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Effects of farming intensification on avian species richness and abundance within Jos metropolis, Nigeria

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Abstract

With an emphasis on pesticide use and landscape features, this study examines how agricultural development affects the diversity and abundance of farmland bird species. The purpose of the study is to evaluate the effects of many factors on bird populations, including cropping patterns, pesticide frequency, and landscape elements including trees, water bodies, hedgerows, and grass cover. The issue being addressed is the decline in biodiversity brought on by an increase in farming practices and a reliance on pesticides that upset ecosystems. The study uses interviews in addition to line transect surveys over five farmlands to collect data on pesticide use and landscape features. The methodology comprised 200-meter transects separated into 100-meter parts for morning and evening bird surveys. Statistical approaches, including species richness and abundance comparison across farmlands with different pesticide use levels and cropping techniques, were used to analyse the data. The results showed that farmlands without pesticides had better biodiversity, while areas with frequent pesticide usage had significantly lower species richness and abundance. Bird diversity was only slightly increased by mixed cropping systems, grass cover, trees, hedgerows, and adjacent water bodies. The study comes to the conclusion that fostering diverse landscapes and lowering pesticide use can help lessen the loss of biodiversity. To improve agricultural bird conservation, it suggests focused interventions, education initiatives, and policies that support biodiversity.

Keywords: Agricultural intensification; Biodiversity loss; Farmland birds; Species richness; Landscape features; Conservation strategies

1. Introduction

Nigeria's agriculture industry has long been the backbone of the country's economy and has played a critical role in both fostering economic growth and guaranteeing food security. But the recent increase in population and the resulting decrease in the amount of land accessible for agriculture have severely taxed this important industry. Farmers have become more and more dependent on fertilisers and pesticides in an effort to maintain high agricultural yields while addressing the challenges posed by declining arable land. Although the stabilisation and improvement of crop output have been greatly aided by these inputs, their widespread usage has had unanticipated negative effects on the environment and human health. In particular, bird species that are essential to preserving ecosystem balance through

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functions like pollination, seed dissemination, and pest control have suffered greatly as a result of the abuse of pesticides. Sadly, 87% of agricultural pesticides have a negative impact on a number of globally endangered bird species, highlighting the urgent need for sustainable farming methods that strike a balance between ecological integrity and productivity. The range and abundance of many farmland bird species have significantly declined over the past three decades, and this decline has been directly attributed to agricultural intensification. Many bird species, especially predators like the Barn Owl and Red Kite, experienced dramatic population reductions as a result of the historical use of organo-chlorine insecticides like DDT. While some afflicted bird populations have recovered partially as a result of the prohibition of these persistent organic pollutants (POPs), there are still significant risks associated with the introduction of newer pesticides. These insecticides kill plants and invertebrates, which reduces the availability of vital food sources. They also have indirect effects that can be fatal. It's estimated that 672 million birds are exposed to pesticides each year in the United States alone. With a 10% acute death rate, 672 million birds are thought to be exposed to chemicals on farms each year. The drop is most noticeable in grassland and wetland birds; in areas such as Europe, between 1980 and 2006, agricultural bird populations declined by as much as 48%. These patterns demonstrate how urgently strict regulations and environmentally friendly farming methods must be implemented in order to stop the loss of biodiversity. Regulations like the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) were put in place to guarantee the effectiveness and safety of pesticide applications in response to the past and present dangers associated with pesticide use. After learning from previous ecological mistakes like the use of Agent Orange and DDT, the United States Environmental Protection Agency (EPA) was established in 1970, which was a major step towards reducing the harmful effects of pesticides on the environment and human health. Public perception and scientific communication nevertheless face difficulties in spite of these regulations. Studies that draw attention to the detrimental impacts of pesticides are more likely to be published in prestigious publications, which distorts public perceptions and encourages false beliefs about the safety of pesticides. This inclination to portray unfavourable results might impede educated policy debates and postpone taking the required conservation action. Consequently, it is critical to promote a thorough and balanced approach to pesticide control that places equal emphasis on safeguarding biodiversity and agricultural output. Stakeholders can collaborate to establish sustainable agriculture methods that protect ecological and economic health by tackling these regulatory and perceptual obstacles.

The region's bird species diversity and abundance have been significantly impacted by the intensity of farming activities in Jos Metropolis. A common result of farming intensification is the widespread use of pesticides, fertilisers, and mechanised farming, which can cause habitat loss and fragmentation (1). Particularly susceptible to these changes are avian species, which significantly depend on a variety of habitats for food, nesting, and breeding. According to studies, the decrease of natural vegetation and the simplification of ecosystems are the main reasons why intensive agricultural landscapes sustain fewer bird species (2). Given the important ecological tasks that birds play, including seed dispersal, pollination, and pest control, this reduction in biodiversity is especially troubling (3). Sustainable agriculture is threatened by the decline in bird diversity in areas where farming is intensifying, in addition to being an ecological problem. Reduced crop yields and a rise in insect populations are two consequences of bird declines, which have a substantial impact on ecosystem services (4). Granivorous animals assist in seed germination and dissemination, whereas insectivorous birds assist in controlling insect populations. Nevertheless, a significant contributing cause to these birds' decline has been the extensive use of pesticides, which kill insects and limit their food supplies (5). Not only does the conversion of forests and wetlands into farms destroy these habitats, but it also makes matters worse by reducing the amount of space available to bird species for foraging and breeding (6). A more sustainable method of farming is needed to lessen the impact of intensified farming on bird populations. Productivity and biodiversity conservation can be balanced with the use of conservation techniques including agroforestry, integrated pest management, and the maintenance of natural ecosystems within agricultural landscapes (7). According to research, landscapes with a mosaic of farmed and wild areas are more likely to sustain higher levels of bird species richness and abundance (8). Farmers in Jos Metropolis and other areas can preserve agricultural output and help conserve bird populations by implementing such measures.

The development of farming has emerged as a significant factor in habitat change and the loss of biodiversity, especially in bird species. Bird populations are negatively impacted by the growth of monocultures, rising pesticide use, and destruction of natural habitats as agricultural techniques change to maximise productivity. For instance, research indicates that intensive farming may result in a decline in the variety and abundance of avian species when crops replace natural vegetation, which provides fewer nutrients for birds (9). Furthermore, mechanised farming simplifies landscapes, which decreases food availability and nesting grounds for many species. These factors ultimately lead to losses in local and migratory bird populations (10). In areas such as Jos Metropolis, where farming is a means of subsistence, the effect of increased farming on bird diversity is becoming more and more unsettling. Studies carried out in many parts of the world reveal comparable trends: in areas with heavy pesticide use, intensive farming is associated with a decline in bird diversity. Pesticide-induced declines in insect populations pose a special threat to avian species that rely on insects as their food supply (11). Furthermore, the transformation of heterogeneous landscapes into

homogeneous agricultural plots diminishes structural habitat complexity, a critical factor for species like ground-nesting birds and those that rely on shrubs and trees as their nesting sites (12). It is possible that sustainable agricultural techniques could lessen some of the detrimental effects of farming intensification on bird populations, as traditional farming systems and agroecological practices tend to support higher avian species diversity and abundance (13).

Changes in farming practices have been a major factor in the dramatic decreases in both the number and range of numerous farmland bird species over the past forty years. Particularly in the UK following its 1973 entry into the EC, agriculture has become more intensive, leading to a number of negative effects, including the decline of mixed farming, a switch from hay to silage, and a rise in the use of agrochemicals. Important natural habitats, including ponds and hedgerows, have been eliminated as a result of these modifications. Synthetic pesticide use increased even more after the 1940s, and by 2000, over 5 million metric tonnes of pesticides were produced worldwide, up from 0.2 million metric tonnes in the 1950s. Nevertheless, only 1% of pesticides actually work to eradicate pests; the remainder contaminate surrounding areas and non-target plants, endangering people, ecosystems, and the well-being of people.

The intricate and mutually reliant relationship between birds and ecosystems means that the extinction of a keystone species due to pesticides or other causes can have far-reaching and unanticipated consequences (14). Numerous instances of newly emerging pest species that result from pesticide-killed natural enemies are documented in the literature on pest management. However, there is scant or no research on the ecological effects of pesticides, particularly in the Nigerian Plateau State study area.

The purpose of the study is to look at three important aspects in order to determine how agricultural practices and avian biodiversity are related. The study evaluates the relationship between fluctuations in the diversity and quantity of bird species and the frequency of pesticide application, investigating the possible effects of pesticides on avian populations. In order to ascertain how farming diversity affects biodiversity, it also examines the effects of various cropping systems, in particular mixed versus monocropping, on the richness and abundance of bird species. The research also examine how landscape characteristics like hedgerows and tree abundance shape bird habitats and how these factors affect the diversity and abundance of bird species in various farming settings.

2. Methodology

2.1. Study Area

The Jos Plateau region of Plateau State, Nigeria, with its coordinates approximately between 9°50' to 10°05' N latitude and 8°45' to 9°01' E longitude, occupies a distinctive ecological zone within the Northern Guinea Savanna Vegetation Belt. This area, part of Nigeria's Middle Belt, is geographically significant due to its unique blend of savanna and mountainous terrain. It shares a boundary with Bauchi State to the northeast, Kaduna to the northwest, Nasarawa to the southwest, and Taraba to the southeast, encompassing an area of 26,899 square kilometres. This diverse landscape makes it an ideal region for studying agricultural practices and their impact on biodiversity. The research focused on farmlands within this area provides insights into how farming methods influence the local ecosystem, especially bird species, which are key indicators of environmental health. The region is an important area for ecological and agricultural studies because of its unique combination of highland and savanna features, as well as its climatic and ecological conditions, which provide a rich habitat for a wide variety of flora and fauna. Its proximity to other states adds to the region's significance because farming practices there may have wider environmental and socioeconomic implications across neighbouring regions.

2.2. Study Period

From May 27 to June 3, 2023, data for the study was gathered, enabling a thorough observation of the region in a variety of weather conditions. Data were collected throughout this period in both the morning and the evening, giving a more comprehensive picture of the environmental dynamics in the Jos Plateau area. It was important to select these precise times because throughout the day, there are variations in temperature, light, and animal activity, particularly in the case of birds. For many species, especially birds, the morning and evening hours are frequently their peak times because these are the cooler times of day when they are foraging, interacting, and being more active. During these periods, data collection ensured a more precise evaluation of how impact the diversity of life. The study's week-long duration allowed it to control for any transient changes in the weather and human activities that might have had an impact on the farmlands, making the dataset more trustworthy for interpreting the region's larger ecological trends.

2.3. Point Selection

To ensure an impartial representation of agricultural techniques in the area, five farms from the Jos Plateau region were randomly chosen for the study. Important variables like pesticide use and the surrounding landscape elements were extensively evaluated during the survey, despite the unpredictability of the selection process. This method was essential for comprehending the wider environmental effects of farming activities on the biodiversity of the area, especially with regard to bird species. The study's incorporation of pesticide use allowed the researchers to evaluate the potential disruption of ecological balances caused by chemical interventions in agriculture, which impact both target and non-target species. Consequently, while the farms were selected at random to prevent bias, the careful observation of pesticide use and landscape features ensured that the study captured the complex interactions between farming practices and the environment, offering deeper insights into how agricultural landscapes in the Jos Plateau affect local ecosystems. The landscape features, such as proximity to water bodies, vegetation types, and land elevation, were taken into consideration to determine their influence on biodiversity.

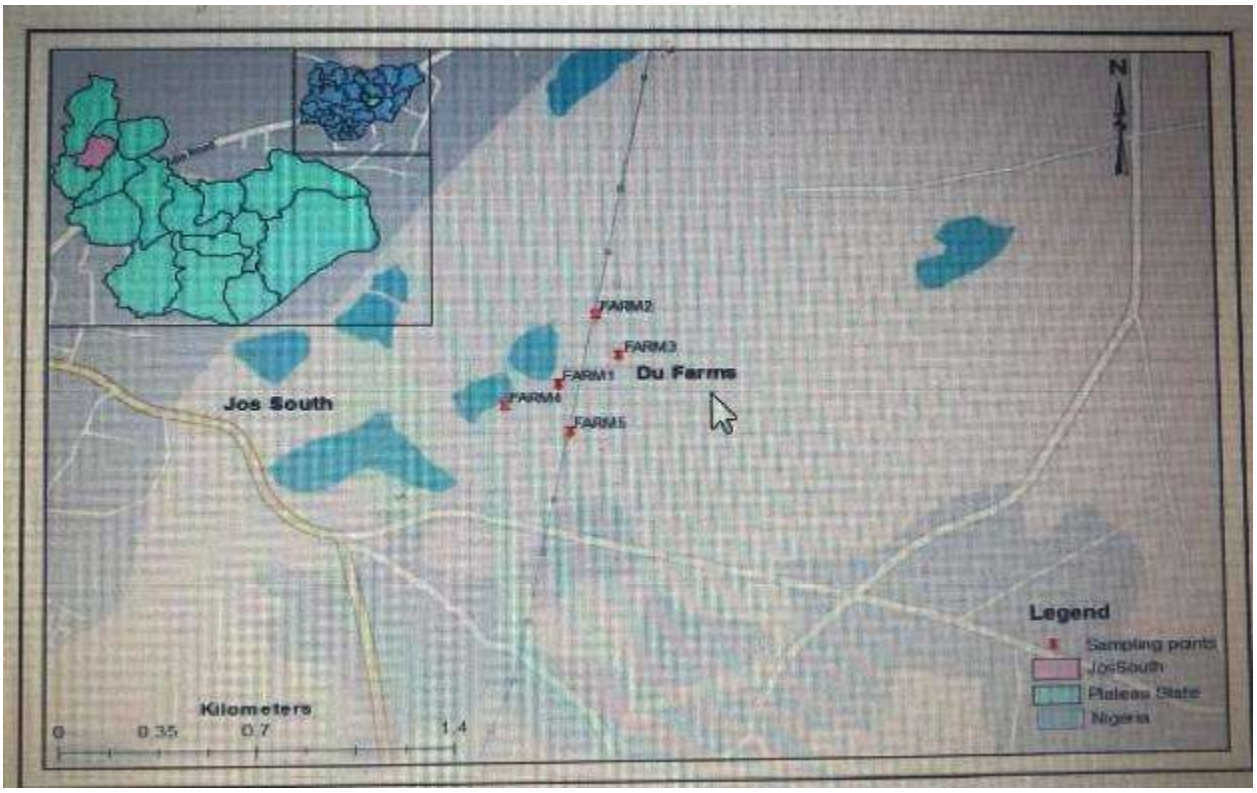

Figure 1 Satellite map showing the randomly selected farms in Jos Metropolis Area of Plateau State. Source: Ministry of Lands and Survey, Plateau State, Jos Source: Ministry of Lands and survey, Plateau State, Jos

3. Transect Methodology

Two 200-meter-long transects were established within each of the chosen farmlands in order to systematically assess the impact of farming practices on bird biodiversity. These transects were placed strategically 100 meters apart in order to ensure adequate spatial coverage of the study area, minimising overlap while maximising the range of bird species that could be observed. Bird counts were conducted along both sides of each transect, with observations made within a 50-meter radius on both the left and right of the observer. This setup allowed researchers to cover a 100-meter-wide swath along each transect, guaranteeing that a broad range of habitats and microenvironments within the farms were surveyed. The 50-meter observation distance was chosen to maximise visibility and accuracy.

3.1. Statistical Analysis

The Shapiro-Wilk test was utilised in order to evaluate the dataset's normality and make sure the data met the assumptions needed for statistical analysis prior to doing the principal analyses. A popular technique for determining if a sample follows a normal distribution—a necessary precondition for many statistical models, is the Shapiro-Wilk test. A Generalised Linear Model (GLM), which is especially helpful for addressing a range of data types, including non-normal distributions, was used to further analyse the data after normality was established. The GLM gave the

researchers a flexible framework for comprehending the intricate connections within the agricultural ecosystem by allowing them to investigate links between a variety of factors, including pesticide use, landscape features, and bird populations. The R software was utilised for data administration and statistical analysis. It is an open-source software with great capacity that is ideal for handling massive datasets and carrying out complex statistical calculations. The data were first entered and reviewed more easily in Excel spreadsheets before being moved into R for further in-depth analysis. The researchers were able to do thorough statistical tests and get valuable conclusions from the study's results by utilising R and its extensive library of packages. The software's features improved the analysis's precision and breadth.

4. Results

891 individual birds from 81 species spread over 34 families, and 8 food guilds were recorded for this study. The following family representations were made: There were nine species belonging to the Estrildidae family: seven from Charadriidae, six from Malaconotidae and Columbidae, five from Sturnidae, four from Cisticolidae and Muscicapidae, and three from Anatidae. Furthermore, two species were identified from each of the following families: Alcedinidae, Pycnonotidae, Passeridae, Burhinidae, Coliidae, Scopidae, Laniidae, Platysteiridae, Accipitridae, Phasianidae, Falconidae, Psittacidae, Motacillidae, Alaudidae, and Hirundinidae. The statistical information for each model is shown in Table 1, which also summarises the bird species richness in relation to hedgerows, tree counts, grass cover, and water bodies. The findings demonstrate that all p-values were higher than 0.05, suggesting that there is no statistically significant correlation ($p < 0.05$, DF = 121 at a 95% confidence interval) between the features of the landscape and the number of birds. This shows that there was no significant relationship between the richness of bird species and the features of the agriculture under survey.

The association between bird abundance and landscape characteristics—tree count, number of hedgerows, amount of grass cover, and presence of a water body—is displayed in Table 2 below. This link was not statistically significant. According to the results, each of the P-values above is ˢ 0.05, indicating that the data are statistically not significant (p~ 0.05, DF=121 at 95% confidence range).

Table 1 Landscape Characteristics and Birds Richness

Land Characteristics	DF	Deviance	AIC	P-Value
Intercept		79.285	372.68	
Hedgerow (Yes)	[2]	79.415	370.81	0.7190
Number of Trees	[2]	79.359	370.75	0.7864
Grass Cover	[2]	79.287	370.68	0.9675
Water Body (Yes)	[2]	79.302	370.70	0.8959

Source: Fieldwor

Table 2 Landscape Characteristics and Birds Abundance

Land Characteristics	Estimate	Std. Error	Z- Value	Pr(>/z/)
Intercept	18.38699	2.25649	8.148	3.68e-16***
Hedgerow (Yes)	-3.58161	0.41625	-8.605	<2e-16***
Number of Trees	-0.33134	0.04305	-7.696	1.40e-14***
Grass Cover	-0.21782	0.03032	-7.185	6.71e-13***
Water Body (Yes)	6.44783	0.78529	8.211	<2e-16***

Source: Fieldwork 2023

5. Discussion

The increase in farming has had a substantial impact on ecosystems, influencing the richness and number of bird species everywhere, especially in Jos. Major reasons for decreasing bird variety have been recognised as the monoculture

conversion of various natural habitats, greater use of pesticides, and loss of natural features such as ponds and hedgerows. The lack of statistically significant relationships between landscape features (such as tree cover, grass cover, and water bodies) and bird richness in this study, despite the large number of individual birds and species recorded, suggests that farming intensification may homogenise the landscape and cause a decline in specialised bird species that depend on a variety of habitats. This pattern is in line with research from other areas where intensive farming methods have deconstructed habitats, decreasing food sources, bird nesting locations, and cover. This has reduced species richness and increased the dominance of generalist species that can adapt to changing conditions. Also, since extensive pesticide use is known to lower insect populations, a vital source of food for many bird species, especially insectivores, the results of this study also suggest that the frequency of pesticide application is a significant factor in bird abundance. By lessening the complexity of habitats needed by birds for feeding and breeding, the transition from mixed farming and traditional cropping systems to monocropping methods may worsen these decreases. The results indicate that, in spite of the high number of individual birds observed, farming intensification results in a general decline in habitat quality, supporting fewer bird species and reducing the ecosystem's capacity to support a diversified avian population. These findings highlight the necessity of more sustainable farming methods that combine agricultural productivity and biodiversity protection in order to preserve avian variety in quickly becoming more intensive agricultural environments, such as Jos City.

6. Conclusion

The study found that agricultural techniques and pesticide application frequency had a significant impact on the richness and abundance of bird species. Compared to farms that used pesticides once or twice a week, those that used them seldom or never showed greater diversity and abundance of bird species. This pattern suggests that regular pesticide usage has a deleterious effect on avian populations, most likely as a result of habitat degradation and a decrease in insect diet. In a similar vein, mixed cropping systems were linked to higher bird species richness than monocropping systems, indicating that a wider variety of avian species are supported by different cropping methods because they offer a variety of habitats and resources. Farmlands with significant grass cover supported higher bird species richness in terms of habitat attributes; farmlands without significant grass cover supported lower bird species richness. On the other hand, the unexpected discovery that reduced avian species richness was linked to the existence of a water body within a 200-meter radius may have been influenced by other environmental factors or the particulars of the investigated area. Similarly, the presence of hedgerows produced an unexpected result: farmland without hedgerows had a higher bird species richness than farmland with hedgerows. These findings imply that some landscape elements may not always correspond with predicted biodiversity results, possibly as a result of intricate relationships between farming methods and ecosystem characteristics. The amount of trees or the proportion of grass cover in farmlands did not significantly correlate with bird abundance, according to the study. Although these habitat traits are important, the lack of statistical significance indicates that their direct impact on bird abundance may be less clear-cut or impacted by other factors not included in this analysis. In summary, these results highlight the necessity of a comprehensive comprehension of the ways in which various farming techniques and landscape attributes impact bird biodiversity, underscoring the significance of incorporating ecological factors into agricultural management.

Avian species are significantly impacted by farming intensification, especially in urban and peri-urban settings like Jos metropolis. The detrimental effects of pesticide use on the richness and number of bird species are among the main worries. By reducing insect populations, a vital food source, and having a direct negative impact on birds that consume pesticide-contaminated food, pesticides decrease the amount of food available to birds (1). Increasing farming intensity, especially with regard to chemical use, disturbs birds' natural foraging and breeding habits, which leads to a slow but steady fall in bird populations. Changes in agricultural spraying methods and the incorporation of other food-rich habitats, such as those made possible by provincial initiatives, can serve as a mitigating measure to safeguard these species. Another advantageous practice that has been emphasised is the establishment of conservation headlands, which are uncropped field edges managed for the benefit of wildlife. Pesticide use is still one of the most urgent problems, and as long as chemical pesticides are used, there will be unavoidable indirect effects on bird populations. These substances disrupt their natural behaviours, like nesting and migrating patterns, in addition to having an adverse effect on their food supplies (3). Reducing or eliminating these adverse consequences would be best achieved by switching to non-chemical resource management strategies, including organic farming practices. In addition to helping birds, this strategy would improve biodiversity on farms, woods, and even urban green spaces where pesticides are commonly used (4). A move towards sustainability and ecological preservation is increasingly likely as farmers investigate these alternate techniques.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of Interest to be disclosed.

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