Analysis of vegetation cover and built-up areas in the Percut watershed landscape, North Sumatra Province using sentinel-2 imagery

B Slamet 1,4*, O K H Syahputra 1, H Kurniawan 2, M Saraan 3 and M M Harahap 1

1 Faculty of Forestry, Universitas Sumatera Utara, Medan, North Sumatra 20155, Indonesia
2 Alumni Faculty of Forestry, Universitas Sumatera Utara, North Sumatra 20155, Indonesia
3 Yayasan Pesona Tropis Alam Indonesia (PETAI), Jl. Panglima Denai. Kota Medan, North Sumatra, Indonesia
4 The Center for Science and Technology Mangrove (PUI Mangrove), Universitas Sumatera Utara 20155, North Sumatra, Indonesia

*Email: bejo@usu.ac.id

Abstract. Changes in land cover have an impact on the health condition of a watershed. This research was conducted by utilizing Sentinel-2 imagery for the recording period 2020 and 2021. Three indices were used in this study, namely, the Normalized Difference Built-up Index (NDBI), Normalized Difference Water Index (NDWI) and Normalized Difference Vegetation Index (NDVI). NDBI analysis indicates there is an increase in the built-up area of 2,092.62 hectares which means land conversion. NDWI classification shows an increase in the wetness area of 308.58 hectares, mainly occurring in the downstream part of the watershed, located to the north. There is an increase in the area of non-vegetated areas reaching 288.96 hectares in the Percut watershed based on the results of the NDVI analysis.

1. Introduction
Landscapes are natural manifestations and anthropic elements, and their structures are the result of physical, biological, political, economic and social interactions, connected or fragmented for different land uses[1]. The occupation of landscapes by human activities that are managed without environmental development planning places great stress on natural systems. The interaction between people and nature determines the type of land use and the recent consequences of fragmented spatial patterns and landscape structures[2]. Human interference in this natural or anthropogenic landscape has changed large and sustainable areas by changing forest cover into fragmented forests, which endangers environmental functions and ultimately reduces the available services provided by ecosystems[3,4], includes problems that occur in the watershed landscape.

Most of the watersheds in the North Sumatra Province are categorized as watersheds that must be restored, meaning they have high land criticality. Human intervention and natural disturbances are insufficient despite the many types of transformations/changes that occur and their resulting impacts on watershed ecosystems. An integrated method allows easy-to-apply and straightforward watershed evaluations to evaluate watershed vulnerabilities by utilizing spatial data sets[5,6].
The utilization of satellite image data for mapping vegetation and built-up areas has advantages compared to terrestrial measurements. Sentinel 2 is one of the satellite images that can provide good results for land cover classification in a particular area [7]. Research vegetation cover and built-up area can be using Sentinel 2 satellite imagery. The land cover classification can be through visual interpretation or an index. The Normalize Difference Vegetation Index (NDVI), Normalize Difference Water Index (NDWI) and Normalize Difference Built-up Index (NDBI) are indices that allow for analysis of vegetation cover and built-up area over a wide area.

NDVI is used to measure plant growth and determine the coverage of vegetation areas using visible red and near-infrared wavelengths. In the process of photosynthesis, leaves or chlorophyll absorbs visible light (0.4 – 0.7 m), and the leaf cell structure strongly reflects near-infrared light (0.7 – 1.1 m). Reflection and absorption at wavelengths are closely related to the number of leaves on a plant [8]. NDWI is one vegetation indices used to determine land cover characteristics by measuring water molecules in vegetation that interact with incoming solar radiation [9]. NDWI value will increase if the vegetation contains a lot of water, or the index will increase from dry soil to open water bodies. NDWI is used as an index to determine land cover characteristics in an urban area [9]. In addition, NDWI is also used to analyze vegetated land cover to separate water and cloud objects [10]. The NDWI index value is large or increases in vegetation that contains a lot of g of water, or the index increases from dry land objects to open water. Zha et al [11] developed the Normalized Difference Built-up Index (NDBI) to identify urban areas and built-up areas quickly. The index creation is based on the unique spectral response in the built-up area, which has a higher short-wave infrared (SWIR) reflectance than near-infrared (NIR) wavelength.

Important information needed in watershed management is land covers, built-up areas and potential areas that can become water catchment areas. This study aims to identify vegetated areas and built-up areas in the Percut watershed by utilizing Sentinel-2 Imagery.

2. Materials and method
This research was carried out in Percut Watershed North Sumatra Province (Figure 1). The research was conducted from May 2021 until July 2021.

2.1. Tools and materials
The tools used are GPS, drone, PC and ArcGIS 10.3 software for land cover mapping.

2.2. Image Analysis
Sentinel 2 image data with processing Level-2A was obtained from the European Space Agency (ESA) in https://scihub.copernicus.eu/, and in this study, two image acquisition times were used, namely the period 2000 and 2021. The 2020 image was taken for the acquisition period between March 1 2020, and July 31 2020, while for 2020, the acquisition period used is between March 1, 2021 and July 31, 2021. Image analysis is carried out using the Google Earth Engine (GEE) platform for Sentinel 2 composite natural colour images, NDVI, NDWI and NDBI. The calculation formula of NDVI mathematically was written as follow [8,12]:

$$\text{NDVI} = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad \text{...(1)}$$

The calculation formula for NDWI as follows [9, 13]:

$$\text{NDWI} = \frac{\rho_{NIR} - \rho_{SWIR}}{\rho_{NIR} + \rho_{SWIR}} \quad \text{...(2)}$$

The calculation formula for NDBI as follows [11, 14]:

$$\text{NDBI} = \frac{\rho_{SWIR} - \rho_{NIR}}{\rho_{SWIR} + \rho_{NIR}} \quad \text{...(3)}$$

Where: $\rho_{NIR}$, $\rho_{RED}$, $\rho_{SWIR}$ were reflectance of near-infrared band, the red visible and short wave infrared band, whereas $d_{SWIR}$ is digital values of short wave infrared band.
3. Results and Discussion

3.1. Landcover Change by Visual Interpretation

Natural colour composite Sentinel 2 imagery produces a good display for land cover identification (Figure 2). The original colour composite uses red (B04), green (B03) and blue (B02) visible light bands in the corresponding red, green and blue colour channels. Natural colour displays make for as good a representation of land cover on Earth as humans do.
Figure 2. Results of visually observing land cover changes in 2020 and 2021 using Sentinel 2 Natural Colour composite

3.2. Normalized Difference Built-up Index (NDBI)
Based on NDBI analysis, in the Percut watershed during the 2020-2021 period, there is an increase in the built-up area of 2,092.62 hectares (Table 1 and Figure 3). The rise in built-up area indicates that there has been a conversion from an undeveloped area to a built site. An increase in the built-up area in a watershed has an impact on an increase in surface runoff. An increase in runoff can increase the danger of flooding due to an increase in runoff discharge.

| Cover          | Year 2021 (Hectares) | Total          |
|----------------|----------------------|----------------|
|                | Built-up Area        | Non Built-up Area |                  |
| Year 2020 (Hectares) | 10.038,50           | 1.506,50        | 11.545,00        |
| Non Built-up Area    | 3.599,12            | 27.652,97       | 31.252,08        |
| Total              | 13.637,62           | 29.159,50       | 42.797,08        |
3.3. Normalized Difference Water Index (NDWI)

An increase in the area indicated as wet, both medium wetness and high wetness, covering an area of 308.58 hectares during the 2020-2021 period (Table 2 and Figure 4). The increase in wettability of a large area mainly occurs in the downstream part of the watershed, to the north of the watershed. The site is generally in the coastal area in the form of mangrove land cover and ponds, which are often inundated with water.

**Table 2.** Changes in the wetness area during the 2020-2021 period

| Cover                     | Year 2020 | Year 2021 |
|---------------------------|-----------|-----------|
|                           | High Wetness | Moderate Wetness | Non-Water Body | Total     |
| High Wetness              | 5,67       | 2,45       | 0,15           | 8,27      |
| Moderate Wetness          | 131,77     | 588,00     | 302,07         | 1,021,85  |
| Non Water Body            | 30,25      | 580,55     | 41,156,15      | 41,766,95 |
| **Total**                 | **167,69** | **1,171,01**| **41,458,37**  | **42,797,08** |
3.4. Normalized Difference Vegetation Index (NDVI)

Overall, based on the NDVI classification in the Percut watershed, there was an increase in unvegetated areas reaching 288.96 during the 2020-2021 period. The field observation and visual analysis of composite images of natural colour Sentinel-2 (Figure 2) show that the cause of the increase in unvegetated areas is due to the taking of soil for the construction of dams. The process of taking soil in the upstream watershed with steep slopes will increase the rate of erosion and sedimentation.

The dynamics of the greenness class, especially from very low greenness to non-vegetated regions, indicate that in the Percut watershed area, there has been a conversion of vegetated land (Table 3 and Figure 5). Greenness index degradation was found in the upstream area of the watershed, which incidentally is an area with steep topography. This land cover degradation impacts decreasing the hydrological function of the land to support the watershed function in flood control.
Table 3. Changes in the area of the greenness index during the 2020-2021 period

| Cover | High Greenness | Moderate Greenness | Low Greenness | Very Low Greenness | Unvegetated Land | Total |
|-------|----------------|--------------------|---------------|--------------------|------------------|-------|
| Year 2020 | | | | | | |
| High Greenness | 26.122.58 | 1.415.81 | 508.71 | 150.21 | 24.59 | 28.221.90 |
| Moderate Greenness | 1.895.17 | 1.389.52 | 736.46 | 171.98 | 38.53 | 4.231.67 |
| Low Greenness | 705.13 | 856.03 | 1.403.74 | 767.02 | 137.97 | 3.869.88 |
| Very Low Greenness | 192.21 | 217.28 | 856.39 | 3.040.43 | 661.42 | 4.967.72 |
| Unvegetated Land | 21.20 | 22.41 | 60.69 | 469.25 | 932.34 | 1.505.90 |
| Total | 28.936.30 | 3.901.05 | 3.565.98 | 4.598.89 | 1.794.86 | 42.797.08 |

Figure 5. Greenness area based on Normalize Difference Vegetation Index (NDVI)
4. Conclusion
Land cover dynamics in the Percut watershed during the 2020-2021 period can be analyzed using NDBI, NDWI and NDVI. There is an increase in the built-up area of 2,092.62 hectares which indicates land conversion. NDWI classification shows an increase in the wetness area of 308.58 hectares, mainly occurring in the downstream part of the watershed, located to the north of the watershed. There is an increase in the area of non-vegetated areas reaching 288.96 hectares in the Percut watershed based on the results of the NDVI analysis.

Acknowledgement
This research was funded by the Ministry of Education, Culture, Research, and Technology through the PTUPT scheme with contract number 12/UN5.2.3.1/PPM/KP-DRPM/2021

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