BIODIVERSITAS
Volume 23, Number 5, May 2022
Pages: 2775-2782

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230560

The building size effect on bird community assemblages in tropical urban ecosystem

ABDIEL ADAM UTAMA, SANDY NURVIANTO♥
Wildlife Management Laboratory, Department of Forest Resource Conservation, Faculty of Forestry, Universitas Gadjah Mada. Jl. Agro No.1, Sleman 55281, Yogyakarta, Indonesia. Tel./fax.: +62- 274-550541, ♥email: sandy_nuvi@ugm.ac.id

Manuscript received: 9 Maret 2022. Revision accepted: 30 April 2022.

Abstract. *Utama AA, Nurvianto S. 2022. The building size effect on bird community assemblages in tropical urban ecosystem. Biodiversitas 23: 2775-2782.* The construction of buildings is one of the factors that cause landscape changes in urban areas. Landscape changes can result in the fragmentation of animal habitats that live in urban areas. Characteristics of urban structures, such as spatial configuration and distribution of building types, are some of the factors that influence the distribution pattern and abundance of bird species in urban areas. This research aimed to describe the effect of building type on the diversity of bird species in Province of Yogyakarta, Indonesia, or *Daerah Istimewa Yogyakarta* (DIY). Bird data were recorded using the point count method, while building type data and vegetation height were obtained by subtracting Digital Surface Model (DSM) data and Digital Elevation Model (DEM) data in the built-up area. The data was recorded from three levels of urbanization, namely urban, suburban and rural. Canonical Correspondence Analysis (CCA) was used to visualize the response of birds to the type of building. After that, the Generalized Linear Model (GLM) was used to determine the effect of the type of building on the diversity of bird species. The results showed that shrub cover affected species richness and abundance of birds. The building types with a height below 18 meters had a negative effect on the abundance and diversity of birds in suburban areas. The abundance of birds in urban areas was positively affected by the type of building with a height of between 18 and 30 meters. The existence of buildings in urban areas can reduce bird feed sources. Making spatial plans that provide more variety of plant cover and diversity of building heights are expected to increase bird diversity in urban areas.

Keywords: Bird diversity, Daerah Istemewa Yogyakarta, urbanization classification, urban ecology

INTRODUCTION

There are no species on this earth that can compete with humans in making changes to the earth's ecosystem. Land use activities conducted by humans have changed the structure of the existing ecosystem on the earth's surface (Foley et al. 2005). The way humans use land has a major contribution to the formation of landscape patterns, which has a major influence on the formation of the community of organisms that live in the landscape (Turner and Gardner 2015). Examples of landscape patterns that are formed are urban areas, villages, wetlands, agricultural land, and semi-natural areas.

The urban area is the center of all human activities with various kinds of development that lead to an increase in the needs of the urban population, including the need for land in various sectors (Jiang et al. 2018; Surya et al. 2021). The positive impact of development is the increase in people's living standards and the increase in facilities and infrastructure in urban areas, while the negative impacts of development include a decrease in environmental quality and disruption of the stability of urban ecosystems (Grimmond 2007; Weng 2011; Švajlenka and Kozlovská 2018; Surya et al. 2020). Another negative impact is the occurrence of habitat fragmentation for animals that have habitats in urban areas, such as birds (Adams 1994; Palomino and Carrascal 2006; Tietze 2018; Souza et al. 2019).

The existence of buildings in urban areas is known to affect the species diversity of birds in a community (Fontana et al. 2011; Souza et al. 2019). The diversity of building heights in an urban area can increase the abundance of bird species which is an indicator of the bird species diversity index (Pellissier et al. 2012). This is because there are bird species that can adapt to environmental conditions in urban ecosystems, such as Eurasian tree sparrow (*Passer montanus*) and yellow-vented bulbul (*Pycnonotus goiavier*), which have habitats in urban or residential areas (Pudyatmoko et al. 2009; Mardiastuti et al. 2020).

Province of Yogyakarta, Indonesia, or *Daerah Istimewa Yogyakarta* (DIY), is an urban area with human activities centered in the city of Yogyakarta. The continuous construction of high-rise buildings in the Province of Yogyakarta can affect the distribution pattern and abundance of bird species that inhabit in the Province of Yogyakarta area. The sustainability of the city's ecosystem as a habitat of animal and plant species is an environmental aspect that needs to be considered in developing urban spatial designs. Good urban spatial design is expected to improve the environmental quality of urban ecosystems. Characteristics of urban structures, such as spatial configuration and distribution of building types, are some of the factors that influence the pattern of distribution and abundance of bird species that have habitats in urban areas (Pellissier et al. 2012). This research aimed to describe the effect of building types on the diversity of bird species in Province of Yogyakarta, Indonesia.

MATERIALS AND METHODS

Study area

The research was conducted from July to August 2021 in the Province of Yogyakarta, Indonesia, or *Daerah Istimewa Yogyakarta* (DIY). Determination of the sample was based on the classification of the urbanization level from Marzluff et al. (2001), which is based on the percentage of built-up area (Marzluff et al. 2001). The delineation process was carried out using Landsat 8 OLI/TIRS image data with the help of QGIS Desktop 3.18 software. Atmospheric correction was done first by changing the reflectance at the satellite to surface reflectance. After that, the percentage of built-up area was quantified using the Semi-automatic Classification Plugin (SCP) tools and the unique values report raster layer tools. In this study, 3 levels of urbanization classification were used, namely rural, suburban, and urban. At each level of urbanization classification, 4×4 km^2 observation grids were established and placed in 4 cardinal directions from the city center (Figure 1). In each grid, measurement plots were established following a systematic random sampling procedure (Morrison et al. 2001) with a 400 m distance between the plots. Total of 300 measurement plots were established in the study area during research period.

Procedures

Bird community

Bird data were recorded using point count method with 50 m radius (Bibby et al. 1992; Ralph et al. 1995) and 10 minutes observation period (Fuller and Langslow 1984). A duration of 10 minutes was used to improve sampling efficiency, especially for cryptic species (Fuller and Langslow 1984; Ralph et al. 1995). Observations were conducted in the measurement plot location within each grid. Every individual of bird and species encountered during the observation were recorded using a tally sheet. Bird community data were presented by abundance, species richness, and Shannon-Wiener (diversity) index.

Building and vegetation height

The height of the building and the height of the vegetation was obtained by subtracting Digital Surface Model (DSM) data and Digital Elevation Model (DEM) data using QGIS 3.18.3 software. DSM data was obtained from the ALOS Global Digital Surface Model "ALOS World 3D - 30m (AW3D30)" provided by the Japan Aerospace Exploration Agency (JAXA). DEM data was obtained from the DEM Nasional (DEMNAS) provided by Badan Informasi Geospatial (BIG). Building height data was classified into 3: H1 (<18 m), H2 (18-30 m), and H3 (>30 m) (Pellissier et al. 2012). While the vegetation height data was classified into 3: herbs (<1 m), shrubs (1-4 m), and trees (>4 m) (Indriyanto 2006).

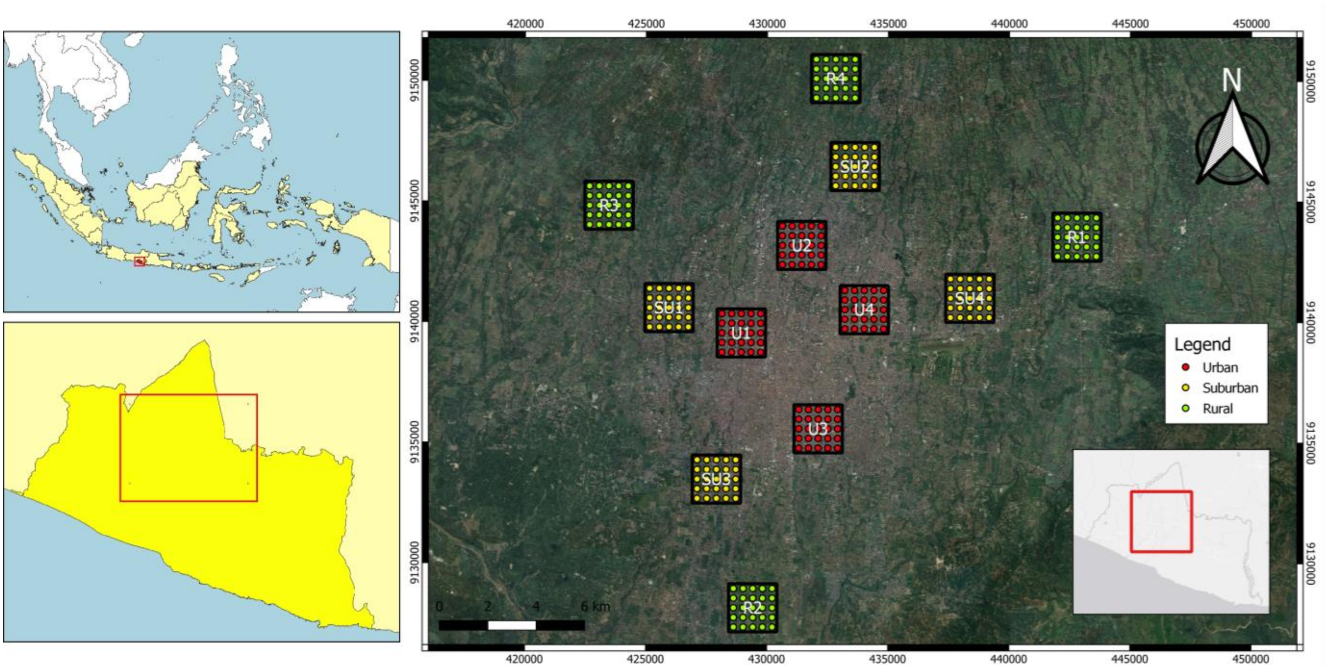

Figure 1. Location of the study area in Province of Yogyakarta, Indonesia which was divided into 3 levels of urbanization; urban (red dots), suburban (yellow dots) and rural (green dots), whereas U1, U2, U3, U4 are the replication grid for urban, SU1, SU2, SU3, SU4 are replication grid for suburban, and R1, R2, R3, R4 are replication grid for rural

Data analysis

We visualized the response of birds to the type of building and vegetation using canonical correspondence analysis (CCA) (McGarigal et al. 2000) (Table 1). CCA is an analysis used to describe the relationship between 2 or more variables. CCA can be seen as an extension of the logic of regression analysis (McGarigal et al. 2000). Further, we analyzed the effect of building types and vegetation on the bird community using a generalized linear model (GLM) (Caprio et al. 2009). Statistical analysis was performed using R 4.1.1 software with the stats (R Core Team 2021) and the vegan 2.5-7 (Oksanen et al. 2020) packages.

Table 1. List of variables to describe the building and vegetation distribution in Province of Yogyakarta, Indonesia

Variables	References
Building cover (%) :	Pellissier et al. (2012)
H1 (<18 m)	
H2 (18-30 m)	
H3 (>30 m)	
Vegetation cover (%) :	Indriyanto (2006)
Herb (<1 m)	
Shrub (1-4 m)	
Tree (>4 m)	

RESULTS AND DISCUSSION

Bird community

The number of bird species found in this study amounted to 37 species, including 30 species in rural areas, 30 species in suburban areas and 26 species in urban area (Table 2). Surprisingly, urban areas had the highest diversity index value (H': 1.696) compared to suburban (H': 1.565) and rural (H': 1.517) (Table 3).

Table 3. Bird abundance, diversity (Shannon-Wiener Index) and species richness in each of the urbanization level in Province of Yogyakarta, Indonesia

Urban classification	Individual abundance	Shannon-Wiener Index	Species richness
Rural	2049	1.517	30
Suburban	2995	1.565	30
Urban	2259	1.696	26

Note: measured in area of 16 km^2 (4 observation grids)

Table 2. Bird species list at each urbanization classification

Species	Latin name	Urbanization Classification		
		Rural	Suburban	Urban
Javan Munia	*Lonchura leucogastroides*	1345	1834	759
Scaly-breasted Munia	*Lonchura punctulata*	187	309	122
White-headed Munia	*Lonchura maja*	8	96	46
Eurasian Tree Sparrow	*Passer montanus*	68	145	788
Cattle Egret	*Bubulcus ibis*	16	1	2
Olive-backed Tailorbird	*Orthotomus sepium*	4	3	2
Zitting Cisticola	*Cisticola juncidis*	50	43	2
Collared Kingfisher	*Todiramphus chloris*	14	16	4
Javan Kingfisher	*Halcyon cyaniventris*	41	14	3
Scarlet-headed Flowerpecker	*Dicaeum trochileum*	7	9	17
Zebra Dove	*Geopelia striata*	59	88	49
Barn Swallow	*Hirundo rustica*	5	1	-
Javan Pond-heron	*Ardeola speciosa*	39	46	6
White-breasted Woodswallow	*Artamus leucorynchus*	8	14	5
Sooty-headed Bulbul	*Pycnonotus aurigaster*	107	234	117
Bar-winged Prinia	*Prinia familiaris*	8	-	-
Common Tailorbird	*Orthotomus sutorius*	5	6	6
Eastern Spotted Dove	*Spilopelia chinensis*	20	13	19
Plaintive Cuckoo	*Cacomantis merulinus*	5	2	-
Rusty-breasted Cuckoo	*Cacomantis sepulcralis*	4	8	1
Freckle-breasted Woodpecker	*Dendrocopos macei*	3	-	-
Common Iora	*Aegithina tiphia*	10	13	2
Olive-backed Sunbird	*Cinnyris jugularis*	12	17	9
Pacific Swallow	*Hirundo tahitica*	2	-	1
Plain Prinia	*Prinia inornata*	4	1	-
Yellow-vented Bulbul	*Pycnonotus goiavier*	4	61	289
Sangkar White-eye	*Zosterops melanurus*	1	-	-
Small Minivet	*Pericrocotus cinnamomeus*	-	8	-
Coppersmith Barbet	*Megalaima haemacephala*	2	-	1
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	-	2	-
Java Sparrow	*Lonchura oryzivora*	-	1	2
Blue-eared Kingfisher	*Alcedo meninting*	-	1	1
White-breasted Waterhen	*Amaurornis phoenicurus*	-	6	-
Sunda Pygmy Woodpecker	*Dendrocopos moluccensis*	-	1	-
Javan Myna	*Acridotheres javanicus*	8	2	1
Pink-necked Green-pigeon	*Treron vernans*	-	-	5
Lesser Coucal	*Centropus bengalensis*	3	-	-
	Total	2049	2995	2259

Note: The colored cells per column represent the abundances of three most dominant species in each urbanization classification

This result implies that urban areas could provide good habitats for bird communities in Province of Yogyakarta, Indonesia, as the lower level of urbanized areas. In line with our findings, Pudyatmoko et al. (2009) reported that bird community assemblage in urban areas of Province of Yogyakarta, Indonesia, had a higher similarity to the forest (35.17%) compared to agroforestry (27%) (despite both of them were considered as the low value of similarity) and had highest conservation value index. The human-made built environment in urban areas has created landscape heterogeneity that could potentially supported more diverse bird species, including rare and endemic species (Pudyatmoko et al. 2009).

Building and vegetation height

Urban areas had the highest building cover composition. Building cover in the study area ranged from 0% to 92.899%. While the vegetation cover ranged from 0% to 77.041%. Buildings with a height of <18 m (H1) dominated all urbanization classifications. The existence of buildings with a height of 18-30 m (H2) could be found in suburban and urban areas. Meanwhile, buildings with a height of >30 m (H3) could only be found at 1 observation point in urban area, specifically on the urban grid 4 (Figure 2). Vegetation cover in rural areas had a higher value than suburban and urban areas because land use in rural areas were dominated by agriculture (Figure 3). In urban areas, agricultural land and open green space could still be found, so there was still vegetation cover up to 26.531% in urban areas.

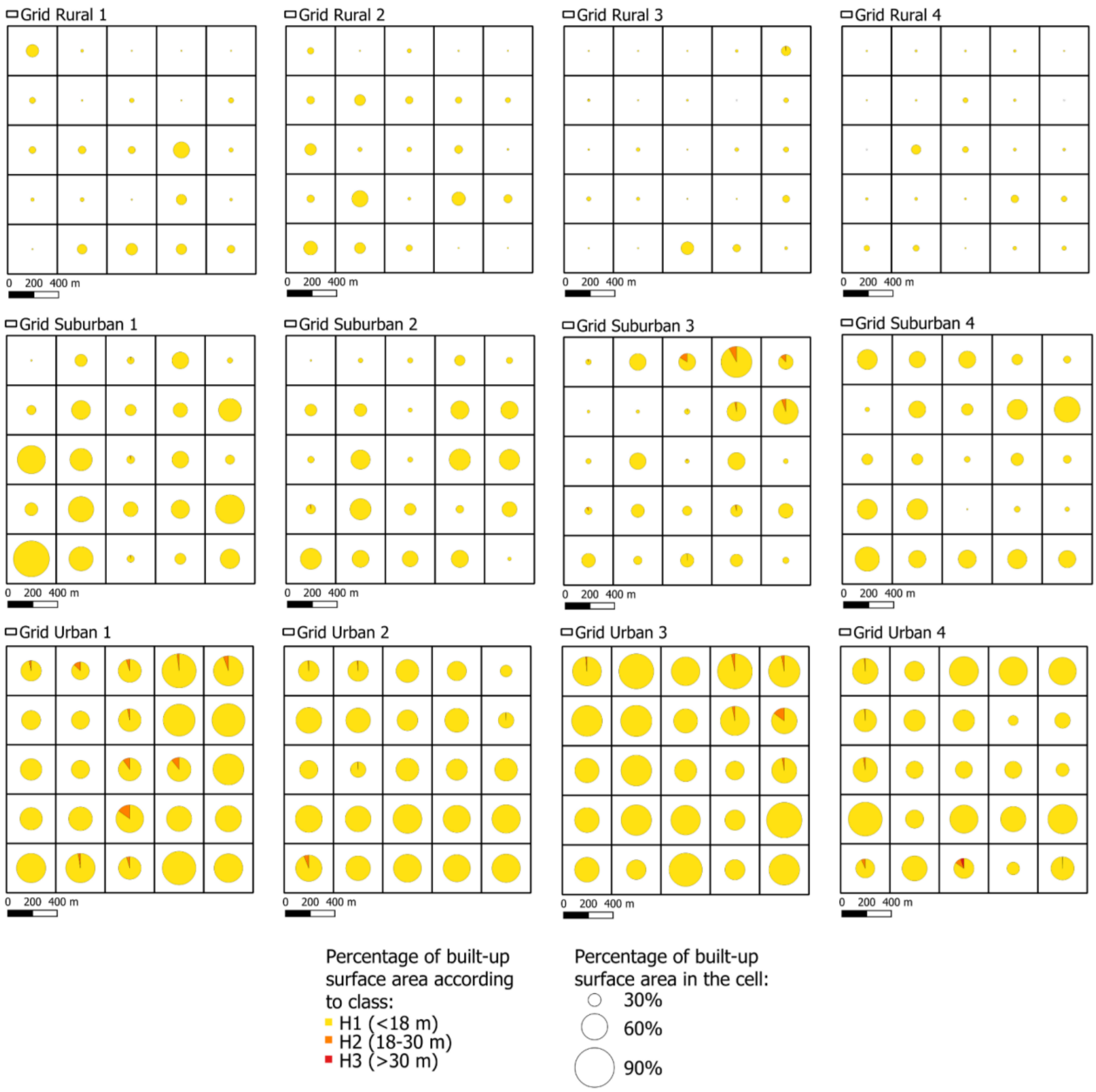

Figure 2. Percentage of each building height class among the built-up surface area in each grid on the study area from the left to the right are grid number 1, 2, 3, and 4, respectively. The size of each chart is proportional to the percentage of total built-up surface area in each observation point

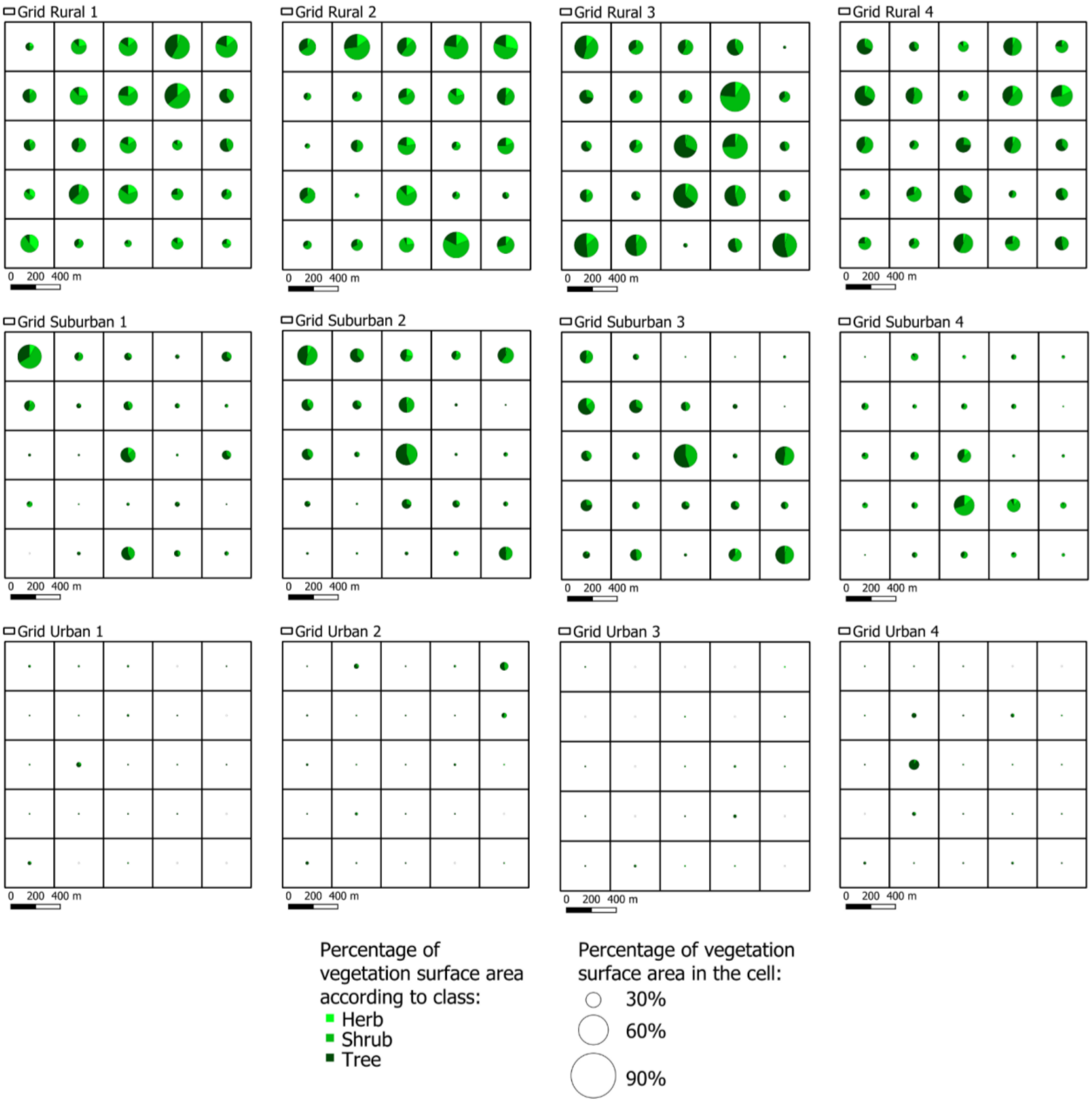

Figure 3. Percentage of each class of vegetation in each grid on the study area from the left to the right are grid number 1, 2, 3, and 4, respectively. The size of each chart is proportional to the percentage of total vegetation surface of the observation point

Bird community response to the type of building and vegetation

Visualization of results using CCA can provide information on the correlation between the bird community and the environmental conditions under study. At all levels of urbanization, bird communities had a correlation with building cover at the height of <18 m (H1) (Figure 4A). In rural areas, bird communities had a correlation with vegetation cover at the herb and shrub level (Figure 4B). In suburban areas, bird communities have a correlation with building cover at the height of <18 m (H1) (Figure 4C). In suburban areas, the bird community was inversely proportional to the value of building cover type H1. In urban areas, bird communities had a correlation with vegetation cover at the herbs level (Figure 4D). In addition to herbs, there was only common iora (*Aegithina tiphia*) that had a positive correlation with building cover at the height of 18-30 m (H2).

The effect of building types and vegetation on the bird community

Based on the results of the GLM analysis in all urbanization classifications (Table 4), the best minimal adequate model (with the lowest AIC value) to predict the effect of building types and vegetation on the bird community showed that vegetation cover in the form of shrubs had a significant influence on individual abundance (0.3389±0.1152, P: 0.004; AIC: 2681.8) and bird species richness (0.02691±0.01251, P: 0.032; AIC: 1349.6). In rural areas, shrub cover also had influence on individual abundance (0.6341±0.1995, P: 0.002; AIC: 879.67). In suburban areas, building type H1 (<18 m) had negative effect on individual abundance (-0.5534±0.134, P: 7.72E-12; AIC: 925.02), species richness (-0.04023±0.01276, P: 0.002; AIC: 458.93), and bird diversity index (-0.00491±0.0.002332, P: 0.037; AIC: 118.32). In addition to the type of building, the heterogeneity of building heights (-7.6611±2.762, P: 0.007) had a negative effect on species abundance, and the average building height (-0.28593±0.12663, P: 0.026) had a negative effect on species richness. In urban areas, building type H2 (18-30 m) had a positive effect on individual abundance (2.244±1.09, P: 0.042; AIC: 831.55).

Discussion

In this study, it can be seen that urban areas had the lowest species richness compared to other areas. This situation is in line with studies that have been carried out related to the relationship between urbanization and bird communities, where species richness was reported to decrease with an increase in building cover in an area (Amaya-Espinel et al. 2019). The study also found unique conditions in the diversity index value in each region. Rural areas have environmental conditions that are more supportive of bird habitat but have the lowest diversity index value of the three levels of urbanization. Heterogeneous habitats in urban areas can provide shelter and forage for certain species, especially for bird species that have habitats in urban areas, such as the yellow-vented bulbul (*Pycnonotus goiavier*) and eastern spotted dove (*Spilopelia chinensis*) (Adams 1994; Pudyatmoko et al. 2009; Souza et al. 2019).

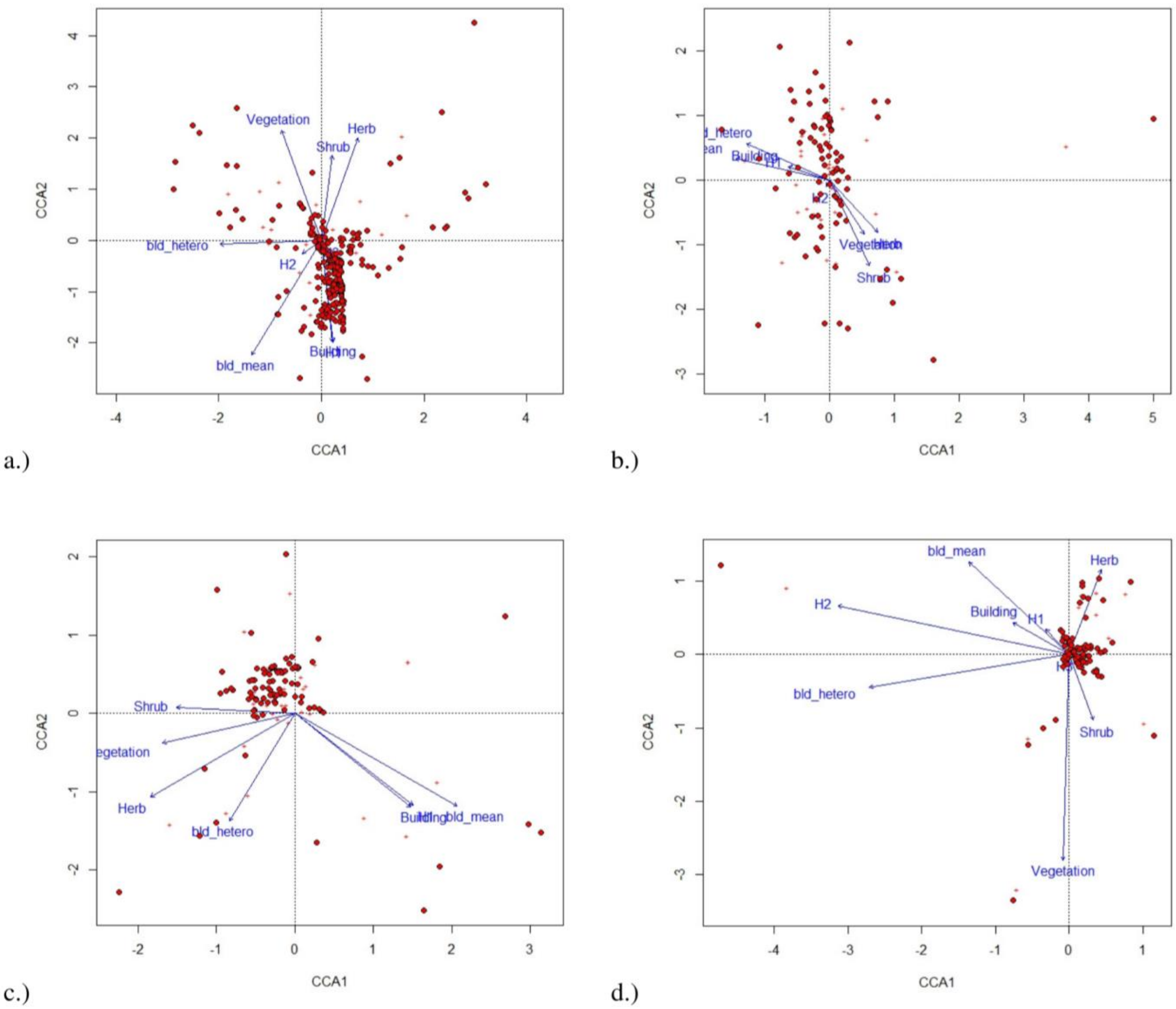

Figure 4. Response of birds to the type of building and vegetation on: A. All levels of urbanization; B. Rural area; C. Suburban area; and D. Urban area. Plots obtained from Canonical Correspondence Analysis

Table 4. The best minimal adequate model to predict the effect of building types and vegetation on the bird community using GLM. The significance of each variable was shown as : *** P < 0.001; ** P < 0.01; * P < 0.05; P < 0.1

Variables	Estimate	SE	T value	P	AIC
Abundance in all urbanization levels (Abundance~Shrub, Res.Dev.=131293, df=298)					
Intercept	24.8359	1.6491	15.06	< 2E-16 ***	2681.8
Shrub	0.3389	0.1152	2.942	0.00351 **	
Species richness in all urbanization levels (Species richness~Shrub, Res.Dev.=1547.7, df=298)					
Intercept	4.13534	0.17905	23.096	< 2E-16 ***	1349.6
Shrub	0.02691	0.01251	2.152	0.0322 *	
Abundance in rural (Abundance~Shrub, Res.Dev.=36461, df= 98)					
Intercept	13.481	4.4219	3.049	0.00296 **	879.67
Shrub	0.6341	0.1995	3.179	0.00198 **	
Abundance in suburban (Abundance~H1+Building Height Heterogeneity, Res.Dev.=56248, df=97)					
Intercept	67.7529	8.3766	8.088	1.74E-12 ***	925.02
H1	-0.5534	0.134	-4.129	7.72E-05 ***	
Building height heterogeneity	-7.6611	2.762	-2.774	0.00665 **	
Diversity index in suburban (Diversity Index ~H1, Res.Dev.=18.002, df=98)					
Intercept	1.072908	0.091724	11.697	< 2E-16 ***	118.32
H1	-0.004913	0.002332	-2.107	0.0377 *	
Species richness in suburban (Species richness~H1+Building Height Mean, Res.Dev.=531.99, df= 97)					
Intercept	8.75255	1.27651	6.857	6.57E-10 ***	458.93
H1	-0.04023	0.01276	-3.152	0.00216 **	
Building height mean	-0.28593	0.12663	-2.258	0.02619 *	
Abundance in urban (Abundance~H2+Building Height Heterogeneity, Res.Dev.=22087, df=97)					
Intercept	31.201	4.235	7.367	5.79E-11 ***	831.55
H2	2.244	1.09	2.06	0.0421 *	
Building height heterogeneity	-3.552	2.084	-1.705	0.0914 .	
Diversity index in urban (Diversity Index ~Building Height Mean, Res.Dev.=12.404, df=98)					
Intercept	1.32531	0.18175	7.292	7.95E-11 ***	81.069
Building height mean	-0.04563	0.0201	-2.27	0.0254 *	

The GLM model showed that shrub cover had a significant influence on the abundance and species richness in all urbanization classifications. In rural areas, shrub cover also had a positive effect on abundance. The existence of shrub cover in an area can provide shelter and a place to find food for several bird species (Iwajomo et al. 2018; Souza et al. 2019). An urban area is an area that had the least shrub cover among all urbanization levels. The addition of shrub cover in urban areas can increase the complexity of the existing vegetation cover (Rico-Silva et al. 2021). The addition of shrub cover is also expected to increase the abundance and species richness of birds (Rousseau et al. 2015).

In suburban areas, building type H1 (<18 m) had a negative effect on abundance, species richness, and bird diversity index. In addition to the type of building, the heterogeneity of building heights had a negative effect on the abundance, and the average building height had a negative effect on species richness. Building cover in built-up areas can create an unfavorable environment for bird species that require forest resources, such as trees and shrubs that can be used as nesting sites (Souza et al. 2019). The presence of building cover can harm birds due to increased predation. This is because the nesting habitats of several bird species can be exposed to predators, especially those that nest above ground.

In urban areas, building type H2 (18-30 m) had a positive effect on abundance. Buildings with a height of 18-30 m tend to function as a substitute for nesting habitats for several species of birds (Pellissier et al. 2012), especially colonial bird species that prefer low to tall building structures (Skórka et al. 2018), especially nesting in building cavities, such as in the areas between the roof and ceiling of a house (Adams 1994; Palomino and Carrascal 2006). This can be seen from the discovery of birds nesting or sheltering on the roof of type H2 buildings in urban areas. According to Pellissier et al. (2012), heterogeneity of building types with a large number of H2-type building covers can increase the abundance of a bird species.

The existence of buildings resulting from urbanization has a serious impact on biodiversity components, such as birds. In this study, it was found that shrub cover had a positive impact on bird abundance. Building cover had different impacts at each level of urbanization. The existence of the type H2 building had a positive impact, while the type H1 building had a negative impact. Making spatial plans that provide more variety of plant cover and diversity of building types based on height is expected to increase bird diversity in urban areas.

ACKNOWLEDGEMENTS

This research was funded by Program Rekognisi Tugas Akhir Universitas Gadjah Mada (Universitas Gadjah Mada Final Assignment Recognition Program). We would like to thank the government and the residents of Province of Yogyakarta, Indonesia, who have permitted us to conduct this research. We would also like to thank Ikhsan Fiqra Naufalianto, Nur Rochim, Dana Risqi Prihandi, Eri Julian Catur Hidayat, M. Akmal Ramadhan, and Astri Chairunnisa for their assistance with fieldwork.

REFERENCES

Adams LW. 1994. Urban Wildlife Habitats: A Landscape Perspective. Minnesota Archive Edition, Minnesota.

Amaya-Espinel JD, Hostetler M, Henríquez C, Bonacic C. 2019. The influence of building density on Neotropical bird communities found in small urban parks. Landsc Urban Plan 190: 103578. DOI: 10.1016/j.landurbplan.2019.05.009.

Bibby CJ, Burgess ND, Hill DA. 1992. Bird Census Techniques. Academic Press Inc., London.

Caprio E, Ellena I, Rolando A. 2009. Assessing habitat/landscape predictors of bird diversity in managed deciduous forests: A seasonal and guild-based approach. Biodivers Conserv 18: 1287. DOI: 10.1007/s10531-008-9478-1.

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR. 2005. Global consequences of land use. Science 309: 570-574. DOI: 10.1126/science.1111772.

Fontana S, Sattler T, Bontadina F, Moretti M. 2011. How to manage the urban green to improve bird diversity and community structure. Landsc Urban Plan 101: 278-285. DOI: 10.1016/j.landurbplan.2011.02.033.

Fuller RJ, Langslow DR. 1984. Estimating of birds by point counts: How long should count last?. Bird Stud 31: 195-202. DOI: 10.1080/00063658409476841.

Grimmond S. 2007. Urbanization and global environmental change: Local effects of urban warming. Geogr J 173: 83-88. DOI: 10.1111/j.1475-4959.2007.232_3.x.

Indriyanto. 2006. Ekologi Hutan. Bumi Aksara, Jakarta. [Indonesian]

Iwajomo SB, Onogwu M, Adelowo YO. 2018. Patterns in bird species richness and abundance in the University of Lagos, Akoka Campus. J Res For Wildl Environ 10: 33-41.

Jiang Y, Hou L, Shi T, Ning Y. 2018. Spatial zoning strategy of urbanization based on urban climate co-movement: A case study in Shanghai mainland area. Sustainability 10 (8): 2706. DOI: 10.3390/su10082706.

Mardiastuti A, Mulyani YA, Rinaldi D, Rumblat W, Dewi LK, Kaban A, Sastranegara H. 2020. Synurbic avian species in Greater Jakarta Area, Indonesia. IOP Conf Ser Earth Environ Sci 457: 012001. DOI: 10.1088/1755-1315/457/1/012001.

Marzluff JM. 2001. Worldwide urbanization and its effects on birds. In: Marzluff JM, Bowman R, Donnelly R (eds). Avian Ecology and Conservation in an Urbanizing World. Springer, Boston, MA.

McGarigal K, Cushman SA, Stafford S. 2000. Multivariate Statistics for Wildlife and Ecology Research. Springer-Verlag New York, Inc., New York.

Morrison ML, Kendall WL, Block WM, Strickland MD. 2001. Wildlife Study Design. Springer-Verlag New York, Inc., New York.

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, Mcglinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H. 2020. Vegan: Community Ecology Package. R package version 2.5-7. https://CRAN.R-project.org/package=vegan.

Palomino D, Carrascal LM. 2006. Urban influence on birds at a regional scale: A case study with the avifauna of northern Madrid province. Landsc Urban Plan 77: 276-290. DOI: 10.1016/j.landurbplan.2005.04.003.

Pellissier V, Cohen M, Boulay A, Clergeau P. 2012. Birds are also sensitive to landscape composition and configuration within the city centre. Landsc Urban Plan 104: 181-188. DOI: 10.1016/j.landurbplan.2011.10.011.

Pudyatmoko S, Kaharuddin, Nurvianto S. 2009. Role of urban environment on conservation of birds diversity in Java, Indonesia. J Biol Sci 9: 345-350. DOI: 10.3923/jbs.2009.345.350.

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Ralph CJ, Sauer JR, Droege S. 1995. Monitoring Bird Population by Point Counts. General Technical Reports PSW-GTR-149. Pacific Southwest Research Station, California, USA.

Rico-Silva JF, Cruz-Trujillo EJ, Colorado Z GJ. 2021. Influence of environmental factors on bird diversity in greenspaces in an Amazonian city. Urban Ecosyst 24: 365-374. DOI: 10.1007/s11252-020-01042-x.

Rousseau JS, Savard JPL, Titman R. 2015. Shrub-nesting birds in urban habitats: Their abundance and association with vegetation. Urban Ecosyst 18: 871-884. DOI: DOI:10.1007/s11252-014-0434-4.

Skórka P, Żmihorski M, Grzędzicka E, Martyka R, Sutherland WJ. 2018. The role of churches in maintaining bird diversity: A case study from southern Poland. Biol Conserv 226: 280-287. DOI: 10.1016/j.biocon.2018.08.013.

Souza FL, Valente-Neto F, Severo-Neto F, Bueno B, Ochoa-Quintero JM, Laps RR. 2019. Impervious surface and heterogeneity are opposite drivers to maintain bird richness in a Cerrado city. Landsc Urban Plan 192: 103643. DOI: 10.1016/j.landurbplan.2019.103643.

Surya B, Ahmad DNA, Bahrun RS, Saleh H. 2020. Urban farming as a slum settlement solution (study on slum settlements in Tanjung Merdeka Village, Makassar City). IOP Conf Ser Earth Environ Sci 562: 012006. DOI: 10.1088/1755-1315/562/1/012006.

Surya B, Salim A, Hernita, Suriani S, Menne F, Rasyidi ES. 2021. Land use change, urban agglomeration, and urban sprawl: A sustainable development perspective of Makassar City, Indonesia. Land 10 (6): 556. DOI: 10.3390/land10060556.

Švajlenka J, Kozlovská M. 2018. Houses based on wood as an ecological and sustainable housing alternative-Case Study. Sustainability 10 (5): 1502. DOI: 10.3390/su10051502.

Tietze TD. 2018. Bird Species: How They Arise, Modify and Vanish. Springer, Cham.

Turner MG, Gardner RH. 2015. Landscape Ecology in Theory and Practice: Pattern and Process, 2nd edition. Springer, New York.

Weng YC. 2011. Developing urban adaptation atrategies for global warming by using data mining techniques: A case study of major metropolitan areas in Japan. In: Stefano C (eds). Global Warming Impacts-Case Studies on The Economy, Human Health, and on Urban and Natural Environments. InTech, Croatia.