Water Supplying Vegetation Index (WSVI) Analysis for Drought Rate Mapping in Bogor Regency

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Abstract. Bogor dubbed as The City of Rain because of the high rainfall, Bogor is also a water conservation area. But in recent years in 2015, there was drought in several subdistricts in Bogor, consisting of 40 districts and distributed in 59 villages. Drought is closely related to the existing water reserves in the soil, good water to land as well as for everyday human needs. This research aims to map levels of drought that occurred in Bogor Regency from 2005 to 2015 using the Water Supplying Vegetation Index (WSVI). Research with Water Supplying Vegetation Index (WSVI) is to map the level of drought is still not much done in Indonesia. Methodology this research is to analyze the data of remote sensing technology and geographic information system (GIS) using the Water Supplying Vegetation Index (WSVI) prepared from Landsat 8 OLI/TIRS and Landsat 5 TM. Obtained that areas with a very high level of drought are Cariu Subdistrict, Babakanmadang Subdistrict, Jonggol Subdistrict, Ciampea Subdistrict, and Cibungbulang Subdistrict. The level of drought can be indicated by the level of humidity. If there is a decrease in vegetation, it can reduce the level of moisture which later can also increase the potential for drought.

1. Introduction

Drought is one of the disasters that can threaten even a tropical country, like Indonesia. [1] Explain that an absence of significant precipitation for a period long enough to cause moisture deficits in the soil through evapotranspiration and decreases in stream flow, so disrupting normal biological and human activities. Crop damage and water shortages are typical results of drought conditions.

The World Meteorological Organization (WMO) divides drought into four types: meteorological drought, agricultural drought, hydrological drought, drought due to land use, and socio-economic drought. Meteorological drought is usually defined on the basis of the degree of dryness and the duration of the dry period. Definitions of meteorological drought must be considered as specific to a region since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. Agricultural drought is closely related to the condition of the availability of water both from rain and irrigation, humidity, which can then impact on agricultural productivity. Hydrological drought is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply. The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Socio-economic drought is a condition of reduced availability of water which can disrupt the socio-economic activities of the community. For example, it affects the production of an item so that it impacts on prices due to the imbalance of supply and demand. [2]. In this study, the drought discussed was classified as a meteorological drought.

Bogor City dubbed as The City of Rain because of the intensity of the annual precipitation totals are higher than other areas. Because of the high rainfall, Bogor is also a water conservation area. But in recent years, especially in the year 2015, there was drought in several subdistricts in Bogor district, consisting of 40 districts and distributed in 59 villages. Drought is closely related to the existing water reserves in the soil, good water to land as well as for everyday human needs.

2. Study Area

This study makes Bogor Regency as a study area. Bogor Regency is one of the districts that are part of the West Java Province, Indonesia. The absolute location of Bogor Regency is at coordinates 6.19° North Latitude to 6.47° South Latitude and 106° 1 'to 107° 103' East Longitude. In the north, Bogor Regency borders Depok City, bordering Lebak Regency in the west, Purwakarta Regency in the east, and Sukabumi Regency in the south. The area of Bogor Regency has an area of 2,301.95 km^2, of which this area covers 5.19% of the area of West Java Province [3].

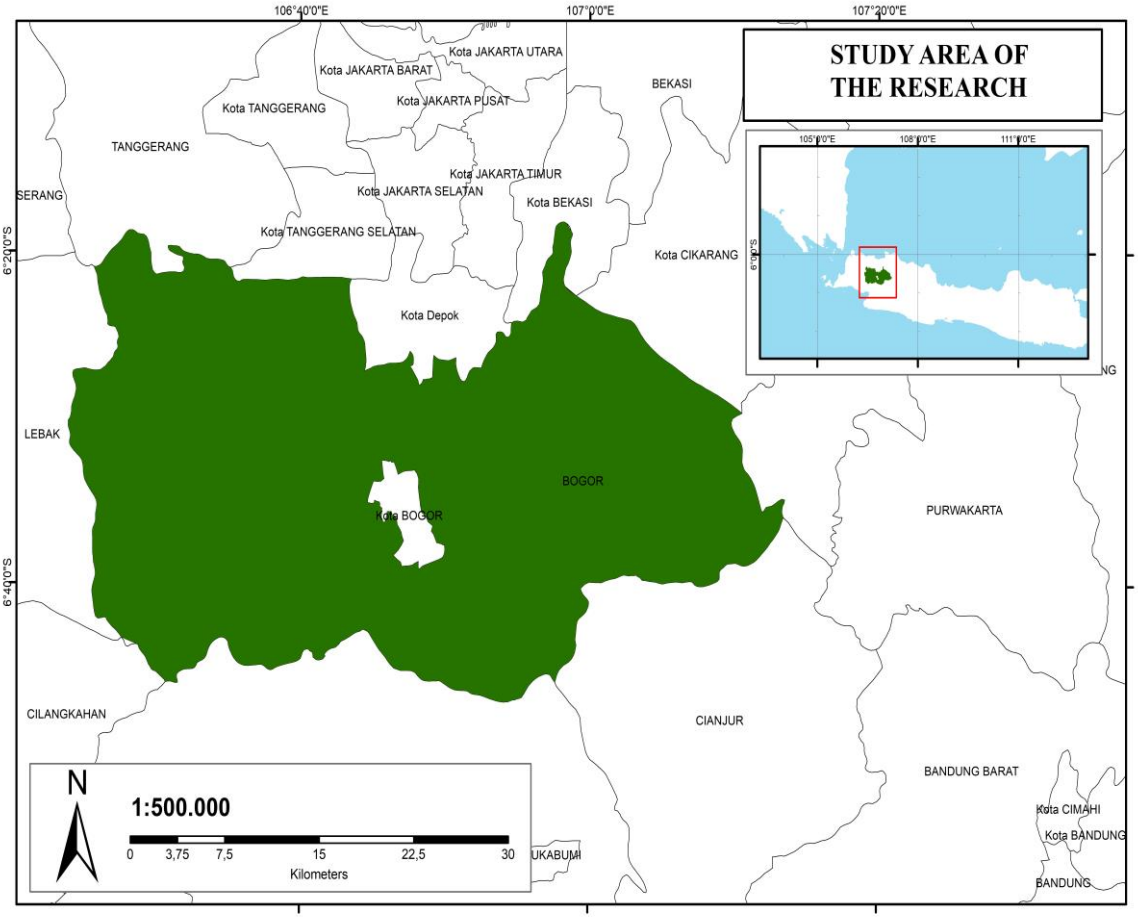

Figure 1. Study area of the research.

3. Methodology

Methodology this research is to analyze the data of remote sensing technology and geographic information system (GIS) using the Water Supplying Vegetation Index (WSVI) prepared from Landsat 8 OLI/TIRS and Landsat 5 TM.

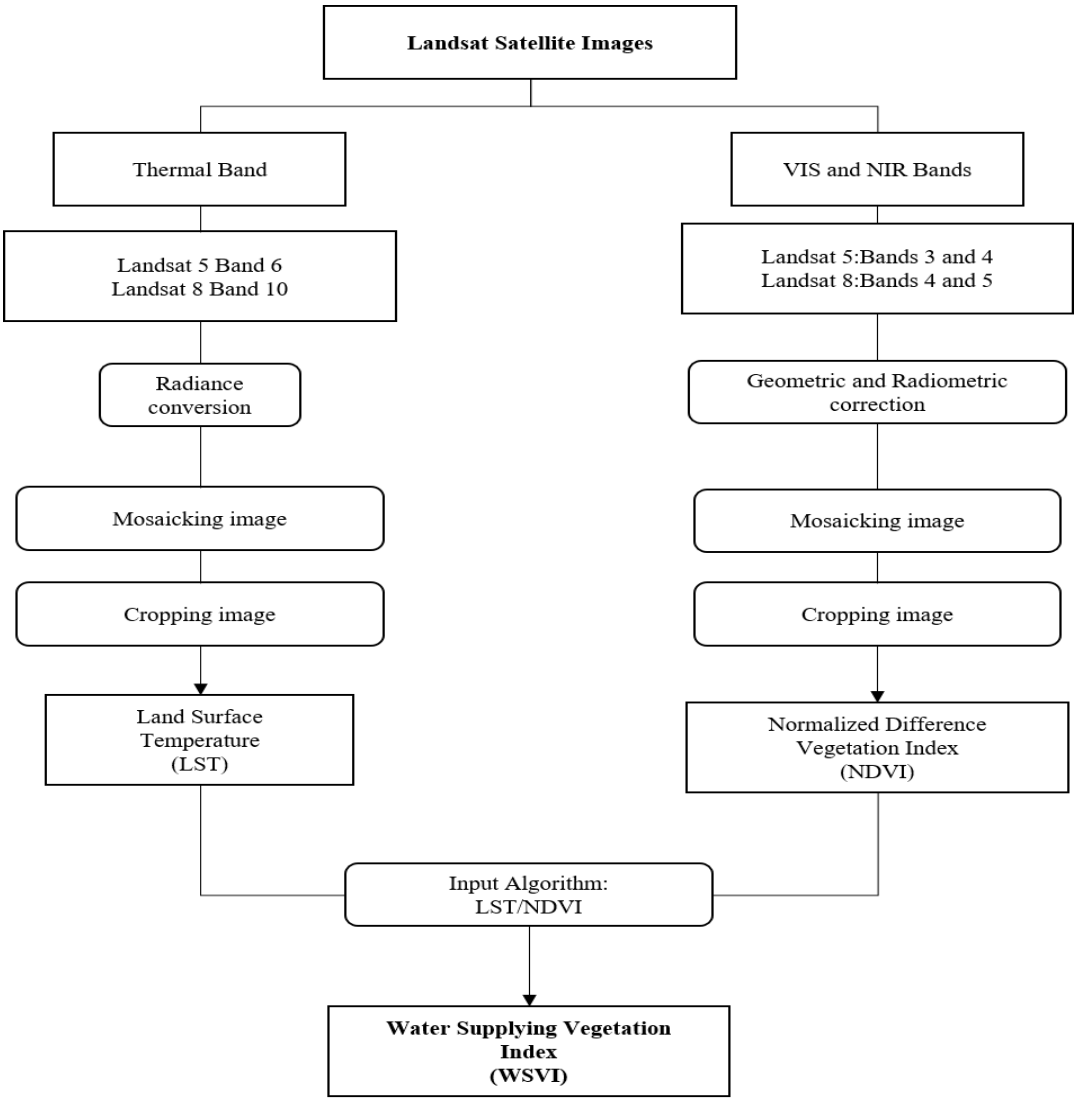

Figure 2. Workflow of research.

Processing Landsat 5 and Landsat 8 images to obtain NDVI, LST, and WSVI using ENVI 5.1 software. Whereas for the layouting process using ArcMap 10.4.

3.1 Data

The data used are 2005 Landsat 5 imagery, 2015 Landsat 8 imagery, and Bogor Regency administrative boundary shapefile. In satellite recording at one time, Bogor Regency produced 2 image scenes. So that Landsat imagery used to cover Bogor Regency has path 122 and row 064 and 065. Shapefile administrative boundaries of Bogor Regency are obtained from the Geospatial Information Agency.

3.2 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a value / index in processing remote sensing data that serves to show the greenness of vegetation or vegetation density by comparing the spectral waves between Near Infrared (NIR) and red waves [4]. For Landsat 5, the band that records red waves is band 3 and those that record NIR waves are band 4. On Landsat 8, the band that records red waves is band 4 and the band that records NIR waves is band 5 [5]. To obtain NDVI use the following algorithm:

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

So if the image used comes from Landsat 5 and Landsat 8, respectively are as follows:

$$NDVI = \frac{band\ 4 - band\ 3}{band\ 4 + band\ 3}$$

$$NDVI = \frac{band\ 5 - band\ 4}{band\ 5 + band\ 4}$$

The resulting value has a range between -1 to 1. The closer the value of 1, the greenness index of vegetation is higher, while the closer to -1 indicates the greenness index of vegetation is lower and even indicates it is not vegetation. [4]. Comparing NDVI values is a useful way for removing seasonal vegetation changes, facilitating the historical interpretations of vegetation cover changes [6].

3.3 Land Surface Temperature (LST)

As the name implies, Land Surface Temperature (LST) is used to present information about region's surface temperature. LST derived from the thermal bands of the satellite data is a key variable for drought assessment [6]. LST has been widely used in many studies such as estimation of energy inventories, moisture monitoring and evapotranspiration, climate change, urban heat island, and environmental studies requiring land surface temperature as the basic input [7]. To produce LST, a thermal band is needed. On Landsat 5 which is a thermal band is band 6 while band 10 is a thermal band on Landsat 8 [5,8]. Then to process it using the following algorithm.

$$L\lambda = M_L * Qcal + A_L \quad (2)$$

Where:
M_L = Scale factor
A_L = Addition factor.
Qcal = Digital Number

Then process it to convert radiance to temperature using:

$$T = \frac{K_2}{\ln(\frac{K1}{CV_R}+1)} \quad (3)$$

Where:
T = Temperature in Kelvin
CV_R = Radiance value in thermal band
K_1 and K_2 = Calibration constant

The last step in processing LST that must be done is to change the value of temperature from Kelvin to Celsius.

$$T_{Celcius} = T_{Kelvin} - 272{,}15 \quad (4)$$

3.4 Water Supplying Vegetation Index (WSVI)

Water Supplying Vegetation Index (WSVI) is the one of indices developed to combine NDVI and LST data to detect moisture condition [6]. When drought occurs, the value range of WSVI is between -4,2

and +4,2, the smaller value of the index means the less vegetation water supply and the more severe drought. In the same way, the greater value means the less severe drought [6 and 9]. WSVI obtained by algorithm:

$$WSVI = \frac{NDVI}{LST} \quad (5)$$

4. Results and Discussion

4.1 Normalized Difference Vegetation Index (NDVI)

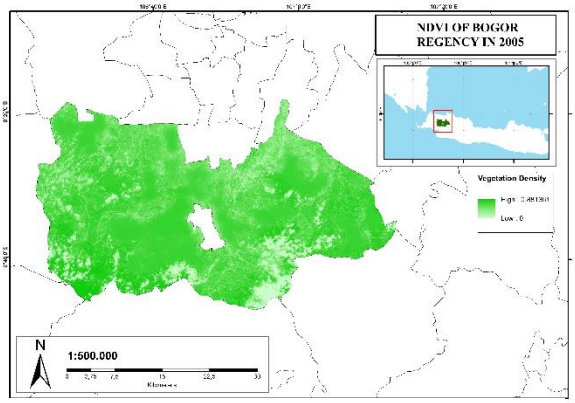

Figure 3. Normalized difference vegetation index (NDVI) in Bogor Regency in 2005.

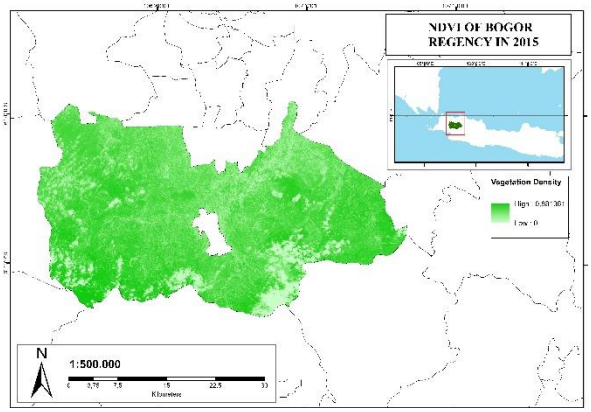

Figure 4. Normalized difference vegetation index (NDVI) in Bogor Regency in 2015.

The Normalized Difference Vegetation Index shows the level of vegetation density. From the results of data processing obtained the highest value of 0.881361. In general, the level of vegetation density in Bogor Regency in 2005 to 2015 was concentrated in the south, east, and west, despite changes in its area. The level of vegetation density decreases further to the middle and to the north, because it is getting closer to urban areas, such as Bogor City, Depok City, and DKI Jakarta Province as the country's capital.

4.2 Land Surface Temperature (LST)

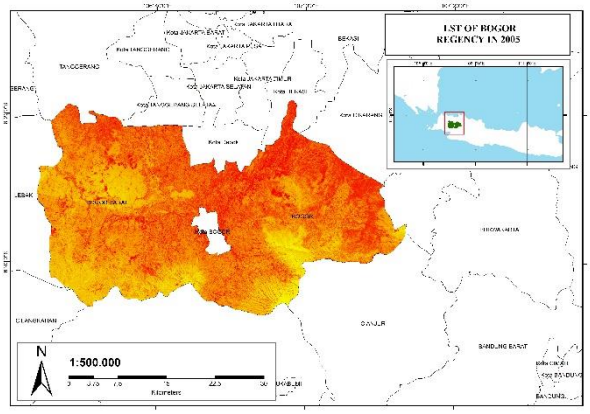

Figure 5. Land surface temperature in Bogor Regency in 2005.

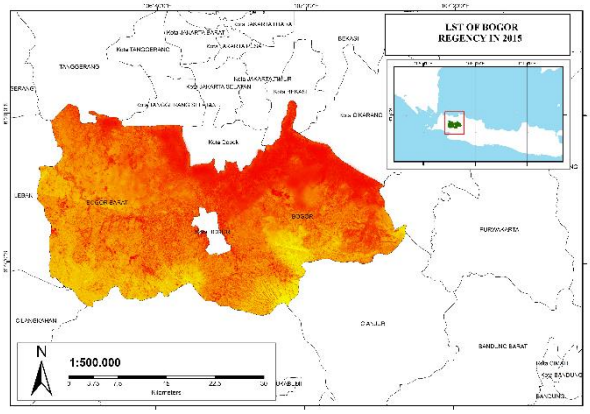

Figure 6. Land surface temperature in Bogor Regency in 2015.

The Land Surface Temperature serves to provide temperature information in units of celsius. We use Landsat imagery recorded in June, where in June the western part of Indonesia, especially Bogor

Regency, is in the dry season so it is possible to obtain maximum temperatures. From the results of data processing shows that in 2005 Bogor Regency had a maximum temperature of 25 degrees Celsius while ten years later, the maximum temperature of Bogor Regency reached 29 degrees Celsius. Areas that have high temperatures are found in the northern and central parts of Bogor Regency, where the area is close to urban areas.

4.3 Water Supplying Vegetation Index (WSVI)

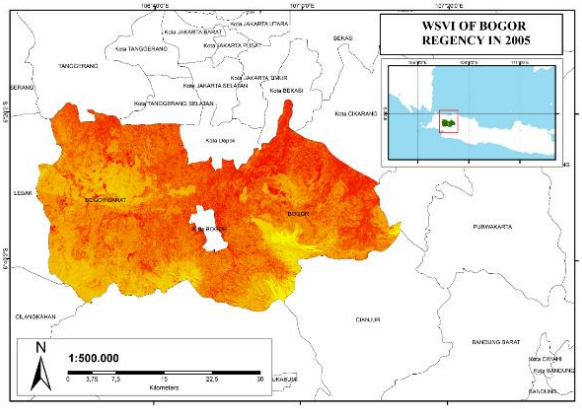

Figure 7. Water supplying vegetation index in Bogor Regency in 2005.

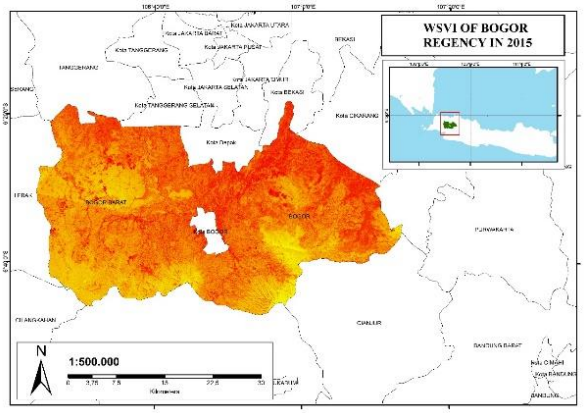

Figure 8. Water supplying vegetation index in Bogor Regency in 2015.

In the results of data processing, color symbols indicate the level of moisture produced from the WSVI method. The humidity level is inversely proportional to the level of drought. The more red the color is displayed, the higher the drought. Bogor Regency has the lowest WSVI value which is -0.0201182 and the highest value is 0.0473963. What distinguishes WSVI Bogor District in 2005 with 2015 is the distribution of its value. From 2005 to 2015 there was a change in the distribution of NDVI and was accompanied by changes in the distribution of LST values. Obtained that areas with a very high level of drought are Cariu Subdistrict, Babakanmadang Subdistrict, Jonggol Subdistrict, Ciampea Subdistrict, and Cibungbulang Subdistrict.

5. Conclusion

The level of drought can be indicated by the level of humidity. If there is a decrease in vegetation, it can reduce the level of moisture which later can also increase the potential for drought. This research expected that can assess and monitor the level of drought so it can be relied upon to determine policy priorities of drought disaster management for the sake of sustainability of water availability, especially in Bogor regency, West Java.

Acknowledgement

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