Journal of Sylva Indonesiana
Journal homepage: https://talenta.usu.ac.id/jsi

Analysis of Vegetation Density and Distribution of Green Belts in the City Center of Medan Using the Normalized Difference Vegetation Index

Nur Hidayat[1], Anita Zaitunah[1,2*], Nelly Anna[1,2], Samsuri[1,2], Evalina Herawati[1], Alfan Gunawan Ahmad[1]

[1]Jl. Lingkar Kampus, Kampus USU Bekala, Simalingkar A, Kecamatan Pancur Batu, Kabupaten Deli Serdang Sumatera Utara, Indonesia
[2]Green Carbon Innovation and Study Center, Universitas Sumatera Utara, Kampus USU 2 Bekala, Pancur Batu, Deli Serdang, 20353, Sumatera Utara, Indonesia
*Corresponding Author: anita@usu.ac.id

ARTICLE INFO

Article history:
Received December 21st, 2025
Revised February 26th, 2026
Accepted February 26th, 2026
Available online February 28th, 2026

E-ISSN: 2622-5093
P-ISSN: 2622-5158

How to cite (IEEE):
N. Hidayat, A. Zaitunah, N. Anna, S. Samsuri, E. Herawati, and A. G. Ahmad, "Analysis of the Green Belt Vegetation Index in the Medan City Center Area", Journal of Sylva Indonesiana, Vol. 09, No. 01, pp. 81-91, Feb. 2026, doi: 10.32734/jsi.v9i01.23249

ABSTRACT

This study evaluates the distribution and condition of vegetation within the green belts of Medan City Center in 2025 by employing the Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 satellite imagery, supplemented by field verification through purposive sampling. The analysis reveals that the findings indicate that non-vegetated category (NDVI < 0.1) dominated, encompassing 12,240.98 hectares or approximately 43.98%, whereas the dense vegetation class (NDVI 0.3–0.4) represents the smallest portion, covering only 3,009.70 hectares (10.81%) of the total area.Vegetation index values within these urban corridors range from a maximum of 0.55 to a minimum of -0.04, where lower values are predominantly associated with built-up areas and open land, while higher values are restricted to riparian buffers and fragmented green spaces. Spatial pattern analysis, utilizing a 500-meter buffer, highlights significant disparities in vegetation distribution and underscores the mounting pressure of urbanization, which has compromised the ecological functions of the city's green infrastructure. Consequently, these findings emphasize the critical need for strategic planning and robust policy interventions to revitalize green open spaces as essential ecological infrastructure; therefore, the primary recommendation focuses on expanding green belt vegetation through intensification and protection efforts to ensure that ecological, social, and aesthetic functions are maintained sustainably within the Medan City Center.

Keywords: Green Belt, Medan City, Normalized Difference Vegetation Index, Vegetation Density, Urban

1. Introduction

Cities serve as centers of social and economic activities encompassing government, industry, trade, transportation, and education sectors. In the city center of Medan, the concentration of these diverse activities has led to increasing population density, directly resulting in the reduction of open spaces. The rapid pace of urban development has altered land functions, including the shrinking of Green Open Spaces (GOS) and green belts that play a crucial role in maintaining urban ecosystem balance [1].

Population growth and the rising demand for socioeconomic needs have imposed significant pressure on non-built-up areas in Medan City Center. The demand for land for residential and commercial purposes has driven the conversion of vegetated land into built-up areas [2], [3]. This land-use change has degraded the ecological functions of green belts as pollution absorbers, street shading elements, and aesthetic components of the city [4]. Consequently, the environmental quality and overall livability in the city center have declined [5], [6].

The Medan City Government seeks to improve environmental quality by ensuring 30.58% of Green Open Space (GOS) provision, in accordance with Regional Regulation No. 13 of 2011. Vegetation within green belts plays an important role in absorbing pollutants, reducing noise, and enhancing air quality and urban aesthetics [7]. Medan City Center green belt, a collector road with high traffic intensity (Public Works Regulation No. 03/2012), was selected as the study site because it represents an area under substantial environmental pressure. The vegetation condition along this green belt was analysed using the Normalized Difference Vegetation Index (NDVI) method, which utilizes satellite imagery and field measurements to objectively assess vegetation density and physiological condition [8]. This method supports the findings of Chen et al. [9], who demonstrated that green belt vegetation effectively reduces traffic-related air pollution levels.

Vegetation in Pekanbaru's green open spaces plays a vital role in absorbing CO_2 emissions, with a capacity of 58.26 tons/ha/year [10]. Similarly, green open spaces at the University of North Sumatra (USU) can sequester up to 6,256.87 tons of carbon per year [11]. In contrast, public green open spaces in Malang absorb only 17,450 tons of CO_2 annually, covering just 42% of transportation emissions [12]. Meanwhile, in Yogyakarta, the sustainability index for green open space management remains low, with an area of only 49.57 ha due to ongoing land conversion [13].

Spatial vegetation analysis is essential to illustrate the distribution and density of vegetation in urban center areas [14]. The results of such analyses provide a strategic foundation for the government, community, and stakeholders to evaluate, plan, and sustainably manage Green Open Spaces (GOS). This study aims to map the spatial distribution, density levels, and condition of vegetation along the green belts in Medan City Center, as well as to identify areas experiencing vegetation decline or degradation, to support urban spatial planning improvement and the optimization of greening programs.

2. Research Method

2.1. Research Area

This study was conducted from May to August 2025 in Medan City, North Sumatra Province. The research location is presented in Figure 1.

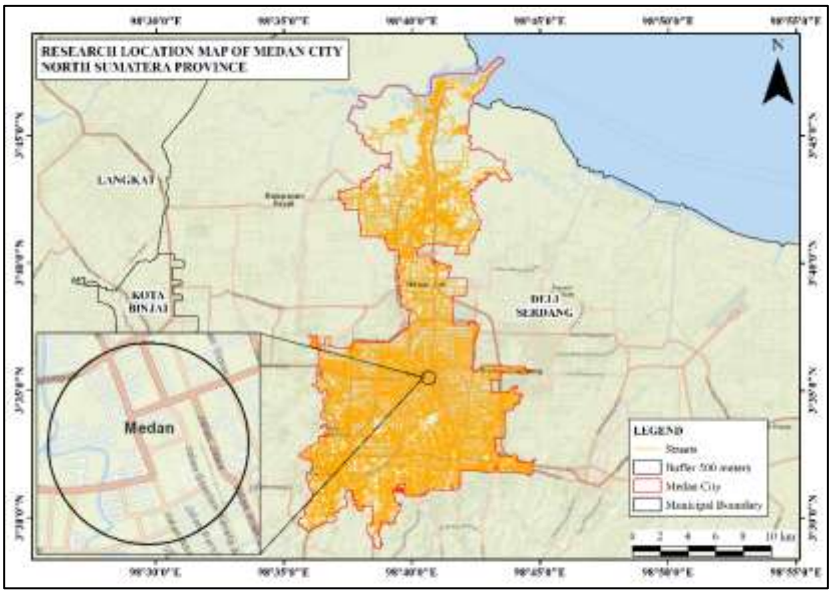


Figure 1. Research location map

2.2. Procedures

The instruments used in this study consisted of tools for collecting field data and for data analysis. Field data collection instruments included the Avenza Maps application, GPS (Global Positioning System), stationery, tally sheet, camera, and mobile phone. Meanwhile, the data analysis tools used were Google Earth, ArcGIS (ArcMap) version 10.8, Microsoft Excel, and Microsoft Word.

The materials used in this study comprised secondary data obtained from other sources and ground-check data, as presented in Table 1.

Table 1. Types of primary and secondary data used in the study

No	Data Name	Data Type	Source	Year
1.	Citra Sentinel-2	Secondary	*https://www.sentinel-hub.com/*	2025
2.	Citra *Google Earth*	Secondary	*Google Earth*	2025
3.	Administrative Map of Medan City	Secondary	Badan Informasi Geospasial (BIG)	2025
4.	Medan City Statistical Data	Secondary	https://medankota.bps.go.id	2024

2.2.1. Data Collection Method

The data collection process involved identifying the primary data required for the analysis. Primary data were obtained through direct field observations (ground checking) using a purposive sampling method. In this approach, 50 sample points were determined based on specific criteria established by the researcher [15].

2.2.2. Data NDVI Analysis

Pre-Processing Stage of Satellite Imagery

1. Band Combination
   Sentinel-2 imagery, retrieved from https://www.sentinel-hub.com as separate spectral bands, was processed into a multispectral composite prior to analysis. Sentinel-2 was selected over Landsat 8 due to its superior 10-meter spatial resolution compared to 30 meters, and its 13 spectral bands, which include the Red Edge band for enhanced NDVI accuracy. Furthermore, its high temporal resolution (5-day revisit cycle) and a reported urban vegetation classification accuracy of 92% [11], [12] make it more effective for detecting urban forests in Medan than Landsat 8.
2. Radiometric Correction
   Radiometric correction was performed to minimize sensor and atmospheric errors in satellite imagery. This process enhances the image contrast and improves the accuracy of reflectance values for subsequent analysis [17].
3. Geometric Correction
   Geometric correction was applied by assigning several Ground Control Points (GCPs) to align the satellite image with actual geographic coordinates [18]. This ensures spatial accuracy between the imagery and the Earth's surface features.
4. Image Cropping
   Image cropping was conducted to extract the area of interest by clipping the imagery according to the administrative boundaries of the study area.

Data Processing Stage

Vegetation indices are mathematical combinations of the red and near-infrared (NIR) spectral bands used as indicators of vegetation presence and condition.

The equation used for calculating the Normalized Difference Vegetation Index (NDVI) as cited in Hatulesila et al. [18] is as follows:

$$NDVI = \frac{(\lambda NIR - \lambda Red)}{(\lambda NIR + \lambda Red)} \quad (1)$$

Information:
NDVI = NDVI value
λNIR = Reflectance value of the NIR band
λRed = Reflectance value of the Red band

After obtaining the NDVI values, classification of vegetation density was performed. NDVI values range from -1 (typically representing water bodies) to +1 (representing areas of dense vegetation). These values are derived by comparing the reflectance of vegetation in the red and near-infrared wavelengths received by the sensor [19].

3. Result and Discussion

3.1. Spatial Distribution of NDVI Values in Medan City

The distribution of NDVI values in Medan City in 2025 shows variation in vegetation density, with values ranging from -1 to +1. NDVI calculations based on Sentinel-2 imagery produced both numerical values and spatial distribution maps that describe the spatial pattern of vegetation coverage. The NDVI value classification for Medan City in 2025 is presented in Table 2.

Table 2. Distribution of NDVI values in Medan City

No	NDVI Values	Area (ha)	Proportion (%)
1	<0.1	12,240.98	43.98
2	0.1-0.2	5,345.91	19.21
3	0.2-0.3	3,422.91	12.30
4	0.3-0.4	3,009.70	10.81
5	> 0.4	3,814.06	13.70
	Total	27,833.56	100.00

Table 2 indicates that in 2025, the most extensive distribution of NDVI values fell within the < 0.1 class, covering 12,240.98 hectares or 43.98% of the total area. Conversely, the smallest distribution was observed in the 0.3–0.4 class, spanning 3,009.70 hectares (10.81%), out of a total calculated area of 27,833.56 hectares. NDVI values below 0.1 signify a lack of vegetation, identifying areas dominated by impervious surfaces, vacant land, or bare soil. Higher NDVI values correlate with denser and healthier vegetation; values exceeding 0.4 generally represent areas with very high canopy density or robust vegetation health, usually corresponding to urban forests or well-maintained green spaces to forest areas [20]. The spatial distribution of NDVI values in Medan City in 2025 is illustrated in Figure 2 below.

An NDVI range of <0.1, with an area of approximately 12,240.98 hectares (43.98% of the city's total area), indicates that most of Medan City in 2025 is dominated by sparse or non-vegetated surfaces such as built-up areas, open land, or thin grass vegetation. Conversely, the NDVI class above > 0.4 covering only 3.814,06 hectares (13,70%), represents a minimal portion of the city characterized by dense vegetation, such as large trees found in specific green open spaces, along riverbanks, or in mangrove areas. The spatial distribution of NDVI values in Medan City in 2025 is illustrated in Figure 2 below.

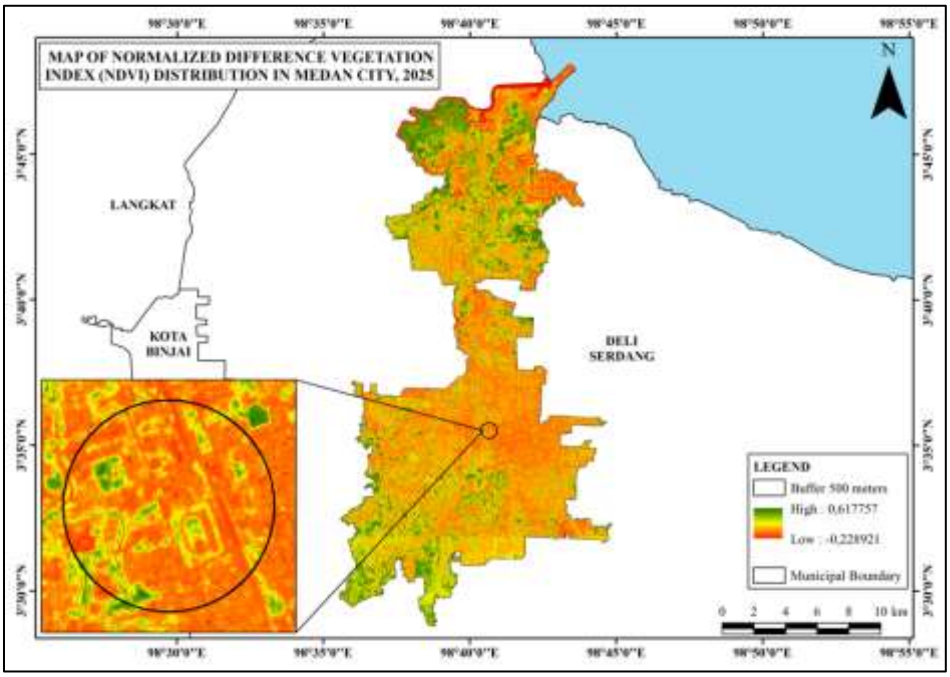


Figure 2. Spatial distribution map of NDVI values in Medan City, 2025

3.2. Vegetation Density Classes in Medan City

The distribution of NDVI values can be used to classify areas based on the dominance of vegetation types, thereby providing accurate spatial information on green cover conditions [21]. Vegetation density refers to the concentration of plant species growing within a particular area, which can be quantitatively assessed using NDVI values derived from Sentinel-2 satellite imagery [22]. In Medan City, vegetation density is categorized into five classes: non-vegetated, sparse, moderate, dense, and very dense [23].

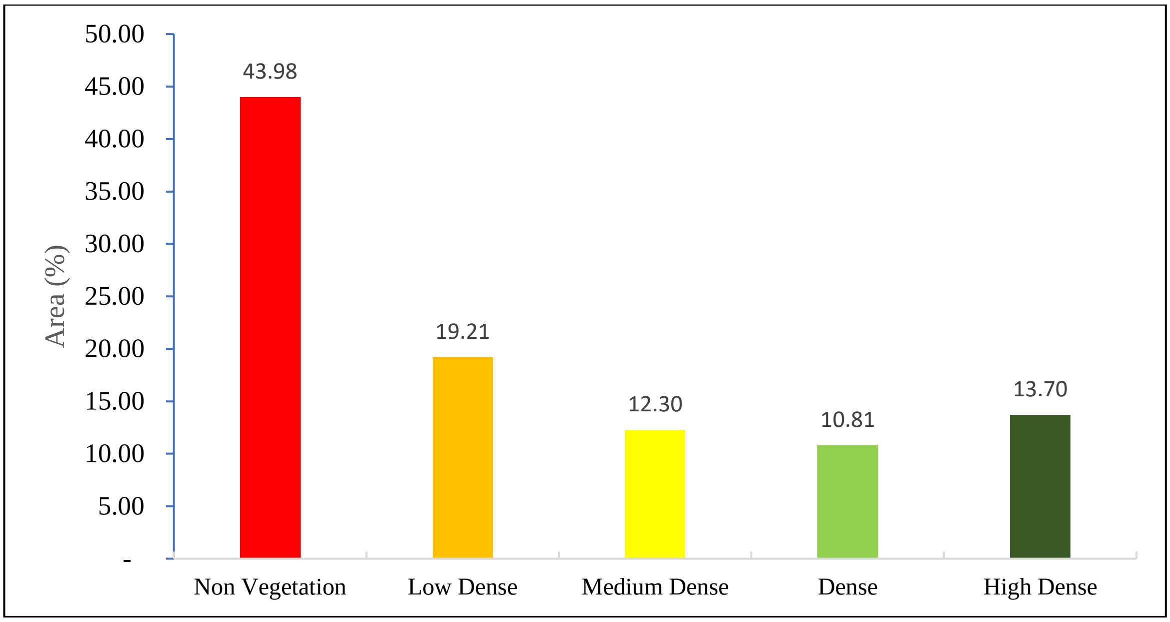


Figure 3. Percentage of vegetation density classes in Medan City

Figure 3 illustrates that in 2025, the dominant land cover in Medan City falls under the non-vegetated category (NDVI < 0.1), encompassing 12,240.98 hectares or approximately 43.98% of the total area. Conversely, the dense vegetation class (NDVI 0.3–0.4) represents the smallest portion, covering only 3,009.70 hectares (10.81%). These figures highlight the scarcity of dense green spaces remaining within the city. This finding aligns with Zaitunah et al. [24], who stated that shifts in urban vegetation cover typically indicate the expansion of built-up areas and the subsequent fragmentation of remaining natural habitats of built-up areas which causes the proportion of areas with high NDVI values to continue to decline.

As illustrated in Figure 3, in 2025, the largest NDVI density class in Medan City was the sparse vegetation category, covering an area of approximately 14,465.70 hectares, or 51.97% of the total city area. Conversely, the smallest class was the very dense vegetation category, covering only 334.13 hectares, or 1.20%. These findings are consistent with the opinion Zaitunah et al. [24], which stated that the expansion of built-up areas has reduced the proportion of high-density vegetation in urban environments, leaving only small remnants of densely vegetated zones. Similarly, Rasheedat and Jodale [25] observed that NDVI and vegetation coverage in various global cities exhibit a comparable trend, showing a decline in vegetation cover due to massive urbanization, particularly across Asian and African cities. Li et al. [26], who analysed NDVI trends across 889 cities worldwide, found that vegetation greenness increased in Europe but decreased in Africa and Asia due to urbanization pressure and land-use change. The reduction in urban vegetation cover in Asian cities has also been linked to environmental impacts such as rising land surface temperatures and deteriorating air quality. According to Hasyim et al. [27], the decline in NDVI values caused by urban expansion is closely correlated with the Urban Heat Island (UHI) effect. Their study revealed that an increase in NDVI by 0.1 could reduce local temperature by approximately 0.339°C, whereas an increase in built-up area could raise temperature by up to 1.075°C. Therefore, maintaining vegetation and green belts is vital for sustainable urban planning and climate res ilience. The spatial distribution of map vegetation density clasess in Medan City in 2025 is illustrated in Figure 4.

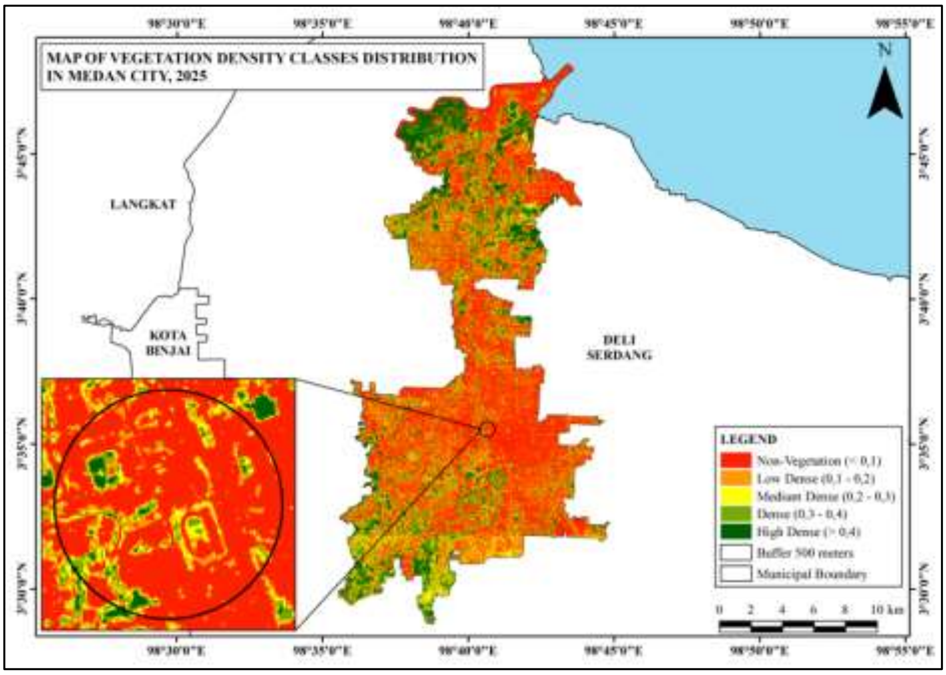
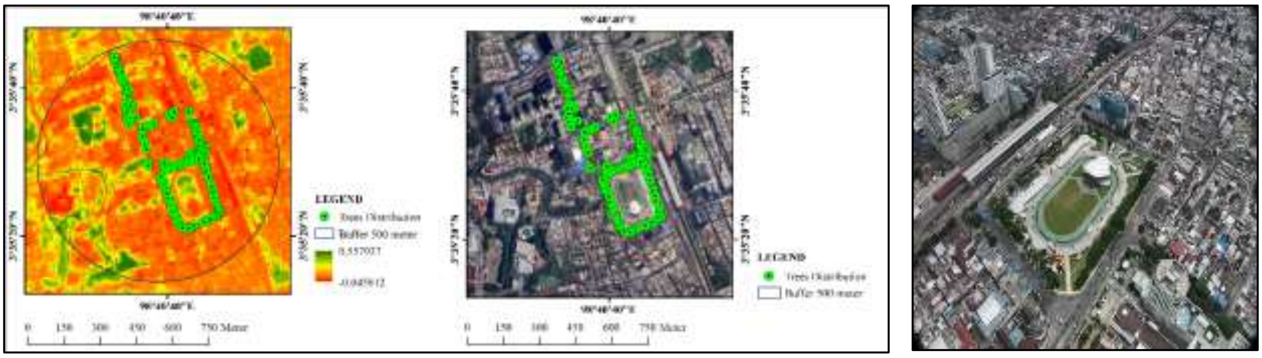


Figure 4. Spatial distribution map of vegetation density classes in Medan City

3.3. Distribution of Vegetation Density Along the Green Belt of Main Roads in Medan City Center

The spatial distribution of vegetation density along the 500-meter buffer of green belts in Medan City Center serves as the main focus for monitoring urban green open space conditions. The NDVI analysis was applied to identify vegetation indices and greenness levels along this corridor, providing accurate and quantifiable spatial data on the urban vegetation status, particularly in major road corridors [28]-[30]. Field observations revealed that most areas within the buffer zone were dominated by residential settlements and business facilities, with only a few green belt segments containing trees of varying density. Visualization through NDVI imagery, Google Earth, and field verification indicated a distinct contrast between areas with very sparse, moderate, and dense vegetation, consistent with NDVI based classification. A visual comparison of NDVI, Google Earth imagery, and field observations for the 500-meter buffer along the Medan City Center green belt is shown in Figure 5.



a) b) c)

Figure 5. Green Belt along Medan City Center, Medan City: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

Based on the analysis presented in Figure 5, the NDVI values along the green belt of Medan City Center ranged from –0.04 to 0.55. The highest NDVI value (0.55) indicates areas with dense vegetation and healthy plant conditions, while the lowest value (-0.04) corresponds to non-vegetated surfaces such as roads and buildings. Field verification (ground check) conducted in 2025 confirmed these findings: areas with NDVI values below <0.1 were dominated by buildings, sidewalks, and parking areas without vegetation cover, whereas higher NDVI values were found in segments with tree-lined streets and small green spaces along road medians. Field observations also revealed that most sections of Medan City Center green belt experienced a decline in vegetation cover due to construction activities and road space restructuring. This pattern is visually represented by the contrast between vegetated and non-vegetated areas in Figure 6.

a) b) c)

Figure 6. Non-Vegetated Class: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

The moderate vegetation density class (NDVI 0.1-0.2) represents areas with limited vegetation cover but still showing photosynthetic activity. Field observations indicate that this class is commonly found along roadside areas with scattered trees, such as office yards, commercial buildings, and shop houses (*rumah toko*) along center area. Vegetation in these areas typically consists of sparsely distributed shade trees and small shrubs surrounding the buildings. The visual comparison for this moderate vegetation density class is shown in Figure 7.

a) b) c)

Figure 7. Sparse Vegetation Class: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

The moderate vegetation density class, with NDVI values ranging from 0.02–0.03, represents areas with limited vegetation cover that still exhibit active photosynthetic processes. Based on field observations, this class was predominantly found along roadside areas interspersed with sparse trees, such as office yards, public facilities, and shop houses (*rumah toko*) along Medan City Center green belt. Vegetation in these areas generally consisted of a few shade trees with low canopy density and small shrubs surrounding buildings. A visual comparison for the moderate vegetation density class is shown in Figure 8.

a) b) c)

Figure 8. Moderate Vegetation Class: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

The dense vegetation density class (NDVI 0.03–0.04) indicates areas with good vegetation cover and high photosynthetic activity. Field observations revealed that this class is primarily found along green belts near Lapangan Merdeka Street, characterized by medium-sized trees with moderately dense canopies and relatively wide spacing between trees. Although the vegetation is not uniformly distributed, its presence contributes to improving air quality and lowering surface temperature in urban areas [31]. Additionally, vegetation in this class enhances the aesthetic value and provides visual comfort for road users. The visual comparison for the dense vegetation density class is displayed in Figure 9.

a) b) c)

Figure 9. Dense Vegetation Class: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

The very dense vegetation density class, with NDVI values greater than >0.4, represents areas with high vegetation cover and optimal photosynthetic activity. Field observations found that this class mainly occurs along riverbanks, where densely canopied trees grow in close proximity. The dense canopy cover creates shaded and humid microclimates, leading to lower surface temperatures compared to surrounding built-up areas. This high-density vegetation plays a crucial role in maintaining microclimate stability, reducing surface runoff, and supporting the ecological functions of urban green belts. The visual comparison for this very dense vegetation class is presented in Figure 10.

a) b) c)

Figure 10. Very Dense Vegetation Class: (a) NDVI; (b) Google Earth Imagery; (c) Field Observation

The spatial distribution of vegetation density along Medan City's green belts can be interpreted through NDVI imagery visualization. In the imagery, bright tones represent sparsely vegetated or built-up surfaces, while darker tones indicate densely vegetated areas, particularly along riverbanks and well-preserved green belts [32]. The variation in NDVI values across the imagery reflects physical conditions and land-cover characteristics observed in the field. Ground verification confirmed that areas with high NDVI correspond to healthy vegetation with dense canopies, whereas residential and commercial zones generally exhibited low NDVI values (<0).

The relationship between NDVI patterns and vegetation density distribution is supported by field validation and Sentinel-2 imagery analysis, demonstrating that both very dense and sparse vegetation classes can be identified and easily verified. International studies such as Zhong and Li. [33] have reported similar patterns in Asian cities, where urbanization pressure significantly reduces NDVI values and vegetation cover, leading to the dominance of sparse vegetation areas. Furthermore, Lu et al. [34] and Sari et al. [35] emphasized that higher NDVI values correspond to greater vegetation density and stronger ecological functions of green belts in maintaining urban environmental quality. These findings reinforce the importance of vegetation density mapping and distribution analysis as a fundamental basis for evaluating spatial planning and formulating sustainable green space management policies [36].

Rapid urbanization in Medan's city center has converted 22% of vegetated areas into built-up land, leading to a significant decline in NDVI values (r = -0.78). This land-use transformation has triggered a 2.1°C increase in the Urban Heat Island (UHI) effect and a 15 $\mu g/m^3$ rise in PM2.5 concentrations within sparse vegetation zones [37]. Currently, Medan's green open space accounts for only 18% (5,256 ha), falling short of the 30% mandate stipulated by Law 26/2007 and Medan Regional Regulation 1/2022 [38]. Conversely, dense vegetation along river green belts (NDVI > 0.51) remains highly effective, sequestering approximately 58 tons of CO_2/ha/year [10].

4. Conclusion

This study maps the spatial distribution and condition of vegetation density within the Medan City Center green belt using NDVI analysis, with values ranging from -0.04 to 0.55. The findings indicate that non-vegetated category (NDVI < 0.1) dominated, encompassing 12,240.98 hectares or approximately 43.98%, whereas the dense vegetation class (NDVI 0.3–0.4) represents the smallest portion, covering only 3,009.70 hectares (10.81%) of the total area. Low NDVI values are primarily concentrated in built-up zones, while high NDVI values are restricted to river green belts. Rapid urbanization and anthropogenic activities have driven a significant decline in dense vegetation cover. Consequently, this mapping provides a critical baseline for evaluating spatial planning and sustainable green space policies, emphasizing the need for vegetation intensification to preserve essential ecological, social, and aesthetic functions.

References

[1] O. O. Green, A. S. Garmestani, S. Albro, N. C. Ban, A. Berland, C. E. Burkman et al., "Adaptive Governance to Promote Ecosystem Services in Urban Green Spaces," *Urban Ecosystems*, vol. 19, no. 1, pp. 77-93, 2016.

[2] E. Ustaoglu and B. Williams, "Determinants of Urban Expansion and Agricultural Land Conversion in 25 EU Countries," *Environmental Management*, vol. 60, no. 4, pp. 717-746, 2017.

[3] R. Fitri, R. Fauzi, O. Seanders, and D. Danniswari, "Land Use Changes and Residential Area Expansion in South Tangerang City, Indonesia," *Southeast Asia: A Multidisciplinary Journal*, 2023

[4] A. Allan, A. Soltani, M. H. Abdi, and M. Zarei, "Driving Forces behind Land Use and Land Cover Change: A Systematic and Bibliometric Review," *Land*, vol. 11, no. 8, p. 1222, 2022.

[5] Z. Tasnim, "*Study on Potential Integration of Greenway on Urban Street Canyon at Planned Residential Area of Dhaka City*," 2018.

[6] S. S. Sinthia, S. Hoque, and M. Arch, "Enhancing Urban Sustainability: Integration of Green Infrastructure on Urban Leftover & Grey Space in the Context of Dhaka," *Int J Research and Innovation in Social Science*, vol. 8, no. 6, pp. 257-279, 2024.

[7] B. T. Asmoro, F. D. Susanti, S. Anam, and A. Maulidia, "Pemberdayaan Pokdarwis dalam Pengelolaan RTH Pasaban Sekartaji Desa Sengguruh Kecamatan Kepanjen Kabupaten Malang," *Jurpikat*, vol. 1, no. 2, pp. 125-135, 2020. (Indonesia)

[8] A. Raihan, "A Review on the Role of Green Vegetation in Improving Urban Environmental Quality," *Eco Cities*, vol. 4, no. 2, p. 2387, 2023

[9] H. Chen, B. Wang, D. S. Xia, Y. J. Fan, H. Liu, Z. R. Tang, and S. Ma, "The Influence of Roadside Trees on the Diffusion of Road Traffic Pollutants and Their Magnetic Characteristics in a Typical Semi-Arid Urban Area of Northwest China," *Environmental Pollution*, vol. 252, pp. 1170-1179, 2019.

[10] R. S. Tinambunan, "*Analisis Kebutuhan Ruang Terbuka Hijau di Kota Pekan Baru*," Tesis, Institut Pertanian Bogor, Bogor, Indonesia, 2015.

[11] S. Samsuri, A. Zaitunah, and O. Rajagukguk, "Analisis Kebutuhan Ruang Terbuka Hijau: Pendekatan Kebutuhan Oksigen: Green Open Space Analysis, Oxygen Requirement Approached in Medan Baru City," *Jurnal Silva Tropika*, vol. 5, no. 1, pp. 305-320, 2021.

[12] H. M. M. Miharja, "Analisis kemampuan ruang terbuka hijau menyerap potensi emisi karbon dioksida (CO_2) antropogenik Kota Malang," Tesis Sarjana, Universitas Brawijaya, Malang, Indonesia, 2020. [Online]. Available: http://repository.ub.ac.id/id/eprint/189861

[13] S. Wulandari, R. Rifardi, A. Rasyad, and Y. Yusmarini, "Status Keberlanjutan Ruang Terbuka Hijau Sebagai Cadangan Karbon Di Kota Pekanbaru (the Sustainability Status of Green Open Space as Carbon Stock in Pekanbaru City)," *Journal of People and Environment*, vol. 25, no. 2, pp. 73-80, 2018.

[14] Y. R. Adrianto, E. Zulaikha, and B. Syairudin, "Analysis of Spatial Area Vegetation Design Factors on Vandalism Intentions of Visitors to Tropical City Park (Surabaya-Indonesia)," *Int J Sustainable Development & Planning*, vol. 20, no. 5, 2025

[15] B. R. Yurianda, D. Setyawan, and Warsito, "Metode Klasifikasi Normalized Difference Vegetation Index Berbasis Citra Landsat 8 untuk Identifikasi Sebaran Kondisi Kesehatan Tanaman Kelapa Sawit di PT. Andira Agro, Sumatera Selatan," *Pedontropika: Jurnal Ilmu Tanah dan Sumber Daya Lahan*, vol. 8, no. 2, pp. 15-24, 2022. (Indonesia)

[16] R. M. Sampurno and A. Thori, "Klasifikasi Tutupan Lahan Menggunakan Citra Landsat 8 Operational Land Imager (OLI) di Kabupaten Sumedang," *Jurnal Teknotan*, vol. 10, no. 2, pp. 1978-1067, 2016. (Indonesia)

[17] M. Nilasari, B. Sasmito, and A. Sukmono, "Aplikasi Penginderaan Jauh untuk Memetakan Kekeringan Lahan Pertanian dengan Metode Thermal Vegetation Index (Studi Kasus: Kabupaten Kudus, Jawa Tengah)," *Jurnal Geodesi Undip*, vol. 6, no. 3, pp. 97-105, 2017.

[18] J. W. Hatulesila, G. Mardiatmoko, and I. Irwanto, "Analisis Nilai Indeks Kehijauan (NDVI) Pada Pola Ruang Kota Ambon, Provinsi Maluku," *Jurnal Hutan Pulau-Pulau Kecil*, vol. 3, no. 1, pp. 55-67, 2019. (Indonesia)

[19] B. Ilmi, E. A. Ayuningtyas, and G. A. Bisa, "Analisis Hubungan NDVI dan LST Berdasarkan Citra Landsat Multitemporal di Kecamatan Lokpaikat," *J Ilmu Alam dan Lingkungan*, vol. 16, no. 2, pp. 31-44, 2025.

[20] M. Alfarhood, A. Alahmad, A. Alalwan, and F. Alkulaib, "Leveraging Satellite Imagery and Machine Learning for Urban Green Space Assessment: a Case Study from Riyadh City," *Sustainability*, vol. 17, no. 13, p. 6118, 2025

[21] T. A. Santoso, D. Arini, and D. M. Driptufany, "Pemetaan Ruang Terbuka Hijau dari Hasil Citra Landsat 8 Menggunakan Metode NDVI di Kota Padang," *Netizen: J Soc Bus*, vol. 1, no. 9, pp. 291-301, 2025. (Indonesia)

[22] N. I. Hikmah and P. Manurung, "Application of Spectral Indices and Deep Learning (Convolutional Neural Network Model) on Land Cover Change Analysis," *Appl Environ* Sci, vol. 3, no. 1, pp. 39-60, 2025.

[23] Ç. Ö. Genç and A. O. Altunel, "Monitoring the Operational Changes in Surface Reflectances After Logging, Based on Popular Indices Over Sentinel-2, Landsat-8, and ASTER Imageries," *Environmental Monitoring and Assessment*, vol. 197, no. 1, p. 120, 2025

[24] A. Zaitunah, S. Samsuri, and F. Sahara, "Mapping and Assessment of Vegetation Cover Change Species Variation in Medan, North Sumatra," *Heliyon*, vol. 7, e07321, 2021.

[25] O. Rasheedat and S. U. Ojodale Samuel, "Geospatial Analysis of Vegetation Health Response to Urbanisation and Land Use/Land Cover Changes in Lokoja, Nigeria Using NDVI," *Integral Research*, vol. 2, no. 4, pp. 49-72, 2025.

[26] L. Li, X. Xin, J. Zhao, A. Yang, S. Wu, H. Zhang, and S. Yu, "Remote Sensing Monitoring and Assessment of Global Vegetation Status and Changes During 2016–2020," *Sensors*, vol. 23, no. 20, p. 8452, 2023.

[27] A. W. Hasyim, B. M. Sukojo, I. A. Anggraini, E. R. Fatahillah, and A. Isdianto, "Urban Heat Island Effect and Sustainable Planning: Analysis of Land Surface Temperature and Vegetation in Malang City," *Int J Sustainable Development and Planning*, vol. 20, no. 2, pp. 683-697, 2025.

[28] T. Dong, M. Tadi, and S. T. Tesfaye, "Unveiling Hidden Green Corridors: An Agent-Based Simulation (ABS) of Urban Green Continuity for Ecosystem Services and Climate Resilience," *Smart Cities*, vol. 8, no. 5, p. 163, 2025.

[29] S. A. Lahoti, M. Thomas, P. Pimpalshende, S. Dhyani, M. Sahle, P. Kumar, and O. Saito, "3-30-300 Benchmark: An Evaluation of Tree Visibility, Canopy Cover, and Green Space Access in Nagpur, India," *Urban Science*, vol. 9, no. 4, p. 120, 2025

[30] A. Salman, A. Haque, M. Rahman, M. J. Rabby, S. Hossen, P. Halder, and R. I. Evan, "NDVI-based Analysis of Green Space Decline and Air Quality in Dhaka: Implications for Sustainable Development Goals," *Environ Earth Sci Res J*, vol. 10, no. 2, 2023.

[31] S. Azizi and T. Azizi, "Urban Climate Dynamics: Analyzing the Impact of Green Cover and Air Pollution on Land Surface Temperature A Comparative Study Across Chicago, San Francisco, and Phoenix, USA," *Atmosphere*, vol. 15, no. 8, p. 917, 2024.

[32] C. Aleixo, C. Branquinho, L. Laanisto, P. Tryjanowski, Ü. Niinemets, M. Moretti, R. Samson, and P. Pinho, "Urban Green Connectivity Assessment: A Comparative Study of Datasets in European Cities," *Remote Sensing*, vol. 16, no. 5, p. 771, 2024.

[33] Q. Zhong and Z. Li, "Long-term Trends of Vegetation Greenness Under Different Urban Development Intensities in 889 Global Cities," *Sustainable Cities and Society*, vol. 106, p. 105406, 2024.

[34] Y. Lu, Y. Yu, L. Sun, C. Li, J. He, Z. Guo, and R. Yu, "NDVI Based Vegetation Dynamics and Responses to Climate Change and Human Activities at Xinjiang from 2001 to 2020," *Scientific Reports*, vol. 15, no. 1, p. 25848, 2025.

[35] N. M. Sari, D. N. Martono, R. H. S. Koestoer, and D. Kushardono, "Remote Sensing-Based Urban Environmental Quality Indicators: A Review," *J Multidisciplinary Applied Natural Science*, vol. 5, no. 1, pp. 228-242, 2025.

[36] D. Wulandari, "Status keberlanjutan ruang terbuka hijau sebagai cadangan oksigen di Yogyakarta," *Jurnal Manusia dan Lingkungan*, vol. 25, no. 2, pp. 123-135, 2018, doi: 10.22146/jml.23817.

[37] F. N. H. Lubis, "*Analisis Hubungan Pertumbuhan Penduduk terhadap Kerapatan Vegetasi dan Bangunan di Kota Medan 2014-2024,"* Tesis S1, Universitas Sumatera Utara, Medan, Indonesia, 2024. [Online]. Available: http://repositori.usu.ac.id/handle/123456789/105245

[38] Perda Kota Medan No. 1/2022 tentang RTRW Kota Medan 2022-2042. [Online]. Available: https://peraturan.bpk.go.id/Details/205589/perda-kota-medan-no-1-tahun-2022