Fragmented urban areas: Can plants encourage birds in Jambi City urban space?

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Abstract. This study aims to estimate the extent to which vegetation can encourage the presence of birds in the urban city area. Forest area, urban plantation, grove area, and residential area are the Muhammad Sabki Urban Forest location for bird and plant observed in some circular plots (r=25 m) in the morning and afternoon. Bird directly and identified using a field guide and marked plant species immediately identified using the Plantamor website. The data were analyzed using the Shannon-Wiener Index (H'), The Margalef Index (Dmg), and some using Correlative and regression analysis with IBM SPSS Statistics 28. The results obtained 23 species and a total of 534 individual birds from all observed urban space habitats. All Shannon-Wiener Index (H') values in each studied habitat type showed a moderate diversity level and low species richness (Dmg). There are 22 plant species that have been identified as places of bird activity. Correlation analysis of the number of plant species on bird species and the number of bird species on bird individuals shows a strong relationship. However, regression analysis shows that the partially analyzed variables have no significant effect, so additional values are needed from other factors.

1. Introduction
Many studies have concluded that vegetation is an essential factor in the diversity of bird species, both in the tropics and temperate regions [1–14]. The researcher investigated birds’ species richness and density in temperate areas earlier in the 20th century; high tree density, low canopy, and few tree species are special characteristics in coniferous forests [3]. Several bird surveys in the tropics also began in that year, where vegetation acted as the prominent activity place for birds such as flowering and fruiting trees [15]. Recording bird species in the tropics is difficult because the character of vegetation cover is denser, and the forest canopy may not be visible from the ground compared to temperate regions [15].

Unfortunately, now birds recording in the tropics cannot be said to be difficult only due to the dense character of the vegetation cover, as Karr report [15]. The IUCN Red List notes that at least 175 bird species have been threatened with extinction over the past five years in both of tropical countries like Brazil (the highest-diversity country in the world) and Indonesia (the second highest-diversity country after) (See figure 1). Almost all low areas are in a damaged condition, fragmented, and degraded for various purposes, thereby changing the structure and composition of vegetation. Birds’ guild type has difficulty matching the type of feed with existing food sources due to changing the vegetation structure and design [1,8]. In
comparison, the status of bird species diversity is often used as an indicator to determine the state of the ecosystem of an area [9,16–18]. In this case, the heterogeneity and complexity of the landscape play an important role because it will be followed by an increase in the number of birds [19, 20], especially in urban landscapes.

![Figure 1](https://www.iucnredlist.org/resources/summary-statistics)

Figure 1. Summary of the IUCN Red List for Bird Extinction for A) Brazil in South America and B) Indonesia in Southeast Asia. This summary shows that Brazil has a total of two species in Extinction while Indonesia has none (Source: https://www.iucnredlist.org/resources/summary-statistics).

Like forests, urban landscapes also represent many socio-ecological factors and processes and their meanings that humans must understand [21, 22]. Cities have small-scale, fragmented vegetation banks and have created a gap between ecology and humans [23, 24]. In Indonesia, the government has launched almost 100 smart cities to integrate human needs with ecosystem sustainability. Although its readiness is still considered far from being feasible, green, and intelligent, especially regarding the availability of functional tree diversity [25], its biodiversity remains an important issue, so it must be considered. All plant species in the urban landscape cannot be ignored. It needs to be considered because of its role in encouraging the smooth hydrological cycle to trigger the presence of other flora and fauna, especially birds [1, 4, 6, 14, 18, 20, 25, 26]. We assumed that the best plant diversity in triggering the presence of birds is available in compact forests, as is a widely used theory. However, this assumption needs to be proven in urban areas which are fragmented into small scales, such as Jambi City in Jambi Province. Cities with all their problems certainly suppress biodiversity, so it is crucial to understand its persistence in the city [10]. Thus, this study aims to estimate the extent to which vegetation can encourage the presence of birds in the urban city area, especially in the Jambi city area. As a note of Global Forest Watch that Jambi City lost 2.16kha of tree cover, equivalent to a 30% decrease in tree cover since 2000, and 1.04Mt of CO$_2$e emissions from 2001 to 2020 [27].

2. Materials and methods

2.1. Study area

This study was conducted in one of the provinces of Indonesia with a high rate of deforestation for various purposes, especially housing and real estate development, namely Jambi Province. The Global Forest Watch noted that Jambi Province lost 1.67Mha of tree cover, equivalent to a 37% decrease in tree cover
since 2000, and 1.21Gt of CO₂e emissions [28]. Several green open spaces that still survive from lost 2.16kha of tree cover [27] in Jambi City in Jambi Province were selected to be observed in 4 categories: forest area, urban plantation area, grove area, and residential area (figure 2).

Figure 2. Location of the research study in Jambi Province, Sumatra Island, Indonesia.

a) Forest area. This forest area is Muhammad Sabki Urban Forest. The vegetation stands area dense with many tall trees. Its conditions cause only a tiny amount of sunlight to touch the forest floor so that only a few plants grow. This area also has a path in it and is close to the lake.

b) The urban plantation area is a monoculture rubber (*Hevea brasiliensis*) planting area owned by the private community, directly adjacent to the grove and residential space.

c) The Grove area is an open area directly adjacent to the Muhammad Sabki urban forest. This area is also called the transition area from the other areas studied. Vegetation stands adjacent to the forest area are open.

d) The residential area is an area planted with yard plants. Canopy cover in this area is classified as open because there is a lack of trees. There are also empty lands overgrown with weeds and grass and directly adjacent to the grove area.

2.2. Bird data collection

Birds in all locations were observed directly in a point count method and identified using the Birds in Sumatra, Java, Bali, and Kalimantan field guide [29] to obtain bird species names and the number of individuals and plant species where birds are active. Observations were made in the morning (6-8 AM) and afternoon (4-6 PM) at the central point of an observation designed to form a circular plot with a viewing distance of 25 meters (figure 3). At each observation location, three observation points were placed with a space between points of 100 m.
Figure 3. Bird watching point design.

Then simultaneously, the plant species were also identified based on the discovery of the bird in the exact location within the point surveyed. It is illustrated, for example, when we found the bird in tree A or plant type B, these plant species were then marked and immediately identified in the field or using photos for later identification on the Plantamor website.

2.3. Data analysis
Descriptive statistics were used to analyze the three study variables, namely data on the number of a) bird species, b) birds individual, and c) plant species observed based on bird encounters. Correlative and regressive analyzes were carried out on these three variables to answer the alleged encouragement of the plant species present in a fragmented city area to the diversity and quantity of individual birds in that place. This analysis was carried out using IBM SPSS Statistics 28 and illustrated with the feature of Office 365. In addition, the level of species diversity between observed locations was analyzed using the Shannon-Wiener Index ($H'$) (see equation 1) [30] while to prove the validity of the diversity. Species richness was measured using The Margalef Index (Dmg) (equation 2), rarely used to assess species richness [17,31] but is sensitive enough to estimate the functional richness of habitats. Both types of measurements are carried out with the following formulation:

$$H' = -\sum \frac{n_i}{N} \ln \frac{n_i}{N}$$

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

Where:

$H'$: Diversity Index of Shannon-Wiener

Dmg: Species Richness Index of Margalef

$n_i$: The number of individuals of each species

$N$: Total number of individuals of all species

$S$: Number of species

Ln: Logaritma natural

There are three means of $H'$ used in the Shannon-Wiener Index. A low diversity of bird species is defined by $H'$ value $<1$; a moderate diversity of species characterized by 1-3 intervals of $H'$ value; and a high diversity of bird species is defined by the value of $H'> 3$. Afterward, specific determination category for the Margalef Wealth Index; if Dmg < 3.5, then the richness is low; if the Dmg value is $3.5 < Dmg < 5$, then the species richness is medium; and if Dmg > five, then the species richness is high.

3. Result and discussion

3.1. Diversity of bird species and their composition in several habitats of Jambi City urban space area
The research findings obtained as many as 23 species and 534 individual birds from all observed urban space habitats. In table 1, there are five species (21.74%) found in all study sites. Another seven species (30.43%) are found in only two to three locations, while species only found in one habitat exist, a total of 11 species (47.83%).
Based on a search through the IUCN Redlist website in table 1, it is known that only three of the 23 species (13.04%) have experienced an increase in the global population to date. A total of 34.78% experienced a decline, and 43.48% of bird species identified in Jambi urban space did not experience an increase or decrease in population (stable) globally. The rest are unknown, or there is no data on population trends. In addition, only *Acridotheres javanicus* is classified as threatened species (Vulnerable). Most (86.96%) of identified species are in a minor Concern (LC) status. This means that the protection or conservation of these birds is weak because they are not in the threatened or near-threatened category (this category refers to [32]), so that the focus or conservation efforts are not prioritized for these species. However, of the 23 species, attention should be paid to species with weak protection status and declining populations (LC-D). There are six species in this condition: *Todiramphus chloris*, *Pycnonotus melanicterus*, *Lalage nigra*, *Pycnonotus brunneus*, *Pycnonotus aurigaster*, and *Passer montanus*. Of the six species, four of them are scattered in all study locations. At the same time, *P. brunneus* is known to be a species that was only found in one individual during the study. In contrast to *P. aurigaster* and *P. montanus*, which were found in the highest number of individuals (see figure 3).

Many individuals of bird species in this fragmented habitat indicate these habitats studied developing and adapting well. However, the spread and reproduces ability of these species in disturbed environments cannot be said to be better globally even though many studies have stated that *P. aurigaster* and *P. montanus* are primarily found in all other study sites [20,33,34] even on a small island [12], and they are referred to as generalist species typical of urban landscapes [9]. There is also a theory that states as a form of the ability of bird species to spread better than other species in a less friendly environment so that it affects the conservation status of these species [35].

On the other hand, the threatened population of a bird species in a given habitat is theoretically related to a shallower elevation temperature gradient [32]. This means that species threatened with population and need conservation priority can adapt to weak temperature elevations. Since most of the bird species in this study's findings are not threatened, it can be argued that there is better adaptability to temperature gradients. However, it does not rule out the possibility of a higher threat in the future if there is a significant temperature change in urban areas. The composition of plants in urban areas needs to be enriched to anticipate this condition. Nationally, a policy for protecting this species in the Indonesian laws and regulations must also be prepared because there has been no protection against it globally. The population records of several species in the findings of this study (table 1) continue to decline.
| Order          | Family          | Indonesia Name                  | Common Name                  | Scientific Name                          | FA | UPA | GA | RA | CS | Pop. Trend |
|---------------|----------------|------------------------------|-----------------------------|------------------------------------------|----|-----|----|----|----|------------|
| Columbiformes | Columbidae      | Perkutut Jawa*)              | Zebra Dove                  | *Geopelia striata*                      | +  | +   | +  |    | LC | S          |
|               | Columbidae      | Tekukur biasa*)              | Spotted Dove                | *Streptopelia chinensis*                | +  | -   |    |    | U  |            |
| Coraciiformes | Alcedinidae     | Cekakak sungai               | Collared Kingfisher         | *Todiramphus chloris* (Syn. Halcyon chloris) | +  | +   | +  |    | LC | D          |
| Cuculiformes  | Cuculidae       | Bubut alang-alang            | Lesser Coucal               | *Centropus bengalensis*                | +  | +   | +  |    | LC | I          |
| Gruiformes    | Rallidae        | Kareo padi*)                 | White-breasted Waterhen     | *Amaurornis phoenicurus*               | +  |     |    |    | LC | U          |
| Passeriformes | Sturnidae       | Kerak kerbau                 | Javan Myna                  | *Acridotheres javanicus*               | +  | +   | +  | +  | VU | D          |
|               | Estrildidae     | Bondol peking                | Scaly-breasted Munia        | *Lonchura punctulata*                  | +  | +   |    |    | LC | S          |
|               | Estrildidae     | Bondol tunggir putih         | White-rumped Munia          | *Lonchura striata*                     | +  | +   |    |    | LC | S          |
|               | Nectariniidae   | Burung madu kelapa           | Brown-throated Sunbird      | *Anthreptes malacensis*                | +  | +   | +  |    | LC | S          |
|               | Dicaeida        | Cabai bunga api              | Orange-bellied Flowerpecker | *Dicaeum trigonostigma*               | +  | +   | +  |    | LC | S          |
|               | Dicaeida        | Cabai merah*)                | Scarlet-backed Flowerpecker | *Dicaeum cruentatum*                  | +  |     |    |    | LC | S          |
|               | Aegithinidae    | Cipoh jantung*)              | Green Iora                  | *Aegithina viridissima*               | +  |     |    |    | NT | D          |
|               | Pycnonotidae    | Cucak kuning                 | Black-capped Bulbul         | *Pycnonotus melanicterus*              | +  | +   | +  |    | LC | D          |
|               | Pycnonotidae    | Cucak kuricang               | Black-headed Bulbul         | *Brachypodius atriceps* (Syn. Pycnonotus atriceps) | +  | +   | +  |    | LC | S          |
|               | Pycnonotidae    | Cucak kutilang               | Sooty-headed Bulbul         | *Pycnonotus aurigaster*                | +  | +   |    |    | LC | D          |
|               | Plocidae        | Gereja erasia*)              | Eurasian Tree Sparrow       | *Paser montanus*                       | +  |     |    |    | LC | D          |
|               | Campophilagidae | Kapan kemiri*)               | Pied Triller                | *Lalage nigra*                         | +  |     |    |    | LC | D          |
|               | Pycnonotidae    | Merbah belukar               | Olive-winged Bulbul         | *Pycnonotus plumosus*                  | +  | +   | +  |    | LC | S          |
|               | Pycnonotidae    | Merbah ceruk                 | Yellow-vented Bulbul        | *Pycnonotus goixier*                   | +  |     |    |    | LC | I          |
|               | Pycnonotidae    | Merbah mata menah*)          | Red-eyed Bulbul             | *Pycnonotus brunnus*                   | +  |     |    |    | LC | D          |
|               | Muscicapidae    | Sikatan bubik**)            | Asian Brown Flycatcher      | *Muscicapa daurica*                    | +  |     |    |    | LC | S          |
|               | Muscicapidae    | Sikatan emas*)               | Yellow-numped Flycatcher    | *Ficedula zanthopygia*                 | +  |     |    |    | LC | S          |
| Piciformes    | Megalaimidae    | Takur ungkut-ungkut*)        | Coppersmith Barbet          | *Psilopogon haemacephalus* (Syn. *Megalaima haemacephalus*) | +  |     |    |    | LC | I          |

Note: *) Unique bird species (only found in one type of habitat); **) Migrant bird species; FA= Forest Area; UPA= Urban Plantation Area; GA= Grove Area; RA= Residential Area; CS= Conservation Status on IUCN; VU= Vulnerable; NT= Near Threatened; LC= Least Concern; D= Decreasing; I= Increasing; S= Stable; U= Unknown
3.2. Diversity index level in all of the habitats studied

All values of the Shannon-Wiener Index ($H'$) in each habitat type studied belong to the habitat group with a moderate level of diversity because they are in the range 1-3. This range of values also shows that the stability of bird communities in some of these urban bird habitats is also stable. However, in terms of species richness in the whole habitat, $Dmg$ value from analysis of the Margalef Index shows a low significance (all values <3.5 even though the $Dmg$ value for forest area is close to that number) (figure 4). This means that all study sites cannot be declared rich in bird species even though the level of diversity is stated to be moderate.
This discrepancy was also shown in two habitats that experienced nonlinearity, namely urban plantation area and grove area. The $H'$ and Dmg values in residential areas are lower than urban plantation areas even though the $H'$ areas are higher. This finding indicates that a large $H'$ value in a habitat will not necessarily have a high level of species richness, like resulting in Gunung Walat Educational Forest [36]. The species richness indicated by the Margalef Index is related to the distribution of individuals within each species (evenness). If a habitat is crowded with birds of the same species, the Dmg value will be smaller than a habitat with few birds of varying species. This occurred in residential area habitats with lower Dmg (the number of detected species was only nine and 175 individuals) compared to urban plantation areas with fewer species. Still, the total number of individuals was not too many (N=45). In addition, the number of specialist species (species found only in specific habitats) in these two habitat types is also tiny. There are two specialist species in the residential area, while none of the unique species is found in the urban plantation area.

However, two other habitats have higher and linear $H'$ and Dmg values, namely forest area and grove area ($H'$ value grove area is also close to $H'$ value in forest area). This finding is also thought to be due to the number of specialist species. There are five in the forest area and four species in the grove area. In addition, it is also influenced by habitat conditions. The forest area (Muhammad Sabki Urban Forest) has a complete variety of habitat modifications, ranging from dense canopy stands, edge areas to riparian areas (close to the lake). Riparian vegetation carries more extraordinary species richness than vegetation close to road or roadside areas [37].

Meanwhile, the grove area is an open habitat bordering the forest area, so it is suspected that there is an edge effect from these two habitats, which is quite good in encouraging various bird species. The edge effect is indicated by the high diversity of bird species in the ecotone area, and specialist species are found in this area [36]. However, the estimation of the existence of this edge effect needs to be tested further by increasing the number and sampling locations between the two locations.

### 3.3. Can plants encourage birds in fragmented urban city areas?

The research findings show that there are 22 types of plants identified as places of bird activity based on the records of their findings. *Acacia mangium*, *Mimusops elengi*, and *Ficus benjamina* are plant species recorded to be visited by birds in the green spaces of Jambi City (figure 5). All three species flower temporally, and *A. mangium* was found to be flowering during this study. *Imperata cylindrica* is also visited by birds, small bird species such as *Lonchura punctulata*. There were 105 individual birds detected, the most among other plant species, but fewer species were detected, meaning that only certain bird species liked this vegetation type.
Figure 5. The number of species and individual birds in each plant species around Jambi Urban Space.

Table 2. Correlation analysis between the number of plant species, bird species, and bird individuals from all observed fragmented habitats

|                          | Number of plant species | Number of bird species | Number of individual bird species |
|--------------------------|-------------------------|------------------------|----------------------------------|
| Number of plant species  | 1                       | 0,88834872             | 0,905503061                      |
| Number of bird species   | 4                       | 1                      |                                  |
| Number of individual bird species | 9                  | 0,61147232             | 0,905503061                      | 1                                  |

Then, the three variables in figure 5 have been analyzed and produced a strong correlation in 2 variables, respectively (see table 2), namely a) the number of plant species to the number of bird species (0,8883), b) the number of bird species to the number of individuals (0,9055). These analyses show that the relationship between the number of species and the number of individuals will undoubtedly be very high because at least one species will be followed by the addition of at least one individual. Meanwhile, the relationship between the number of plant species and individual birds shows a meager value. Thus, the relationship between these two variables will not be tested further. The connection to be tested is the following variables:
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The results of regression testing with a 95% confidence interval produce the following formulation (3), (4):

\[ Bs = 2.1455Ps + 88.8 \quad ; \quad R^2 = 0.7892 \quad ; \quad \text{Pvalue: 0.1117} \]  
\[ IBs = 7.28Ps + 68.44 \quad ; \quad R^2 = 0.3739 \quad ; \quad \text{Pvalue: 0.3885} \]

Where:

- Bs: Number of bird species
- IBs: Number of individual bird species
- Ps: Number of plant species

Bs in equation 3 is the formula used to estimate the number of bird species that can increase if there is an increase in the number of plant species in the city. At the same time, IBs in equation 4 is a formulation that we can use to estimate the number of individual birds when one type of plant is planted. Based on the two formulations (Bs and IBs), it means that if at least one plant species favored by several bird species is grown in urban public areas, the number of birds will increase by 11 species and 76 individuals. This condition is supported in theory, where the amount of well-organized vegetation in urban spaces can increase biodiversity, especially birds [2].

Unfortunately, the variables analyzed in the resulting formula are partial and cannot be declared to have a significant effect because the P-value is more remarkable (> 0.05). It means the additional values from other factors are needed to obtain a complete and reliable estimate for the use of this formulation, or it may state that non-partial analysis is necessary. Although there is a strong relationship between wildlife and the surrounding plants, like the existence of birds is inseparable from vegetation [1, 4, 6, 8–10, 14, 38], urban space is another limiting factor for the existence of birds. Fragmentation of urban habitats with little plant-based green space and green roofs can solve narrow urban spaces and expensive land [18]. Another factor that can be used can be the presence of vegetation on buildings or city walls. This vegetated wall can also present a variety of bird abundance compared to an empty wall [14]. But the most important thing is the awareness that comes from the local knowledge of the general urban community about an urban living system [21]. This ecological knowledge is the basis for future urban planning, including awareness of urban communities to plant plants that can encourage bird species in their yards [22].

4. Conclusion

Suppose there are positive future changes in an extended period then will increase the number and types of urban green open space vegetation. In that case, the number of species and individual birds in urban areas will increase. The two formulas produced are not significant enough to estimate the increase and growth of bird species in urban areas. We must be pretty confident because the two tests on the level of diversity and species richness from each location studied showed at least some hope. However, the findings of this study do not suggest that urban land cover is in the form of monoculture vegetation.

5. References

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