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Avifaunal Biodiversity and Abundance in Organic and Conventional Rice Ecosystem in the Cauvery Deltaic Region of Tamil Nadu

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ABSTRACT

Many studies have looked into the benefits of organic farming on soil ecology, but their effectiveness in biodiversity conservation, especially in bird communities in the organic ecosystem of Tamil Nadu, is less investigated. This research was conducted to determine the effects of organic farming methods on bird species, frequency and diversity in the Cauvery deltaic region of Tamil Nadu specifically, in rice ecosystems. In the Thaladi season of September and October 2022, bird monitoring was carried out in five pairs of organic and conventional rice habitats. This research documented a total of 726 birds, represented by 31 species, 19 Families and 11 Orders. Insectivorous birds were the most abundant species in organic rice ecosystems when compared to conventional ecosystems. This was observed across all three dietary guilds namely insectivore, granivore, and omnivore. A study on birds indicated that they had a higher value of species diversity in organic ecosystems (H = 3.06 Shannon-Weiner Diversity Index, R = 31 Species richness, J = 0.89 Evenness). In contrast, species diversity in conventional ecosystems was lower (H = 2.80, J = 0.87 and r = 25). This research has empirically demonstrated the advantages of organic farming, particularly in the Cauvery Deltaic region's organic rice habitat. It also provides quantifiable evidence that clearly shows its effectiveness in increasing the number of avian insectivores.

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1. Introduction

Biodiversity is at risk due to the effects of climate change and the introduction of non-native, invasive species. Moreover, agricultural intensification has further aggravated this problem. In the past few decades, agricultural intensification has had a severe impact on biodiversity, particularly when it comes to wildlife inhabiting farmland areas. This has been especially noticeable in birds [1]. Farmland birds have seen a drastic population collapse due to both local and landscape scale alterations. This includes an increase in agrochemicals [2], as well as the destruction of semi-natural habitats like high-diversity grasslands [3].

In the current scenario of Indian agriculture, the concern is given to the negative trend of farmland biodiversity. Environmental protectionist in the country demands the peasants follow environmentally friendly farming. There comes the concept of organic farming. Organic farming, which covers approximately 2.4% of the cultivable land in the Indian Subcontinent, has gotten a lot of attention because of its potential to improve biodiversity. Certified organic farming prohibits the use of agrochemicals, such as pesticides and inorganic fertilizers, but differs from conventional farming in terms of crop selection and rotation. Scientists have suggested that organic farming has the potential to improve biodiversity by restoring some of the heterogeneity that's been lost from farmland [4].

Organic farming increases the diversity of invertebrates and birds in homogeneous landscapes [5-8]. In the Cauvery Delta region of Tamil Nadu, there is limited data available on the effects of traditional and organic farming methods on biodiversity. With this background, the focus of this research was on the bird groups that live in the rice ecosystem in Cauvery deltaic region, Tamil Nadu. This research is the first to examine and quantify the differences in bird species richness or abundance between organic and conventional rice cultivation in Tamil Nadu. The results of this assessment provide valuable insight into the impact that organic farming has on avian biodiversity.

2. Materials and Methods

2.1. Study Area

Field surveys were conducted in the rice ecosystem of the Cauvery Deltaic region, Tamil Nadu, India. This Deltaic region is the rice bowl of the State and accounts for a large part of the production of food grains and ensures food security for the State. Within the study area, five different sites were chosen, each with a pair of conventional and organic rice ecosystems. To reduce the influence of environmental structure on birds in each rice ecosystem, the distance between the two rice fields at a site was set to 1 kilometer. To prevent spatial autocorrelation in each area studied, five sites were distributed over a distance of more than 5 kilometers. This research looked into the details of pesticide management in both traditional and organic rice ecology. Soil of the experimental field was sandy clay loam in texture belongs to Alathur series, classified taxonomically as *Typic Haplustalf* that are most suitable and convenient for the cultivation of rice and fallow pulses. Chemical fertilizers, fungicides, insecticides and mite killers are usually employed in regular rice systems. Microbial inoculants and other herbal pest-repellant mixtures, as well as organic manures, are used to grow organic rice (Table **1**).

2.2. Bird Counts

During September and October 2022, we conducted bird counts during the Thaladi season. Taking advantage of good weather (no rain and light wind) we visited each field twice between 6:30 a.m. and 4:00 p.m. To reduce the impact of sampling time on bird detection across the research area, which included scattered sites, surveys were done consistently from 06:00 a.m. to 11:00 a.m. in the morning and from 04:00 p.m. to 06:00 p.m. in the evening. We avoided observations during dawn, before 05:00 a.m., and dusk, after 06:00 p.m. This helped keep detection conditions consistent and prevented changes from varying light and activity levels. This schedule ensured that data were collected during times of high bird activity, while avoiding the midday hours when movement and vocalization were lower. On every visit, two fields from each pair of locations were sampled on the same day. One bird sampling site was placed in the center of each field while additional sampling points were randomly placed at a minimum distance of 200m on each farm.

Table 1: Crop management practices followed in two farms.

Agronomic Practices	Organic	Conventional
No. of Years of organic farming	15 years	-
Fertilizer	-	150:50:50 kg of NPK ha^{-1}
Nutrient management	Dhaincha incorporation, Biofertilisers, enriched vermicompost, FYM	-
Intercropping	Dhaincha and incorporated at 40 DAS	No such practice
Micronutrient deficiency	Panchagavya @ 3%	Micro nutrient spray @ 2%
Growth promotion	Panchagavya @ 3%	-
Weed control	Hand weeding	Hand weeding + herbicide (pendimethalin 30% EC, pretilachlor + bensulfuron methyl 6.6% GRand post emergence herbicide bispyribacsodium 10%SC)
Pest control	Herbal pest repellant, 3G extract	Profenophos @100 ml ha^{-1} Fibronil , Flubendamide @ 2ml/lit, Dimetheoate @ 1.5ml/lit, Imidachloprid 1.5ml/lit, Thiachloprid @ 2ml/lit, Thiomethaxam @ 2ml/lit
Crops followed	Rice-pulses	Rice-pulses

During each visit, all bird species that were seen or heard within a 200 m radius of the sampling point were recorded over a 5-minute observation period. To avoid double counting and ensure accuracy, only birds that were actively using or perching within the sampling area were included, while birds flying high overhead or merely passing through without using the habitat were excluded. However, migratory species that were present and actively utilizing the habitat during the survey were included in the dataset, as the objective was to assess overall species diversity rather than breeding density. To identify the species, a 10x50 binocular was used. The findings were then confirmed through Collins Bird Guide [9] and Clements [10] classified them into families and orders.

Every bird species was identified as an insectivorous species, granivorous, or omnivorous species depending on their diet [11]. To evaluate the bird population in each rice ecosystem, three parameters were taken into consideration: total species richness (quantity of species observed), total abundance (quantity of individuals) and abundance for three dietary guilds. Species richness and Abundance of birds were assessed by [12].

2.3. Biodiversity Index

To determine species diversity [13], the Shannon–Wiener Index (H’) was used, with species abundance serving as the main parameter [14].

$$H = \sum_{i=1}^{s} p_i \ln p_i$$

Bird species evenness was examined to assess how uniformly individuals were distributed among the recorded species. The Evenness Index (J) was calculated to measure this, comparing observed diversity to the potential maximum diversity using the equation [15]:

$$J = \frac{H'}{\ln S}$$

where *H’* is the Shannon–Wiener diversity index and *S* is the total number of species observed.

To identify the dominant species at each site, the Margalef Index was applied [16], calculated as:

$$D = \frac{(S-1)}{\ln N}$$

where S is the total number of species and N is the total number of individuals. Higher D values indicate greater species richness.

The Simpson's Similarity Index (SI) was used to evaluate the similarity of species composition among different habitats [17], following the formula:

$$SI = \frac{2C}{A+B}$$

where A and B represent the total number of species in two habitats being compared, and C represents the number of species common to both. The coefficient ranges from 0 to 1, where 0 indicates no similarity and 1 indicates complete similarity between sites.

2.4. Statistical Analysis

Since the data did not follow a normal distribution, we used a non-parametric Kruskal–Wallis test to examine whether farming practices had an impact on bird abundance across various feeding guilds. The comparison of bird diversity and abundance indices across farming practices was conducted across five sampling plots (N = 5). Principal Component Analysis (PCA) was used to perform ordination analyses in order to visualize changes in the composition of bird communities and to determine the main factors affecting species distribution across sites. Pearson's correlation coefficient was used to analyze the relationship between habitat parameters and diversity indices. SPSS (version 16.0) was used for all statistical analyses, and MetaboAnalyst software was utilized to create PCA correlation maps.

3. Results

3.1. Avifaunal Abundance and Diversity

Surprisingly, no extensive research has yet been done to document the various types of birds in the specifically organic field in the Cauvery deltaic region of Tamil Nadu. Subsequently, any ecological studies of birds in that area heavily depend on research from other areas. Diversity and species composition parameters showed a considerable variation among the different rice ecosystems (Table **1**). There were a total of 31 bird species and 726 individuals registered in the rice ecosystem belonging to 11 orders (Fig. **1**) and 19 families. Of the total of 726 individuals, 439 were found on organic rice, in contrast 287 individuals, in conventional land (Table **S1**).

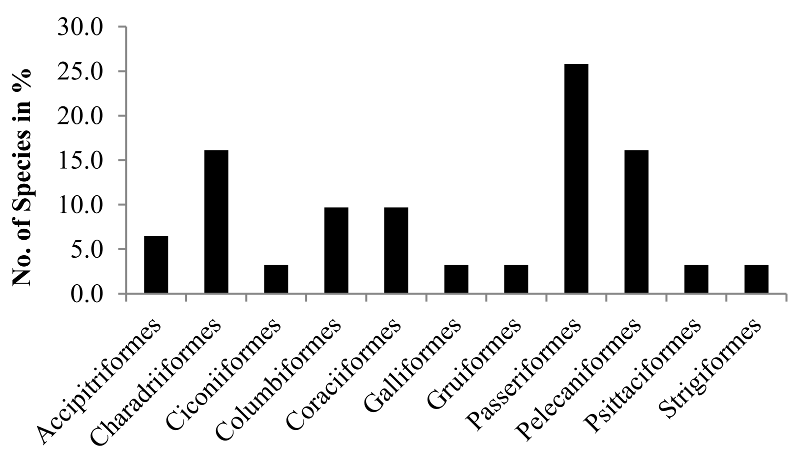


Figure 1: Bird species observed in conventional and organic rice ecosystem under different order.

Passeriformes was the predominant order observed, comprising 22 species (26%) of the entire population. It was followed by Pelecaniformes and Charadriiformes. On the other hand, Galliformes, Gruiformes, Ciconiformes and Strigiformes were witnessed with a single species each making them the least dominant orders (Fig. **1**).

Foraging guilds, mostly represented by insectivores and omnivores, and granivore guilds exhibited similar trends (Table **2**). Within the three guilds, greater abundance and richness were observed on organic sites for insectivores.

Table 2: The five parameters (mean ± standard error) describing bird communities observed in organic and conventional rice ecosystem.

	Organic (*N*=5)	Conventional (*N*=5)
Total species richness	6.2 ± 0.33	5.0 ± 0.31
Total abundance	88 ± 2.57	57.4 ± 2.32
Abundance of insectivores	50 ± 1.70	29 ± 1.36
Abundance of granivores	8.2 ± 0.32	4.6 ± 0.30
Abundance of omnivores	29.6 ± 0.94	23.8 ± 1.75

(Note: statistical tests were not performed for these observed values).

Generally, conventional farms held lower densities of birds than organic farms, the density on conventional farms not exceeding that on organic farms in 25 out of 31 cases for individual species. Organic habitats had higher values of species diversity (H'= 3.06) than conventional habitats. The highest evenness (E=0.89) was recorded in the organic and in conventional (E=0.87). The Evenness index showed slight variation between organic and conventional habitats, indicating that these two sites had an even distribution of birds (Table **3**).

Table 3: Biodiversity indices for avifauna found in conventional and organic rice ecosystem.

Indices	Organic	Conventional
Shannon Wiener diversity index	3.06	2.80
Simpson index	16.9	13.7
Pielou's Evenness index	0.89	0.87
Margaleaf index	4.93	4.24
Menhinick's index	1.48	1.48

The Ardeidae family was the most dominant in terms of numbers, with 5 species representing 16% of all identified species at the family level (Table **4**). During the study, Peafowl (*Pavocristatus*), Intermediate Egret (*Ardea intermedia*), Cattle Egret (*Bubulcus ibis*) and Common Parakeet (*Psittacara holochlorus*) were some of the most commonly sighted species. They were present in numbers 93, 74, 72 and 66 respectively which contributed to around 42% of all birds spotted in that area.

3.2. Correlation and PCA Analysis

Correlation analysis of bird species was performed to determine the relationship between changes in the avifaunal species in accordance with the effects of two different farming practice (Fig. **2**). Depending on the species, the correlation map showed different correlation patterns in organic and conventional bird species. Particularly Individual guilds were positively correlated among them. Few granivores showed a positive correlation with insectivores (Fig. **2**, Table **S2**).

The avifaunal data were subjected to principal component analysis (PCA) and biplots were also produced to determine the association of the avifaunal species and their impact on farming system.

Table 4: Familial abundance of avifauna under the conventional and organic rice ecosystem.

Family Name	Organic		Conventional	
	Absolute Abundance	Relative Abundance (%)	Absolute Abundance	Relative Abundance (%)
Accipitridae	2	6.5	1	4
Alcedinidae	1	3.2	1	4
Ardeidae	5	16.1	5	20
Charadriidae	1	3.2	1	4
Ciconiidae	1	3.2	0	0
Columbidae	3	9.7	2	8
Coraciidae	1	3.2	1	4
Corvidae	1	3.2	1	4
Dicruridae	1	3.2	1	4
Estrildidae	3	9.7	3	12
Meropidae	1	3.2	1	4
Motacillidae	2	6.5	1	4
Phasianidae	1	3.2	1	4
Psittacoidae	1	3.2	1	4
Rallidae	1	3.2	1	4
Recurvirostridae	1	3.2	0	0
Scolopacidae	3	9.7	2	8
Strigidae	1	3.2	1	4
Sturnidae	1	3.2	1	4
Total	31	100	25	100

All the identified avifaunal abundance (726 individuals) were subjected to PCA analysis and was reduced to 5 major principle components (PC) using the normalized data that indicates major differences between the farmland birds (Table **S3**). The PCs with eigenvalues greater than 1 were retained in the study. The Fig. (**3A**) shows the scores plot for the 2 farming systems. According to PCA score graph, the species composition among the 2 farming practices differed statistically and significantly from one another. In the PCA score plot, out of 5, 4 sites of organic fields are closely located on the positive side which shows that the high degree of birds similarity among them (Table **S4**).

The extracted five pcs explained 88.6% of the total variance as depicted in scree plot (Fig. **3B**). The 40.6% of variance explained by PC1 and was attributed by cattle egret, indian pond heron, little egret, cinnamon bittern, intermediate egret and peafowl. Similarly, the PC2 (17.6% variance) was associated with White Browed Wagtail (*Motacilla maderaspatensis*), Red Wattled Lapwing (*Vanellus indicus*), Whimbrel (*Numenius phaeopus)* and Common Parakeet (*Melopsittacus undulatus*). Likewise, 11.2% of the variance contributed to PC3 was correlated with indian pond heron and house crow. The PC4 with 10.6% variance was attributed By Little Egret (*Egretta garzetta*), Cinnamon Bittern (*Ixobrychus cinnamomeus*), Intermediate Egret (*Ardea intermedia*), Common Parakeet (*Melopsittacus undulatus*). PC5 (8.6%) was majorly highlighted by Chestnut Munia (*Lonchura atricapilla*), Cattle Egret (*Bubulcus* ibis) and Red Wattled Lapwing (*Vanellus indicus*). PCA biplot showed that conventional field survey is lying on the negative side whereas organic on positive. The highest PC score was obtained for ORG 1 & ORG 5.

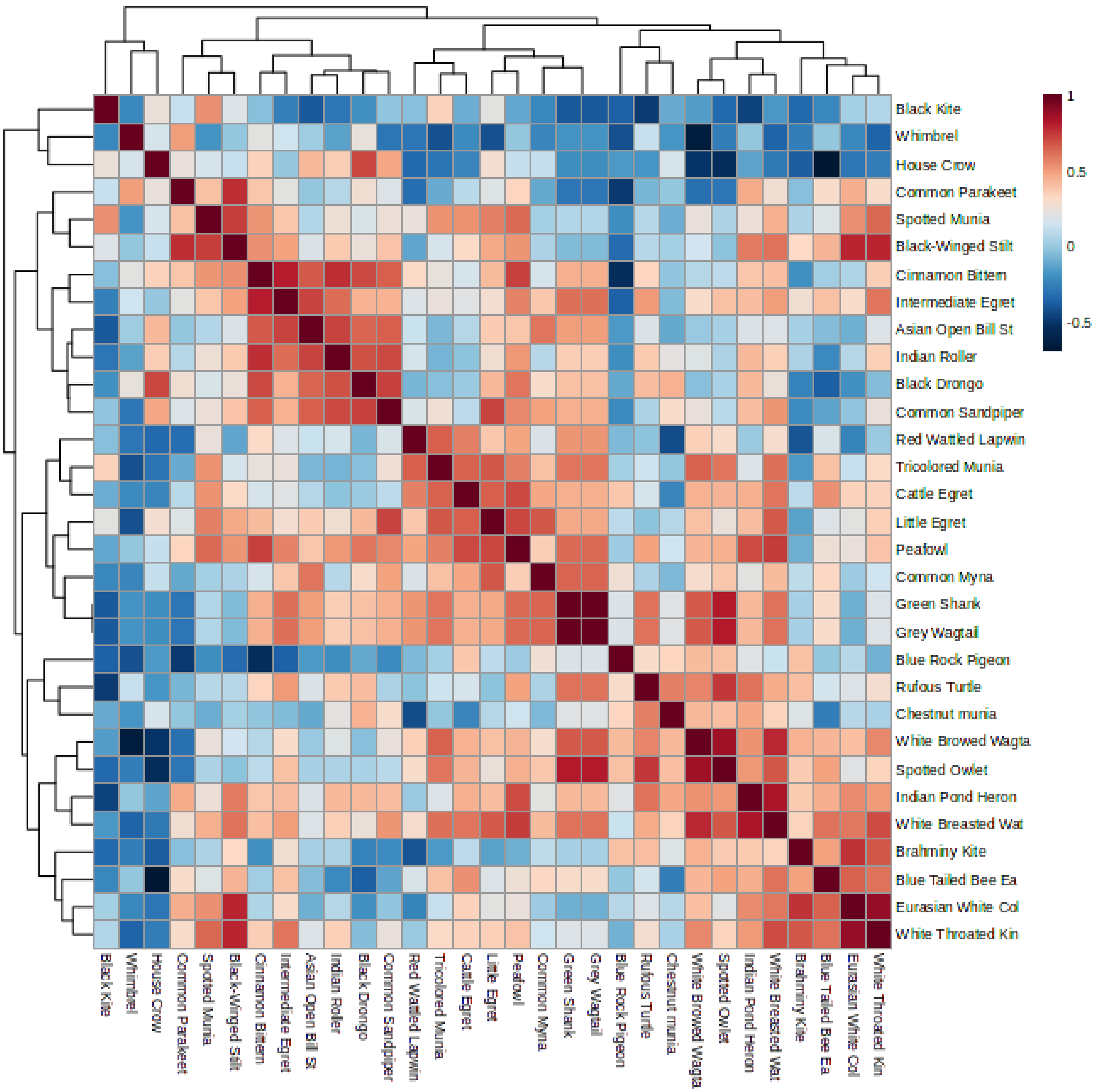
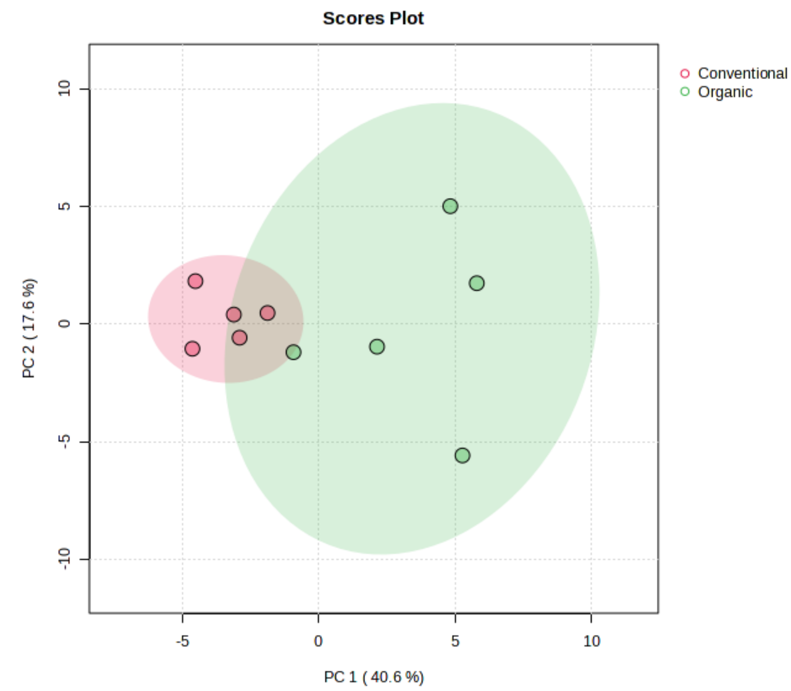


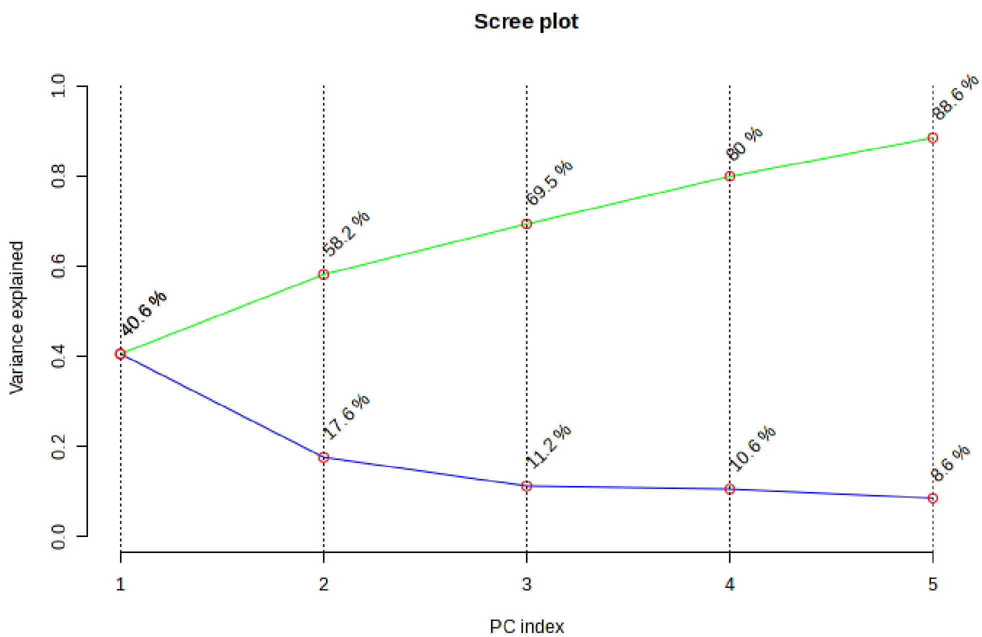
Figure 2: Correlation map showing the interrelationship between the species under different guilds. Brown colour indicates the positive correlation whereas dark blue denotes negative relationship.

4. Discussion

In our study, farming practices affected species richness and abundance of birds. The highest abundance (439 individuals) was recorded in organic and 287 in conventional fields. On average, bird abundance on organic field was 1.5 times higher than on conventional. The diverse vegetation community and vegetation strata of the organic rice ecosystem may have supplied multiple niches for birds, allowing the organic environment to support more avian species. During the research, 31 species of birds were identified. All of them were found in organic crops and almost all (25) were located in conventional rice crops. Bird abundance and species richness were significantly higher in organic sites as compared to conventional sites. Differences in habitat characteristics and bird feeding behaviour could be associated with the number of species and individuals of species in the ecosystem studied in this research. Our study demonstrated that the vegetation structure can be an important factor in shaping the associations of birds with their environment, agreeing with several previous works [18].



(**A**)



(**B**)

Figure 3: (**A**) PCA score plot (**B**) PCA scree plot.

Insectivores dominated the foraging guilds followed by omnivores. Organic sites showed more abundance and richness in insectivorous omnivorous, and granivorous guilds than conventional ones. The ratio of insectivores, omnivores and other diet types was distinct in both organic and conventional rice ecosystems. Specifically, there were more insectivores in the organic whereas omnivores were more common in the conventional system (Table **5**; Fig. **4**). Based on the obtained results, it is clear that the granivores especially the peafowl population is abundant in both study sites. This is because the study area is dominated by rice cultivation thus becoming the usual habitat and foraging for this species. A relatively peaceful living has also contributed to their incremental rise in the study area.

Table 5: Identity and abundance of bird species observed in this study.

Dietary Guild	Common Name	Scientific Name	Family	ORG	CON	Total
Granivore	Eurasian White Collared Dove	*Streptopelia decaocto*	Columbidae	3	0	3
	Asian Open Bill Stork	*Anastomus oscitans*	Ciconiidae	4	0	4
	Spotted Munia	*Lonchura punctulata*	Estrildidae	6	3	9
	Tricolored Munia	*Lonchura Malacca*	Estrildidae	11	7	18
	Rufous Turtle	*Streptopelia orientalis*	Columbidae	4	1	5
	Chestnut munia	*Lonchura atricapilla*	Estrildidae	13	12	25
Insectivore	White Browed Wagtail	*Motacilla maderaspatensis*	Motacillidae	13	6	19
	Cattle Egret	*Bubulcus ibis*	Ardeidae	40	32	72
	Red Wattled Lapwing	*Vanellus indicus*	Charadriidae	8	6	14
	Black Drongo	*Dicrurus macrocercus*	Dicruridae	11	8	19
	Spotted Owlet	*Athene brama*	Strigidae	7	5	12
	Green Shank	*Tringa nebularia*	Scolopacidae	4	0	4
	Indian Roller	*Coracias benghalensis*	Coraciidae	6	3	9
	Brahminy Kite	*Haliaster Indus*	Accipitridae	2	0	2
	Blue Tailed Bee Eater	*Merops philippinus*	Meropidae	4	1	5
	Whimbrel	*Numenius phaeopus*	Scolopacidae	9	11	20
	Indian Pond Heron	*Ardeola grayii*	Ardeidae	27	15	42
	Little Egret	*Egretta garzetta*	Ardeidae	31	19	50
	Grey Wagtail	*Motacilla cinerea*	Motacillidae	4	0	4
	Common Sandpiper	*Acititis hypoleucos*	Scolopacidae	9	4	13
	White Throated Kingfisher	*Halcyon smyrnensis*	Alcedinidae	8	1	9
	Cinnamon Bittern	*Ixobrychus cinnamomeus*	Ardeidae	16	5	21
	Intermediate Egret	*Ardea intermedia*	Ardeidae	45	29	74
	Black-Winged Stilt	*Himantopus himantopus*	Recurvirostridae	6	0	6
Omnivore	White Breasted Waterhen	*Amaurornis phoenicurus*	Rallidae	8	1	9
	Blue Rock Pigeon	*Columba livia*	Columbidae	3	3	6
	House Crow	*Corvus splendens*	Corvidae	18	19	37
	Common Myna	*Acridotheres tristis*	sturnidae	24	19	43
	Black Kite	*Milvus migrans*	Accipitridae	6	7	13
	Common Parakeet	*Psittacara holochlorus*	Psittacoidae	36	30	66
	Peafowl	*Pavocristatus*	Phasianidae	53	40	93
Total Abundance				**439**	**287**	**726**
Total Species richness				**31**	**25**	**31**

It is essential to take into account various habitats, dietary requirements (including border crop planting, hedge row planting and nesting trees), behaviors and impacts on crops. Organic farming may benefit seedeaters and omnivores, by offering complementary resources for foraging and roosting [19].

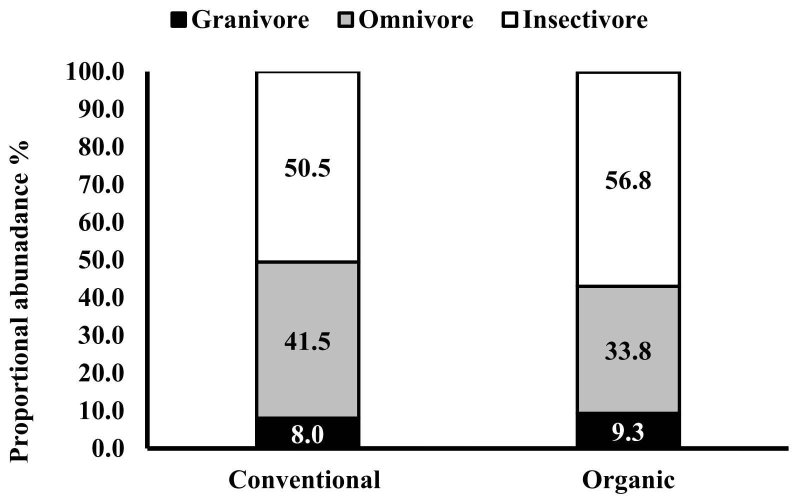


Figure 4: Proportional abundance of the three dietary guilds observed in conventional and organic rice ecosystem.

All the studied biodiversity indexes favoured the organic ecosystem. Species diversity in various habitats can be attributed to many factors, such as the availability of food, protective cover and nest sites, the adaptability or resilience of the species, as well as any threats they may face [20]. Bird species diversity, richness and abundance depend heavily on the vegetation composition in an area. This consequently affects food sources, nesting places and protection for birds, depending on their habitat preferences and feeding behaviour [15].

A total of 31 bird species were observed, and 25 of them were common to both habitats. The similarity index between the two habitats was 0.89, implying that organic and conventional ecosystems have more similar bird species (Table **3**). The prevailing wetland ecosystem which is a habitat for most of the species identified in the study favoured the similarity of species in both the ecosystem. However, a few species have been missed in the conventional ecosystem. Declining in the species of a conventional rice ecosystem might be due to the following reasons; 1. Those species may or may not be available in the ecosystem, 2. If available, human error in observing of birds, 3. The mismatch of birds visiting and observation time in the field.

In the present study, it was noted that the number of individuals in the conventional rice ecosystem was lower (53%) compared to the organic rice field. The reason might be due to the low availability of food and breeding habitats, which could have caused the birds to migrate to other locations where food and breeding habitats are plentiful which is in accordance with Tsegaye [21].

Many factors such as the excess application of agrochemicals, diminishing organic content in the soil, soil compaction and denser crop cultivation have resulted in less food supply for birds at the agricultural level. Conventional rice farms make use of synthetic chemical pesticides, such as broad-spectrum neurotoxic insecticides, to protect their crops. These pesticides can have a direct effect on birds by affecting the central nervous system, or they can have an indirect effect by limiting the amount of food available.

In addition, land conversion for agricultural expansion may push the birds to migrate to natural habitats nearby. Intensive farming in natural areas has an impact on species diversity [22]. Cutting trees and removing vegetation for construction, as well as charcoal and firewood manufacturing, are all common anthropogenic risks in the current study region. Hence, this kind of anthropogenic disturbance and habitat deterioration could have reduced the bird population in a variety of ways. Destruction of avian habitats has a direct impact on bird survival and reproduction [23].

In contrast to conventional farming, organic farming had a positive effect on the diversity of bird species, particularly those that feast on insects.

Out of the sampled farms, organic farming was used which varied from conventional farming in terms of both crop management (e.g. using pesticides and chemicals, cropping system) and physical farm management (e.g.

constructing hedges). There is much variation in the structure of field boundaries and crop rotation methods employed. Boundary type and structure differed between the two ecosystems and were expected to promote bird density on organic farms [24, 25]. The wide hedges and border trees in organic rice act as a food and habitat source for avians [26] which resulted in increased density of wide range avian species. Our study corroborates previous findings, which also found the positive effect of organic farming on bird abundance and species richness [27, 28].

Furthermore, PCA analysis also confirmed that the variations in species to both organic and conventional in the study affirmed the role of vegetation in the survival and abundance of different avifauna in the habitat it lives.

In particular, we found the highest effect of organic farming on bird species due to heterogeneous landscapes. In contrast, in areas with large patches of open landscape, the effect was higher and registered less number of avifaunal individuals. Our results suggest that organic farming may benefit farmland birds in heterogeneous farmland mosaics by promoting complementary resources under specific seasonal and landscape contexts, as it has been observed before [29, 30]. Finally, when comparing organic and conventional farming, total bird abundance decreased as the proportion of trees decreased. This effect was also observed in three dietary guilds. Successful bird conservation in farmland also requires consideration of farmers' concerns.

Land capturing for commercial purpose (building construction, industrial establishment) in economically fertile rice areas is a major threat to Cauvery deltaic zone farmland biodiversity. In the adjacent villages of the study region is posing severe threat to the agricultural land as they are being converted to non agriculture use. In this context, government of Tamil Nadu and India is promoting heterogenous landscapes based organic and natural farming to protect the biodiversity-rich habitats on marginal land.

4. Conclusion

Organic farming has the potential to benefit bird species richness and abundance in heterogeneous farmland, especially as it comes to seed-eating species, but such beneficial effects depend on landscape context. From the present study, it is clearly evinced that, the vegetation structures are the most criterion for determining the bird species composition and abundance in a locality. Obviously, birds and species abundance were high in the organic rice ecosystem as they had border trees that acted as a nest for breeding birds and food. The study suggested that there was a variation of species diversity parameters among two different ecosystems.

Conflict of Interest

The authors declare no conflict of interest.

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Supplementary Material

Supplementary Tables **S1-S4** are available on publisher's website along with published article.

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