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Avian community composition and feeding guilds in the agricultural area of Padangsidimpuan City, North Sumatra, Indonesia

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Abstract. *Siregar NH, Siregar RAD, Simbolon P. 2026. Avian community composition and feeding guilds in the agricultural area of Padangsidimpuan City, North Sumatra, Indonesia. Biodiversitas 27 (5): d270524. https://doi.org/10.13057/biodiv/d270524.* Agricultural expansion has altered tropical landscapes and may influence bird communities. This study aimed to examine bird community composition, feeding guild structure, and conservation implications in agricultural areas of Padangsidimpuan City, North Sumatra, Indonesia. Data were collected from August to September 2025 using point count surveys at three sites selected based on dominant agricultural land use and environmental variation, particularly elevation and vegetation differences. Each site included five observation points spaced 200 m apart, totaling 45 observation events with three repeated surveys per point. A total of 907 individual birds were recorded, representing 60 species from 30 families. The highest species richness and diversity were recorded in Aek Najaji (diversity index: 2.87; richness index: 6.30), followed by Bonan Dolok and Lubuk Raya. Differences among sites indicate variation in species composition and abundance despite similar land-use types. Nine feeding guilds were identified, with insectivores representing the highest number of species (17 species), followed by frugivore-insectivores (13 species). Higher diversity observed at sites with more heterogeneous vegetation and topography suggests a potential association between habitat complexity and bird communities, although habitat variables were not quantitatively analyzed. These findings indicate that agricultural landscapes may contribute to supporting bird diversity. Management practices such as maintaining mixed garden systems, preserving natural vegetation, and retaining riparian elements may support the persistence of bird communities in agricultural landscapes.

Keywords: Bird diversity, functional guild, mixed gardens, point count, Shannon-Wiener

INTRODUCTION

Indonesia is a megadiverse nation with an exceptionally high abundance of avian species. According to Avibase (2025), approximately 1,877 bird species are recorded, whereas Burung Indonesia (2025) documents 1,835 species. Birds perform essential ecological functions, including seed dispersal, pollination, pest regulation, scavenging, and contributions to nutrient cycling, thereby supporting ecosystem stability and resilience (Sekercioglu 2006; Maas et al. 2013; Katuwal et al. 2018; Hakim et al. 2020; Mariyappan et al. 2023; Lima et al. 2025). Beyond their extensive ecological roles, birds possess characteristics that make them a key faunal group in community ecology research. Their broad geographic distribution, relative ease of detection, diverse ecological niches, well-documented taxonomy, ecological specialization, and sensitivity to habitat alteration render them robust bioindicators for assessing environmental change, particularly in landscapes modified by human activities (Sekercioglu 2006; Pangestu et al. 2023; Lima et al. 2025).

In community ecology, feeding guild classification provides a functional framework for understanding how bird communities respond to habitat structure by grouping species according to similarities in food resources and foraging strategies (Root 1967; Azman et al. 2011; Sekercioglu 2012). Each guild contributes to distinct ecosystem functions that are critical for ecosystem stability and exhibits varying levels of sensitivity to land-use change. For example, insectivores regulate insect populations, frugivores facilitate seed dispersal, granivores contribute to seed dynamics, and nectarivores support pollination processes (Sekercioglu 2006; Panda et al. 2021; Mariyappan et al. 2023). Different feeding guilds show contrasting responses to habitat alteration. Insectivorous guilds particularly understory and ground-foraging species and specialist frugivores are generally more vulnerable to natural vegetation degradation and habitat fragmentation. In contrast, generalist guilds such as omnivores and some granivores tend to persist or even increase in abundance in structurally simplified and open agricultural environments (Sekercioglu et al. 2002; Watson 2015; Farwig et al. 2017; Duckworth and Altwegg 2021; Moore et al. 2023).

Agricultural expansion and intensification are among the primary drivers of global biodiversity change. The widespread conversion of forested areas into agricultural land has become a significant global issue, substantially affecting wildlife, including the dynamics of bird communities. Alterations in the composition and functional structure of bird communities arise from changes in vegetation structure, reduced habitat heterogeneity, shifts in food availability, loss of shelter resources, and modified predator dynamics (Tscharntke et al. 2005; Sekercioglu 2006; Azman et al. 2011; Bain et al. 2020; Rabbetts et al. 2023). In tropical regions, including parts of Southeast Asia, agricultural systems are increasingly dominated by large-scale monocultures characterized by simplified vegetation stratification, conditions that may disproportionately affect functionally specialized bird guilds. Although research on land-use change and bird communities continues to expand, studies explicitly linking feeding guild structure to agricultural landscape characteristics at the local scale in Sumatra remain limited (Azman et al. 2011; Kremen and Merenlender 2018; Bain et al. 2020; Giese et al. 2024).

This knowledge gap is evident in Padangsidimpuan City, North Sumatra, Indonesia, where the agricultural sector dominates the landscape and constitutes a major component of the regional economy (Pasaribu 2015). Previous studies in this area have primarily focused on bird species inventories (Siregar and Siregar 2019), without examining community structure or the composition of feeding guilds within agricultural landscapes. Accordingly, this study aims to (i) analyze bird community composition, (ii) examine feeding groups based on primary food resources and foraging strategies, and (iii) assess the conservation implications for the management of agricultural areas in Padangsidimpuan City. We hypothesize that sites with higher vegetation heterogeneity and the presence of riparian elements will support greater species diversity.

MATERIALS AND METHODS

Study area

This study was conducted in the agricultural area of Padangsidimpuan City, North Sumatra Province, Indonesia (01°18'07"-01°28'19"S, 99°18'53"-99°20'35"E). Field surveys were conducted at three agricultural sites: Padangsidimpuan Hutaimbaru Subdistrict (Lubuk Raya Urban Village), North Padangsidimpuan Subdistrict (Bonan Dolok Urban Village), and Padangsidimpuan Batunadua Subdistrict (Aek Najaji Village) (Figure 1). The city encompasses approximately 159.28 km² and exhibits heterogeneous topography, with elevations ranging from 260 to 1,100 m above sea level. This elevational variation contributes to landscape heterogeneity and may influence vegetation structure and bird community composition. The selection of these sites was based on the predominance of agricultural land use and the presence of environmental variation, particularly differences in elevation and vegetation types within Padangsidimpuan City.

Habitat description

The first location is in the Lubuk Raya of Padangsidimpuan Hutaimbaru District. The site is close to Mount Lubuk Raya (1,862 m asl), which is an inactive volcano in the Dolok Lubuk Raya Nature Reserve in South Tapanuli Regency. The second location is in the Bonan Dolok of North Padangsidimpuan District. The third site is in Aek Najaji, Padangsidimpuan Batunadua District, from a topographic perspective, a small river runs through the study area, and there are plants of all sizes along its banks (Table 1 and Figure 2). All three research sites are mixed gardens characterized by the presence of various types of woody plants, fruit trees, and understory vegetation at varying densities.

Table 1. Environmental attributes of the study sites

Site	Altitude (m asl)	Dominant crops	River
Lubuk Raya	690	*Salacca sumatrana*, *Persea* sp., *Hevea brasiliensis*, *Zea mays*, *Azadirachta* sp., vegetables	-
Bonan Dolok	352	*Salacca sumatrana*, *Hevea brasiliensis*, *Durio zibethinus*, *Arenga pinnata*, *Mangifera* sp., *Elaeis guineensis*	-
Aek Najaji	400	*Hevea brasiliensis*, *Aleurites moluccanus*, *Citrullus lanatus*, *Mangifera* sp., *Durio zibethinus*, vegetables	✓

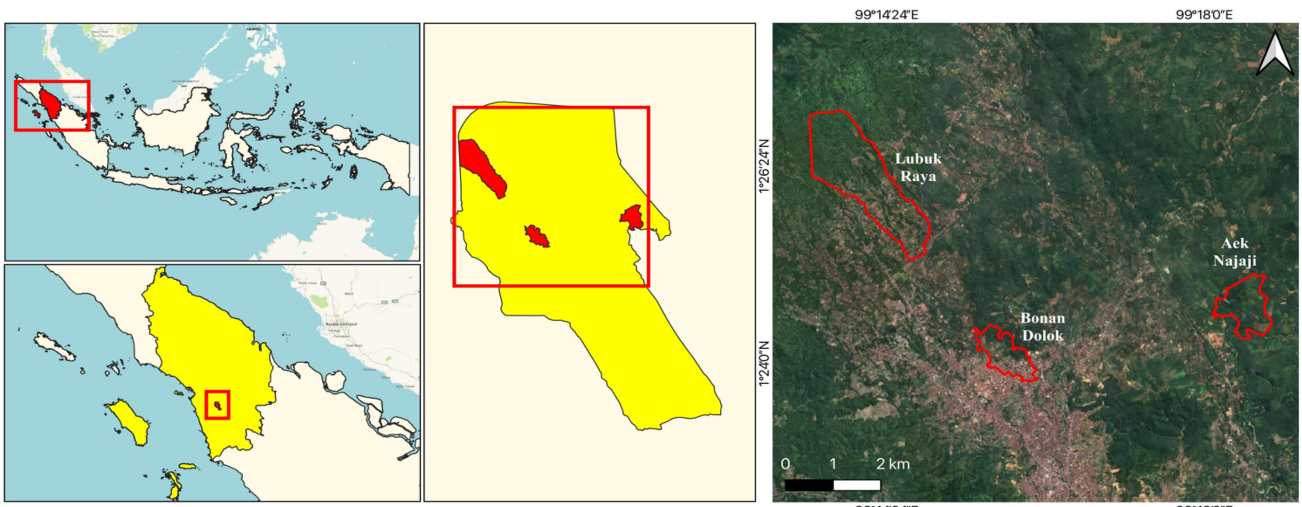

Figure 1. Map of the agricultural study area in Padangsidimpuan City, North Sumatra, Indonesia

Figure 2. Habitat conditions in agricultural areas. A. Lubuk Raya, B. Bonan Dolok, C. Aek Najaji

Table 2. The definition of feeding guild

Feeding guilds	Abbreviations	Food source
Carnivore	CAR	Large arthropods and vertebrate prey
Frugivore	FRU	Fleshy fruits
Granivore	GRA	Grain, seeds, and nuts
Omnivore	OMN	Plant (grain, seed, leaf, stem, root) and animal (insect, mollusk, fish, etc.)
Insectivore	INS	Small arthropods
Carnivore-Insectivore	CAR-INS	Primarily small mammals, birds and fish feeders but shift to insects when the formers are scarce
Nectarivore-Insectivore	NEC-INS	Feed primarily on nectar but shift to insects when nectar is low
Frugivore-Insectivore	FRU-INS	Primarily fruit feeders but shift to insects when fruits are scarce
Granivore-Frugivore	GRA-FRU	Feed primarily on grains or seed but shift to fruit when grains are low

Data collection

Bird surveys were conducted from August to September 2025 using the point count method in three villages located in different subdistricts. Observations were carried out during peak bird activity periods, namely in the morning (06:00-10:00 AM) and late afternoon (04:00-05:30 PM). Surveys were not conducted under adverse weather conditions, such as rain or strong winds, to ensure observer safety and maintain detection reliability. The field team consisted of three members: one primary observer and two assistants. All species detections and identifications were performed by the same observer to minimize inter-observer bias, while the assistants were responsible for data recording and logistical support. At each study site, five fixed observation points were established, with a minimum distance of approximately 200 m between points to reduce the likelihood of double counting individuals. Each point was surveyed three times on different days. Both morning and afternoon sessions were conducted at each point during each survey round, resulting in a total of 45 sampling events. Prior to each count, a 5-minute settling period was allowed to minimize disturbance effects following the observer's arrival. This was followed by a 15-minute observation period. During each session, all bird species seen or heard within a 50 m radius of the observation point were recorded. Individuals detected beyond the 50 m radius were excluded from the analysis (Fontúrbela et al. 2020; Nugroho et al. 2021; Neupane et al. 2022; Nugroho et al. 2023). The 50 m radius was applied to reduce bias associated with decreasing detection probability as distance from the observer increases (Suhonen et al. 2022). Nevertheless, detectability remains an inherent limitation of this study, particularly at greater distances and in habitats with dense vegetation. Furthermore, as the surveys were conducted exclusively during the dry season (August-September 2025), the findings were not generalized to bird communities during the rainy season. Flyover individuals were excluded from the counts, as they were assumed not to be using the habitat surrounding the observation point (Ong'ondo et al. 2022). Bird observations were conducted using Nikon Prostaff P3 8×42 binoculars, a Nikon Coolpix P1100 camera for photographic documentation, and a digital audio recorder to capture bird vocalizations. Species identification followed Eaton et al. (2021), Birds of the Indonesian Archipelago: Greater Sunda and Wallacea, and nomenclature adhered to the Bird Species List of Indonesia (Burung Indonesia 2025).

Data analysis

Species diversity was assessed using three complementary metrics: (i) the Shannon-Wiener diversity index (H’) to quantify overall species diversity within the community; (ii) the Margalef richness index (DMg) to estimate species richness; and (iii) Pielou’s evenness index (J’) to evaluate the relative distribution of individuals among species. The evenness index reflects the extent to which individuals are proportionally distributed across species within a community (Magurran 2004). A one-way analysis of variance (ANOVA) was performed to evaluate differences in the Shannon-Wiener diversity index (H′) among the three study sites. The analysis was based on H′ values calculated at each individual sampling point (five sampling points per site), rather than on diversity values aggregated at the site level. All statistical analyzes were conducted using PAST software version 4.03. When significant differences were detected, post hoc comparisons were performed using Tukey's Honestly Significant Difference (HSD) test.

The threat classification of avian species adheres to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (https://www.iucnredlist.org/en). The assessment of avian conservation status in Indonesia adheres to the Regulation of the Minister of Environment and Forestry No. P.106/MENLHK/SETJEN/KUM.1/12/2018. The classification of bird feeding guilds was conducted to examine functional variation among avian groups. In this study, feeding guild analysis was performed descriptively by grouping bird species according to their primary food resources and foraging strategies. Bird feeding guilds are categorized as: Table 2 (Katuwal et al. 2018; Tyan 2020; Panda et al. 2021; Mokhter et al. 2022; Nugroho et al. 2023; Shafie et al. 2023).

RESULTS AND DISCUSSION

Avian community composition in agricultural area

A total of 907 individual birds were recorded across the three study sites, consisting of 60 species from 30 families (Table 3). Aek Najaji exhibited the highest species richness (38 species, 20 families), followed by Bonan Dolok (34 species, 20 families), while Lubuk Raya showed the lowest richness (28 species, 16 families). These findings indicate differences in taxonomic representation among sites, despite their relatively similar land-use contexts. The families Megalaimidae and Nectariniidae accounted for the highest number of species (five species each), followed by Cisticolidae, Columbidae, and Muscicapidae (four species each). In contrast, the remaining sixteen families were each represented by a single species (Figure 3).

Based on individual abundance, the most dominant species were *Pycnonotus goiavier* (142 individuals), *Passer montanus* (141 individuals), *Hirundo javanica* (76 individuals), *Lonchura punctulata* (65 individuals), and *Geopelia striata* (46 individuals). In contrast, fifteen species were each represented by a single individual, namely *Spilornis cheela*, *Chloropsis venusta*, *Chalcophaps indica*, *Cacomantis merulinus*, *Hemiprocne longipennis*, *Psilopogon australis*, *Caloramphus hayii*, *Muscicapa dauurica*, *Cyornis umbratilis*, *Niltava grandis*, *Ficedula westermanni*, *Synoicus chinensis*, *Chrysophlegma miniaceum*, *Amaurornis phoenicurus*, and *Turnix suscitator*.

Bird species diversity across the three study sites showed variation, with the Shannon-Wiener diversity index ranging from 2.69 to 2.87 (Table 4). The highest diversity index value was recorded in Aek Najaji, followed by Bonan Dolok and the lowest in Lubuk Raya. A similar pattern was observed for species richness, with the highest value in Aek Najaji, followed by Bonan Dolok, and the lowest in Lubuk Raya. Species evenness was comparable across the three sites, indicating a similar distribution of individuals among species. The highest individual abundances were recorded for *P. goiavier*, *P. montanus*, and *H. javanica*. Differences in diversity, species richness, and evenness indices among sites indicate variation in species composition and the distribution of individuals across the three study locations.

Statistical analyzes were conducted on the Shannon-Wiener diversity index (H′) values calculated at each sampling point across the three study sites, with five sampling points per site and three replications. Prior to comparative analysis, assumptions of normality and homogeneity of variances were evaluated. The Shapiro-Wilk test indicated that H′ values in Lubuk Raya (W: 0.854, p: 0.209), Bonan Dolok (W: 0.962, p: 0.825), and Aek Najaji (W: 0.845, p: 0.179) were normally distributed ($p>0.05$). These results were consistent with the Anderson-Darling, Lilliefors, and Jarque-Bera tests, all of which yielded non-significant results ($p>0.05$), confirming that the normality assumption was satisfied. Homogeneity of variances was assessed using Levene's test, which indicated no significant differences in variance among sites, both when based on the mean (p: 0.210) and the median (p: 0.411), as all p-values exceeded 0.05. Given that both assumptions were met, a one-way analysis of variance (ANOVA) was subsequently performed.

A one-way ANOVA revealed a significant difference in Shannon-Wiener diversity index (H′) among sites ($F(2,12)$: 25.22, $p<0.001$). The effect size was large (ω^2: 0.763), indicating that approximately 76% of the variance was explained by site differences. Tukey's HSD test showed that Aek Najaji differed from Lubuk Raya (Q: 9.891, $p<0.001$) and Bonan Dolok (Q: 6.461, p: 0.002), whereas no significant difference was detected between Lubuk Raya and Bonan Dolok (Q: 3.43, p: 0.076). This pattern reflects higher diversity index values in Aek Najaji.

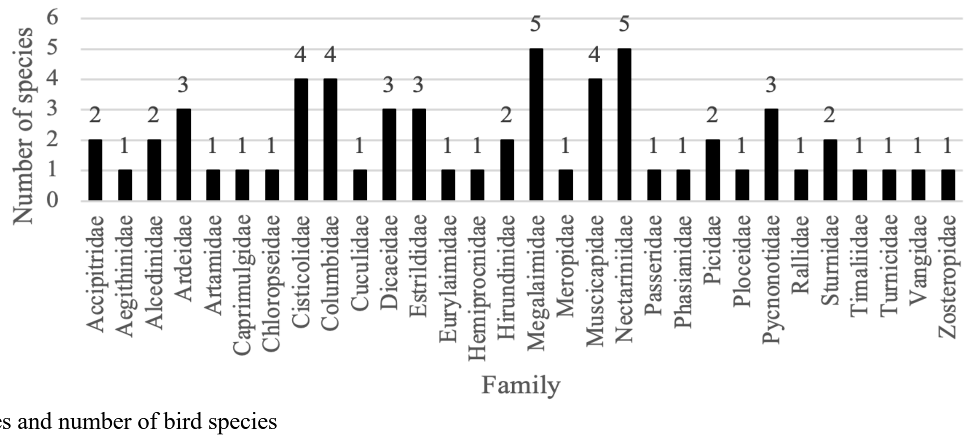

Figure 3. Families and number of bird species

Table 3. List of observed birds, feeding guild and status

Scientific name	Common name	Location	Feeding guild	Status		
				IUCN	Protection	CITES
Accipitridae						
Spilornis cheela	Crested serpent-eagle	AN	CAR	LC	P	II
Ictinaetus malaiensis	Black eagle	LR	CAR	LC	P	II
Aegithinidae						
Aegithina tiphia	Common iora	LR, BD, AN	INS	LC	NP	NL
Alcedinidae						
Halcyon smyrnensis	White-breasted kingfisher	LR, BD	CAR-INS	LC	NP	NL
Todiramphus chloris	Collared kingfisher	LR, BD, AN	CAR-INS	LC	NP	NL
Ardeidae						
Ardea alba	Great white egret	AN	CAR	LC	P	NL
Bubulcus ibis	Cattle egret	AN	CAR	LC	NP	NL
Egretta garzetta	Little egret	BD, AN	CAR	LC	NP	NL
Artamidae						
Artamus leucoryn	White-breasted woodswallow	BD	INS	LC	NP	NL
Caprimulgidae						
Caprimulgus affinis	Savanna nightjar	BD	INS	LC	NP	NL
Chloropseidae						
Chloropsis venusta	Blue-masked leafbird	LR	FRU-INS	NT	P	NL
Cisticolidae						
Orthotomus atrogularis	Dark-necked tailorbird	BD, AN	INS	LC	NP	NL
Orthotomus ruficeps	Ashy tailorbird	LR, BD, AN	INS	LC	NP	NL
Prinia familiaris	Bar-winged prinia	AN	INS	NT	NP	NL
Prinia flaviventris	Yellow-bellied prinia	LR, AN	INS	LC	NP	NL
Columbidae						
Spilopelia chinensis	Eastern spotted dove	LR, BD, AN	GRA-FRU	LC	NP	NL
Geopelia striata	Zebra dove	LR, BD, AN	GRA	LC	NP	NL
Chalcophaps indica	Grey-capped emerald dove	BD	GRA-FRU	LC	NP	NL
Treron vernans	Pink-necked green-pigeon	BD, AN	FRU	LC	NP	NL
Cuculidae						
Cacomantis merulinus	Plaintive cuckoo	BD	FRU-INS	LC	NP	NL
Dicaeidae						
Dicaeum trigonostigma	Orange-bellied flowerpecker	LR, BD, AN	FRU-INS	LC	NP	NL
Dicaeum minullum	Plain flowerpecker	LR, BD, AN	FRU-INS	LC	NP	NL
Dicaeum cruentatum	Scarlet-backed flowerpecker	LR, BD, AN	FRU-INS	LC	NP	NL
Estrildidae						
Lonchura punctulata	Scaly-breasted munia	LR, BD, AN	GRA	LC	NP	NL
Lonchura striata	White-rumped munia	BD	GRA	LC	NP	NL
Lonchura maja	White-headed munia	LR, BD, AN	GRA	LC	NP	NL
Eurylaimidae						
Cymbirhynchus macrorhynchos	Black-and-red broadbill	AN	CAR-INS	LC	NP	NL
Hemiprocnidae						
Hemiprocne longipennis	Grey-rumped treeswift	BD	INS	LC	NP	NL
Hirundinidae						
Hirundo rustica	Barn swallow	BD, AN	INS	LC	NP	NL
Hirundo javanica	House swallow	LR, BD, AN	INS	LC	NP	NL
Megalaimidae						
Psilopogon haemacephalus	Coppersmith barbet	LR, AN	FRU-INS	LC	NP	NL
Psilopogon australis	Yellow-eared barbet	AN	FRU-INS	LC	NP	NL
Psilopogon mystacophanos	Red-throated barbet	LR	FRU-INS	NT	P	NL
Psilopogon oorti	Black-browed barbet	LR	FRU-INS	LC	P	NL
Caloramphus hayii	Malay Brown barbet	AN	FRU	NT	P	NL
Meropidae						
Merops viridis	Blue-throated bee-eater	BD, AN	INS	LC	NP	NL
Muscicapidae						
Muscicapa dauurica	Asian Brown flycatcher	LR	INS	LC	NP	NL
Cyornis umbratilis	Grey-chested jungle-flycatcher	LR	INS	NT	NP	NL
Niltava grandis	Large niltava	LR	FRU-INS	LC	NP	NL
Ficedula westermanni	Little pied flycatcher	LR	INS	LC	NP	NL
Nectariniidae						
Cinnyris jugularis	Olive-backed sunbird	BD, AN	NEC-INS	LC	NP	NL
Leptocoma brasiliana	Maroon-bellied sunbird	LR, BD, AN	NEC-INS	LC	NP	NL
Anthreptes simplex	Plain sunbird	AN	NEC-INS	LC	NP	NL

Anthreptes malacensis	Brown-throated sunbird	BD	NEC-INS	LC	NP	NL
Aethopyga siparaja	Crimson sunbird	LR, AN	NEC-INS	LC	P	NL
Passeridae						
Passer montanus	Eurasian tree sparrow	BD, AN	GRA	LC	NP	NL
Phasianidae						
Synoicus chinensis	Blue-breasted quail	LR	OMN	LC	NP	NL
Picidae						
Dinopium javanense	Common flameback	LR, BD	INS	LC	NP	NL
Chrysophlegma miniaceum	Banded woodpecker	BD	INS	LC	NP	NL
Ploceidae						
Ploceus philippinus	Baya weaver	AN	GRA	LC	NP	NL
Pycnonotidae						
Pycnonotus aurigaster	Sooty-headed bulbul	LR, BD, AN	FRU-INS	LC	NP	NL
Pycnonotus goiavier	Yellow-vented Bulbul	LR, BD, AN	FRU-INS	LC	NP	NL
Pycnonotus simplex	Cream-vented bulbul	AN	FRU	LC	NP	NL
Rallidae						
Amaurornis phoenicurus	White-breasted waterhen	AN	OMN	LC	NP	NL
Sturnidae						
Aplonis panayensis	Asian glossy starling	BD	OMN	LC	NP	NL
Acridotheres javanicus	Javan myna	AN	OMN	VU	NP	NL
Timaliidae						
Mixornis gularis	Pin-striped tit-babbler	BD	FRU-INS	LC	NP	NL
Turnicidae						
Turnix suscitator	Barred buttonquail	BD	OMN	LC	NP	NL
Vangidae						
Hemipus hirundinaceus	Black-winged flycatcher-shrike	AN	INS	LC	NP	NL
Zosteropidae						
Zosterops melanurus	Sangkar white-eye	AN	OMN	VU	NP	NL

Note: Location: LR: Lubuk Raya, BD: Bonan Dolok, AN: Aek Najaji. Feeding Guild: Carnivore: CAR, Frugivore: FRU, Granivore: GRA, Omnivore: OMN, Insectivore: INS, CAR-INS: Carnivore-Insectivore, NEC-INS: Nectarivore-Insectivore, FRU-INS: Frugivore-Insectivore, GRA-FRU: Granivore-Frugivore; Current condition: IUCN: IUCN Red List at https://www.iucnredlist.org/en. LC: Least Concern; NT: Near Threatened; VU: Vulnerable; Protection: Status pertains to PERMEN LHK No. P.106/MENLHK/SETJEN/KUM.1/12/2018; P: Protected, NP: Not Protected; CITES; II: Appendix II; NL: Not Listed

Table 4. Diversity indices of bird species

Parameters	Lubuk Raya	Bonan Dolok	Aek Najaji
Number of individuals	223	328	356
Number of species	28	34	38
Diversity index	2.69	2.72	2.87
Richness index	5.18	5.70	6.30
Evenness index	0.80	0.77	0.79

Feeding guild

A total of nine bird feeding guilds were identified in Padangsidimpuan City, each consisting of a different number of species. The guilds included carnivore, omnivore, frugivore, granivore, insectivore, carnivore-insectivore, nectarivore-insectivore, frugivore-insectivore, and granivore-frugivore. Based on species richness, the most represented guilds were insectivores (28%), followed by frugivores-insectivores (22%), and both granivores and omnivores (10% each) (Figure 5). The least represented guild was granivores-frugivores (3%). These results indicate that insectivores and frugivores-insectivores guilds had the highest species representation within the observed bird community.

Based on individual abundance and relative proportion, granivores constituted the most abundant feeding guild (301 individuals; 33.19%), followed by frugivores-insectivores (246 individuals; 27.12%) and insectivores (165 individuals; 18.19%). The remaining guilds were represented at lower abundances, including omnivores (53 individuals; 5.84%), granivore-frugivores (40 individuals; 4.41%), carnivores (39 individuals; 4.30%), nectarivores-insectivores (38 individuals; 4.19%), carnivore-insectivores (16 individuals; 1.76%), and frugivores (9 individuals; 0.99%). This pattern contrasts with that observed for species richness, where insectivores constituted the most species-rich guild, followed by frugivore-insectivores, as well as granivores and omnivores, whereas granivore-frugivores were the least represented. This discrepancy highlights that species richness does not necessarily correspond to patterns of individual abundance within the community.

All varieties of feeding guilds were identified in Bonan Dolok and Aek Najaji; however, only eight feeding guilds were observed in Lubuk Raya. The sole feeding guild absent in Lubuk Raya was frugivore. In Lubuk Raya, the most dominant feeding guilds were insectivores (10 species out of 28) and frugivore-insectivores (9 species out of 28). Meanwhile, the feeding guilds with the fewest numbers were carnivore, omnivore, and granivore-frugivore, each consisting of only one species. In Bonan Dolok, the most dominant feeding guilds were insectivores (11 species out of 34 species) and frugivore-insectivores (7 species out of 34 species), and the lowest feeding guilds were carnivore and frugivore, each consisting of only one species. In Aek Najaji, the most dominant feeding guilds were insectivores

(9 species out of 38 species) and frugivore-insectivores (7 species out of 38 species), while the lowest feeding guild was granivore-frugivore, with only one species found (Figure 6).

Bird conservation status

According to the Regulation of the Minister of Environment and Forestry No. P.106/MENLHK/SETJEN/KUM.1/12/2018, eight species recorded in this study are legally protected (Table 3): *S. cheela*, *Ictinaetus malaiensis*, *Ardea alba*, *C. venusta*, *Psilopogon mystacophanos*, *Psilopogon oorti*, *C. hayii*, and *Aethopyga siparaja* (Figure 4). Three of these species belong to the family Megalaimidae and two to the family Accipitridae. Based on the IUCN Red List categories, 53 species were classified as Least Concern (LC), five species as Near Threatened (NT), and two species as Vulnerable (VU) (Table 3). Species categorized as Near Threatened include *C. venusta*, *Prinia familiaris*, *P. mystacophanos*, *C. hayii*, and *C. umbratilis*. The two Vulnerable species recorded were *Acridotheres javanicus* and *Zosterops melanurus*. In addition to their national protection status, *S. cheela* and *I. malaiensis* are listed under Appendix II of CITES (Table 3).

Discussion

Avian community composition in agricultural area

The findings of this study indicate that bird species diversity and richness were higher in habitats with more heterogeneous vegetation and topography, particularly in Aek Najaji, in line with the initial hypothesis. These results are in agreement with Nugroho et al. (2023), who reported that species richness and diversity tend to increase with more advanced stages of vegetation succession. Similarly, Hološková et al. (2025) and Zellweger-Fischer et al. (2018) demonstrated that bird species richness is positively associated with increasing vegetation complexity and landscape heterogeneity. From a theoretical perspective, variation in landscape elements at broader spatial scales reflects greater ecological space, which facilitates niche differentiation and promotes species coexistence (Stein et al. 2014). In the present study, the higher diversity observed in Aek Najaji is likely associated with its more heterogeneous habitat structure, including mixed agroforestry systems, semi-natural vegetation, a small river, and rice fields. However, this interpretation should be considered as an inference based on observed habitat conditions, as habitat variables were not quantitatively analyzed.

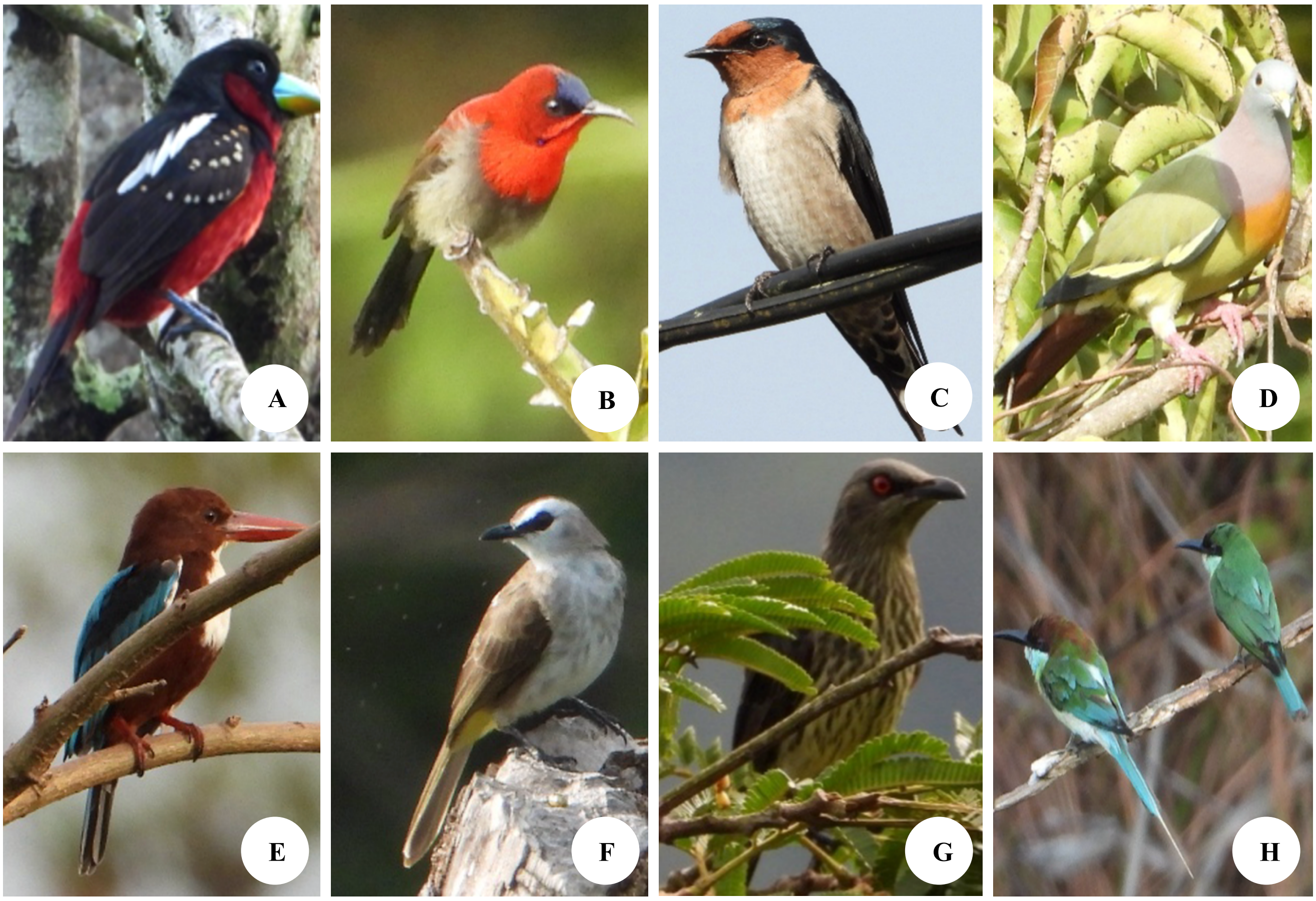

Figure 4. Various avian species. A. *Cymbirhynchus macrorhynchos*, B. *Aethopyga siparaja*, C. *Hirundo javanica*, D. *Treron vernans*, E. *Halcyon smyrnensis*, F. *Pycnonotus goiavier*, G. *Aplonis panayensis*, H. *Merops viridis* (Image by NH Siregar 2025)

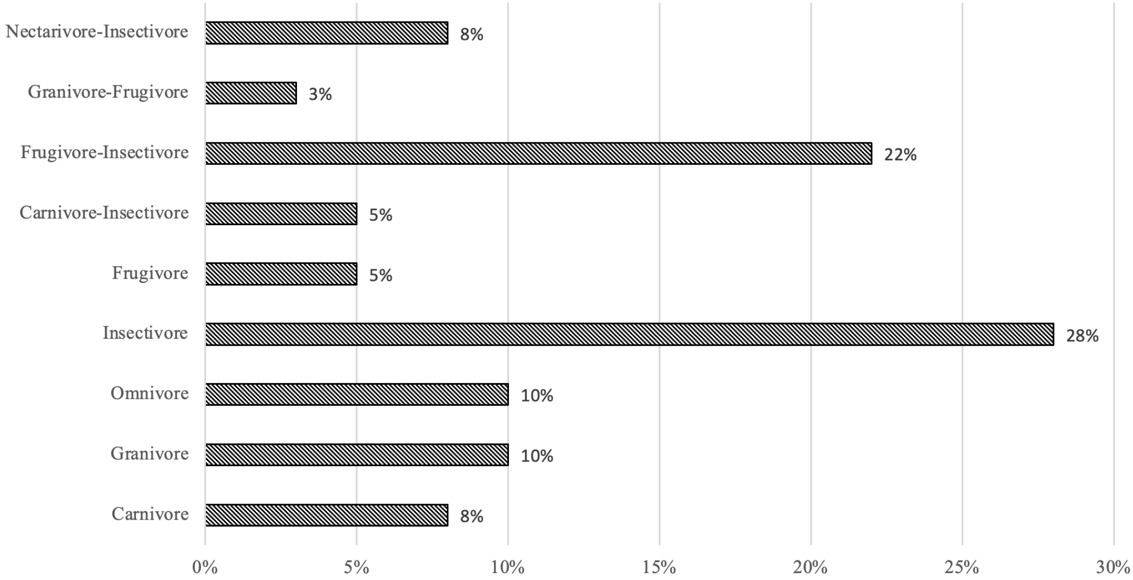

Figure 5. Avian feeding guild composition based on species richness in the agricultural area of Padangsidimpuan City, North Sumatra, Indonesia

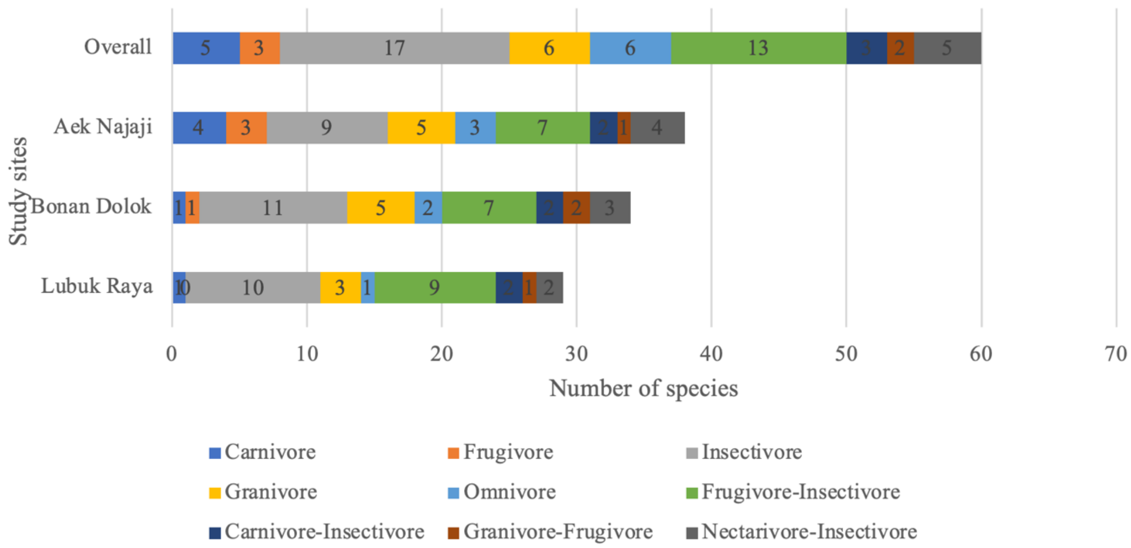

Figure 6. Distribution of bird species based on feeding guilds across study sites

The present study recorded a higher number of bird species compared to Siregar and Siregar (2019), who documented 44 species from 24 families in Padangsidimpuan City. This difference may not solely reflect ecological variation, but could also be influenced by differences in site coverage, sampling methods, sampling effort, and the timing of data collection. The number of species recorded in this study is also higher than that reported by Mulyani et al. (2025), who documented 30 species from 17 families in agricultural areas of South Tapanuli and Mandailing Natal Regencies, North Sumatra Province.

P. goiavier recorded the highest abundance, followed closely by *P. montanus* and *H. javanica*. Despite its high overall abundance, *P. montanus* was absent from Lubuk Raya and was recorded only in Bonan Dolok and Aek Najaji. This distribution pattern suggests habitat-specific preferences or varying levels of adaptability across sites. Similiar with the present findings, Hakim et al. (2020) identified *P. montanus* as the dominant species in mixed gardens, home gardens, and catch-crop systems. Similarly, Robles et al. (2022) reported that *P. montanus* is capable of persisting in fragmented urban landscapes characterized by significant anthropogenic disturbance, demonstrating a high tolerance to human presence.

Withaningsih et al. (2025) emphasize the role of mixed gardens and rice fields as anthropogenically modified habitats that remain critical for avian conservation, as they provide both foraging resources and nesting sites for a wide range of species. Similarly, Das et al. (2025) demonstrated that intercropping systems integrating rice and fruit crops, together with crop rotation practices, support higher levels of bird diversity and species richness compared to fallow land. Collectively, these findings indicate that agricultural landscapes can sustain avian diversity, particularly feed guild structure, when managed through appropriate practices such as intercropping, crop rotation, the maintenance of fallow areas, and the prevention of conversion to residential land use.

Farmers have the potential to increase bird species richness and abundance, even within relatively small farms in intensive agricultural landscapes. However, improvements at the landscape scale require farmers' awareness of the impacts of their management practices, as well as coordinated, collaborative actions across farms (Zellweger-Fischer et al. 2018). This is particularly important given the significant role of birds in supporting sustainable agriculture. Their ecological functions include pest regulation through insect consumption, pollination (e.g., by members of the Nectariniidae family), seed dispersal, and broader contributions to ecosystem processes. As a result, the presence of birds can support crop protection, improve soil fertility through nutrient inputs, reduce reliance on pesticides via biological control, and help maintain biodiversity and ecological balance in agricultural landscapes (Kasar 2025; Withaningsih et al. 2025).

Feeding guilds

The elevated feeding guild of insectivores aligns with the studies undertaken by Nugroho et al. (2023). Research on the tropical urban landscape of Bogor revealed that insectivores constituted the predominant feeding guild across all habitats, including woods, plantations, urban areas, and agricultural land. This aligns with the findings of Pangestu et al. (2023), who researched the tropical peatland of the Orang Kayo Hitam Forest Park buffer area in Jambi, discovering that 10 out of 29 bird species are insectivorous. According to the study by Fathani et al. (2025) conducted in the Wetlands of Muara Gembong, Indonesia, 16 out of 54 bird species identified are insectivorous. The quantity of feeding guilds among insectivores is significantly higher. Similarly with the findings of Azman et al. (2011), Katuwal et al. (2018), Panda et al. (2021), Sidhu et al. (2022), Shafie et al. (2023), Aycart-Lazo et al. (2025), and Mulyani et al. (2025).

The prevalence of insectivores indicates a substantial supply of insects in the research area. Vegetation structure significantly influences the richness of insectivorous bird species more than other factors (Nugroho et al. 2023; Aycart-Lazo et al. 2025). Insectivorous avian species are associated with the regulation of pest populations in agricultural areas (Sidhu et al. 2022; Nugroho et al. 2023; Otieno and Mukasi 2023; Aycart-Lazo et al. 2025; Withaningsih et al. 2025). Enhancing the function of birds as natural predators is an efficient ecological strategy that can diminish the need for pesticides in agricultural areas. Consequently, the existence of birds is crucial for regulating pest populations in agricultural settings (Pangestu et al. 2023; Withaningsih et al. 2025).

The secondary predominant feeding guild is frugivore-insectivores, applicable to all three research sites. The Megalaimiade family predominantly constitutes this feeding guild, primarily subsisting on fruit and, during the nesting season, insects. Frugivorous birds can employ insects as a supplementary food source, hence enhancing their reproductive success across diverse habitats (Nugroho et al. 2023). The third predominant feeding guild comprises granivores and omnivores, with granivorous and omnivorous avians exhibiting greater tolerance to human activity. Both groups are frequently located in residential areas or acquire sustenance directly from humans. Consequently, their distribution patterns are predominantly affected by food availability rather than seasonal fluctuations (Katuwal et al. 2018).

All nectarivore-insectivores species belong to the Nectariniidae family, which comprises five species: *C. jugularis*, *Leptocoma brasiliana*, *A. simplex*, *A. malacensis*, and *A. siparaja*. Nectarivores have a crucial role in ecosystems as pollinators, hence enhancing the resilience of degraded ecosystems through the augmentation of seed production facilitated by birds (Pauw and Louw 2012). The carnivorous group comprises five species of the Accipitridae and Ardeidae families. As raptors, members of the Accipitridae family play a crucial role in the ecosystem as apex predators and scavengers, hence regulating the population of their prey. Raptors have a crucial role in regulating the populations of rodents, pests, and scavengers, so they aid in disease control, maintain biodiversity, and preserve ecological balance (Donázar et al. 2016).

Within the frugivore category, only three species were identified, and no frugivores were detected in Lubuk Raya. The scarcity of fruit-eating avifauna is attributable to the deficiency of fruit-bearing trees in anthropogenic environments (Katuwal et al. 2018). The presence of frugivores in an environment is crucial for seed distribution, as they function as seed dispersers. Within the carnivore-insectivore category, merely three species were identified, and the granivore-frugivore category contained only two species: *S. chinensis* and *C. indica* from the Columbidae family. Granivore-frugivores ingest a combination of seeds, succulent fruits, and nuts (Nugroho et al. 2023).

Bird conservation status

The classification of bird species conservation status is referred to both national and international standards. The national standard complied to the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.106/MENLHK/SETJEN/KUM.1/12/2018, while the international standards were derived from the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The safeguarding of flora and fauna species in Indonesia, as required by the Regulation of the Minister of Environment and Forestry No. P.106/MENLHK/

SETJEN/KUM.1/12/2018, is expected to significantly enhance bird conservation through precise species identification. This research found eight protected species in accordance with the Regulation of the Minister of Environment and Forestry No. P.106 of 2018. The conservation of these eight species is necessitated by their diminishing populations resulting from various threats. Threats to numerous avian species encompass illegal hunting, illegal trading, and hobbyist bird keeping (Nugroho et al. 2023). The demand from the songbird and decorative bird trade persists in fueling hunting and trapping (Hadinoto et al. 2025).

According to the IUCN Red List of Threatened Species, the majority of bird species are classified as Least Concern, indicating that they are generally widespread, numerous, and present a low risk of immediate extinction. Five species are classified as Near Threatened, indicating the species are at significant risk of becoming endangered (Vulnerable, Endangered, or Critically Endangered) in the near future. Two bird species are classified as Vulnerable, signifying a heightened danger of extinction in their natural habitats in the future. This study conducted bird identification in accordance with CITES, identifying two species classified as Appendix II, indicating they are not currently endangered but may become so if trade remains unregulated. Both species are protected under the Regulation of the Minister of Environment and Forestry Number P.106 / MENLHK / SETJEN / KUM.1 / 12/2018.

The findings of this study indicate that agricultural areas in Padangsidimpuan City support relatively high avian diversity, including the presence of several protected species as well as endemic species categorized as Near Threatened and Vulnerable. These results suggest that agricultural areas may function as important habitats for bird communities within human-modified landscapes. In this context, conservation efforts are likely to play a key role in maintaining avian diversity and associated ecosystem functions under ongoing environmental pressures. Our recommendations for conservation implications are as follows. First, maintaining mixed garden systems while limiting the expansion of monoculture practices may help preserve vegetation heterogeneity, which is associated with higher bird diversity. Second, the expansion of green open spaces and the maintenance of natural vegetation along habitat boundaries may support avian communities. In addition, the restoration of vegetation in degraded riparian zones could contribute to improving habitat quality and enhancing landscape connectivity for birds. The planting of fruiting and flowering trees may also provide additional food resources, such as fruits, nectar, and associated insects, thereby supporting a wider range of avian feeding guilds. Third, strengthening law enforcement related to the capture and trade of birds, particularly protected species, may help reduce anthropogenic pressures on bird populations. This effort could be supported by improved monitoring of bird trade in both traditional markets and digital platforms to enhance compliance with existing conservation regulations. Finally, increasing public awareness of the importance of bird conservation and habitat protection through education, outreach, and environmental campaigns may contribute to fostering more sustainable interactions between human activities and biodiversity.

In conclusion, agricultural areas in Padangsidimpuan City supported 60 bird species from 30 families. The highest species richness was recorded in Aek Najaji (38 species, 20 families), followed by Bonan Dolok (34 species, 20 families), and the lowest in Lubuk Raya (28 species, 16 families). Feeding guild analysis identified nine guilds, with insectivores representing the highest number of species, followed by frugivore-insectivores. These findings suggest that mixed garden systems with greater vegetation heterogeneity may contribute to the presence and composition of bird communities in agricultural landscapes.

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