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Analysis of Green Space Changes at Gunung Gede - Cilibende Campus Using Geographic Information System

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Abstrak: IPB Gunung Gede - Cilibende Campus is part of IPB University, which is used by IPB Vocational School and IPB Business School. With limited land, the increase in the number of students and lecturers, as well as the development of campus infrastructure and facilities, has the potential to increase carbon emissions on campus. Therefore, it is necessary to have a green space that acts as a carbon dioxide (CO_2) absorber and creates a healthier environment at IPB Gunung Gede–Cilibende Campus. This study aimed to analyze land use and changes in green space at the IPB Gunung Gede Campus - Cilibende. The processing involved secondary data of satellite imagery of the IPB Gunung Gede - Cilibende Campus in 2019-2023 collected from Google Satellite using Google Earth Pro. Digitization was performed to determine the land use area for calculating the green space ratio and minimum green space requirement. The land use at IPB Gunung Gede - Cilibende Campus consists of forests, plants, buildings, parking areas, and roads. The percentage of green space in 2019 was 64.05%, and by 2023, it had decreased to 45.13%, which is smaller than the minimum green space requirement of 58%. The Green Roof concept can be applied as a business activity to increase the green space area. By applying the Green Roof concept, IPB Gunung Gede - Cilibende Campus gets an additional green space of 16.5%, so the total green space ratio in 2023 becomes 61.63%.

Keywords: green space, open space, infrastructure, IPB University, sustainability

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1. Background

The IPB Gunung Gede - Cilibende Campus is one of the 18 sites owned by IPB. The IPB Gunung Gede - Cilibende Campus is the main campus for the Diploma Program of Bogor Agricultural University, which is then known as the IPB Vocational School. According to the Performance Report of IPB University in 2022, the IPB Vocational School Study Program organizes educational programs consisting of 17 study programs with a capacity of 7,128 students at the IPB Gunung Gede-Cilibende Campus and Study Programs Outside the Main Campus (PSDKU) IPB Sukabumi Campus. Along with the number of students who continue to increase every year, the IPB Gunung Gede - Cilibende Campus requires sustainable development to provide adequate facilities such as teaching labs, gymnasiums, greenhouses, and other facilities while still having green spaces that meet the standards.

Significant progress has been made in the sustainability movement in higher education since the 1990s in the areas of research, campus operations, strategic planning, and community service [1]. The concept of a sustainable campus is adopted by a campus that involves technology, personality, community, and programs that form a lifestyle that supports the environment for all individuals involved in it [2]. The campus has two methods to implement the concept of sustainability on campus, namely through campus greening efforts and education on sustainability principles [1]. Campus greening is emphasized through the management of green spaces on campus. According to the WHO Russo and Cirella (2018) [3], a minimum of 9 m^2 of green space per individual is recommended, with an ideal urban green space value of 50 m^2 per capita. The development of green open areas on campus can positively impact the quality of teaching and learning activities [4]. The improved quality of teaching and learning will lead to increased public interest in studying at the IPB Gunung Gede Campus - Cilibende.

Plants can absorb CO_2 through photosynthesis, where CO_2 is absorbed and O_2 is released back into the free air. The CO_2 netted by vegetation is used in the respiration process, whereas the remainder contributes to the formation of biomass [5]. Vegetation growing on the Earth's surface can store approximately 150,000 million tons of CO_2 each year and release approximately 400,000 million tons of oxygen into the atmosphere. On a timescale, 1 ha of green leaves can absorb 8 kg of CO_2 per hour, equivalent to the production of CO_2 by 200 humans breathing at the same time. In addition, each hectare of trees can neutralize CO_2 emissions from 20 motor vehicles. However, the ability of each type of vegetation to absorb CO_2 varies [6].

Along with the development of the IPB Gunung Gede - Cilibende Campus, the number of students continues to increase. According to the Directorate General of Higher Education, in 2020 alone, there was an increase in the number of students of 617,224 students which was the result of the reduction of new students with students who had graduated. According to the Ministry of Education, Culture, Research, and Technology of Bogor Agricultural University in 2022 and 2023, the growth of IPB University students in 2022 was 1,421 students, which is 4.3% of the total number of students (32,786). The increase in the number of students in higher education is reflected in the growing public interest in higher education. However, this growth also presents challenges, especially in meeting the need for adequate teachers, learning facilities and laboratories.

The increase in the number of students and lecturers, as well as the construction of lecture halls, campus facilities, and laboratories, has the potential to increase carbon emissions on campus due to greater energy consumption and more intensive construction activities and facility usage. Green spaces act as carbon dioxide (CO_2) sinks, store carbon, and create clean and comfortable air [7]. By maintaining and expanding green spaces, campuses can reduce their negative impact on the environment and support sustainability of the surrounding environment. Therefore, maintaining green spaces as carbon sinks is important to overcome the increase in carbon emissions and create a healthier and more sustainable environment for the entire campus community, especially at the IPB Gunung Gede - Cilibende Campus, which has limited land. This study aimed to analyze land use and green space changes at the IPB Gunung Gede - Cilibende Campus.

2. Methods

The location of the Green Space Change Analysis was carried out at the IPB Gunung Gede-Cilibende Campus, Bogor City, West Java. It is located between 6° 35′ 25" South Latitude and 106° 48′ 35" East Longitude. The IPB Gunung Gede - Cilibende campus covers an area of 13.82 ha [8].

2.1. Material

The materials used in this study were secondary data in the form of satellite images and the boundaries of the IPB Gunung Gede - Cilibende Campus area. The satellite images used were from 2019 to 2023. The boundaries of the IPB Gunung Gede-Cilibende Campus area refer to the digitization

map of the IPB Gunung Gede-Cilibende Campus drone from the Sustainable Campus Development Agency. The satellite imagery used was obtained from Google Satellite using the Google Earth Pro application. Satellite image data for the last five years were downloaded from Google Earth Pro using the Historical Imagery feature.

2.2. Research Procedure

The procedure for processing the research data involved several steps. First, secondary data of 2019-2023 satellite imagery of the IPB Gunung Gede - Cilibende Campus were collected from Google Satellite using the Google Earth Pro application. Subsequently, georeferencing was performed on the 2019-2023 satellite image of the IPB Gunung Gede - Cilibende Campus using ArcMap 10.8. Subsequently, a manual digitization process was performed to calculate the land-use area. During digitization, geographical objects are identified, their coordinates are determined, and information about them is recorded from maps, aerial imagery, or satellite imagery as digital data [9]. The result of this digitization process was a shapefile format file. A shapefile (shp) is a data format used to store spatial information in vector form, which includes planes, lines, and points, as well as data related to these three types. Shapefiles are a nontopological data format that can store various types of spatial data in an easily accessible manner. The structure of a shapefile consists of three files with different file extensions: the main file (shp) is used to store spatial information, the index file (shx) serves as an index to accelerate data searches, and the dBase table (dbf) stores attributes related to the spatial data. The types of spatial data that can be stored in the main file (shp) include points, a collection of points, a single line or collection of lines (polyline), and a single plane or collection of planes (polygon) [10]. After obtaining the area, the green space ratio was calculated based on the area and minimum green space requirement.

The land cover classification in this study was divided into five categories: buildings, parking lots, roads, green space, and ground surface. Buildings are physical manifestations of construction work, such as lecture halls, laboratories, and offices. Parking lots are areas or spaces specifically designed for parking vehicles. Roads are solid surface paths, such as asphalt or concrete, used for vehicular movement. Greenfields are collections of large trees and areas covered by vegetation. The ground surface refers to the uppermost part of the land or earth surface that cannot be classified as a greenfield.

Open spaces are open areas not enclosed by permanent buildings or structures and are available for public use. Open spaces encompass various land types, including parks, squares, and other public spaces designed for recreation, aesthetics, and social activities [11]. The relationship between open and green spaces is close because green space is a part of open space that is specifically dedicated to vegetation and the natural environment. Green spaces, such as urban parks, gardens, and forests, function as open green spaces that provide ecological benefits such as air filtration, temperature reduction, and groundwater quality improvement. Thus, open spaces integrated with green spaces can improve people's quality of life, support environmental sustainability, and create healthier and more comfortable spaces for daily activities [12].

Green spaces are part of open spaces. The minimum area of green space that needs to be owned by IPB Gunung Gede - Cilibende Campus can be calculated using **Equation** (**1)**. The amount of green space was obtained by summing the areas of forests, plants, and lakes. The green space ratio can be calculated using **Equation (2)**. The green space ratio projection equation for the future was obtained from the trendline green space ratio data for the 2019-2023 IPB Gunung Gede - Cilibende Campus with the help of the Microsoft Excel application.

The equation used to calculate campus green space requirements based on UGS values is given by **Equation (1)**. The equation used to calculate the green space ratio can be determined using **Equation (2)** [3].

$$KGS = \frac{M + D + TD \times UGS}{LK} \times 100\% \quad (1)$$

$$RGS = \frac{LH}{LK} \times 100\% \quad (2)$$

Description:

KGS = Green space requirement (%)
M = Number of students
D = Number of lecturers
TD = Number of teaching staff
Ideal UGS = 50 m^2/capita
UGS min = 9 m^2/capita
LK = Area of IPB Campus Gunung Gede - Cilibende (m^2)
RGS = Green space ratio (%)
LH = Green Space area (m^2)
LK = Area of IPB Campus Gunung Gede - Cilibende (m^2)

3. Results and Discussion

3.1. Land Use of IPB Campus Gunung Gede - Cilibende Year 2023

In 2023, IPB Gunung Gede - Cilibende Campus had an open space area of 74.99% and a green space area of 45.13%, with a total population of 8,971 people [6]. The land use map of the IPB Gunung Gede - Cilibende Campus is shown in **Figure 1**.

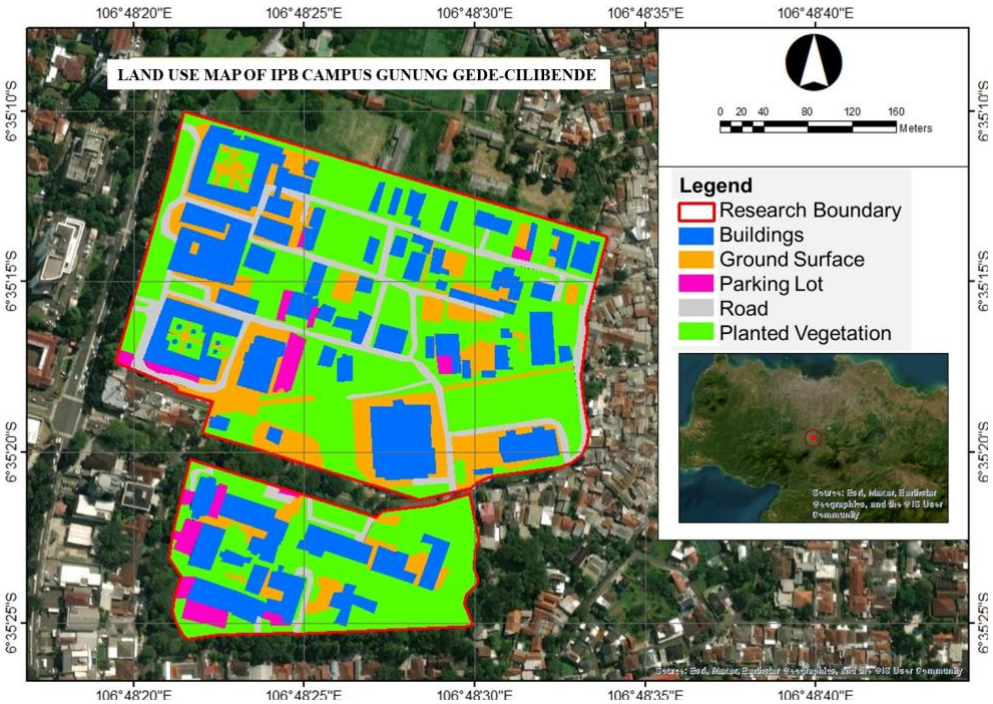

Figure 1. Land use map of IPB Campus Gunung Gede - Cilibende Year 2023

The open space areas consisted of forest areas, plants, roads, ground surfaces, and parking lots. The open-space area does not include building infrastructure. The green space area only consists of forests and plants. IPB Gunung Gede - Cilibende Campus has forest and plant areas as green space for research in various fields of study, such as forestry study programs that want to study forest ecology and wastewater treatment using wetlands in the campus area as a research location [8].

Table 1. Land use planning of IPB Gunung Gede - Cilibende Campus in 2023

No	Landuse	Percentage (%)	Area (m^2)
1	Building	28.55	39,660
2	Ground surface	13.93	18,935
3	Parking lot	3.0	4,231
4	Road	9.33	12,966
5	Green space	45.13	62,492
	Total		138,242

As shown in **Table 1**, the infrastructure area of the IPB Gunung Gede - Cilibende Campus in 2023 comprised 28.55% buildings, 9.33% roads, and 3.05% parking lots. Building infrastructure can be used as a learning area and support student activities, both academic and non-academic, such as UKM activities, organizations, and student resource development. The road and parking lot areas are used for campus residents' access and mobility. The higher the increase in the number of campus residents, the higher the infrastructure needs in the campus.

3.2. Land Use Change of Gunung Gede - Cilibende IPB from 2019 to 2022

Since 2019, land use changes at the IPB Gunung Gede - Cilibende campus have shown significant dynamics. Based on the results of data processing using a geographic information system (GIS), there is an increase in building area in line with the increasing need for infrastructure and teaching and learning facilities. In addition to buildings, parking lots and roads have also expanded to accommodate increased mobility and accessibility needs, which has contributed to the reduction of green spaces. The land use in 2019 is shown in **Figure 2**, and **Table 2** describes the land use until 2022.

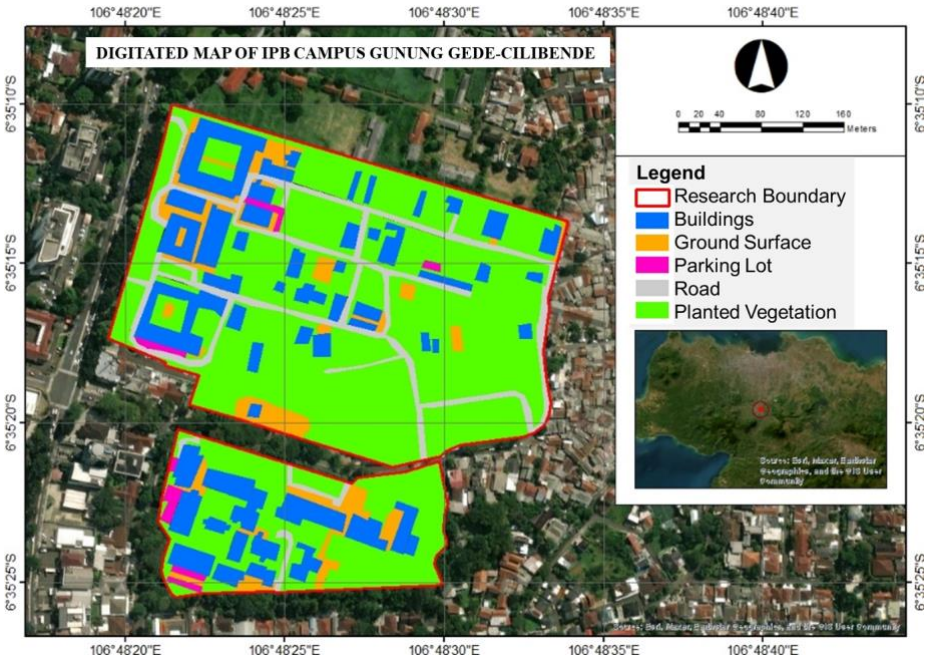

Figure 2 Land Use of Gunung Gede - Cilibende IPB in 2019

Tabel 2 IPB Land Use Gunung Gede - Cilibende 2019 -2022

No	Landuse	2019		2020		2021		2022	
		%	Area (m^2)	%	Area (m^2)	%	Area (m^2)	%	Area (m^2)
1	Building	19.70	27,233	20.05	27,812	22.97	31,793	25.01	34,640
2	Ground surface	6.44	8,902	7.96	11,044	8.66	11,991	10.70	14,829
3	Parking lot	1.31	1,810	1.11	1,534	2.13	2,948	2.51	3,471
4	Road	8.50	11,750	8.62	11,960	6.58	9,106	8.65	11,986
5	Green space	64.05	88,544	62.26	86,353	59.66	82,586	53.13	73,603
		Total	138,242		138,242		138,242		138,242

Based on **Figure 2** and **Table 2**, in 2019, the percentage of available green space amounted to 64.05%, which shows that green space at the IPB Gunung Gede–Cilibende campus in 2019 was still dominant as part of efforts to maintain the balance of the campus ecosystem and provide a healthy learning environment. The percentage of buildings (19.70 %) and parking lots (1.31 %) shows the need for infrastructure development and learning facilities to accommodate learning activities, and the accessibility of IPB civitas has not reached a high number.

As shown in **Figure 2** and **Table 2**, in 2022, the percentage of available green spcae was 53.13%, a decrease of 6.53% from the previous year. There was a decrease in the percentage of green space and a considerable increase in the percentage of ground surface in 2022, which occurred because 2022 was the beginning of preparations for development in the following year. While the percentage of buildings amounted to 25.01%, there was an increase of 2.04%, which shows that infrastructure development has increased from the previous year. Green space changes that occurred from to 2019-2023 saw a change from a 64.05% decrease in the area to 45.13%, in contrast to the building area, which increased from 19.70% to 28.55%.

3.3. Green space changes of IPB Gunung Gede - Cilibende Campus

IPB University is one of the campuses with the best agricultural background in Indonesia [13]. This is indicated by the large number of students enrolled at IPB University. Based on the data, there was an increase in the number of students from 2019-2020 to 2021-2023. In 2023, the number of students at IPB Gunung Gede-Cilibende reached 8,689. The number of students, education staff, and lecturers at IPB Gunung Gede-Cilibende are shown in **Figure 3**.

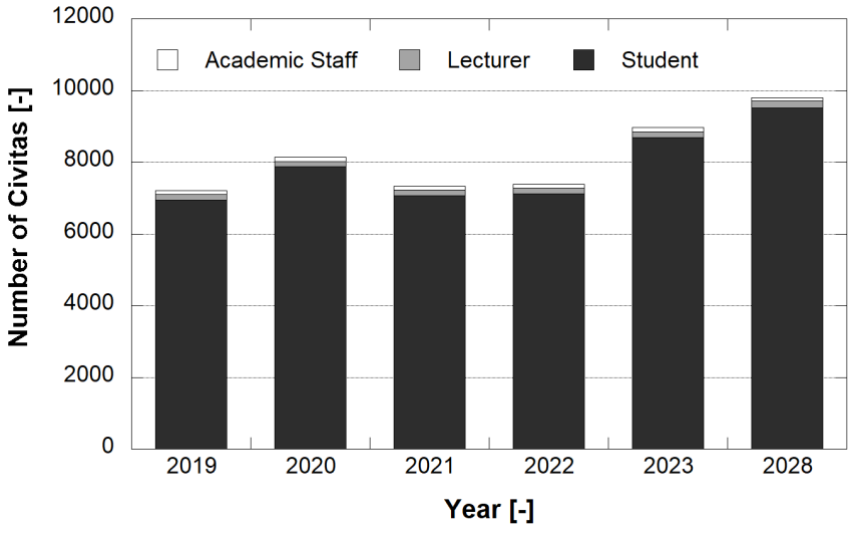

Figure 3 Number of students, lecturers and staff of IPB Gunung Gede - Cilibende

Figure 3 shows that the statistical model illustrates the comparison of the number of students each year at IPB Gunung Gede - Cilibende, and that the number of students tends to fluctuate every year. There was a significant decrease in 2021, which decreased by approximately 814 students from 2020. This is due to the reduced interest of prospective applicants for the IPB Gunung Gede - Cilibende Campus[14].

The number of students is directly proportional to the reputation of the higher education institution, especially if the students are qualified [15]. The reputation of an educational institution is very important because it can provide a good view of the quality of the institution from the people in Indonesia. The more qualified the students, the higher their academic achievement. In addition, an increase in the number of students will also be directly proportional to tuition fee income, which can be used for campus investments, such as increasing the number of facilities supporting student activities and improving academic quality that can produce good student products. The achievement output of students greatly impacts the reputation of the institution.

Universities and learning institutions in Indonesia and worldwide are diverse and have different reputations. Based on QS World University Rankings (WUR) in 2023, IPB University ranked 22nd out of 40 universities from QS WUR institution in the category of the largest number of students. With a large number of students, IPB University has improved the quality of its campus facilities. One of them is in the Gunung Gede - Cilibende IPB Campus area, which also adds and improves the quality of campus facilities, such as infrastructure, as a student learning area. This affects the area of green space in the IPB Gunung Gede - Cilibende Campus area. The graph of changes in the green space area at the IPB Gunung Gede Campus - Cilibende is shown in **Figure 4**.

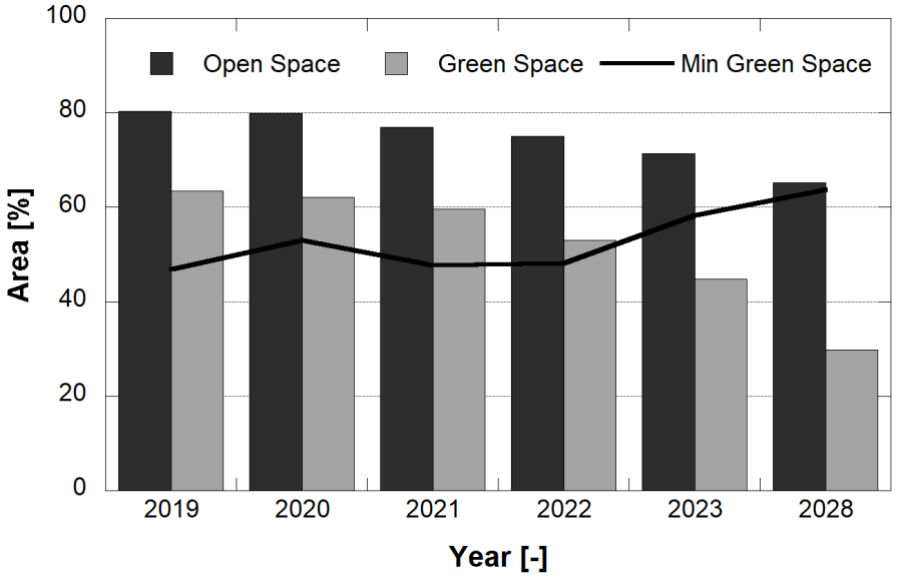

Figure 4 Changes in Green Space Campus IPB Gunung Gede - Cilibende

In **Figure 4**, it can be seen that there is a decrease in the area of green space from 2019-2023, and it starts to be below the minimum green space requirement graph starting in 2023. The average green space area is 56.8% or approximately 7.85 ha of the total area of the IPB Gunung Gede - Cilibende Campus. Therefore, it is necessary to maintain the green space area in the IPB Gunung Gede - Cilibende Campus environment by increasing the alignment of infrastructure needs and green space areas.

3.4. Application of Green Roof at IPB Gunung Gede Campus - Cilibende

The concept of green roofs was introduced in Indonesia in recent years. The principle of green roofs is derived from sustainability, namely, the ability of various earth resources to interact with human cultural and economic systems, as well as the ability to adapt to ongoing environmental changes[16]. A green roof is a roof that uses plant materials. Green roofs can be applied to flat or sloping roofs. In general, the green roof layer consists of roof construction, a waterproofing membrane, drainage, planting media with a thickness of up to 2 m, and plants. The soil used typically contains lightweight clay granules and crushed stone[17].

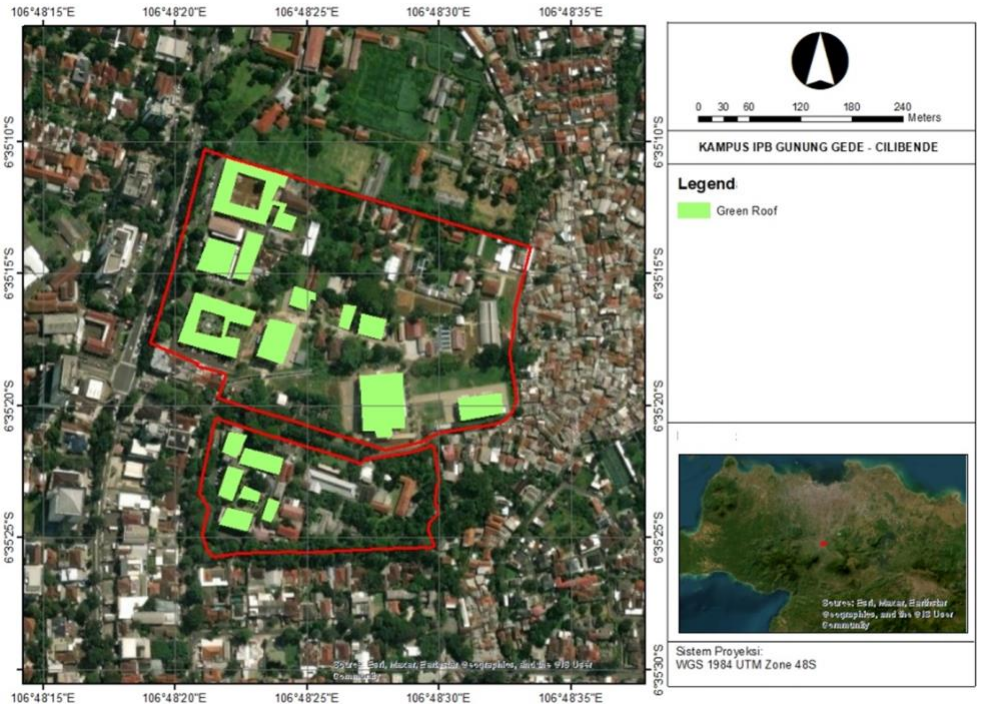

Figure 5 Implementation of Green Roof at IPB Campus Gunung Gede - Cilibende

If the implementation of the green roof is in accordance with **Figure 5**, then the IPB Gunung Gede - Cilibende campus will get an additional green space area of 22,897 m^2, which will increase the percentage of green space ratio by 16.5%. By summing the green space ratio produced by the green roof with the available green space in 2023, the total green space ratio was 61.63%. This figure is above the minimum green space limit in 2023, which is 58%. Thus, the application of the green roof concept is effective in increasing the need for green spaces on limited land. This certainly requires further review of the building structure so that it can be applied to the Gunung Gede - Cilibende IPB Master Plan.

4. Conclusion

The IPB Gunung Gede - Cilibende Campus has an area of 13.82 ha with a population of 8,971 people in 2023. Campus residents include students, lecturers, and educational staff. The land use at IPB Gunung Gede - Cilibende Campus consists of forests, plants, buildings, parking areas, and roads. The percentage of green space in 2019 was 64.05%, and by 2023, it had decreased to 45.13%, which is smaller than the minimum green space requirement of 58%. The Green Roof concept can be applied as a business activity to increase the green space area. By applying the Green Roof concept, IPB Gunung Gede - Cilibende Campus gets an additional green space of 16.5%, so the total green space ratio in 2023 becomes 61.63%.

References

[1] Simangunsong TL. Pengelolaan Sampah Kampus untuk Mewujudkan Kampus Berkelanjutan (Sustainability Campus): PROZIMA (Productivity, Optimization and Manufacturing System Engineering) 2017;1:59–63. https://doi.org/10.21070/prozima.v1i1.707.

[2] Phramesti R, Yuliastuti N. Kajian Keberlanjutan Universitas Negeri Semarang (UNNES) Sebagai Kampus Konservasi (studi Kasus: UNNES Sekaran, Semarang). Teknik PWK (Perencanaan Wilayah Kota) 2013;2:183–90. https://doi.org/10.14710/tpwk.2013.1451.

[3] Russo A, Cirella GT. Modern Compact Cities: How Much Greenery Do We Need? International Journal of Environmental Research and Public Health 2018;15:2180. https://doi.org/10.3390/ijerph15102180.

[4] Gandasari I, Hotimah O, Miarsyah M. Pemanfaatan Ruang Terbuka Kampus Sebagai Potensi Menjaga Lingkungan. Jurnal Green Growth Dan Manajemen Lingkungan 2020;9:71–85. https://doi.org/10.21009/JGG.092.04.

[5] Putri SI. Laju Penyerapan Emisi CO2 Berdasarkan Nilai Fluks Karbon pada Ruang Terbuka Hijau (Studi Kasus : Kampus IPB Darmaga Bogor). 2017.

[6] Setyowati DL. Iklim Mikro Dan Kebutuhan Ruang Terbuka Hijau Di Kota Semarang (the Micro Climate and the Need of Green Open Space for the City of Semarang). Jurnal Manusia dan Lingkungan 2008;15:125–40. https://doi.org/10.22146/jml.18685.

[7] Wulandari S, Rifardi R, Rasyad A, Yusmarini Y. Status Keberlanjutan Ruang Terbuka Hijau Sebagai Cadangan Karbon Di Kota Pekanbaru (the Sustainability Status of Green Open Space as Carbon Stock in Pekanbaru City). Jurnal Manusia Dan Lingkungan 2018;25:73–80. https://doi.org/10.22146/jml.23817.

[8] Satria A, Slamet AS, Kosasih A, Purwito A, Siregar IZ, Putra H. Campus Setting as Living Labs: Lessons from IPB University, Bogor, Indonesia. Journal of Sustainability Perspectives 2023;0:257–62. https://doi.org/10.14710/jsp.2023.20712.

[9] Longley PA, Goodchild MF, Maguire DJ, Rhind DW. Geographic Information Science and Systems. 4th ed. US: John Wiley & Sons, Inc; 2015.

[10] Santoso CS. Sistem Informasi Real Time Gis Untuk Monitoring Sistem Cors (continously Operating Reference Station) Di Kantor Wilayah Badan Pertanahan Provinsi Jawa Timur. Jurnal Manajemen Informatika 2018;9.

[11] Febriarto P. Pemanfaatan Ruang Terbuka (Open Space) Untuk Tempat Berkumpul Di Jalur Pejalan Kaki. MJA 2021;22:111–24. https://doi.org/10.26905/jam.v22i2.5757.

[12] Chiesura A. The role of urban parks for the sustainable city. Landscape and Urban Planning 2004;68:129–38. https://doi.org/10.1016/j.landurbplan.2003.08.003.

[13] Sudrajat A, Kartika L. Faktor-Faktor Yang Memengaruhi Keputusan Mahasiswa Dalam Menyewa Tempat Tinggal Di Kampus Institut Pertanian Bogor Dramaga. Jurnal Ekobis : Ekonomi Bisnis & Manajemen 2021;11:197–213. https://doi.org/10.37932/j.e.v11i1.157.

[14] Mardiana R, Putra H, Qayim I, Helmi A, Anggraini E, Jayanegara A, et al. Magazine Sustainabilty of IPB University 2023. Badan Pengembangan Kampus Berkelanjutan IPB 2024.

[15] Imanudin SAA. Pengaruh faktor mahasiswa dan faktor universitas terhadap prestasi akademik dan dampaknya terhadap reputasi Universitas Kristen Petra. Universitas Kristen Petra, 2015.

[16] Suryandari L, Danusastro Y. Peranan Riset Dan Peningkatan Keterampilan Arsitek Lanskap Dalam Menghadapi Penerapan Konsep Green Building. Jurnal Lanskap Indonesia 2011;3. https://doi.org/10.29244/jli.2011.3.2.%p.

[17] Nur'aini RD. Analisis Konsep Green Roof Pada Kampus School of Art, Design and Media Ntu Singapore Dan Perpustakaan Ui Depok. NALARs 2017;16:161–8. https://doi.org/10.24853/nalars.16.2.161-168.