Heliyon 7 (2021) e07637

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Mapping and assessment of vegetation cover change and species variation in Medan, North Sumatra

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ARTICLE INFO

Keywords:
Change detection
NDVI
Urban
Vegetation cover

ABSTRACT

Vegetation existence contributes to environmental quality in urban areas. The increase in population and development of cities has led to land conversion with lesser vegetated areas. Information on land cover change is needed, especially for urban regional planning with green open space consideration. The research aims to analyze urban vegetation cover and its changes in two sub-districts of Medan between the years 1999 and 2019. Normalized difference vegetation index (NDVI) and change analysis were conducted in the research. The diversity of plants within these areas was observed. The results showed changes in vegetation cover areas in the mentioned years. In 1999, most areas were under a highly dense vegetation class, while in 2019, they were under a low-density vegetation class. This finding indicates a decrease in vegetation cover as a result of increasing built-up areas. Within the vegetation cover, it was found many tree species and agricultural plants. Those vegetations existed in some areas: city parks, house yards, gardens, agricultural fields, etc. A special emphasis should be placed on riverside areas with less vegetation in order to provide a higher level of protection, particularly in the event of a flood. To increase the vegetated areas and maintain the environmental quality, optimizing the land by replanting in the area with no or less vegetation should be done.

1. Introduction

Urban areas are a place of more than half of the population in the world. By 2050, it is expected 66% of the population will be living in those areas. The continued population growth and urbanization have caused many problems that hamper environmental sustenance [1].

Cities are a mosaic of habitats that change through time. It shows environmental heterogeneity due to variation within and even among cities [2]. The urban landscape is considered the most complex and heterogeneous landscape among different land surface features [3].

Complex environmental problems have accompanied the enormous growth of cities. The city environment is influenced by global and local climate changes, pollution from transport, industries, and local heating sources [4]. Urbanization is considered one of the main factors affecting global change [5]. Climate change and urbanization are the two primary drivers that can alter vegetation growth processes in the environment [6].

The development of urban areas was led by the increase in population [7]. It is in relation to the urbanization within the areas. It gives an impact to land cover change due to the need for housing and economic-related actions. As [8] said, there are transformations of various Land Use Land Cover (LULC) types into urban/built-up areas due to rapid urbanization. A significant contributor to land cover change is rapid urban expansion [9].

The formation of vegetation is an important component in the urban structure due to a wide range of ecosystem services in the area. As mentioned by [4], one of the important functions to improve the environmental and residential quality of the city is climate modification.

Providing information on land cover and use change, including in vegetation areas, is a must for improving urban spatial planning in relation to the improvement of environmental quality. Remote sensing and geographic information systems are powerful scientific tools for supporting analysis and monitoring of land use and land cover change. Remote sensing systems provide valuable measurements to study changes in the various environmental factors [10]. Further, they provide the means for observing regions. Remote sensing-based results indicated that vegetation conditions decrease significantly as the proportion of built-up land increase [11]. To analyze land-use change and natural resource degradation and subsequently understand the relationship between the two processes, mapped urban stain and vegetation cover using multi-temporal satellite images [12].

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https://doi.org/10.1016/j.heliyon.2021.e07637
Received 5 June 2021; Received in revised form 30 June 2021; Accepted 19 July 2021

Landsat images have been used widely in urban studies. Many research used the image for land use land cover detection and change analysis in remote sensing and GIS application. Those research are including urban growth monitoring [7, 8, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24].

Medan as one of the major cities in Indonesia has faced the same problem as any major city in the world. An increase in the population and development of the city has led to the conversion of vegetated land for other purposes, especially settlements and buildings. Medan has 21 sub-districts with a total area of 265 km^2. Each sub-district has its own area characteristics. Medan Baru and Medan Selayang sub-districts are among the areas that are overgrowing and experiencing land cover changes, including an increase in built-up areas and a decrease in vegetation areas.

NDVI and change analysis was conducted in this research. The NDVI has been proven to accurately detect various land cover changes [25]. In order to detect changes in vegetation cover, this research was aimed to analyze the vegetation cover areas and their changes in Medan Baru and Medan Selayang sub-districts. Changes between the years 1999 and 2019 were analyzed. The NDVI is a powerful tool for understanding past vegetation, monitoring its current state, and predicting its future [26, 27, 28]. NDVI as one of the most widely used tools to assess atmosphere and bare soil background through image spectral properties, facilitating image interpretability. It has been used for land use/built-up cover areas [29].

It was found vegetation cover changes to be related to differences in urbanization rates, gross domestic products, population densities, and stages of urban development among the cities [30]. Land-use change is one of the main impacts of human activities and profoundly impacts vegetation change [31]. To ensure that ecosystem services are provided, vegetation cover should be considered in urban planning in urban core and peripheral areas [30]. Therefore, having information on vegetation cover change in urban areas will be useful in planning a better environment by assuring the optimal existence of green space within the areas.

2. Materials and methods

The area of the research was sub-districts of Medan Baru and Medan Selayang (Figure 1). Processing and analysis of the research data were carried out in Forest Management Laboratory, Faculty of Forestry, Universitas Sumatera Utara.

Landsat images of the years 1999 (date August 20) and 2019 (date August 11) were downloaded through www.earthexplorer.usgs.gov. The software used for remote sensing and GIS analysis were Erdas Imagine 8.5 and ArcGIS 10.3. A ground check had been conducted in the research areas. Radiometric corrections were performed using Erdas 8.5 to correct errors that occurred in satellite imagery by sharpening the contrast. Image cropping was conducted to obtain a specific research location.

NDVI transformation was carried out using band infrared and red of Landsat. The principle of the NDVI is to measure the level of greenness. The intensity of greenness is correlated with the density of the vegetation crown, which is related to leaf chlorophyll content. A comparison between the red (R) reflectance and the near-infrared (NIR) parts of the electromagnetic spectrum was calculated. The selection of these wavelengths results from the absorption and reflection characteristics of vegetation. Due to absorption processes, especially in the red part of the electromagnetic spectrum, it was associated with the leaf chlorophyll content. In near-infrared part of the electromagnetic spectrum, there is a very strong reflection that corresponds to multiple reflections in the leaf inner cell structure due to the cells' water content [32].

The NDVI can estimate vegetation coverage. If the value of the NDVI is greater than others, this indicates that vegetation coverage is better [33]. The more the NDVI value tends to +1, the more it is related to vegetation cover and its vigor [32]. The value ranging between -1 to +1 of the NDVI has a different presentation on its land use. Clouds, water, and non-vegetation objects have an NDVI value of less than zero. The greater the value of the NDVI, the higher the density, and vice versa for a lower value. Negative values indicate areas with water, marshy surfaces, man-made structures, rocks, clouds, snow; bare land usually gives values that fall within 0.1–0.2, while plants always have positive values ranging between 0.2 and 1. For healthy, dense vegetation canopy, the values are above 0.5 while sparse vegetation with the range of values of 0.2–0.5. Generally, the NDVI values are between 0.2 and 0.4 for sparse vegetation areas and 0.4 to 0.6 for moderate vegetation, and anything above 0.6 indicates the highest possible green density [34]. The following formula was used:

$$\mathrm{NDVI} = \frac{\mathrm{IR} - \mathrm{R}}{\mathrm{IR} + \mathrm{R}} \quad (1)$$

where,

IR = reflectance value of infrared band.

R = reflectance value of the red band.

With the aid of NDVI transformation, information can be obtained on vegetation elements' existence in the whole area. The ground check gave valuable information on land use and land cover classes found in the field. So, we can obtain the range of values of the NDVI within some classes. The classification was conducted to divide the areas into different vegetation density classes. The range of values was defined by considering the vegetation existence in the field and the NDVI values. It was mentioned by [29] that different NDVI threshold values were used for classifying various land-use/cover classes (water bodies, badlands, bare soil, and built-up land, agriculture, grassland, and forest).

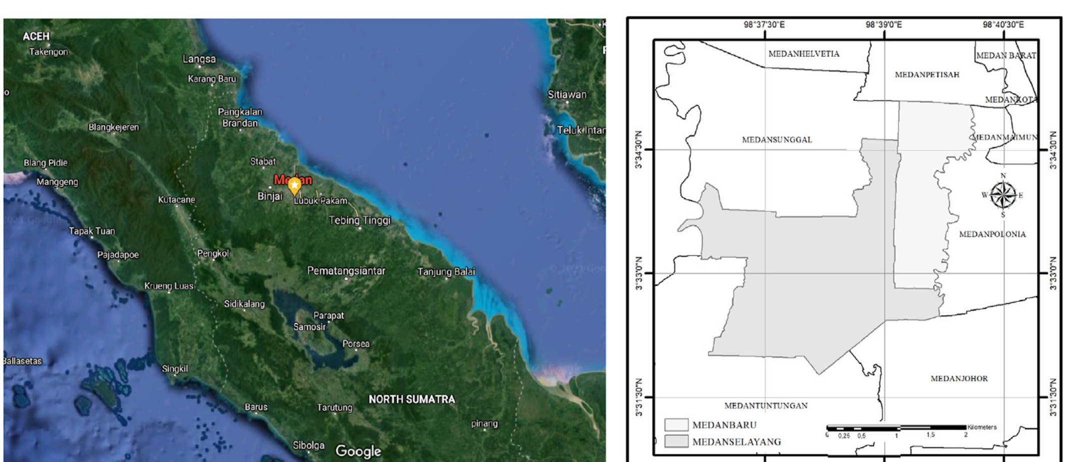

Figure 1. Research location map.

In this research, the location was classified into five classes, namely non-vegetation, low dense, medium dense, dense, and high dense classes. The classification can show the difference in vegetation density within the whole area [25]. In order to see the change in vegetation density, a change analysis was conducted [28, 35, 36].

Change analysis was conducted by overlaying vegetation density map of year 1999 and 2019. From the analysis, we were able to assess the change of vegetation cover within the observation years. This research provides information on the change of vegetation cover in any specific areas in the research location.

The ground check was an important part of the research. In the field, there were recorded the location and the land use land cover types found. In terms of vegetation, there were identification of type and species.

3. Results and discussion

3.1. Distribution of NDVI values in Medan Baru and Selayang subdistricts

The NDVI compares the total amount of visible red light absorbed with the amount of reflected near-infrared light by a surface [34]. It basically uses a mathematical ratio to compare the amount of absorbed visible red light and the reflected near-infrared light.

In the year 1999, the Medan Baru and Medan Selayang sub-districts had the highest NDVI value in the range >0.4, which is 609.66 ha (29.96%) of the total area, while the smallest in the range of NDVI <0.1, which is 151.94 ha (7.47%) of the total area (Table 1). These are quite different from the year 2019 (Table 2), which shows the NDVI of the Medan Baru and Medan Selayang subdistricts, where they had the highest NDVI value in the range of 0.1–0.2. It comprised an area of 768.09 ha (37.73%). The smallest NDVI range >0.4 covered 226.04 ha (11.1%) of the total area. A comparison of each NDVI area class is illustrated in Figure 2.

Figure 3 shows the comparison of the NDVI values distribution of the years 1999 and 2019. There are increasing areas with lower NDVI values in the whole area. Definitely, there is a decrease in areas with high values of NDVI. This means that there are prominent changes in vegetated areas to less or no vegetated areas.

Based on field checks, there are nine land cover classes, namely buildings, roads, mixed gardens, oil palm, settlements, trees, grass, rice fields, and shrubs. The division of objects and the range of NDVI values can be seen in Table 3.

Human activities have led to land-use change with a strong influence on the existence of vegetated land. Land-use changes driven by human activities are a consequence of any development. As stated by [22] farmland, forest land, and grassland are converted to construction land due to urban expansion along with economic and social development. Furthermore [22], highlighted the contribution of the NDVI in studying the impacts of land-use change on vegetation.

In the sub-district of Medan Baru and Medan Selayang, the NDVI value range lies between 0.04–0.49. Based on a ground check, there are land covers in each range of the NDVI. Land cover with the NDVI value less than 0.1 to 0.2 are building areas, roads, and settlements, while land cover with the NDVI value 0.2–0.4 is mixed gardens, land with trees, grass, rice fields, and shrubs. There is more dense vegetation in the area with NDVI values higher than 0.4, including oil palm, trees, and shrubs. Visualization of each land cover can be seen in Figure 4.

The denser the vegetation, the higher the NDVI value. The low NDVI value will represent the low vegetation density. There are variations of the NDVI values in each land cover class due to the variation of objects found in the field; for example, there are trees alongside the road and trees in between houses in settlement areas. Some trees can also be found near buildings, and some near rice fields, grassland, and shrub. The higher the NDVI values found in areas with trees, shrubs, and oil palm. The lower value is found in settlements and roads.

The spatial resolution of Landsat images contributes to the variation of NDVI values of each land cover class as there are many objects found in areas of 30 m. There is also due to existence of vegetation in each land cover classes as mentioned above.

Table 1. Distribution of the NDVI values in Medan Baru and Medan Selayang in 1999.

No	NDVI	Area (Ha)	% Area
1	<0.1	151.94	7.47
2	0.1–0.2	346.11	17.01
3	0.2–0.3	447.15	21.97
4	0.3–0.4	479.97	23.59
5	>0.4	609.66	29.96
Total		2,034.84	100.00

Table 2. Distribution of NDVI values in Medan Baru and Medan Selayang in 2019.

No	NDVI	Area (Ha)	Area (%)
1	<0.1	243.47	11.96
2	0,1–0,2	768.09	37.73
3	0,2–0,3	468.48	23.02
4	0,3–0,4	329.43	16.18
5	>0.4	226.04	11.10
Total		2,035.50	100.00

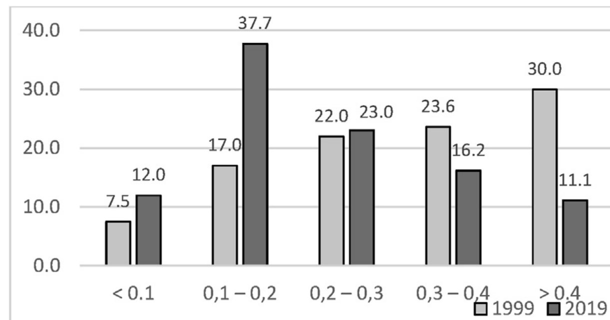

Figure 2. Comparison of areas of NDVI values distribution (%) in the years 1999 and 2019 in Medan, North Sumatra.

3.2. Vegetation existence in Medan Baru and Selayang subdistricts

Based on the finding in the field and some references in the classification of NDVI [37, 38, 39], the vegetation density class was divided into five classes: the non-vegetation class with an NDVI value <0.1, a low dense class with an NDVI value of 0.1–0.2, medium dense with NDVI values of 0.2–0.3, dense class NDVI value of 0.3–0.4, and high dense class with NDVI values of >0.4.

Table 3. NDVI values range of each land cover validated by ground check, in urban areas of Medan, North Sumatra.

Nº	Class	NDVI Range
1	Settlements	0.04–0.28
2	Road	0.04–0.29
3	Buildings	0.06–0.29
4	Mixed Garden	0.24–0.50
5	Grass	0.26–0.44
6	Trees	0.26–0.52
7	Rice fields	0.30–0.46
8	Shrubs	0.30–0.52
9	Oilpalm	0.45–0.49

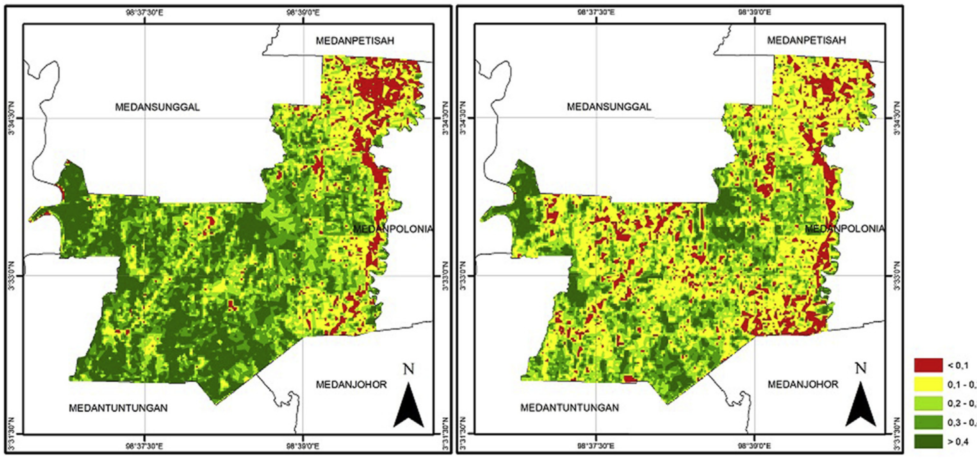

Figure 3. Comparison of the NDVI values between the year 1999 (left) and 2019 (right) in Medan, North Sumatra.

3.2.1. Non-vegetation class

Non-vegetation classes are roads, dense settlements, and tall buildings. There is small existence and or no vegetation in this class. The non-vegetation class consists of residential areas, business areas represented by tall buildings near the main road, and congested streets in the flyover area. Some campus areas of the University of North Sumatra, which is located in Medan Baru, show non-vegetation density classes. The library, faculty building, and administration office center building belong to this class. Areas that belong to the non-vegetation class illustrated in Figure 5.

3.2.2. Low dense class

In the low dense class, the vegetation density is low. Areas that belong to this class are roads, buildings, settlements, and bare lands with less vegetation. Low dense class is found in some areas in the city surrounded by buildings and existing vegetation. There are also trees along the path of the road and around houses. The species found here are *Plumeria rubra*, *Mangifera indica*, *Pterocarpus indicus*, *Gnetum gnemon*, *Polyalthia longifolia,* and *Areca catechu*. In the campus area of the Universitas Sumatera Utara (USU), there are some buildings with trees around them. The species found here are *Terminalia catappa, Casuarina equisetifolia*, *Mangifera*

a b. c. d. e.

Figure 4. Visualization of non vegetation (a), low dense (b), medium dense (c), dense (d) and high dense (e) areas in the field.

Figure 5. Non-vegetation class area.

Figure 6. The low dense class.

indica, and *Ficus benjamina*. Areas that belong to the low dense class can be seen in Figure 6.

3.2.3. Medium dense class

In the medium dense class, the density of vegetation is rather high. There are roads, buildings, and settlements, where those covers have vegetation; for example, individual trees near those covers.

Medium dense class is found in settlements with a large yard with various trees. There are also gardens in the area of settlement. The research identified trees, herb and shrub including agricultural plant. Among those species are *Leucaena* leucocephala, *Solanum melongena, Vigna unguiculata, Musa paradisiaca, Manihot esculenta, Mangifera indica, Theobroma cacao, Morinda citrifolia,* and *Artocarpus heterophyllus.* It also includes a city park with trees such as *Swietenia mahagoni, Pterocarpus indicus, Leucaena leucocephala, Adenanthera pavonina, Polyalthia longifolia, Mangifera indica, Mimusops elengi, Artocarpus altilis, Plumeria rubra, Nephelium lappaceum, Delonix regia), Gnetum gnemon, Cocos nucifera, and Annona muricata*. In the campus area of the USU, library parks and some faculties have areas with trees. The species found here are *Swietenia mahagoni, Polyalthia longifolia, Filicium decipiens, Pinus merkusi, Mimusops elengi, Alstonia scholaris,* and *Syzygium aqueum.* Areas that belong to the medium dense class can be seen in Figure 7.

3.2.4. Dense class

In the dense class, rice fields, shrubs, trees, and mixed gardens were found. People grow cassava, sugar cane, corn, banana, and oranges. Trees are found around the areas. The dense class includes shrubs, grasses, and trees such as *Gnetum gnemon, Durio zibethinus, Swietenia mahagoni, Ficus benjamina, Tectona grandis, Mangifera indica,* and *Tamarindus indica*. In some areas, community-owned gardens belong to this class with species such as *Musa paradisiaca, Zea mays, Saccharum ficinarum, Carica papaya, Vigna unguiculata, Arachis hypogaea,* and *Cocos nucifera*. There is a mini-stadium, saga park, auditorium park, and research farmland in the USU campus area. The research found many tree species. The tree species are *Annona muricata, Durio zibethinus, Artocarpus heterophyllus, Persea americana, Psidium guajava, Tamarindus indica, Mangifera indica, Ficus benjamina, Mimusops elengi, Leucaena leucocephala, Polyalthia longifolia, Terminalia catappa, Areca catechu, Adenanthera pavonina, Pinus merkusii, Swietenia mahagoni, Aleurites molucana, Pometia pinnata, Syzygium aqueum, Hylocereus undatus, Carica papaya,* and *Nephelium lappaceum.* Areas that belong to the dense class can be seen in Figure 8.

3.2.5. High dense class

While in high dense, there are dense vegetation found including trees, oil palm, rice fields, very dense shrubs, and mixed gardens. High dense class includes land overgrowing with trees accompanied by shrubs, land planted with oil palm, vast rice fields, and mixed gardens owned by the community planted with various plants such as *Citrus nobilis, Zea mays, Cymbopogon citratus, Solanum torvum, Artocarpus altilis, Saccharum officinarum, Cocos nucifera, Etlingera elatior, Theobroma cacao, Carica papaya, Manihot esculenta, Musa paradisiaca,* and *Psidium guajava*. The high dense class was found in the campus forest which is consisting of some species. The species are *Swietenia mahagoni, Artocarpus heterophyllus, Psidium guajava, Paraserianthes falcataria.* In USU administration center park is also found *Terminalia catappa, Terminalia mantaly, Ficus elastica, Swietenia mahagoni, Syzygium oleana, Ficus benjamina, Durio zibethinus,* and *Pterocarpus indicus.* Areas that belong to the high dense class can be seen in Figure 9.

Figure 7. The medium dense class on research site.

Figure 8. Dense class areas.

Figure 9. High dense class.

The increase of population growth and development of the Medan areas as a big city was followed by the increase of built-up areas and settlements and a decrease of vegetated land. Changes in rice fields and gardens into housing areas are examples of conversion. The ground check shows dense settlements and multi-story buildings are found more than vegetated lands such as trees, rice fields, and community-owned gardens. The decrease in vegetation areas could have a bad impact on the quality of the environment, i.e., problems of flood due to a decrease in water absorption areas. A total of 5,965 people were affected by the floods that occurred in four sub-districts in Medan City, North Sumatra Province in December 2020. The water level reaches 3–5 m. Floods occurred due to high-intensity rain which caused the Deli River, Babura River and Denai River to overflow [40]. Most areas along the river were an open area with less vegetation.

Many vegetated lands were converted into housing and buildings. Moreover, some vegetation areas were replaced by roads and public facilities. Vegetation cover changes could lead to environmental problems, such as the incident of flood in the rainy season, bad air quality due to pollution, and health problems. In urban contexts, vegetation surfaces are very important for the well-being and health of the urban population. The NDVI is often correlated with socioeconomic and/or sociodemographic data to demonstrate the inequality in environmental settings that themselves influence individual health and questions of environmental justice [32].

Medan has faced some flood incidents, especially in the areas near the river. Some of the areas have no or less vegetation on the side of the river with the NDVI values less than 0.1. This situation can worsen unless there is an improvement of areas by replanting trees and better planning the areas. This requires preparing both the community and land conditions. The land-use planning process was used to provide alternative and possible land uses as well as management activities to ensure land-use sustainability [41].

The fast population growth and the significant exploitation of natural resources imply great modifications in the environment, causing environmental impacts, including the average temperature increase of the Earth. Understanding the effects of changing land cover allows greater agility in public managers' decisions to mitigate the effects of urban heat and the formation of heat islands by vegetation insertion in densely occupied areas [42].

Many problems in urban areas need serious attention, such as pollution [43, 44, 45, 46, 47, 48, 49], environmental pollution and health [50], urban water security [47, 51]. Urban vegetation has an important role in ensuring the ecological security of cities. Rapid urbanization in China has radically changed the urban vegetation cover. Isolation of the contributions of human activities from the observed vegetation can help understand the effects of human activities on urban ecosystems [52].

The research shows big changes in vegetated areas into other land uses as the field check found the existence of built areas in the city. Settlements and buildings with no or less vegetation are prominent. NDVI analysis shows the change of dense vegetation class into the lower class, especially the change into non-vegetation and the low-density class.

A big part of the urban land occupation is composed of highly dense buildings and large paved and impermeable areas, which support the high increase in the air temperature in the center of urban areas, which creates microclimates in different zones of the city, causing heat islands [53].

In that case, the modeling of the urban sprawl effect on vegetation-cover is realized by the NDVI) After observing and characterizing the areas altering by the urban expansion, the results displayed that in 17 years, the urban growth of Annaba decreased the vegetation cover by 28.50 % [13].

Urban studies show a wide scope of discussion with the same aim that is to overcome problems and built a good environment for man and nature. Such studies are including a study on urban resilience [54, 55]. Issues on building a smart sustainable cities are also among those studies [56, 57, 58]. There are also studies on urbanization strategy and planning [59, 60, 61], insights for the future of urban ecosystem services research [62].

Paying attention to the construction of green space and green roads in cities, reducing urban land use, rationally distributing land resources, and strengthening environmental management and protection are important ways to improve the ecological environment level of vegetation in Zaozhuang City [33]. The research confirmed the importance of vegetation structures in the process of mitigating urban climate extremes and improving environmental quality [4]. The need to avoid the development of fringe areas outside the urban core areas to mitigate vegetation degradation effectively and the effectiveness of urban landscape planning should be encouraged by having positive influences of urbanization on vegetation growth [6]. An integrated system of green areas will enable the city to sustainably develop its natural resources [63]. The research provides information on vegetation's condition by giving information on the location and the density of vegetation within the area. It is valuable information for urban planning to achieve the highest quality of the environment and supporting the health of the community.

4. Conclusions

The research found a decrease of high and dense vegetation areas into lower and non-vegetated areas within 20 years. It means there is a decrease in vegetation cover due to changes to non-vegetation cover or land cover areas with less vegetation. The NDVI could further explore the change of vegetation cover in urban areas and take part in monitoring and urban planning. There are many tree species and agricultural plants within the vegetated areas. Those vegetations existed in some areas in example city parks, house yards, gardens, agricultural fields, etc. A special emphasis should be placed on riverside areas with less vegetation in order to provide a higher level of protection, particularly in the event of a flood. In order to increase the vegetated areas and maintain the environmental quality, it is recommended to optimize the land by replanting in the area with no or less vegetation.

Declarations

Author contribution statement

Anita Zaitunah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Samsuri: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Fauziah Sahara: Performed the experiments; Wrote the paper.

Funding statement

This work was supported by Indonesian Directorate of Research and Community Service, Indonesia; Ministry of Research and Technology and National Research and Innovation Agency, Indonesia (No. 11/AMD/E1/KP.PTNB/2020).

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

Thank you to Indonesian Directorate of Research and Community Service, Indonesia; Ministry of Research and Technology and National Research and Innovation Agency and Universitas Sumatera Utara for the support.

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