Urban land use challenges to vegetation index of green open spaces

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Abstract. Green open space as nature-based solutions (NBS) infrastructure must be prioritized to continue providing environmental services. Green open spaces can reduce risks from possible threats. The NDVI, as the green open space vegetation index value, measures the function of the area in the Mount Tidar Botanical Gardens (MTBG) Magelang where maintaining ecology and vegetation density services as measured by the NDVI value. Environmental challenges from outside the MTBG are increasing of NDBI that changes in urban land use, which widely changes vegetation density. The methods used in this study are comparison remote sensing interpretation for NDVI and NDBI by Sentinel satellite imageries were analyzed as environmental interaction of biotic, abiotic, and cultural in 2019 and 2023. The results showed that the change in area of plant density in Magelang City, which was initially 61.85%, was moderate and dense vegetation in 2019, decreased to 47.79% now. Magelang City's population growth of 1.02% requires 455.60 km2 of residential area, while green open space MTBG has stayed the same at only 3.8% of Magelang City Area. Vegetation density in MTBG is still above 99% from 2019 to 2023, dominated by vegetation with a density index of up to 96%.

1 Introduction

Green cover and urban open space (RTH) are understood as areas that are only provided for all types of vegetation accessible to residents and do not cover the atmosphere above them. Places like this are open to the public and encourage improvements in the quality of life of urban residents. The existence of green open spaces is a nature-based solution for urban communities. The first good impact is supporting public health, where the atmosphere and existing vegetation can reduce gases that are detrimental to health. Another good impact is that it can increase social interaction and togetherness by using green open spaces as a meeting medium [1].

Environmental services from green land drive urban sustainability and attract commercial and social activities to open land, impacting the local economy. The increasing population, migration, and health hazards related to climate change have made people realize the need

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for green open spaces as infrastructure for nature-based solutions (NBS) that must be prioritized to continue providing environmental services related to climate change [2]. NBS is an option chosen as a solution based on natural conditions and, as much as possible, supported by its availability by nature, making costs minimal and providing environmental, social, and economic benefits in helping to provide resilience and resilience. Various solutions applied from nature certainly provide more and more diversity in natural features and processes to urban activities and development management of existing resources in natural landscapes and seascapes [3]. Everything that is done based on a nature-based solution requires stages of adaptation by the community and local stakeholders with resource efficiency that does not provoke competition between those who use it, as well as seeking interventions that are carried out systemically and comprehensively so that they do not appear sporadic or only at certain times.

Based on contemporary weather conditions and future predictions, the Intergovernmental Panel on Climate Change (IPCC) highlights how open spaces and other open spaces, such as canals and green public areas, build resilience in facing the risks of climate change [4]. Even though it is limited in area, green open space provides a platform for developing biodiversity, mainly vegetation, and directly reduces the risk of poor air quality.

Vegetation analysis included in this case is urban green open space, essential in achieving sustainable urbanization goals. The existence of information about vegetation must be considered in providing resources that can support treatment for managing various urbanization problems, including controlling and moderating them. Furthermore, urban biophysical processes are influenced by the spatial distribution of urban green open spaces [5]. Existing vegetation is part of the process of developing necessary conservation strategies. The availability of environmental benefits can benefit the economic and social aspects provided by the presence of trees, parks, and other types of green open space for urban residents and people who visit these cities.

The importance of urban vegetation information means that green open space is a precious resource in monitoring urban land use, which is dominated by buildings. Analysis of urban development is not only at the level of reviewing problems such as air, air runoff, land pollution, carbon emissions, and livability but can be studied through land use, which is directly related to the availability and documentation of urban green space. Public orientation, in this case land use that reduces vegetation density, needs to be considered as part of policy settings by the government [6].

The land use that is believed from various facts and research evidence shows that the growth of urban development influences the availability of green open space in the increasing area of residential areas due to the pressure of population growth. The more people there are, the more settlements will increase. A housing complex is not just a residence but also a place for residents to carry out activities and supporting facilities. For example, in residential areas, besides housing, there are also places for education, health, and supporting networks for water and electricity resources.

Normalized Difference Vegetation Index (NDVI) is an essential and simple measurement method that has been used in the literature for classification of vegetation density and land use land cover (LULC) in various landscapes [7-9]. Ghaderpour et al. [8] show that NDVI values can differ with differences in surface temperature. Based on the principle of maintaining ecology and services, vegetation density, measured by NDVI values, supports control and decisions based on data to moderate problems.

The study looked at the NDVI index value and compared it with the availability of green open space. Land use is used to see the need and availability of green open space through organizations in line with population growth. The percentage of area allocated for existing urban green open space can be a cornerstone between the environmental policy launched and its implementation in the field.

2 Method

This study was carried out to obtain the results of a study regarding the NDVI index value in green open spaces in the Mount Tidar Botanical Gardens (MTBG) Magelang. Magelang is said to be a city with beauty and diversity of vegetation, like gardens, so it is called TUIN VAN JAVA or the garden of Java Island. The existence of MTBG has an essential meaning for the urban area of Magelang, which is located between mountain basins and has characteristics of sedimentary landforms with volcanic origin. This urban area was formed in the sedimentary plains and hills ecoregion, sandwiched between the Merbabu, Merapi, and Sumbing mountains.

There are various types of vegetation on MTBG, although in the past the building started with planting Mahogany (Swietenia spp.), Khaya (Khaya senegalensis) and Damar (Agathis dammara) which are often found along the road up to the peak land of MTBG. MTBG activities are controlled with the principle of maintaining ecology and vegetation services even though they are used as nature tourism. In this study, MTBG vegetation was measured using NDVI values. Good density indicates that the supporting conditions for plant existence are well managed. The following impact is how environmental services from MTBG can be delivered to the Magelang Community. NDVI data was obtained from Sentinel 2 satellite image analysis.

The methods used in this study are comparison remote sensing interpretation for NDVI and NDBI by Sentinel satellite imageries were analyzed as environmental interaction of biotic, abiotic, and cultural in 2019 and 2023. Sentinel-2 (S2) is a product of the Earth observation mission developed by ESA through the Copernicus Program to obtain terrestrial observations to support environmental services and management in the event of natural disasters. This research uses Sentinel S2 L2A data. The Sentinel-2 L2A image is interpreted using near-infrared and Red light [10] in channels 8A and 4. NDVI has been calculated with the following expression:

$$NDVI = (NIR-Red) / (NIR+Red) \quad (1)$$

Where NIR is near-infrared light, and Red is visible red light. Sentinel satellite imagery was analyzed by looking at the dynamics of vegetation density in 2019 and 2023.

The NDVI calculation results are in the range between -1 to 1. Negative NDVI values represent areas with surface air, buildings or artificial structures, rocks, clouds, and snow. NDVI values of 0.1-0.2 are shown on bare soil. Plants are represented by positive NDVI values ranging between 0.2 and 1, and vegetation with a healthy, dense canopy is above 0.5. Sparse or medium-density vegetation will usually be shown in the NDVI range of 0.2 to 0.5.

Challenges from outside the MTBG are increasing along with changes in urban land use in Magelang, which have considerably changed the density of Magelang vegetation. NDVI has been calculated with the following expression:

$$NDVI = (SWIR-NIR) / (SWIR+NIR))) \quad (2)$$

NDBI stand for Normalized Difference Built-up Index and Band SWIR is band shortwave infrared.

Population data was obtained from Magelang Statistics in Report, which shows population growth from 2019 to 2023. This data also calculates the necessary changes needed to increase land use for the organization. Apart from that, the percentage of green open space provided for the area of Magelang City was also calculated.

The results of the index of NDVI figures from 2019 and 2023 show the vegetation density index in MTBG compared between the two times. In addition, it will be seen which

vegetation density class dominates. These data serve as a reference for directing urban development in Magelang, which currently accommodates a service center city and urban garden on the island of Java.

3 Results and discussion

The NDVI index assessment for the 2019 situation is precisely based on Sentinel-2 L2A, which recorded conditions in Magelang City on 12 August 2019 and 30 August 2019. After processing the NIR and RED channels following the NDVI formula, it was discovered that on 12 August 2019, the condition of the MTBG was covered by plants with a proportion of 99.95% of the 701,674 m2 MTBG land area.

Most green space studies use vegetation indices derived from satellite imagery, such as the Normalized Difference Vegetation Index (NDVI) to indicate the amount of green space around where participants live. NDVI cell values represent percent vegetation, and median or average values within distance-based buffers or administrative boundaries can be used.

The MTBG area, which is almost entirely covered by vegetation, is dominated by vegetation with a dense density reaching 95.22% of the MTBG area. Meanwhile, vegetation with moderate density is minimal; namely 3.59%, and plants with sparse density are only 2.24%. The land in MTBG, which is open land because it is not utilized or used as visitor facilities such as roads and buildings, is only 0.05% of the area of MTBG. The NDVI classification results for MTBG are presented in Table 1.

Table 1. NDVI of MTBG at 12 August 2019.

Classification	NDVI	Area (m2)	%
Dense	0.9 - 1	0	0.00%
Dense	0.8 - 0.9	136.832	19.50%
Dense	0.7 - 0.8	483.473	68.90%
Dense	0.6 - 0.7	47.7999	6.81%
Moderate	0.5 - 0.6	14.5954	2.08%
Moderate	0.4 - 0.5	10.5817	1.51%
Sparse	0.3 - 0.4	5.10839	0.73%
Sparse	0.2 - 0.3	2.91908	0.42%
Open Soil	0.1 - 0.2	0.36489	0.05%
No Vegetation	-1 - 0.1	0	0.00%

Date: 12-Aug-19

Dense Vegetation 95.22%

Vegetation Coverage of MTBG 99.95%

Source: Interpretation of Sentinel-2 L2A

Vegetation conditions that meet the MTBG conservation and protection goal provide direct services for visitors and the people of Magelang City. Nevertheless, land use conditions outside the MTBG completely differ from land use within the MTBG. The Magelang City area surrounding the MTBG shows data that on the same day, 12 August 2019, it is still worthy of being called the Garden of Central Java. This data can be seen from Table 2, which provides clarity that vegetation covers 82.59% of Magelang City, where lush plants with high vegetation density exist in one-fifth of the Magelang City area.

Table 2. NDVI of Magelang City at 12 August 2019.

Classification	NDVI	Area (m2)	%
Dense	0.9 - 1	0	0.00%
Dense	0.8 - 0.9	0.30	1.63%
Dense	0.7 - 0.8	1.77	9.54%
Dense	0.6 - 0.7	1.69	9.11%
Moderate	0.5 - 0.6	1.77	9.55%
Moderate	0.4 - 0.5	2.19	11.83%
Sparse	0.3 - 0.4	3.34	18.03%
Sparse	0.2 - 0.3	4.25	22.90%
Open Soil	0.1 - 0.2	2.33	12.55%
No Vegetation	-1 - 0.1	0.90	4.85%

Date: 12-Aug-19

Dense Vegetation 20.28%

Vegetation Coverage of Magelang City 82.59%

Source: Interpretation of Sentinel-2 L2A

The subsequent NDVI processing on Sentinel Imagery is for September 20, 2023 conditions. The MTBG conditions a year later did not provide a striking difference, even though there was a decrease in vegetation density as indicated by the NDVI classification. Vegetation still dominates up to 99.90% of the MTBG area, and high or dense vegetation density is present in 94.19% of the MTBG area.

Table 3. NDVI of MTBG at 20 September 2023.

Classification	NDVI	Area (m2)	%
Dense	0.9 - 1	2547.57	0.36%
Dense	0.8 - 0.9	236560	33.71%
Dense	0.7 - 0.8	391234	55.76%
Dense	0.6 - 0.7	30570.9	4.36%
Moderate	0.5 - 0.6	14557.6	2.07%
Moderate	0.4 - 0.5	12737.9	1.82%
Sparse	0.3 - 0.4	9098.47	1.30%
Sparse	0.2 - 0.3	3639.39	0.52%
Open Soil	0.1 - 0.2	727.878	0.10%
No Vegetation	-1 - 0.1	0	0.00%

Date: 20-Sep-23

Dense Vegetation 94.19%

Vegetation Coverage of MTBG 99.90%

Source: Interpretation of Sentinel-2 L2A

Looking at an area wider than MTBG, namely the administrative boundaries of Magelang City, it is known that the decrease in vegetation density in MTBG also occurred in Magelang City as an area around MTBG. This decline can be seen from the reduced vegetation cover to 75.38%, or a decrease of around 7.21% compared to the previous year's conditions. The

density of lush vegetation has also decreased to less than one-fifth of the area in Magelang City.

Table 4. NDVI of Magelang City at 20 September 2023.

Classification	NDVI	Area (m2)	%
Dense	0.9 - 1	0.01	0.00%
Dense	0.8 - 0.9	0.58	3.11%
Dense	0.7 - 0.8	1.54	8.28%
Dense	0.6 - 0.7	1.37	7.40%
Moderate	0.5 - 0.6	1.44	7.78%
Moderate	0.4 - 0.5	1.87	10.10%
Sparse	0.3 - 0.4	2.81	15.17%
Sparse	0.2 - 0.3	4.36	23.51%
Open Soil	0.1 - 0.2	3.11	16.75%
No Vegetation	-1 - 0.1	1.46	7.87%

Date: **20-Sep-23**

Dense Vegetation 18.82%

Vegetation Coverage of Magelang City 75.38%

Source: Interpretation of Sentinel-2 L2A

The decrease in vegetation density is accompanied by changes in land use in Magelang City. A city that has declared itself a city with services is undoubtedly trying to invite economic movement, which must be kept from using land for economic purposes. Challenges from land use outside the MTBG, as challenges from non-open green space areas, will undoubtedly change the calculation of vegetation density in Magelang City—this open green space in a situation that provides hope for mitigating climate change. However, at the same time, the reduced density of surrounding land use vegetation makes open green space the only way to reduce the risk of climate change.

Existing land use in Magelang City shows that the existing area of residential land in Magelang City reached 1234.85 Ha or reached 66.7% of the total area of Magelang City. Magelang has great potential as a tourist area, both natural and cultural, as well as economic development based on agriculture as agropolitan [11]. The population projection for Magelang City from 2022 to 2041 was carried out using population data from 2012 to 2021. After carrying out the calculations, it can be seen that the population projection will use the arithmetic analysis method. Data on the population of Magelang City from 2012 to 2021 was obtained from BPS Magelang City. The following is a graph of population projections from 2022 to 2041 per 5 years.

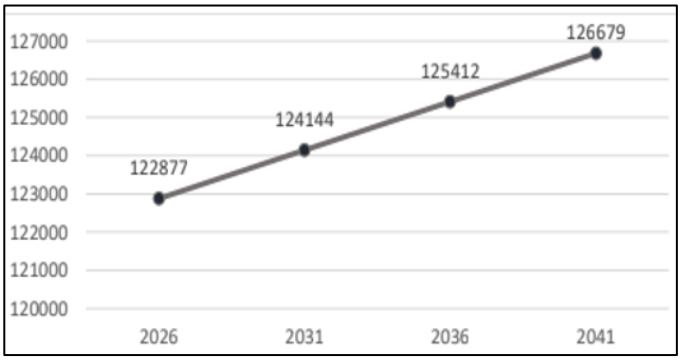

Fig. 1. Magelang City population projection.

Challenges from outside the MTBG are increasing with changes in Magelang's urban land use, which widely changes vegetation density. The results showed that the change in area of plant density in Magelang City, which was initially 61.85%, was moderate and dense vegetation in 2019, decreased to 47.79% now. Magelang City's population growth of 1.02% requires 455.60 km2 of residential area, while green open space MTBG has stayed the same at only 3.8% of Magelang City Area. Vegetation density in MTBG is still above 99% from 2019 to 2023, dominated by vegetation with a density index of up to 96%.

Fig. 2. Mount Tidar as the part of Magelang City region.

Magelang City's population growth of 1.02% requires dominant area Magelang City area. Land use for buildings shows an increase. On the other hand, land use in the form of mixed vegetation and rice fields decreased [12]. There is no clear indicator system used in all places to assess changes in land use and ecological carrying capacity, so studies regarding green open spaces are still open [13] while green open space MTBG has stayed the same at only 3.8% of Magelang City Area. Vegetation density in MTBG is still above 99% from 2019 to 2023 dengan kelas kepadatan vegetasi yang rimbun masih lebih dari 94,19%. Dominated by vegetation with a dense vegetation index of up to 96%.

Fig. 3. Mount Tidar NDVI changed from July 13th to September 30th, 2023.

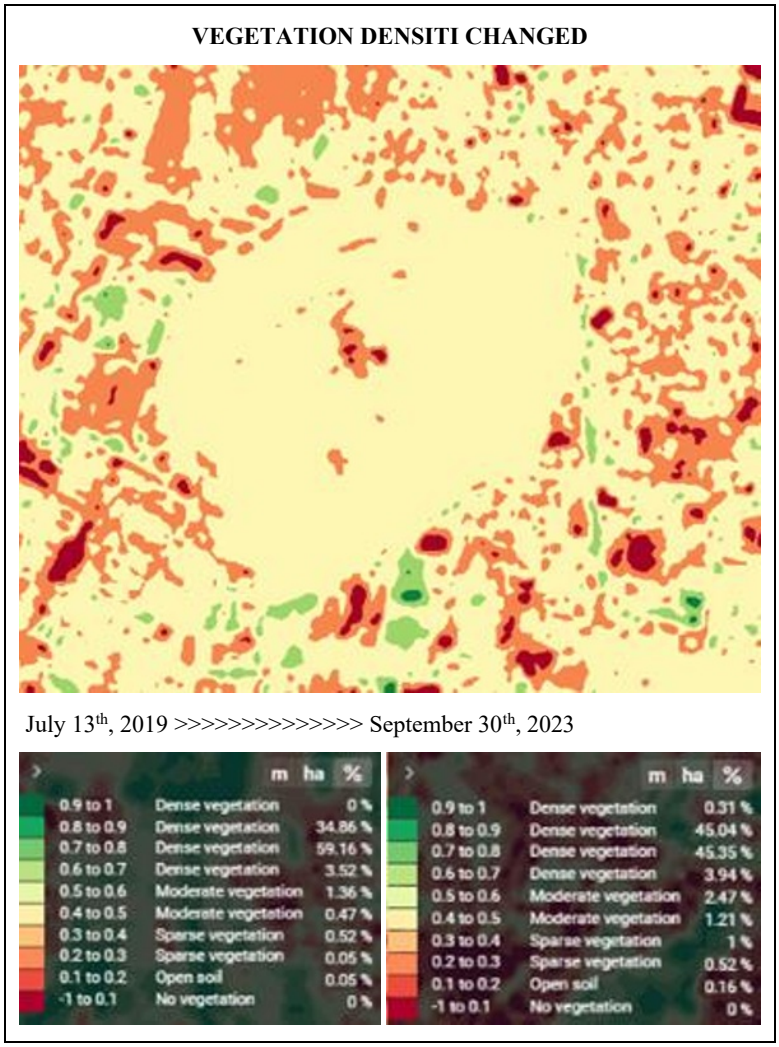

Fig. 4. NDVI improvement of Mount Tidar from July 13th to September 30th, 2023.

Urban green spaces are areas covered with vegetation, such as parks, street trees, urban farms, residential yards, and roof gardens [14]. These spaces provide aesthetic value and many environmental, social and economic benefits that are essential to ensure the long-term sustainability and livability of urban environments. For example, green spaces can act as carbon sinks, absorbing CO2 from the atmosphere, and mitigating the impact of global warming [15]. Additionally, they reduce the urban heat island effect, providing much-needed protection from city noise. Urban green spaces also play an important role in preserving biodiversity in areas where urbanization has lost natural habitat.

Use data from the Normalized Vegetation Index (NDVI) to display city greenery. This data is taken from remote sensing images using geographic data processing software (eg ArcGIS). This measure helps determine the extent of green space on a particular horizontal plane in an urban area. From the image interpretation, NDBI of Magelang City has been increasing. In 2019, the high density of building are 97,600 m^2 and increase 330,000 m^2 ehere equal in 0,73%.

Yang, et. al. [16] show that green spaces can account for up to 20% of the variation in active travel. In general, the influence of green space areas on active travel is positive. Active travel, as a subset of environmentally friendly transportation, is broadly defined as “travel where the passenger's sustained physical activity directly contributes to their movement” [17] and typically includes but is not limited to walking, running , cycling, and swimming [17]. In an era characterized by increasing urbanization and increasing sedentary lifestyles, the promotion of active travel has emerged as an important way to improve individual and environmental well-being [16]. Engaging in active travel regularly provides excellent opportunities for physical exercise [18]. Running or cycling as a mode of commuting or leisure can help individuals achieve recommended levels of physical activity, which helps reduce the risk of cardiovascular disease, counteract fat mass, prevent disease, and alleviate metabolic syndrome and insulin sensitivity. In addition, active travel can reduce the risk of disease [19]. Many studies show that physical activity can reduce the likelihood of developing dementia, and adequate physical activity is significantly correlated with better sleep quality and cognitive performance, which is critical for reducing the onset of functional limitations. In addition, physically active individuals are more resilient and have better emotional control, and experience less psychological distress [20].

Table 5. Tree planting.

Date	Activities	Name of Seeds	Number of
January 2022	Police Corps	Sandalwood	60
13 March 2022	Private Corporate Events	Teak wood	25
April 2022	Magelang Notary Association	Fruit and Non- Fruit	30
18 May 2022	Bogor Newspaper Birthday	Tamarind, Salam, Kanthil, Jackfruit	12
13 - 14 December 2022	Magelang Junior High School	Fruit Plants	30
15 Desember 2022	Private Vocational School	Guava	15
January 2023	GRTK Planting	Buah Roda dan Bodhi	3
24 Februari 2023	Protective Tree and Food Fruit for Monkeys	Sourdough, Guava, Tamarind	100
14 Maret 2023	Green School Program	Durian	10

Source: MTBG

This study is very efficient and achieves great effectiveness by using data from remote sensing. The weakness of this study is the use of data from satellites which may include an interpretation section that requires additional explanatory discussion from field and cultural visits. Exposure to air pollution and lack of green space exacerbate the adverse effects of heat waves on cognitive function. Green space is an effort to mitigate heat. Previous observations have highlighted the potential benefits of green spaces in mitigating extreme heat and reducing the risk of death and other negative health impacts in environments with extreme heat [21-23]. Based on these findings, it is plausible that the incidence of cognitive impairment may be influenced by the combined effects of extreme heat, high levels of air pollution, and lack of green space. On the one hand, exposure to hot environments can increase the concentration of air pollutants, which can amplify the adverse effects of air pollution and cause greater damage to the nervous system [24-26]. On the other hand, green spaces can help cool the air, reduce infrared radiation, and increase humidity levels, thereby reducing the risk of heat stress [27-29]. However, as noted above, few studies have investigated the combined impacts of heatwaves, air pollution, and exposure to green spaces.

4 Conclusion

Challenges from outside the MTBG are increasing with changes in Magelang's urban land use, which widely changes vegetation density.

The results showed that the change in area of plant density in Magelang City, which was initially 61.85%, was moderate and dense vegetation in 2019, decreased to 47.79% now. Magelang City's population growth of 1.02% requires 455.60 km2 of residential area, while green open space MTBG has stayed the same at only 3.8% of Magelang City Area. Vegetation density in MTBG is still above 99% from 2019 to 2023, dominated by vegetation with a density index of up to 96%.

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