** Convert the present checklist into a quantitative monitoring dataset by adopting fixed-duration counts at a subset of plots, enabling statistical comparison and trend detection.
4. **Expand Survey Coverage Across Post-Monsoon Migrant Season:** Extend monitoring beyond the February–July window to cover the post-monsoon peak of migrant arrivals, improving inventory completeness and seasonal representation.
5. **Record Individual Counts to Enable Abundance-Based Indices:** Begin recording individual numbers during surveys to enable computation of abundance-based diversity indices such as the Shannon–Wiener index for robust ecological assessment.
6. **Establish Long-Term Monitoring to Track Canopy Maturation Effects:** Implement repeated surveys over time to document increases in canopy frugivores, nectarivores and cavity-nesters as planted trees (Melia dubia, mango, jackfruit, coconut) mature.
7. **Incorporate Water Bodies as Equal Habitat Assets in Conservation Planning:** Formally recognise farm ponds, borewell-fed channels and traditional tanks as discrete, reportable co-benefits in project documentation and biodiversity outcome reporting.
8. **Implement Repeated Seasonal Surveys for Trend Detection:** Conduct surveys across multiple seasons and years to detect changes in species composition, frequency of occurrence and feeding guild structure over the project lifecycle.
9. **Verify Uncertain Records Through Photographic Documentation:** Use photographic verification to resolve ambiguous records (e.g., European Stonechat) and improve taxonomic confidence in future monitoring rounds.
10. **Scale Monitoring to Representative Subset of Project Plots:** Extend standardised monitoring to a representative subset of all project plots to ensure findings are generalisable across the full ARR project area.
11. **Align Biodiversity Indicators with CCB Standards Requirements:** Ensure biodiversity monitoring design and reporting align with Climate, Community and Biodiversity (CCB) Standards administered by Verra to qualify for co-benefit labels.
12. **Document Ecosystem Services Provided by Insectivorous Guilds:** Quantify and report the pest-suppression, pollination and seed-dispersal services delivered by recorded bird assemblages to demonstrate tangible farmer benefits from biodiversity co-benefits

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XI-ETHICAL CONSIDERATIONS

This research uses publicly available secondary data with ethical adherence to proper citations and avoiding confidentiality breaches, and acknowledging the benefits arising from the positive application of AI tools when necessary

XII-LIST OF ACRONYMS

ARR	Afforestation, Reforestation and Revegetation
CCB	Climate, Community and Biodiversity (Standards)
FO	Frequency of Occurrence
IUCN	International Union for Conservation of Nature
KSNDMC	Karnataka State Natural Disaster Monitoring Centre
LC	Least Concern
MRV	Monitoring, Reporting and Verification
NT	Near Threatened
VCS	Verified Carbon Standard

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