The impact of landuse and the relationship between NDVI on the bird species richness in Sukmajaya District, Depok

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Abstract. A high human population increase will affect the landuse change, and as a result, there will be a conversion of green areas into residential and industrial lands. The natural habitat of wildlife such as avifauna will be highly fragmented and even lost. This research was conducted in Sukmajaya District, which was the most densely populated sub-district in Depok City. Normalized Differences Vegetation Index (NDVI) can show the vegetation map of an area. Sukmajaya sub-district is dominated by residential areas, about 62.1 % of the total area of this sub-district is residential area and leaving only 21.2 % of the vegetated land fragmented by buildings as habitat for wildlife. Therefore, it is necessary to conduct research on how different landuse types affect avifauna species richness which is important as input for stakeholders in avifauna conservation efforts. The research was conducted by using point count method in a total of 37 observation points divided into residential areas, industrial areas, and vegetated lands. The results of this study indicated that the correlation between landuse and avifauna species richness can be explained by the characteristics of the landuse habitat. Using linear regression, all habitat characters, such as NDVI, total individual vegetation, number of vegetation types, canopy cover, human activity disturbance, and temperature can simultaneously predict the value of the Margalef species richness index. The number of vegetation types and canopy cover are the characters that most influence the avifauna species richness in this study.

Keywords: Avifauna, land use, Margalef Index, NDVI

1. Introduction

The city of Depok has experienced many changes in recent years, especially in terms of population growth. Data from the Central Statistics Agency (BPS) shows that in 2019 Depok City has a very high population growth with 2,406,826 people which was increased 3.5 % from the previous year. In general, urbanization has a positive impact on the economy because it can be a force for economic growth and poverty reduction. However, on the other hand, urbanization also causes problems for the environment. The denser population in a city will result in reduced open space for water absorption, increased waste problems, air and water pollution, and increased environmental temperature [1]. In addition, urbanization will also destroy and eliminate natural habitats for biodiversity. This is due to changes in...
natural habitats into developed land by humans. A high population increase will change the land use of an area. As a result, there is a conversion of green vegetated land into residential and industrial land [2].

Due to the high population growth, the original habitat of wildlife such as birds will be increasingly fragmented and even lost [3]. Changes in natural habitat associated with the urbanization process can lead to the extinction of biotic species and homogenization [4]. These changes cause threats to biodiversity at different scales [5]. One of the groups of living things that is affected by urbanization is the avifauna community. For this reason, it is important to see the effect of green vegetation density patterns and landuse on the richness of avifauna species in the area. The presence of avifauna in an area is important because birds have different niches in the environment, and therefore playing a role in restoring damaged land, spreading crops, attracting tourists, controlling pest populations, biogeographic cycles, and also as an indicator of environmental quality [6]. Although the effects of urbanization can benefit some birds, particularly urban birds [7], other species usually could not preserve stable populations in these modified areas. Human activities in the surrounding environment also affect the presence, distribution and abundance of avifauna in the area.

According to BPS data for 2020, Sukmajaya District has a population of 321,600 people which occupy an area of 17.35 km². This population makes it the most populous sub-district in Depok City, reaching 18,555 people/km². Visual observations show that landuse types in Sukmajaya District vary widely. However, green vegetated land which should have been the habitat for many types of wildlife, including birds, was lost and replaced by other land uses. The Normalized Difference Vegetation Index (NDVI) is one of the data from satellite image processing that can measure the level of greenness of vegetation in an area, NDVI is commonly used because of the high level of sensitivity in measuring the vegetation index and is able to analyze various habitat variations as well as predict the primary plant productivity [8]. Therefore, the aim of this study is (1) to evaluate the effect of land use to bird species richness, and (2) to determine the relationships of NDVI values and other habitat variables to bird species richness.

2. Materials and method

2.1. Study area
The research was carried out from August 24 – October 24, 2020 in Sukmajaya District, Depok City, West Java. The research area is divided into 3 different types of land use, namely industrial, residential, and green vegetation.

2.2. Data collection
The research began with the determination of land use patterns in Sukmajaya District using the ArcGIS 10.7 software. Then, 37 observation points were determined across these categories with the following details: there are 29 points in residential areas, 6 points of observation in green vegetation areas, and 2 points in industrial areas. The point in the residential area is symbolized by the dot code (R), the industrial area with the dot code (I), and the vegetated land with the dot code (H). After that, the research was continued with data collection in the field, both avifauna observations and habitat profile data observations. Observations were made in three repetitions. Then, the research was continued with data processing consisting of NDVI mapping and correlation analysis between NDVI, land use and species richness of avifauna with SPSS v software. 24.0. After the observation point is determined, the next step is observing avifauna and habitat profile. Bird observations were carried out using the point count method in 15 minutes intervals [9]. Observations were made in the morning from 06.00–08.00 and complementary data were taken in the afternoon at 16.00–17.30. Bird observations were tended to be more effective in the morning and evening, because that time is the optimal time for avifauna to carry out activities such as foraging [9].
2.3. Data analysis
Multiple linear regression tests were calculated using SPSS software version 26.0. The confidence value used was 95%. We hypothesized that there will be a correlation between NDVI and other habitat variables to bird species richness.

3. Results and discussion
The results of the bird observations in the period of 24 August to 24 October at 37 points spread across the Sukmajaya District area, recorded 22 species of birds with a total of 1,125 individuals from seven orders, Apodiformes, Charadriiformes, Columbiformes, Cuculiformes, Passeriformes, Pelecaniformes, Piciformes, with the order Passeriformes dominated both the number of species and the number of individuals. Our results suggested that there was no significative distinction between the presence of birds and the number of individuals. During the observation, 764 out of 1127 individuals belonged to the Passeriformes group with 14 avifauna species. The mean of Margalef Index at all observation points is 1.63, the highest index in green vegetated area (2.57), followed by the industrial area is 1.70 and residential area (1.17). During the observation, the point with the highest Margalef Index is at point H-2 in vegetated land with a value of 2.64 while the lowest point is point I-2 in industrial areas with a value of 0.37.

Of the 22 species observed, the Eurasian Tree Sparrow and Sooty Headed Bulbul were the species that occupy all observation points, while the Little Egret (Egretta garzetta) is the least observed species, occupying only one point during observation. This was directly proportional to the number of observed bird individuals, the Eurasian Tree Sparrow (Passer montanus), the Sooty Headed Bulbul (Pycnonotus aurigaster) and the Cave Swiftlet (Collocalia linchi) as the species with the most observed individuals, 318, 233, and 220 individuals. While the avifauna with the fewest individuals was the Little Egret (Egretta garzetta) with only one individual. During the observation, we found that the dominant birds were the urban exploiter avifauna. Urban exploiter is avifauna that has a high adaptability in densely populated urban areas, such as the Eurasian Tree Sparrow and the Sooty Headed Bulbul. However, it does not mean that urban avoider birds do not need green vegetation to live. Urban avoider birds still need green vegetation to live with a broader ecological plasticity [10]. Other avifauna urban exploiter found in Sukmajaya District were Cave Swiftlet, Spotted Dove and Rock Pigeon. This is called biotic homogenization, because the urban exploiter birds dominating and replacing the original avifauna which are unable to adapt to habitat changes [11]. This change was due to the undergoing a transformation into an urban area that occurred continuously in several areas in the sub-district of Sukmajaya.

Kark also said that there are several characteristics possessed by a species which enable this species to adapt and develop in urban areas: 1) the ability to live and forage without fear of human existence; 2) the ability to exploit human-related resources, such as human waste disposal; 3) the habits of friendly, do not disturb and attack humans; 4) nesting and foraging behaviour; and finally, the flexibility of behaviour towards urban pressures which also affects the ability to exploit urban areas [11]. When viewed from the type of feeding guilds, the birds recorded were birds that eat insects, seeds, fish, fruits, and nectar. Some granivores also eat insects and seeds. Likewise, the Eurasian Tree Sparrow is facultative granivores because these avifauna also eat insects, caterpillars and other small invertebrates. This is related to the available resources. Some granivores will replace their edible seeds with other seeds or other food depending on the abundance of readily available food. This is often related to the crop harvest season. Apart from food availability, age and geographic factors also influence the food preferences for birds [12].

Our results showed that of the 22 species recorded during the observation, all of these species can be found in the vegetated land category, 14 species can be found in residential areas, and only 9 species were found in industrial areas. Total avifauna individuals recorded during the observation were 1125 individuals, with 788 individuals in residential areas, 67 individuals in industrial areas, and 270 in areas with green vegetation (figure 1). If averaged based on the type of landuse, there were
28 individuals at each point of the residential area, 48 individuals at each point in the industrial area, and 47 individuals at each point of green vegetated land. The average Margalef Index in the residential category was 1.18 (table 1). This makes the residential area as the category of land use type with the lowest species richness during the observation. According to Ortega Alvarez, the type of land use was closely related to the avifauna community: 1. whether there was any disturbance/stressor to the avifauna community, such as human activities, pets, and pollution; 2. the variety of habitats available; and finally, the available food and water resources [13].

Referring to this question, at least some of the factors that resulted in the lowest species richness in the housing area were: first, the composition of the vegetation represented by the average number of vegetation species and individuals found in that type of land use. The mean number of different vegetation types found at each point in the housing area was 3.2 species and the average number of individuals found at each point was 4.4 individuals (table 1). This amount is the lowest number compared to other categories. According to Paker, the positive correlation between vegetation composition and species richness of avifauna was associated with the food sources provided by the vegetation [14]. Vegetation will provide food for avifauna, not only in the form of fruit and nectar, but some plants will provide nest sites for other animals, such as arthropods, which feed insectivores avifauna. Second, another important factor affecting the presence of avifauna is human activity. Human activity in this study can be seen through the sound intensity variable. In residential areas, the average sound intensity produced was the highest at 70.11 dB. Third, recorded canopy openings for these land uses were lowest across all categories. The average canopy cover at all observation points in the residential area was only 15%. This was due to the smaller number of individual plants and the types of individuals that are often found in this category was individuals with small crowns.

![Figure 1. Mean of total species, mean of total individual, mean of index Margalef.](image)

| Land use type | Mean of total vegetation species | Mean of total vegetation individual | Mean of temperature (°C) | Mean of sound intensity (dB) | Mean of canopy cover (%) |
|---------------|---------------------------------|-----------------------------------|--------------------------|----------------------------|--------------------------|
| Residential   | 3.26                            | 4.48                              | 30.4                     | 69.30                      | 16.13                    |
| Industrial    | 5.09                            | 6.27                              | 30.08                    | 66.64                      | 18.49                    |
| Green Area    | 7.41                            | 9.47                              | 28.82                    | 55.31                      | 22.58                    |
Another thing that causes the Margalef Index in the housing category tend to be low was that the type of vegetation in housing is sometimes adjusted to the wishes of the landowner. It can also be seen from the data that 25 individual vegetation or the equivalent of 20 percent of the total individual vegetation found at home is the Areca nut plant (Roystonea regia) which was a plant intentionally planted in housing to add the aesthetic value of an area. Unfortunately, the selection of ornamental plants was more numerous and various types are grown based solely on the beauty of appearance. This phenomenon not only has a catastrophic impact on native vegetation, but native wildlife is also affected and experienced a decline in the number of individuals. Bird species is one of the most affected wildlife species [15].

In the industrial area (table 2), the average Margalef Index value was higher than the housing category, namely 1.70. However, referring to the distribution of data at the two points, there is a very clear difference between point I-1 and point I-2. At point I-1, there are far more species and individuals than I-2 and automatically the Margalef Index at these two points is very different, even the I-1 industrial area has a higher Margalef Index value than some points in the residential area. This is because the industrial area landscape design, in contrast to I-2 at point I-1, consists of a large area of green vegetation surrounding the outer side of the factory area. The types of vegetation planted varied considerably, and the number of trees planted was quite large. This will automatically invite the presence of avifauna to be around the area and increase the diversity index.

Of the 22 types of avifauna recorded in this study, all can be found in the vegetated areas. Of these, there are five types of avifauna that are not found in other land use categories, namely Aegithina tifia, Artamus leucorycus, Egretta garzetta, Isobrychus sinensis, and Zosterops palpebrosus. In the vegetated land use category, the point with the lowest Margalef Index value is on H-5. This may be caused by three factors. First, the land area of point H-5 was much narrower than other vegetated land points. After calculating the calculated geometry of the ArcGIS 10.7 application, the area of the H-5 point was the smallest vegetation point, which was about 0.02 km$^2$. This affects the preference of avifauna, which prefers large areas to fragmented areas [16, 17]. Second, the composition of the vegetation at point H-5 also affected the composition of the presence of avifauna. Point H-5 was the point with the most vegetation in all observation points with 13 individual vegetation. However, in terms of the number of vegetation types, this point tended to be low compared to other points in the vegetation land category, which is only 6 different vegetation. This may be related to the variety of types of food provided by vegetation [18]. Although NDVI can predict the vegetation density in an area, NDVI still depends on the types that make up the vegetation density. It can be seen that point H-5 is the point with the highest vegetation density in all observations with 13 vegetation individuals, but eight of the total individuals or the equivalent of 61% are Papaya and Banana plants which are groups of plants with small crowns. This causes NDVI at point H-5 to be not higher than points on other vegetated land, even though the vegetation density recorded at that point is higher than points on other land (figure 2).

Using linear regression, it can be seen that the value of R squared obtained from linear regression modeling tends to be very high ($R^2 = 0.951$). This is suggested that all independent variables calculated simultaneously can explain 95.1 % of the variation of the dependent variable, the Margalef Index significance correlation to number of vegetation types ($P = 0.001$) and canopy cover ($P = 0.009$).

| Land use type | Area code | Number of species | Number of individual | Margalef Index | Number of vegetation |
|---------------|-----------|-------------------|----------------------|----------------|---------------------|
| Industrial    | I-1       | 9                 | 55                   | 1.996          | 7                   |
| Industrial    | I-2       | 2                 | 15                   | 0.369          | 3                   |
This is in accordance with research [14] which states that the more diverse types of vegetation that exist in an area, the more avifauna is present. The large canopy cover will also invite the presence of birds. Plants with larger crowns will provide ample food for birds. Not only fruit and nectar, but in trees with large crowns provide habitat for insects, a food source for food. A large crown was also a better place to protect from predators [19].

The positive correlation between NDVI and species richness suggested that NDVI can be used to predict the richness of bird species. This was also supported by the research from the United States Geological Survey in Arizona, United States in 2013. The study concluded that NDVI could be used as a model to predict the abundance and diversity of birds. However, environmental factors that cannot be calculated through remote sensing, such as vegetation structure, remain the most important factors in predicting the avifauna abundance and diversity [20].

4. Conclusion
Landuse attributes can simultaneously affect the value of bird species richness in Sukmajaya District. The relationship between NDVI and bird species richness is positive.

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