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Impact of Oil Palm Plantation Expansion on Avian Species Diversity in Banggai District, Central Sulawesi

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ABSTRACT

The growth of oil palm plantations, which converts land use patterns to monocultures, is believed to impact the diversity of animal species, particularly birds. Bird species diversity is one of the important indicators for assessing environmental quality and requires more attention. Various studies have shown that the development of oil palm plantations can reduce bird diversity, although on the other hand, with the development of oil palm plants, bird diversity can increase. Therefore, the objective of this study was to evaluate the number of species, richness, uniformity, and diversity of bird species in different types of land cover. This study was conducted from March to May 2024. The study was carried out in oil palm plantations in Banggai District, Central Sulawesi. The research locations included both mature and young oil palm plantations, as well as areas with high conservation value (HCV). Bird species diversity was assessed through direct observations along transects that were 1 km in length, or adapted to the field conditions, and 100 meters wide. The data analysis focused on the species richness, diversity, and evenness indices. The findings revealed a total of 55 bird species present in the oil palm plantations. The mature oil palm areas had the highest number of bird species, with 41 species, while the young oil palm areas had the lowest, with 34 species. The highest species richness index was recorded in the mature oil palm areas, with a value of (Dmg = 8.02), and the lowest in the young oil palm areas, with (Dmg = 6.36). The evenness index in the study areas was relatively uniform, ranging from 0.8 to 0.9, which is close to 1. This suggests that managing oil palm plantations in a way that preserves the original forest land cover can help maintain bird species diversity.

1. INTRODUCTION

Oil palm is an edible oil-producing crop with high economic value, significantly contributing to Indonesia's economy, particularly within the plantation subsector [1, 2]. Over the last few decades, Indonesia's Crude Palm Oil (CPO) production has increased from 2.658 million tons in 1991 to 35.3 million tons in 2017 [3]. This condition has made palm oil the biggest contributor to foreign exchange in Indonesia's plantation sector, making the country the largest exporter of palm oil in the world. The strong global demand for crude palm oil (CPO) has fueled the expansion of oil palm plantations in tropical regions, including Indonesia. However, the land cleared for expanding plantation areas has sparked international concerns over the degradation of natural resources, environmental harm, and the decline in biodiversity [4, 5].

The expansion of oil palm plantations, which alters land use into monoculture, is thought to affect the diversity of wildlife species, especially birds. This has sparked various reactions from different parties, claiming that the growth of oil palm plantations has led to a reduction in biodiversity. Land cover conversion to oil palm plantations is believed to harm biodiversity through deforestation or forest conversion [6]. This process has led to biodiversity declines across most taxa [7], with bird species diversity being particularly affected [8]. Consequently, bird diversity is increasingly used as an indicator of environmental quality requiring special attention. Research [6] showed that the development of oil palm plantations resulted in a decrease in bird diversity. However, with the development of management in oil palm plantations, especially with the existence and optimization of the role of HCV areas, bird diversity began to increase in oil palm plantations. Birds can adapt to diverse environments due to their varied foraging strategies, with some species favoring open habitats [8]. The study [9] in oil palm plantations in West Sulawesi Province emphasized that the change in land cover from forests to oil palm plantations results in both positive and negative consequences. Positive effects include the introduction of new species, while negative effects involve the loss of native species due to land cover transformation. However, the number of species gained was greater than the number of species lost. The presence of endemic bird species such as *Eudynamys melanorhynchus* and *Spilornis ruffipectus* indicates that oil palm plantations can provide suitable habitats for these species. In this regard, managing the vegetation and forested areas around oil palm plantations is a key priority, as

it plays a critical role in increasing species abundance and diversity [10-12]. The transformation of land cover into oil palm plantations is believed to be the primary factor behind the decline in bird species diversity. In connection with this, this study aims to determine species diversity by identifying the number of species, species richness, and species evenness at various ages of oil palm plants.

2. MATERIAL AND METHODS

2.1 Time and study sites

The study was carried out from March to May 2024 in the oil palm plantations of Banggai District, situated at coordinates 1°22'22.7"S, 122°18'06.0"E. Banggai Regency, situated in the tropical zone, experiences a tropical climate with warm temperatures throughout the year, typically ranging from 24℃ to 32℃. Rainfall in Banggai is generally high, with two main seasons: the wet season from November to April and the dry season from May to October. Due to substantial rainfall, which can exceed 2,000 mm per year depending on the location and time of year, the area has relatively high humidity. The research was conducted in old oil palm plantations, young oil palm plantations, and areas designated as high conservation value (HCV).

2.2 Research methods

Direct Observations

Bird species diversity data were obtained by making direct observations on transects 1 km long or adjusted to field conditions and 100 m wide.

Data collection took place in the morning from 06:00 to 08:00 WITA and in the afternoon from 16:00 to 18:00 WITA. A single transect line was set up and repeated three times in each of the three land cover types within the oil palm plantations, which were:

1. Young palm oil plantation area
2. Old palm oil plantation
3. High conservation value area (HCV)

2.3 Data analysis

Data analysis was performed to assess species diversity and the level of community similarity between land cover types within large oil palm plantations. The analysis involved both quantitative and qualitative descriptive approaches. Quantitative analysis utilized species diversity indices, while qualitative descriptive analysis involved describing the general condition of each land cover type. The purpose of this data analysis is to determine the species diversity value at various ages of oil palm plants in large oil palm plantations. The species richness index and species evenness are calculated as follows:

Number of species (S)

The number of species refers to the total count of bird species observed during the study period. This includes all species encountered during the observations in the different land cover types.

Analysis of species diversity using the Shannon diversity index (H')

To assess species diversity, the Shannon diversity index (H') [13] was used with the following formula:

$$H' = -\sum_{i=1}^{s} (p_i \ln p_i)$$

where,

H′=Shannon Diversity Index

S=Number of species

p_i=Proportion of the number of the i-th individual (calculated as *ni*/*N,* where *ni* is the number of individuals of species *i* and *N* is the total number of individuals observed)

ln=Natural logarithm

This index helps to understand how different species interact within an ecosystem by considering both species richness (the number of different species) and evenness (the distribution of individuals among those species). By analyzing species diversity, researchers can study how species occupy their ecological niches and function within food webs. Comparing species diversity data over time enables the assessment of the impacts of human activities such as deforestation, urbanization, and land use changes on biodiversity.

Species richness index (Dmg)

The species richness index (Dmg) is utilized to determine the species richness within each community observed. The formula used is as follows:

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

where,

Dmg=Species richness index

S=Number of species

N=Total number of individuals of all species

The species richness index helps to quantify the number of species in a given area. This index is a crucial tool for assessing the level of biodiversity, which is a key indicator of the health of an ecosystem. By calculating the number of species, it provides insight into the ecological diversity of the area, indicating how well the ecosystem can support a variety of species.

Evenness index (E)

The evenness index (E) is used to determine how evenly individuals are distributed among the different species in each community observed. The formula used is as follows:

$$E = \frac{H'}{\ln(S)}$$

where,

E=Evenness index

H'=Species diversity

S=Number of species

The evenness index provides insight into the distribution of individuals across species in a community. A high evenness value indicates that individuals are distributed relatively evenly among species, suggesting a balanced community. A low evenness value, on the other hand, indicates that a few species dominate the community, with the majority of individuals belonging to these species. This index helps to understand the ecological balance and the dominance or rarity of certain species within the community.

Table 1. Composition and diversity of avian species across various land covers at the study site

Species	Families	Land Cover		
		Old Palm	Young Palm	HCV
Spilornis rufipectus	Acciptridae	1	0	3
Ictinaetus malayensis		1	0	1
Haliastur indus		0	1	2
Nisaetus lanceolatus		2	0	0
Halycyon chloris	Alcedinidae	12	8	5
Alcedo atthis		0	0	2
Collocalia esculenta	Apodidae	0	11	3
Aerodramus vanikorensis		6	20	12
Ardea purpurea	Ardeidae	4	0	1
Egrettta garzetta		3	1	1
Artamus leucorhynchus	Artamidae	6	2	5
Penelopides exhartus	Bucerotidae	2	0	1
Aceros cassidix		0	1	1
Lalage sueurii	Campephagidae	2	1	3
Caprimulgus affinis	Caprimulgidae	1	4	0
Ptilinopus melanospilus	Columbidae	0	2	0
Ducula aenea		1	4	0
Chalcophaps indica		2	1	0
Macropygia amboinensis		1	1	0
Ducula forsteni		1	0	1
Columba vitiensis		1	0	2
Columba livia		1	0	0
Streptopelia chinensis		3	6	0
Streptopelia tranquebarica		2	2	1
Corvus enca	Corvidae	3	8	5
Centropus bangelensis	Cuculidae	5	2	7
Phaenicophaeus calyorhynchus		2	0	4
Chrysococcyx russatus		0	0	1
Dicaeum celebicum	Dicaeidae	1	3	5
Dicrurus hottentottus	Dicruridae	2	0	8
Lonchura mallaca	Estrildidae	2	3	0
Falco moluccensis	Falconidae	0	1	0
Halcyon coromanda	Halcyonidae	0	0	1
Hirundo tahitica	Hirundinidae	6	9	3
Cacomantis merulinus	Cuculidae	0	0	5
Macrocephalon maleo	Megapodiidae	1	0	3
Hypothymis azurea	Monarchidae	1	3	2
Cinnyris jugularis	Nectariniidae	2	2	3
Anthreptes malacensis		4	9	1
Leptocoma aspasis		0	2	5
Oriolus chinensis	Oriolidae	0	0	2
Passer montanus	Passeridae	13	12	0
Mulleripicus fulvus	Picidae	0	0	3
Loriculus stigmatus	Psittaculidae	0	1	4
Pycononotus aurigaster	Pycnonotidae	12	16	0
Pycononotus goiavier		4	9	0
Gallirallus torquatus	Rallidae	16	12	0
Amaurornis phoenicurus		4	3	0
Gallirallus philippensis		3	2	0
Scissirostrum dubium	Sturnidae	2	0	4
Cridotheres javanicus		2	10	0
Trichastoma celebense	Timaliidae	0	0	3
Turnix suscitator	Turnicidae	7	6	0
Tyto alba	Tytonidae	1	0	0
Tyto rosenbergi		1	0	0
Total Individual		**146**	**178**	**113**
Total Species		**41**	**34**	**35**
Shannon Diversity Index (H')		**3.32**	**3.15**	**3.32**
Evenness Index (E)		**0.89**	**0.89**	**0.93**

3. RESULTS AND DISCUSSIONS

3.1 General condition of the observation location

Old palms

The old oil palm plantations observed were 22 years old. The area has a dense canopy cover, with a forest floor that supports various understory species such as *Asystasia gangetica*, *Ageratum conyzoides*, and ferns like *Nephrolepis biserrata* and *Pleocnemia irregularis*. The plantation is located along the company's primary access road, close to a

residential area. Additionally, a stream flows through the plantation, and the soil surface is covered with undergrowth and aquatic plants.

Young palm

The young oil palms at the research site are 2 years old, with an open canopy cover. The plantation floor is mainly dominated by undergrowth, with *Mucuna bracteata* as the most common species. The area features undulating and hilly topography. It is situated adjacent to oil palm plantations that are 6 to over 15 years old, and it is also in close proximity to high conservation value (HCV) areas.

High conservation value (HCV) area

The high conservation value (HCV) area is a natural forest that has been preserved since the plantation was established and is adjacent to the Bangkiriang Wildlife Sanctuary. The canopy is dense, preventing sunlight from reaching the forest floor. The dominant vegetation species in the area include Mahogany (*Swietenia mahagoni*), Ketapang (*Terminalia catappa*), *Ficus sp.*, various species of rattan (*Calamus sp.*), and *Imperata cylindrica*. The HCV area is bordered by 3-year-old oil palm plantations, with a rocky stream, known as the Sumgai stream, running through its center and flowing into the Toili watershed.

3.2 Diversity of bird species

A total of 437 individual birds from 55 species were recorded in the oil palm plantation areas (Table 1). The highest number of bird species was observed in the old palm plantations, with 41 species, while the lowest was found in the young palm plantations, with 34 species. This difference is due to the greater diversity of understory plants in old oil palm plantations compared to young oil palm plantations. The old palms are surrounded by a variety of understory plants, including ferns, weeds, and wild palm saplings. According to study [14], Shrubs in oil palm plantations are vital because they provide shelter, nesting sites for birds, and habitats for insects. This factor influences the higher bird population in old palm plantations compared to the young palms and HCV areas.

Research conducted on three land covers revealed that the land cover with the highest number of species and species richness was the ST (old oil palm) area, which had 41 bird species and a species richness index of 8.02 (Figure 1). In contrast, the SM (young oil palm) land cover only recorded 34 bird species, with a species richness index of 6.36. The next highest number of bird species was recorded in the HCV land cover, which hosted 35 bird species and had a species richness index of 7.19. This could be attributed to the fact that the site features tall and diverse vegetation. The composition of vegetation types plays a very important role in influencing the presence of bird species [15]. According to studies [16, 17], a relatively heterogeneous vegetation composition creates more varied ecological niches, which allows different bird species to coexist [18]. It has been demonstrated that the structural complexity of oil palm plantations is influenced by the larger and denser structure of oil palm trees that are 15 years or older. This, in turn, has an impact on the distribution and foraging behavior of bird species. The presence of oil palm plantations also influences animal species diversity, often leading to a decline in wildlife diversity in certain areas. According to study [19], there is a reduction in bird species richness in oil palm plantations. Similarly, the diversity of other animal species has also been found to decrease. For instance, some studies indicate a decline in mammal diversity in these areas [20].

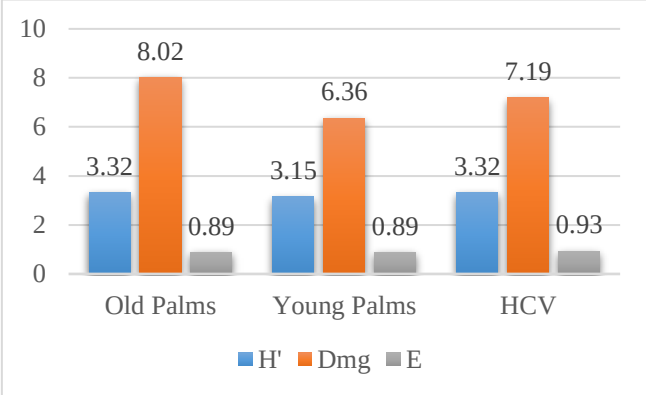

Figure 1. A visual representation of the number of species, species richness, and species evenness of birds in different land cover types

The higher bird population observed in the oil palm plantation area is hypothesized to be attributable to the overgrowth of epiphytes and other undergrowth, which serves as a source of attraction for numerous bird species. As study [21] argued, bird species diversity is influenced by several factors, including the abundance of epiphytes, fruit availability, the openness of the forest floor, and the composition of tree species. Furthermore, the relatively less dense canopy cover in these areas makes it easier for observers to spot birds.

The evenness values at the old palm and young palm research locations are relatively similar, both at 0.89, while the highest evenness value is found at the HCV (NKT) location, with a value of 0.93. This suggests that there is no dominant species in these land covers. Study [22] stated that a higher evenness index indicates that no species dominates the community. According to study [23], if each species has a similar number of individuals, the evenness of species in the community will reach its maximum value. However, if the number of individuals in each species is significantly different, the evenness will have a minimum value.

Figure 2. Examples of avian species observed across various land cover types in the oil palm plantation area

The bird species found at the observation site are diverse, with individuals occupying habitats that suit their ecological

needs. Notably, several species were found across nearly all types of land cover in the oil palm plantations. According to study [24], bird species that can inhabit almost all types of habitats typically have a broad range of habitat preferences and exhibit high adaptability to various environmental conditions. Species such as *Pycnonotus aurigaster*, *Gallirallus torquatus*, *Corvus enca*, and *Dicrurus hottentottus* (Figure 2) are examples of birds that can be found in almost all land cover types within the plantation. The presence of these bird species across different land cover types is influenced by various factors. Besides the suitability of their preferred habitats, the availability of food sources is also a critical factor in determining their distribution. These species are primarily insectivorous, frugivorous, and granivorous, and the variety of food resources across land cover types supports their presence.

The species similarity index is a crucial metric for assessing the degree of similarity in bird species across different areas within the study site. The bird species similarity index was found to be 0.75, indicating a high level of similarity between the species present in the various land covers. This high similarity is likely due to the comparable characteristics of the land cover types in the study area. According to study [23], a high community similarity value can arise when the land cover types share similar features. Additionally, study [24] suggested that a high bird community similarity, or one close to 100%, can be influenced by similar ecosystem conditions and the proximity of the habitats to each other. This suggests that the land cover types in the study area provide similar environmental conditions, which support a similar range of bird species.

The presence of forests maintained as HCV areas is one of the most effective sustainable oil palm plantation management strategies in providing habitat space for various bird species, in addition to enrichment through planting various native tree species such as *Ficus sp.*, *Calamus sp.*, and *Arenga pinnata*.

3.3 Conservation status of birds

This study found that among the 55 bird species observed in the oil palm plantation, 12 are protected under Indonesia's Government Regulation No. 7 of 1999. This plantation is home to a greater diversity of protected bird species compared to other areas. These species come from various families, including *Nectariniidae*, *Alcedinidae*, and *Accipitridae*. Some of the notable protected species present include *Cinnyris jugularis*, *Ardea purpurea*, *Alcedo atthis*, and *Spilornis rufipectus*. The presence of these protected species emphasizes the importance of conserving habitats within oil palm plantations to safeguard biodiversity, including species that are vulnerable or endangered.

In this oil palm plantation, there are more bird species included in the CITES and IUCN Red List appendices than in the previous plantation. There are 2 bird species included in CITES appendix 2, namely *Penelopides exhartus* and *Aceros cassidix*. The *Macrocephalon maleo* bird species is included in appendix 1 of CITES and according to the IUCN Red List is a protected bird. Excessive trade will increase the potential for extinction of these appendix-listed species.

4. CONCLUSIONS

The findings indicate that 55 bird species were identified across the oil palm plantation areas. The highest number of species was observed in the old oil palm area, with 41 species, while the young oil palm area had the lowest number of species at 34. In terms of species richness, the old oil palm area also showed the highest index (Dmg = 8.02), whereas the young oil palm area had the lowest species richness (Dmg = 6.36). These results suggest that older oil palm plantations offer more favorable conditions for a greater variety of bird species compared to younger plantations. The evenness index in the study area is relatively balanced, with values ranging from 0.8 to 0.9, indicating a distribution of species that is close to being even. To further preserve biodiversity, one effective strategy is to maintain natural habitats, such as areas with high conservation value (HCV). Furthermore, it is imperative for oil palm plantations to acknowledge the significance of avian species diversity within the ecosystem, particularly those that function as natural pest controllers. These birds can help reduce the costs associated with pest management in oil palm plantations, highlighting the ecological and economic benefits of conserving bird diversity. It is hoped that in the future, research on bird species diversity at the genetic level can be carried out so that it can be known whether there are genetic changes after land cover changes into oil palm plantations.

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