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Scientific World Journal, vol. 2021, Article ID 5519011, 1
https://doi.org/10.1155/2021/5519011.

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Kind regards,

Prof Karoly Nemeth
Massey University
New Zealand

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1 submitted

Report

Reviewer 1 22.02.2021

In this paper, the authors apply remote-sensing techniques to map Universitas Padjadjaran campus and vicinity by comparing the area of Urban Green Space (UGS) and Floor Area Ratios (FARs) of the campus in 2015 and 2017 using WV2 data.
The abstract need to be improved.
The Introduction Section needs to be totally reformulated. No state of the art is giving.
The authors used NDVI to identify built areas. However, there are more adequate indices to estimate build areas. These need to be discussed and properly justified.
Too much theoretical information.
The references need to be updated and the reference list extended.
The results should be better discussed.

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Application of High-Resolution Remote Sensing for Regional Mapping of University Campus

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Irwan Ary Dharmawan SA CA [1], Muhammad Rahadianto[2], Edward Henry[3], Cipta Endyana[4], Muhammad Aufaristama[5] + Show Affiliations

ID 5519011

Article Type

Research Article

Journal

The Scientific World Journal

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Abstract

The purpose of this study was to apply remote-sensing techniques to map a university campus and vicinity by comparing the area of Urban Green Space (UGS) and Floor Area Ratios (FARs) of the campus in 2015 and 2017. Additionally surface runoff analysis were also conducted. For our research, we used WorldView-2's high-resolution satellite imagery with a resolution of < 0.5 m in the Universitas Padjadjaran (Padjadjaran University, or Unpad) Jatinangor campus, Jawa Barat, Indonesia. Our approach was to interpret the imagery by running Normalized Differentation Vegetation Index (NDVI) to distinguish UGS and FAR, and using Digital Elevation Model (DEM) interferometric synthetic aperture radar data with hydrologic analysis to identify the direction of surface runoff. The results obtained are as follows: UGS remained more extensive compared to FAR, but the difference decreased over time owing to infrastructure development. Surface runoff has tended to flow toward the southeast in direct relation to the slope configuration

> Author Declaration

> Files 2

— Editorial Comments

Recommendation

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Journal of Sensors

Application of High-Resolution Remote Sensing data for Regional Mapping of University Campus

Irwan A. Dharmawan,[1] Muhammad A. E. Rahadianto,[1] Edward Henry,[2] Cipta Endyana,[3] and Muhammad Aufaristama[4]

[1] Department of Geophysics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Jl. Raya Bandung Sumedang km. 21, Jatinangor, Sumedang 45363, Jawa Barat, Indonesia.
[2] Directorate of Facilities, Infrastructures and Asset Management, Universitas Padjadjaran, Jl. Raya Bandung Sumedang km. 21, Jatinangor, Sumedang 45363, Jawa Barat, Indonesia.

[3] Faculty of Geological Engineering, Universitas Padjadjaran, Jl. Raya Bandung Sumedang km. 21, Jatinangor, Sumedang 45363, Jawa Barat, Indonesia.
[4] University of Twente, Faculty for Geo-Information Science and Earth Observation (ITC), P.O. Box 6, 7500 AA Enschede, The Netherlands

Correspondence should be addressed to Irwan A. Dharmawan; iad@geophys.unpad.ac.id

Abstract

The purpose of this study was to apply remote-sensing techniques to map a university campus and vicinity by comparing the area of Urban Green Space (UGS) and Floor Area Ratios (FARs) of the campus in 2015 and 2017. ~~Additionally~~Additionally, surface runoff analysis ~~were~~was also conducted. For our research, we used WorldView-2's high-resolution satellite imagery with a resolution of < 0.5 m in the Universitas Padjadjaran (Padjadjaran University, or Unpad) Jatinangor campus, Jawa Barat, Indonesia. Our approach was to interpret the imagery by running Normalized ~~Differentation~~ Difference Vegetation Index (NDVI) to distinguish UGS and FAR, and using Digital Elevation Model (DEM) interferometric synthetic aperture radar (SAR) data with hydrologic analysis to identify the direction of surface runoff. The results obtained are as follows: UGS remained more extensive compared to FAR, but the difference decreased over time owing to infrastructure development. Surface runoff has tended to flow toward the southeast in direct relation to the slope configuration.

Comment [a1]: An introductory sentence is needed

Comment [a2]: Where?

Comment [a3]: The exact spatial resolution need to be given

Introduction

The Universitas Padjadjaran (Padjadjaran University, or Unpad) Jatinangor campus is in Jatinangor District, Sumedang Regency, Jawa Barat, Indonesia. The geographic location of the study area (the campus and vicinity) is south and east of 107°46′28″S and 6°55′33″E with altitudes of ~725–810 m above sea level. The Unpad comprises 16 faculties spread throughout the ~178 Ha campus (see Figure 1), which has extensive areas of vegetation, including an arboretum open to visitors and plantations that provide a learning environment for student discussions. Lake Cekdam on the Unpad campus, which is near the university's arboretum, has an area of ~1 Ha and serves as a reservoir to collect rainwater.

Comment [a4]: This is the study ar the introduction must begin with the state of art

Figure 1: Study area [1], showing boundaries of 178 Ha Unpad campus, including plantations.

Comment [a5]: Which plantations?

As a large area within Jatinangor, Unpad must have a stake in the development and preservation of Urban Green Space (UGS). The Unpad campus also has infrastructure problems that need to be studied and addressed. One of them is based on the strict Regional Regulation (Perda) of Sumedang Regency no. 2 of 2012 concerning Regional Spatial Planning, which states that the ratio of UGS to Floor Area Ratio (FARs) for any business activity, large or small, must meet or exceed 60%:40% [2]. The need for Unpad to add other buildings requires consideration of these regulations.

Comment [a6]: quantify

Another problem is the impact of campus land-use and land-cover changes that affect surface runoff. A recurring negative impact is flooding during the rainy season. Further analysis of surface runoff is needed to maintain and enhance the capability of the land to use or absorb standing water [3], which can be a source of water reserved for use by the current Unpad campus.

Comment [a7]: (LULC)

Comment [a8]: Reference?

~~Rapid technological advances have produced satellite sensors capable of providing imagery at very high spatial resolution, which can be used in remote-sensing data analysis~~. Remote sensing combines science and art to obtain data and information about objects that exist on the Earth's surface by using tools that are not directly related to the object being studied [4]. Remote-sensing techniques have been widely used in many applications, such as for urban-planning purposes [5–9]. While most of the urban research has been done on large cities or metropolitan areas [5,9–13], in a few cases it is applied to specific areas such as a university campus or school. However, some previous researchers have used only low- to moderate-resolution satellite data [6,7,12–15].

Comment [a9]: Examples of some these studies should be given

The purpose of our research is in line with Unpad's mission to reach a sustainable campus. In our research, we used high-resolution multitemporal imagery from the WorldView-2 DigitalGlobe satellite for campus evaluation, planning, and development, and we field validated the resulting dataset

Remote Sensing for Regional Mapping

WorldView-2 Satellite Sensor and Digital Elevation Model (DEM)

The WorldView-2 Satellite, ~~the latest generation satellite from DigitalGlobe~~, was launched in October 2009. The remote-sensing imagery produced has a high spatial resolution and also has a more-complete spectral resolution than the previous DigitalGlobe imagery sensor. The spatial resolution of WorldView-2 products is 0.46–0.5 m for panchromatic imagery and 1.84 m for eight-channel multispectral imagery. Channels capture a range or spectrum of ~~colors~~ wavelengths ~~of only certain wavelengths (~~Table 1). These specifications are quite adequate for spatial analysis of natural resources and the environment. A cloud free high-resolution WorldView-2 (WV-2) image acquired on June 14th 2015 and September 17th 2017 were used in this study. The WV-2 satellite is a high spatial resolution space-borne sensor launched in 2009 with eight multispectral bands ranging from blue to the near infrared parts of the electromagnetic spectrum and one panchromatic band (450–800 nm) [16].

Table 1: WorldView-2 channel type classification [17].

Channel type	Wavelength range (nm)	Spatial resolution (m)
Panchromatic	450–800	0.46
Coastal blue	400–450	1.84
Blue	450–510	1.84
Green	510–580	1.84
Yellow	585–625	1.84
Red	630–690	1.84
Red edge	705–745	1.84
Near infrared 1	770–895	1.84
Near infrared 2	860–1040	1.84

The specific or best-use application of each of the eight channels [17] recorded in multispectral imagery is as follows:

- Coastal blue: vegetation analysis, bathymetry, atmospheric correction.
- Blue: vegetative analysis, bathymetry, atmospheric correction.
- Green: analysis of healthy plants, plant strength, categorization of plants assisted by yellow channels.
- Yellow: detection of yellowness of vegetation, both on land and in water.
- Red: distinguishing vegetation, classification of land, roads, geological features.
- Red edge: measuring plant health and classifying plants.
- Near infrared 1: estimation of water content and plants biomass, separation of waterbodies from vegetation, identification of vegetation types and soil types.
- Near infrared 2: same as near infrared 1 but less influenced by the atmosphere.

To identify built-up land features through unsupervised classification, Masek et al. (2000) established a technique based on a normalized difference vegetation index (NDVI) [18]. Moreover, the used of WV-2 image for detailed mapping is expanding due to the it's very high spatial resolution.

Several studies have attempted to extract classification and feature detection from remotely sensed images with very high spatial resolution [16, 19-21]. Given land classification limitations such as time-consuming field surveys, accurate and timely.

Comment [a10]: 0% of cloud cover

Comment [a11]: repetitive

Comment [a12]: in text format

Comment [a13]: there are more adequate indices to estimate build areas. This need to be discussed

Also, one of the remote-sensing products is the DEM, which is a digital model of a topographic surface or terrain. More specifically, a DEM is a digital dataset portraying the geometry of the shape of part of the Earth's surface and consists of a set of points sampled from the surface by an algorithm that defines the surface in terms of coordinates [22]. The term DEM was popularized by the U.S. Geological Survey (USGS). DEMs are usually there are more adequate indices to estimate build areas. This need to be discussed odeveloped from remote-sensing data, but they can be developed from field-survey data. They are often used in Geographic Information Systems.

Comment [a14]: it was already refined?

Elevation has been mapped from both satellite and aircraft synthetic aperture radars (SARs) since the 1960s [23]. A SAR synthetically simulates a very long antenna using the forward movement of the aircraft. Aircraft or spacecraft carrying SARs also record data from onboard differentially corrected global positioning systems (GPS) and an inertial navigation systems (INS) to determine the location and roll, pitch, and yaw of the craft.

This study focuses on the use of a special type of SAR called an interferometric synthetic aperture radar (IFSAR) to derive topographic information. IFSAR exploits the coherent nature of SAR echoes (i.e., the signals are recorded in both amplitude and phase) to measure difference in the phase from each patch of the surface when observed from slightly different locations and/or times. These phase differences can be attributed to differences in path length between the two signals. The path-length differences are a function of: (1) the distance and angles of the radar antennas making the observations, (2) the topography of the surface, (3) a change in the position of patches of the surface, and (4) differences in atmospheric or ionospheric conditions along the two paths. If the two observations are made simultaneously from a pair of radar antennas on a single platform, item (1) above is well known and the effects of items (3) and (4) are negligible, leaving item (2), the surface topography, as the controlling factor [24]. Therefore, a fixed-baseline dual-antenna interferometric system is the preferred method for the extraction of DEMs. In this study we use 5 m resolution IFSAR for DEM.

Comment [a15]: This is only theoretical information….no added values to the paper

Land Use ~~Cover~~ and Land Cover (LULC)~~Use~~

Land cover is the condition of the observed biophysical appearance of the Earth's surface. Land cover can be grouped into vegetated and nonvegetated areas [25]. Vegetated-areas classification includes irrigated rice fields, rainfed rice fields, tidal rice fields, plantations, mixed crops, dryland forests, wetland forests, shrubs, savanna, imperata grasslands, and swamp grass. Nonvegetated-areas classification includes open land on a caldera, lava, stretch of beach sand, beach shoals, sand dunes, riverbanks, built land, settlement, industrial buildings, road network, railroad network, high-voltage electricity network, domestic/international airport, land not built, mining, landfill deposits, lakes, rivers, irrigation channels, and coral reefs.

Supported by land-cover information, further analysis yields land-use information. Land use includes all types by humans, including land use for agriculture, office buildings, sports fields, houses, businesses, hospitals, and cemeteries [26]. Land has an important function in human life. However, changes in land use from nonbuilt to built can reduce the ability of land to absorb rainwater. In this study, land use was classified as UGS or FAR, in accordance with Perda [1].

The classification UGS is an open, extensive clustered area or path used for plants, both growing naturally and intentionally planted. It is divided into two types, public and private green space. Public UGS is owned and managed by the city or regency regional government for the benefit of the general community; examples include city parks and cemeteries, urban forests and green belts, and land along rivers and railroads. In contrast, private UGSs belong to certain institutions or individuals, and their use is limited to certain owners or permitted people or groups; examples include private yards or gardens as well as the grounds around community-owned buildings that have private plantings.

FAR refers to the percentage that the ground-floor area of a building may occupy compared to the available land area. To be included in FAR, a structure must consist of a sizable section of roofed-over rooms that have walls of height > 1.2 m or it must be within the definition of projected buildings, which are open spaces at ground level that are under the building.

Surface-Runoff Direction

Surface runoff is water flowing on the ground surface owing to impermeable ground or soil's having reached full infiltration capacity. This runoff flows downslope toward and into a basin or depression in the land surface [27]. After such filling, the water further flows freely over the ground. DEM analysis can be used to map water-flow direction and water accumulation. This hydrologic approach to map surface runoff is based entirely on topographic differences.

Methodologhy

Band-Ratio Method

The band-ratio method is an important technique for preprocessing satellite data, particularly in areas with notable topographic differences [28]. This method is useful for increasing spectral differences between channels and for reducing topographic effects. Dividing one channel with another channel produces an image that shows the relative channel intensity. This band-ratio method is applied to identify certain objects that are difficult to discern when using only single channels. Examples of its application include the transformation of the normalized difference vegetation index (NDVI) and the normalized difference water index.

NDVI

Remote sensing of vegetation depends on unique spectral characteristics associated with biophysical processes that occur within plants. For instance, leaves absorb and disperse radiation, and the level of absorption or scattering is a function of the wavelength [29]. Green leaves absorb radiation from the visible light channel (blue–red end of the spectrum) and reflect radiation from the near-infrared channel. Strong absorption in the red channel has been correlated with biomass production. Reflection associated with the near-infrared channel is related to the leaves' internal light scattering and green-leaf density, which increases with photosynthetic activity [30]. This transformation of the NDVI combines the band ratio and channel-reduction methods [31] involving the red channel absorbed by green leaves and near-infrared channels reflected by green leaves. NDVI often used in analysis of ~~land-use/land-cover~~LULC changes [32-36]. The equation to calculate the NDVI is

Comment [a16]: ?

Comment [a17]: Reference?

Comment [a18]: References are needed

$$NDVI = \frac{I_{nir} - I_{red}}{I_{nir} + I_{red}} \quad (1)$$

where I_{nir} is the reflection intensity received by the near-infrared-channel sensor (spectrum of wavelengths in the range 840–1060 nm), and I_{red} is the reflection intensity received by the red-channel sensor (spectrum of wavelengths in the range 630–690 nm). The NDVI value is close to −1 if it does not detect the presence of vegetation (buildings, water, snow, etc.) but is 1 if it detects vegetation. The denser the vegetation is, the closer the value of NDVI is to 1.

Comment [a19]: The correct term must be reflectance. Also, the origin reference to NDVI must be given: Reed, B.C., Brown, J.F., VanderZee D., Loveland, T.R., Merchant, J.W., Ohlen, D.O., 1994. Measuring phenological variability from satellite imagery. J. Veg. Sci. 5 (5), 703–714.
Also more reference regarding NDV should also be given, for instance: Duarte, L., et al. (2018). PhenoMetr An open source software applicatio to assess vegetation phenology metrics. Computers and Electronics Agriculture, 148, 82–94.

Land-Cover Analysis

To compare vegetated and nonvegetated areas of the Unpad campus, we performed land-cover analysis using NDVI transformation processing, which can distinguish areas of vegetation from those without vegetation (buildings, water, bare fields, etc.). We interpreted the NDVI results against RGB (red–green–blue color gamut) images to categorize the index values according to how they correlate with the type of land cover. We classified the land cover into five types: water, buildings, empty land, low/sparse vegetation, and high/dense vegetation. Next we applied histogram analyses of the pixel values of the NDVI images to calculate areal extent and percentage of vegetated and nonvegetated land cover within the Unpad campus boundary. For the total land area, as defined by the National Standardization Agency for 2010 [23], we added vegetated and nonvegetated land and applied Equations (3) and (4) to derive the overall percentages of each ($\%A_{veg}$ and $\%A_{nonveg}$):

$$\%A_{veg} = \frac{A_{veg}}{A_{tot}} \times 100\% \quad (3)$$

and

$$\%A_{nonveg} = \frac{A_{nonveg}}{A_{tot}} \times 100\% \quad (4)$$

assuming

$$A_{tot} = A_{veg} + A_{nonveg} \quad (5)$$

where A_{tot}, the total area, is 178 Ha, A_{veg} is the area of vegetated land cover, and A_{nonveg} is that of nonvegetated land cover. We also compared 2015 and 2017 imagery of the Unpad campus to determine land-cover change.

Comment [a20]: Why these two ye were selected?

Land-Useage Analysis

We conducted analyses of UGS and FAR in several stages—ground truthing, categorization of UGS and FAR, and comparison of UGS and FAR in 2015 versus 2017. The UGS category includes both land deliberately planted (gardens, parks, etc.) and land covered by natural plant growth. In contrast, the FAR category consists of land that is covered over by roads, buildings, or other manmade structures. Ground truthing, conducted to minimize errors in image interpretation, was performed by marking locations that are not clearly visible on a digital map (such as areas covered by dense tall plants). Such checks were conducted

Comment [a21]: ?

periodically; the first such field inspection was done on November 11, 2018. To classify UGS versus FAR (done by using QGIS software's shape tool), we considered the results of field checks, image color analysis, and NDVI transformations. This type of data was stored as shapefiles (using *.shp format) so that it can be opened in other GIS software. We also ran extensive calculations on the UGS and FAR data and compared 2015 and 2017 results to assess their relative decrease and increase. On the basis of designations by the Perda [1], we determined total land area as the sum of the UGS and FAR areas. Accordingly, we used Equations (6) and (7) to derive the overall percentages of each ($\%A_{UGS}$ and $\%A_{FAR}$):

Comment [a22]: Indicate all the fie inspections

$$\%A_{UGS} = \frac{A_{UGS}}{A_{tot}} \times 100\% \tag{6}$$

and

$$\%A_{FAR} = \frac{A_{FAR}}{A_{tot}} \times 100\% \tag{7}$$

assuming

$$A_{tot} = A_{UGS} + A_{FAR} \tag{8}$$

where A_{tot} is the total area (UGS and FAR combined), A_{UGS} is the total area of just UGS, and A_{FAR} is the total area of just FAR.

Surface-Runoff Analysis

To determine trends in the various directions of water flow and also to gather information on surface-water accumulation, we used DEM data to do surface-runoff analysis. The DEM data that we used was corrected by applying the fill sinks algorithm [37]. Such analysis is done in successive stages, the first for flow direction and the second for flow accumulation. The initial flow-direction analysis is done for each pixel, for which we used Saga GIS software's D8, or eight-direction, analytical method. The results are in the form of raster map data with separate values for each pixel based on the flow-direction tendencies generated from the DEM data.

The principle of flow analysis using the D8 algorithm (see Figure 2) is to identify and select the most-significant decrease for each cell as the flow direction. For each pixel, the algorithm finds the greatest difference in value compared to surrounding pixels to assign one of eight flow-direction values: 1 for east, 2 for southeast, 4 for south, 8 for southwest, 16 for west, 32 for northwest, 64 for north, and 128 for northeast.

Flow accumulation is derived by summing the flow directions of the cells flowing to a calculated cell (called weight). The higher a cell's calculated weight, the greater the possibility of flow accumulation in the cell. Flow accumulation may be associated with river flow. Pixel results from applying the flow-direction algorithm are then retranslated according to the number of surrounding pixels with incoming flow. Pixel values are large if there are many such pixels but are small or zero if the adjacent pixels receive low or no flow.

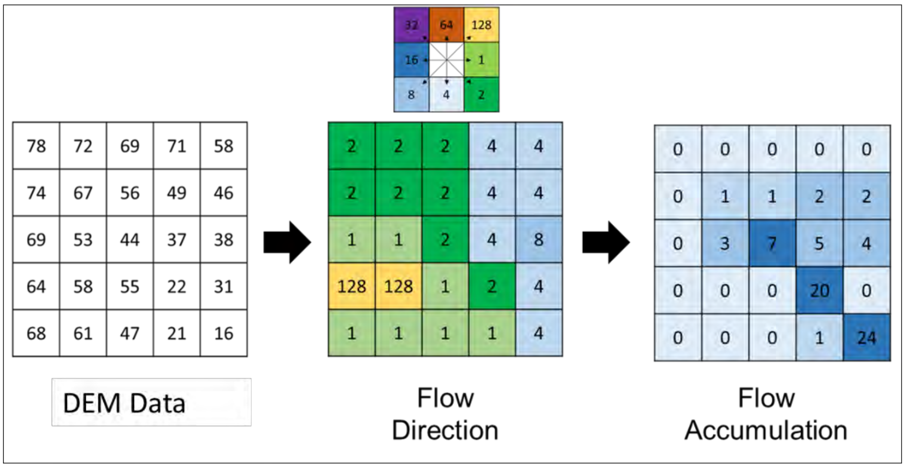

Figure 2: Schematic of algorithm for flow direction and accumulation. Diagram in upper middle shows eight flow directions (and their labels).

Comment [a23]: The DEM could b given

Result and Discussion

Land Cover

The change in land-cover type for the Unpad campus area were determined from NDVI image maps by comparing 2015 and 2017 results (see Figure 3). We conducted an analysis of the 2015 map data and concluded that NDVI values in the range −0.2–0 indicate water or wet areas on the map; this range identified pools or puddles, lake, the arboretum rice fields, the fountains near the rectorate building, and the ponds on the Unpad's plantation. Buildings and vacant land are shown by the NDVI range 0–0.4, which are scattered throughout Unpad. Vegetation is indicated by NDVI values 0.4–1; the higher the NDVI value, the denser the vegetation that is represented. From the NDVI data, we categorized water, buildings, and bare fields as non-vegetated areas. Areas of sparse and dense vegetation we categorized as vegetated areas. We then used the same NDVI classification to analyze the 2017 data. There are obvious differences between the 2015 and 2017 maps (see Figure 3). For instance, the building/open ground areas (pale yellow) and sparse vegetation areas (green) on these image maps are more dominant than the dense vegetation (blue) areas, which means what was dense vegetation in 2015 has been reduced by 2017. In contrast, water storage (red) in did not change between 2015 and 2017.

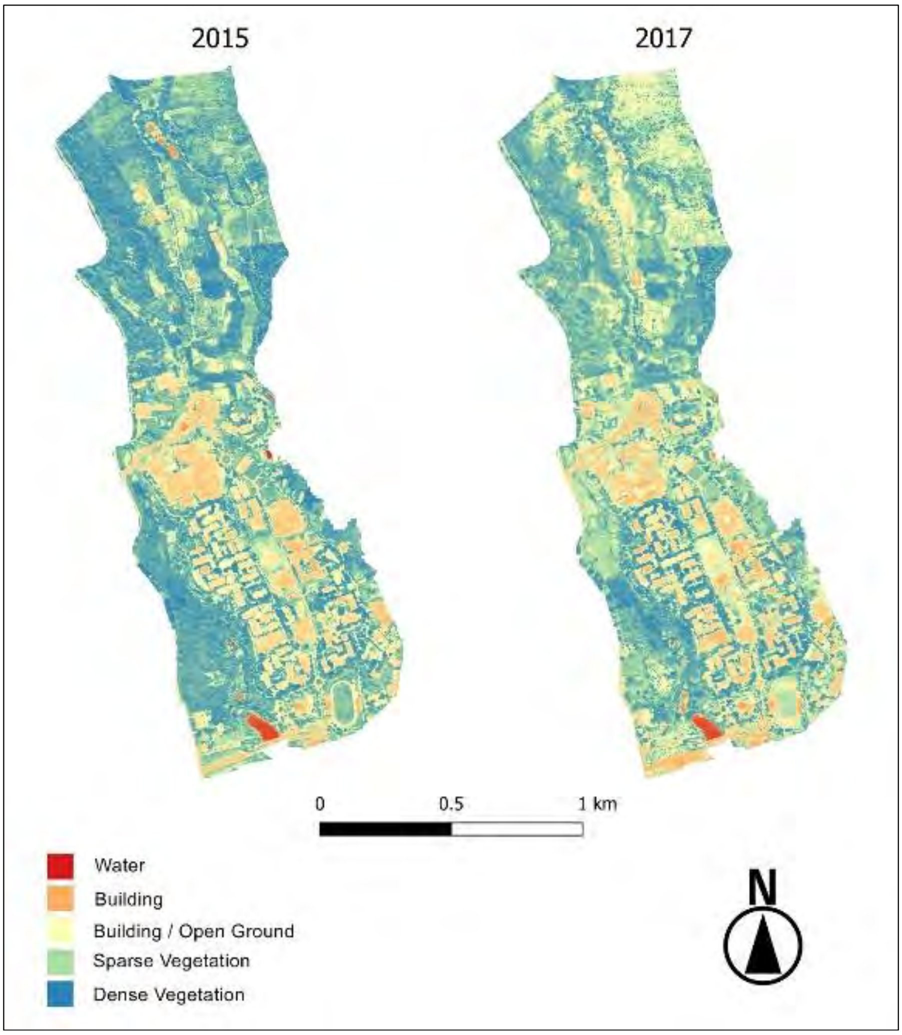

Figure 3: Comparison of Unpad campus land use in 2015 and 2017 based on NDVI analysis.

To derive the percentage of each area, we ran a histogram analysis (see Figure 4); the x-axes show the ranges of NDVI values, and the y-axes show numbers of pixels that indicate that range of values. For 2015, the sum number of pixels for the vegetated areas is 288,092, whereas the sum number of pixels for non-vegetated areas is 155,196 pixels; accordingly, for 2015, the vegetated areas amount to ~115.68 h~~H~~a, or 64.99% of the ~178 h~~H~~a, and the non-vegetated areas amount to ~62.32 h~~H~~a, or 35.01% of the ~178 h~~H~~a, or ~53.36 h~~H~~a less than the vegetated areas. The results of histogram analysis for 2017 show differences compared to 2015. The dominant NDVI range for 2017 is 0.4–0.6 with a total of 138,422 pixels; the total number of pixels representing non-vegetated areas (water, buildings, and open ground) is 217,049, whereas that for the vegetated areas is 237,768 pixels. Hence, for 2017, the vegetated areas amount to ~93.06 h~~H~~a, or 52.28% of the ~178 h~~H~~a, and the non-vegetated areas amount to ~84.94 h~~H~~a, or 47.72% of the ~178 h~~H~~a, or ~8.12 h~~H~~a less than the vegetated areas.

From the histogram results it is apparent that by 2017, the vegetation area had decreased by 12.71% since 2015, while correspondingly the non-vegetated areas had increased by 12.71% since 2015. This change was dominated by dense vegetation loss to areas of sparse vegetation or bare fields. It is estimated that this decline in vegetation is due to new building development.

Comment [a24]: More information needed

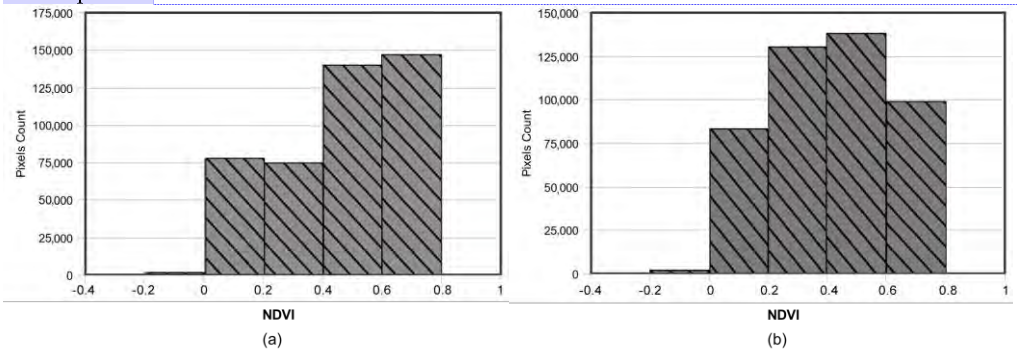

Figure 4: NDVI pixels histograms. (a) 2015; (b) 2017.

Land Use

From the results of interpretation of NDVI image data and subsequent ground truthing, we derived image maps showing UGSs and FARs for 2015 and 2017 (see Figure 5).

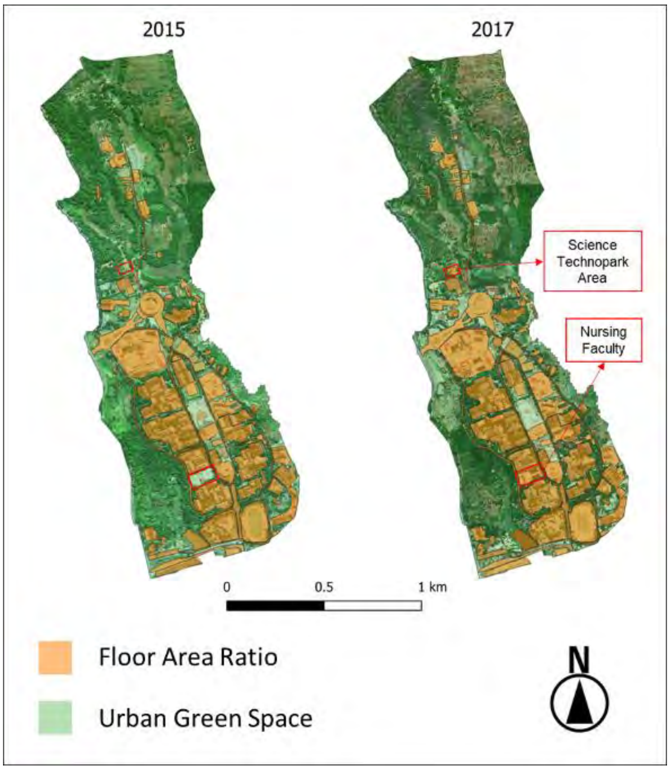

Figure 5: Comparison of Unpad campus land use in 2015 and 2017 based on NDVI analysis.

On the land-use map produced by NDVI analysis (see Figure 5), orange areas (FAR) represent buildings and roads, and green areas (UGS) represent spaces covered by plants, including intentional plantations and the Unpad's arboretum. The results of the 2015 image-map analysis showed that the UGS areas included 124.31 h~~H~~a (69.84% of the total 178 h~~H~~a area), while the FAR areas amounted to 53.69 h~~H~~a (30.16% of the total area), representing a difference between UGS and FAR of 70.62 h~~H~~a. The north end of the study area is dominated by UGSs in the form of plantations (see Figures 1 and 5), and the south is dominated by FAR areas (mostly campus buildings). When we compared the 2015 and 2017 results of image-map analysis, we found only small differences in the areas between the two years: UGS in 2017 amounted to 123.38 h~~H~~a (69.31% of the total 178 Ha), and FAR included 54.62 h~~H~~a (30.69% of the total area). Accordingly, from the two datasets, FAR in 2017 showed an absolute increase of 0.53% compared to 2015, and UGS correspondingly experienced an absolute decrease of 0.53% compared to 2015. The reason for the difference in FAR is the addition of two buildings on the Unpad campus: the Nursing Faculty buildings and Science Technopark Area (see Figure 5). According to Perda, these results indicate that Unpad is still allowed to build 16.58 Ha.

Comment [a25]: Which type of plantations?

Comment [a26]: Reference is miss

Surface-Runoff Direction

Based on the DEM map of the Unpad area (see Figure 6), the maximum altitude (red) is 852.9 m above sea level, and the minimum (blue) is 708.1 m above sea level. Accordingly, from these data, we found the difference across the entire Unpad campus to be 144.8 m and the dominant slope to be that toward the southeast.

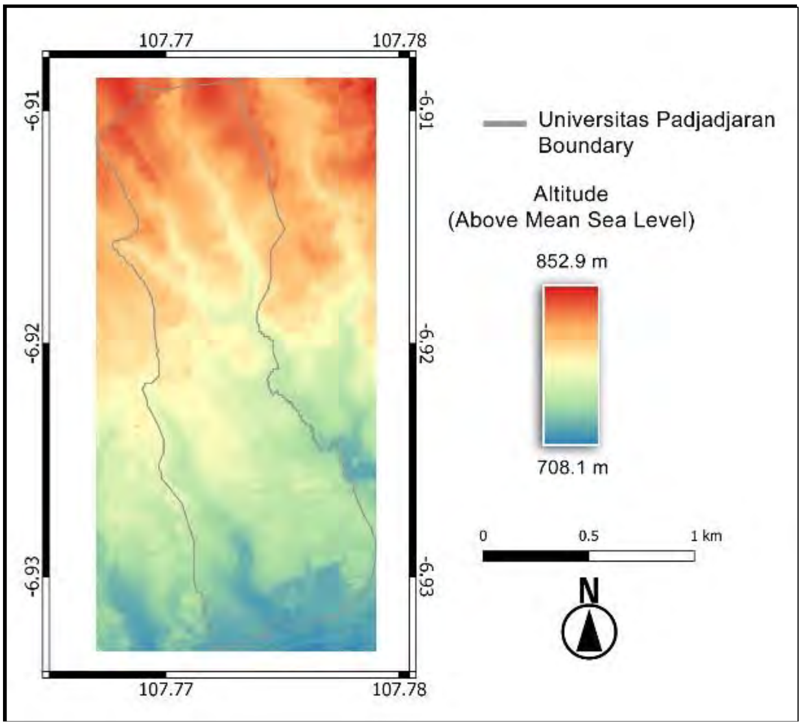

Figure 6: ~~Digital Elevation Model~~DEM of study area.

The results of our flow-direction analysis using the D8 method (see Figure 7) indicate the possible flow direction by pixel based on the slope ~~of the land~~. The Unpad campus boundary of the Unpad area is indicated by a gray line. From this map, it is apparent that in the southern part of the Unpad campus (bounded by gray line), the pixels are dominated by green and blue, indicating that water flow is mainly in the south and toward the southeast. Our data analysis confirmed the direction of flow to be directly proportional to the direction of the dominant slope.

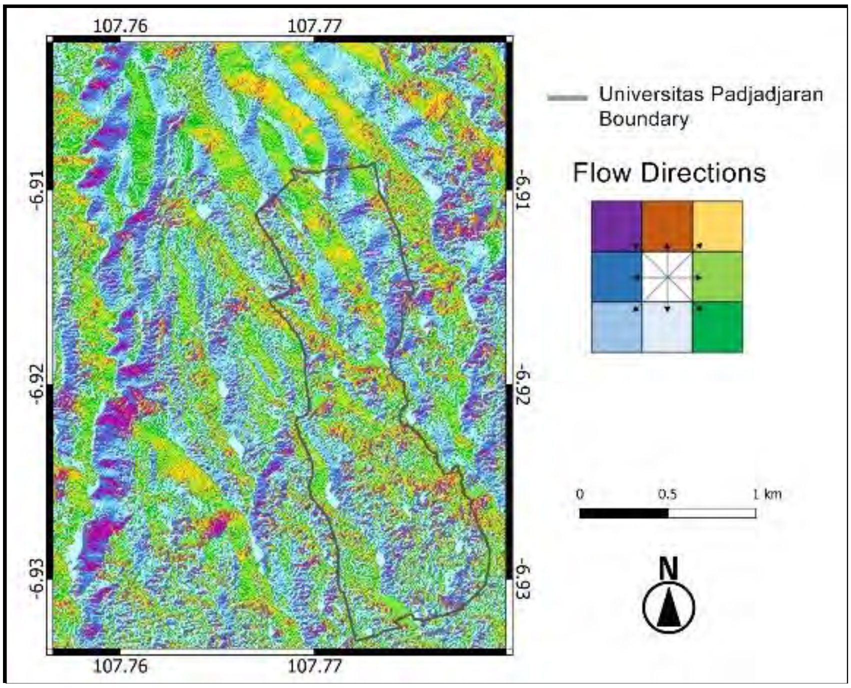

Figure 7: Flow-direction map of Unpad campus and vicinity.

From the results shown in the flow-direction map (see Figure 7), we obtained a flow-accumulation map (see Figure 8), which describes the direction of accumulated water flow. Accumulated flow (blue) is directed from lighter blue toward the darker blue. The map shows some accumulated streams that flow from the north of Unpad toward the east and southeast. This water-flow pattern can be matched to the known streamflow network around the Unpad Jatinangor campus. Another evident stream flows through the Unpad arboretum and empties into Unpad's Lake Cekdam. To the west of the Unpad campus, other water flow through the area comes from the north or northwest. The highest accumulation occurred in the eastern part of the Unpad area and was downstream from water-flow accumulation that began to the north of Unpad.

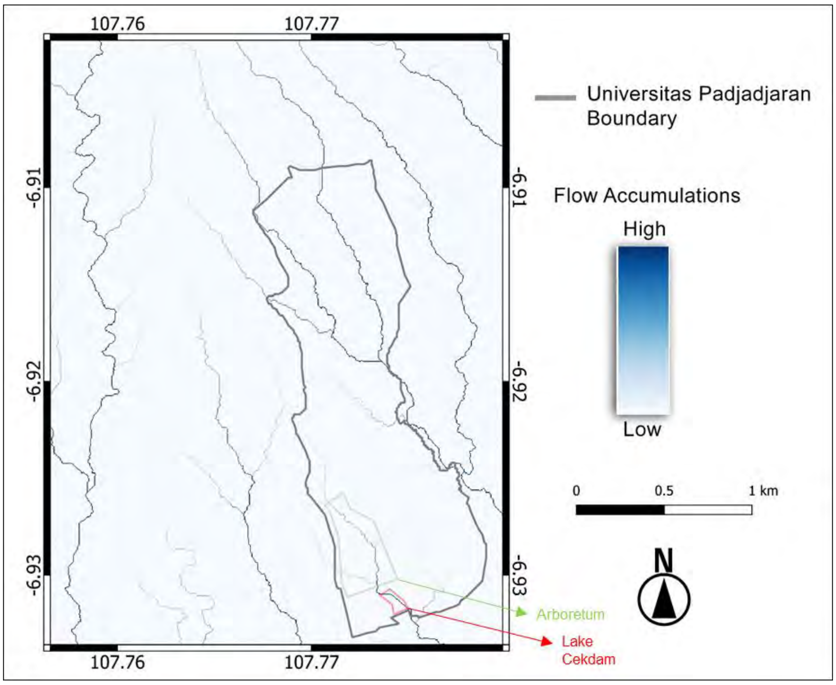

Figure 8: Flow-accumulation map of Unpad campus and vicinity.

Conclusion

From the results of this study, we found that 64.99% of the total area of the Unpad Jatinangor campus in 2015 was covered by vegetation and 35.01% of the total area was no vegetation, whereas in 2017 the land cover was 52.28% vegetated and 47.72% non-vegetated. Thus, vegetated land cover decreased by 12.71% during 2015–2017, and, correspondingly, nonvegetated land cover increased by 12.71% during the same period.

We also found that in 2015, the UGS of the Unpad Jatinangor campus occupied 69.84% of the total area, while FAR areas amounted to 30.16% of the total area. For 2017, UGS amounted to 69.31% and FAR 30.69% of the total area. Accordingly, UGS decreased by an absolute 0.53% during 2015–2017, while FARs increased by the same amount during that period so that the area of land that can be built is 9.31% (16.58 Ha). Therefore, the Unpad campus is still in compliance with the Regional Regulation (Perda) of Sumedang District number 2 of 2012 concerning Regional Spatial Planning, which states that the ratio UGS:FAR for each business activity (including large industry) must be at least 60%:40%.

We also analyzed water-flow surface runoff and found it was dominated by flow toward the south and southeast, with accumulation in the northeastern part of Unpad through Unpad's Arboretum and into Lake Cekdam on the Unpad campus.

Data Availability

Underlying data is available upon request.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgments

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