Spatio-temporal pattern of urban forest vegetation density, Medan Baru city, Indonesia

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Abstract. The growth of urban areas and the population generally requires the guarantee of a healthy and comfortable environment. The expansion of physical developments and urban areas, year after year, can no longer support human existence. In Indonesia, the city should have at least 10% of its surface area committed to private urban forest and 20% for public urban forest. Jakarta is Indonesia's largest city, and has only 9.98% urban forest coverage. Medan Baru city is facing the same issue, as it continues to grow year after year. The population requires a comfortable environment, which includes safe drinking water and clean, fresh air. As a result, vegetation is an important component of Medan Baru sub-district that offers numerous benefits. It is necessary to conduct research on the analysis of vegetation density in the Medan Baru, using vegetation indices such as Normalized Difference Vegetation Index (NDVI). The research aimed to analyze vegetation density change and mapping the vegetation density of Medan Baru city. The research found the largest area was relatively dense vegetation, about 262.00 hectares (47.87%). The research also found a decrease in urban forest quality, indicated by an increase in the sparse density class of 41.90 hectares and a decrease in the relative-dense vegetation class with 51.65 hectares. This reduction of vegetation density will reduce the urban forest quality by influencing urban forest capability in absorbing carbon dioxide and alleviating the oxygen productivity volume. Areas with lower stand density must be considered in future urban development planning. Moreover, decrease in vegetation density and urban forest area should be a primary consideration in Medan urban forest management.

1. Introduction
Medan Baru is a sub-district in the downtown area that includes commercial and service areas. Medan's open space is limited in comparison to the space required for various purposes. In 2030, the region's population is expected to be 43,553 people, with a density of roughly 75 persons per hectare [1]. The problem of land usage is exacerbated by the growing number of physical developments and urban areas can no longer support human population increase year after year.
The need for housing will increase every year, but this is not accompanied by available residential land. Limited land for settlements has reduced vegetation space in urban areas triggered by land-use changes and decreased environmental quality. Limited land for settlements has reduced vegetation space in urban areas triggered by land-use changes and consequently decreased environmental quality. For instance, urban water quality may be reduced due to decrease in the size of urban water catchment areas and drainage issues that can disrupt water flow.

Vegetation is an important component of urban areas that provides numerous benefits. The benefits of urban vegetation can directly or indirectly affect the surrounding air by changing the atmospheric conditions of the environment [5]. Vegetation supports the mitigation of the urban heat effect. It also can reduce water runoff in areas with a higher impervious surface. Meanwhile, vegetation can play a role as a windbreak for pedestrians and pollution from multiple sources [2, 3, 4]. Vegetation is a diverse component of urban areas. In urban ecosystems, species diversity is critical. It will help prevent the catastrophic loss of species-specific pathogens or insects. Maintaining diversity is frequently the goal of urban planting designs in cities [6].

The population increase and vegetation space decrease need to be controlled and managed. Given the density and value of the trees in the Medan Baru area, additional work is required to manage the urban canopy and mitigate any costs associated with conflicts between trees and infrastructure throughout the city [8]. Assessment through vegetation density time series data is crucial to analyze changes in vegetation density in the Medan Baru city. Data on changes in vegetation density are required as a preventive measure and as the framework for managing the area while spatial data on sustainably planned urban areas is required for sustainable land management. Therefore, it is necessary to conduct research on the analysis of vegetation density in the Medan Baru sub-district. The study's objectives were to (1) determine the level of vegetation density in the Medan Baru sub-district in 2007 and 2018, and (2) analyze changes in vegetation density in the Medan Baru sub-district between 2007 and 2018.

2. Research methods

2.1. Time and research location
This study was carried out in Medan Baru sub-district from April to June 2018, Medan, North Sumatra. The map in figure 1 illustrates the research location. Geographically, the Medan Baru sub-district is located between 03° 55' 34" (N) and 98° 65' 82" (E). Data analysis was carried out at the Forest Management Laboratory, Forestry Study Program, Faculty of Forestry, University of Sumatera Utara.
2.2. Material and tools
The study used demographic data, thematic maps, and Landsat satellite imagery path/row 129/57 acquired in the years 2007 and 2018. Personal computers, digital cameras, GPS (Geographics Positioning System), and writing instruments were used in this research. EXCEL, ERDAS IMAGINE 9.4, and ARCGIS 10 were used to process and analyze the data.

2.3. Data collection
In this study, the data collection method was used by downloading the Landsat 5 path/row 129/57 image in 2007 and the Landsat 8 OLI path/row 129/57 image in 2018 from earthexplorer.usgs.gov. Data gathered by direct observation at the research site was referred to as primary data (ground checking) by recording the coordinates of the field observation points from the GPS as well as the conditions around the field points.

2.4. Data analysis
The Landsat imagery downloaded from the earthexplorer.usgs.gov site has several bands, and each band is separate. Therefore, it is necessary to combine the image bands first in order to make radiometric corrections. ERDAS IMAGINE was used to perform the image band merging. A radiometric correction was performed to reduce interference in the image caused by the influence of the atmosphere. It is accomplished by sharpening the contrast.

2.5. NDVI transformation
NDVI transformations were carried out using ARCGIS 10.1 software against the red, and near-infrared bands are band 3 (Red / Red) and 4 (Near Infrared) for Landsat 5 and bands 4 (Red / Red) and 5 (Near Infrared/Near-Infrared) for Landsat 8. The working principle of NDVI is to measure the level of greenness. The intensity of greenness in the Landsat images correlates with the density level of the vegetation canopy and detects the greenness level with leaf chlorophyll content. The value range
between -1 to +1 resulting from this NDVI transformation has a different presentation on land use. The greater the NDVI value, the higher the density, and conversely, the lower the value. It is assumed that the lower value represents the lowest density or no vegetated area. According to [9], the formula used is as follows:

\[ NDVI = \frac{IR - R}{IR + R} \]  

Note: \( NDVI \) = normalized difference vegetation index  
\( IR \) = reflectancy value of infrared band (band 4,5)  
\( R \) = reflectancy value of red band (3,4)

NDVI values were categorized into five classes to determine the vegetation density in Medan Baru sub-district, namely: non-vegetation (< 0.0), sparse vegetation (0.0 - 0.2), relatively dense vegetation (0.2 - 0.4), dense vegetation (0.4 - 0.6), and very dense vegetation (> 0.6). This was done by using the equal interval in the ArcGIS software [10]. Analysis of changes in vegetation density was carried out by overlaying the vegetation density map for 2007 and 2018.

3. Results and discussion

3.1. Normalized difference vegetation index (NDVI)

The NDVI is a value derived from a number of spectral bands and remote sensing images, with the vegetation index derived from the emission of vegetation energy. The composite vegetation index is calculated using the energy emitted by vegetation on a remote sensing image to indicate the plant's life-size and number. Accessibility, cost-effectiveness, worldwide coverage, thermal band, extended region, good data quality, spectral resolution, and spatial resolution are all advantages of the Landsat image employed [11, 12]. Table 1 shows the findings of image processing in 2007 utilizing the NDVI analysis of the Medan Baru sub-district. Four classes of NDVI represent different vegetation density classes. The largest NDVI in the dense class represented 313.66 Ha or 57.31%, while the smallest value in the sparse vegetation represented 32.54 Ha or 5.94%.

| No | NDVI   | Class                  | Area (Ha) | Percentage (%) |
|----|--------|------------------------|-----------|----------------|
| 1  | 0-0.2  | sparse vegetation      | 32.54     | 5.94           |
| 2  | 0.2-0.4| relatively dense       | 313.66    | 57.31          |
| 3  | 0.4-0.6| dense vegetation       | 156.98    | 28.68          |
| 4  | > 0.6  | very dense vegetation  | 44.14     | 8.07           |

Total 547.31 100.00

The range of Medan Baru NDVI classes in 2018 is shown in table 2. In 2018, the NDVI transformation of Landsat 8 imagery generated NDVI values for Medan Baru that were distributed all over four classes (table 2). The relatively dense class had the largest area among the four classes, with 262.01 ha, or 47%, in the NDVI range of 0.2-0.4. The smallest NDVI area of 0-0.2 with sparse vegetation-covered an area of 74.44 Ha or 13.60%. Field checks showed areas with less than zero or negative (low) NDVI values were the water bodies, no vegetation cover, and built areas. For the grass and shrubs area, the NDVI value ranged from 0.2 to 0.4, representing the relatively dense vegetation class. High NDVI values ranging from 0.6 to 0.8 are categorized as rainforests, wherein the city represents the urban forest with high vegetation density. This follows the statement of [13], which stated that NDVI from the range of 0.3-0.8 represents high above-ground biomass. Meanwhile, a low NDVI value, namely 0.1, is found in the form of built-up areas, roads, and water bodies. The NDVI value is relatively dense, represented by shrubs, and grass in NDVI values ranging from 0.2 to 0.3. Urban forests, palm oil plantations, and mixed agriculture had NDVI values ranging from 0.6 to 0.8.
Table 2. NDVI value class distribution of Medan Baru city, the year 2018

| No | NDVI       | Class               | Area (Ha) | Percentage (%) |
|----|------------|---------------------|-----------|----------------|
| 1  | 0 - 0.2    | sparse vegetation   | 74.44     | 13.60          |
| 2  | 0.2 - 0.4  | relatively dense vegetation | 262.01   | 47.87          |
| 3  | 0.4 - 0.6  | dense vegetation    | 127.14    | 23.23          |
| 4  | > 0.6      | very dense vegetation | 83.73     | 15.30          |
|    |            | **Total**           | **547.31**| **100.00**     |

3.2. Vegetation density class

Based on the NDVI value obtained from image processing, the vegetation density class was divided into four classes: sparse vegetation, relatively dense vegetation, dense vegetation, and very high dense vegetation. The greater the NDVI value, the higher the vegetation density, and vice versa, the lower the value. This NDVI class is related to the presence of vegetation in the land. Similarly, [14] stated that NDVI is correlated with several biophysical components of plants including vegetation canopy and vegetation cover. [14] further states that the increase in NDVI is influenced by the Leaf Area Index (LAI), which is the leaf area of the vegetation canopy. Of the four classes, the vegetation density class that experienced an increase in area was the sparse density class (yellow color), as illustrated in figure 2.

Figure 2 shows that the yellow area in 2018 was larger than in 2007. This occurs due to changes in land use, where vegetated land is converted into settlements. The development of housing and commercial areas in Medan Baru is believed to reduce green open space. Residential development
correlated to Medan city population growth, increased by about 0.8% in 2016. It is coherent with the statement [15,16] that population growth increases the demand for public activity, clean air, and socializing space. This requirement can be met by increasing the capacity and quality of urban forests.

The dense vegetation was concentrated in the city center (green color), while the sparse vegetation was found at the edge of the city of Medan Baru (figure 2). The densely forested area is the educational institution area, where one of Sumatera largest universities is located. A good landscape architecture arrangement in the area has designated the appropriate proportions for the urban forest. Urban forests can improve the quality of the environment, the quality of life of individuals and communities and provide various environmental services to individuals and society, resulting in a healthier and more comfortable environment for its citizens. [17,18, 19, 20].

The NDVI value can be used to classify vegetation quality and density level according to the dominance of plants in the field [24]. According to [22], the surface of vegetation with an NDVI value range of 0.1 indicates grasslands and shrubs. More than 0.1 to 0.8 indicate tropical forests and NDVI values close to +1, indicating vegetation cover. Based on the ground check result, the vegetation density class was sparsely dense in tree streets and settlements with vegetation (figure 3). In the class of relatively dense vegetation, it was a public burial place and vegetated land (figure 4). Grasslands, shrubs, and Agriculture-crop were in the dense vegetation class (figure 5). Meanwhile, the very high dense class had the urban forest, oil palm plantations, and a collection of trees with dense crowns (figure 6). This vegetation density study shows that the sparse vegetation density classes in the field were mostly settlements with relatively little vegetation (figure 3.c).

On the other hand, the vegetation density class is relatively dense in grasslands/public burial areas and bare land (figure 4.c). The dense vegetation density class in the field is high shrubs and grasses (figure 5.c), while the very dense vegetation density class is an urban forest (figure 6.c). Urban forests with tree stands are better able and effective at reducing temperatures in densely populated urban areas. According to [22], vegetation in a city reduces the difference in temperature in cities with temperatures in other areas around cities.

**Figure 3.** Illustration of sparse dense vegetation; (a) sparse dense vegetation on the image; (b) dense vegetation in the field; (c) sparse dense vegetation on Google Earth.

**Figure 4.** Illustration of relatively dense vegetation; (a) relatively dense vegetation on the image; (b) relatively dense vegetation in the field; (c) relatively dense vegetation on Google Earth.
Figure 5. Illustration of dense vegetation; (a) dense vegetation on image; (b) dense vegetation in the field; (c) dense vegetation on Google Earth.

Figure 6. Illustration of very high dense vegetation; (a) very high dense vegetation on the image; (b) very high dense vegetation in the field; (c) very high dense vegetation on Google Earth.

Medan Baru is a dense residential area, residential area, and green open area [21]. This situation affects vegetation density in the Medan Baru sub-district, depending on land use and utilization patterns. Green space or vegetated areas can be detected using the vegetation index from Landsat 8 OLI imagery [10]. The vegetation index value is influenced by the greenish color of the scanned object. The recording is obtained from the greenish emission value of the components recorded by the image [22, 23]. According to [23], NDVI values are influenced by several factors, including the sun's angle, which is indicated to affect reflectance, red light, infrared, the effect at atmosphere, and cloud conditions at the time of recording. Therefore, this was taken into account in the selection of satellite image recording time.

3.3. Changes in vegetation density area in Medan Baru district in 2007 and 2018

Changes in the area of Medan Baru vegetation density were obtained by overlaying maps in 2007 and 2018. Changes were obtained by analyzing using NDVI analysis on maps for 2007 and 2018. Changes in vegetation density in the Medan Baru sub-district can be seen in table 3 below.

Table 3. Vegetation density changed of Medan Baru, the year 2007 and 2018

| No | Vegetation density         | 2007        | 2018        | Change       |
|----|---------------------------|-------------|-------------|--------------|
|    |                           | Area (Ha)   | (%)         | Area (Ha)   | (%)         | Area (Ha) | (%) |
| 1  | sparse vegetation         | 32.54       | 5.94        | 74.44       | 13.62       | 41.90     | 7.66         |
|    | relatively dense vegetation| 313.65      | 57.30       | 262.00      | 47.87       | 51.65*    | 9.43*        |
| 2  | dense vegetation          | 156.97      | 28.68       | 127.13      | 23.22       | 29.84*    | 5.46*        |
|    | very dense vegetation     | 44.13       | 8.06        | 83.73       | 15.29       | 39.60     | 7.23         |
|    | Total                     | 547.31      | 100.00      | 547.31      | 100.00      |           |               |

Note (*): decreased
Table 3 shows that there was a change in vegetation density in 2007 and 2018. In 2007, the relatively dense vegetation class had an area of 313.65 Ha or 28.68%. However, it experienced a decrease to 262 Ha or about 9.43% of the total area. Meanwhile, the sparse dense vegetation class experienced an increase in area in 2018 to 41.9 Ha or 7.66%. In addition, the very dense vegetation class also increased by 39.6 Ha or 7.23%.

The results of ground checks showed that land changes influence changes in vegetation density. The Medan Baru area itself is an urban area where land-use change can occur rapidly and dynamically. The identification of land use in the field shows that bare land and vegetated land were used to build settlements and other developed land. Changes in vegetation density in the area occur due to changes in land use related to an increase in population, which causes land use to become residential areas in the area. This is in accordance with [25] the statement that population growth is one of the main factors in settlement development. Along with the increase in population, it is always followed by increased land use for settlements. Therefore, the increase in population always increases every year in line with the increase in changes in land use. The higher population growth causes the limited area of an area, which underlies changes in land-use change. The development of housing and commercial areas in Medan Baru is believed to reduce green open space. Residential development correlated to the city of Medan's population growth, which increased by about 0.8% in 2016 [1]. The existence of vegetated areas in urban areas contributes to improving the quality of the urban environment for the better [17,18, 26, 27], and biodiversity in urban areas acts as a buffer and ecosystem balance. The vegetation density decrease of Medan Baru has an impact on increasing temperature and decreasing water catchment areas.

The map of changes in the vegetation density of Medan Baru in 2018 can be seen in the map of vegetation density change (figure 7), where it had a very dense vegetation density even though it was small. The map depicts the change in vegetation density from 2007 to 2018. According to [28, 29, 30], the forest area required for urban forests is proportional to population and industrial growth. Thus, the area and density of urban forests should increase in response to population growth. This research found elevated vegetation density (purple and red color) in several spots. The red colors represent dense class increments, i.e., from sparse dense vegetation to very dense vegetation. It demonstrates that the city government is doing outstanding work to maintain and protect the urban forest [31,17]. However, this research has also found a decrease in vegetation density in some city areas (dark green color).
4. Conclusions

There was a change in the vegetation density class between 2007 and 2018. In 2007, the largest area of vegetation density class was a relatively dense vegetation class with an area of 313.66 hectares or about 57.31%. The smallest vegetation density class was the sparse-dense vegetation class, which was 32.54 Ha or 5.94%. However, in 2018, the largest area of vegetation density class was in a relative-dense class with an area of 262.01 Ha or 47.87%, while the smallest vegetation density area in the sparse class was 74.44 Ha or 13.60%. This research found a decrease in the quality of urban forests, which was indicated by an increase in the sparse density class of 41.90 Ha or 7.66%, and a decrease in the density class of relative-dense vegetation with 51.65 Ha or 9.43% of the area. An increase in the settlement area triggered a decrease in vegetation density. A decrease in vegetation density will reduce urban forest capability to absorb carbon dioxide and alleviate the oxygen productivity volume, ruining urban forest quality. As a consequence, areas with decreased stand density should be considered in future urban development planning. This is suggested to be implemented to minimize the further decline of urban forest areas. Decrease in vegetation density and urban forest area should also be a primary consideration in Medan urban forest management to ensure the urban forest area and quality can be preserved.

Figure 7. Distribution change map of Normalized Difference Vegetation Index (NDVI) - Medan Baru Year 2007 and 2018
5. References

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