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Identification of drought level using normalized difference latent heat index on Maros Watershed

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Abstract. One of the impacts of climate change is drought. Drought is a hydrological problem that significantly affects survival on earth. This study aims to identify drought through the approach of one of the indices related to water, namely Normalized Difference Latent Heat (NDLI). NDLI values were obtained through a multispectral Landsat OLI calculation process, namely band 3 - green, band 4 - red, and band 6 – SWIR. Each band interprets variables related to heat and water content. The coverage area of research is in the Maros watershed, which is one of the watershed supplying water to the city of Makassar. Maros watershed has an area of ± 72,000 ha with relatively high human activity. NDLI values range from +1 to -1, where positive values indicate areas with good water content with latent heat and poor water content. In Maros watershed, NDLI values ranged from 0,37 to -0,25. Based Drought classification level, the level of drought in Maros watershed is moderately wet to moderately drought, and mildly wet is the most extensive drought levels in Maros watershed.

1. Introduction

About 80 percent of natural disasters that occurred in Asia is the impact of climate change [1]. Indonesia is one of the Asian countries that have three rain regions, namely Mosul, equatorial, and local, that cause climate variability. Climate change causes climate variability in Indonesia to experience abnormal natural symptoms, namely the uncertainty of the rainy and dry seasons [2]. Efforts to overcome global warming can be made by reducing carbon dioxide (CO2) emissions in the atmosphere [3] [4]. These phenomena occur in almost all regions of Indonesia, including in South Sulawesi Province, which has quite complex ecosystem characteristics. The climate in South Sulawesi Province indicated it would increase in temperature of 0,29°C - 0,39°C per decade. The Projections stated an increase in the intensity of rainfall, but the rainy season will be shorter.[5] These phenomena could potentially lead to landslides, flooding, and drought.

Water availability in the future is expected to decrease. In 2020 - 2040, the average decrease in river flow around the Lekopancing Dam (Maros watershed) is 17-19 percent, and in the Bilibili Dam (Jeneberang watershed) will also decrease, except in the rainy season it will be slightly increased [5]. Similar projections also show that almost the same condition that the water crisis occurred due to changes in the earth's surface temperature and climate change from the year 2011 – 2030 [6]. The problem of water availability or drought crisis has also become a national strategic issue and was discussed at the Conference of Parties (COP) 21 in 2015 in Paris. For these reasons, then the world should prepare for adaptation to drought, but the current studies and research on the drought is still less than the study and research on the other.

One of the causes of drought is the rise in earth's surface temperature [6]. Earth's surface temperature can be measured with a latent heat index through the analysis of remote sensing. Normalized Difference Latent Heat Index (NDLI) is one way to measure the earth's surface temperature. Latent heat is the heat energy absorbed or released on a surface. It is the essence of the hydrologic cycle and energy balance at the surface of the soil and air [7].

Makassar is the center of community activities in South Sulawesi, with a population of 1,508,154 people [8], with a high level of water demand. Maros watershed is one of the watersheds that have a contribution in terms of water availability in Makassar City, especially in the eastern and northern. Local governments have made efforts to address the problem of water availability through project development of the water supply system with the construction of the Water Treatment Plant (IPA), which comes from Lekopancing (Maros Warershed) and Bili-bili (Jeneberang Watershed). However, these efforts have not been able to keep pace with the growth rate of Makassar City [9]. From these descriptions, this research was focussed on the analysis of the level of drought using NDLI in the Maros watershed by analyzing surface reflectance to the atmosphere so that it can predict thermal energy above the earth's surface and assess latent heat waves to indicate the level of water availability.

2. Materials and methods

This study was conducted using the locus of analysis in the Maros watershed. Data processing and analysis of research conducted over four weeks in October 2019, at the Laboratory of Forestry Planning and Information Systems, Hasanuddin University. The data used is Digital Elevation Model (DEM) data derived from DEMNAS (http://tides.big.go.id/DEMNAS/index.html) to obtain watershed boundaries using hydrology analysis and Landsat 8 OLI path 114 row 064 recording at 02: 10: 30.6034009 GMT January 6, 2019, derived from the U.S. Geological Survey (USGS) (https://earthexplorer.usgs.gov/). While the software used for data processing is ENVI for radiometric and atmospheric correction and ArcGIS for NDLI analysis and data integration. The stages of data processing and analysis consist of radiometric correction, composite band, and continued with the interpretation of latent heat as illustrated in Figure 1 Framework for Research Activities

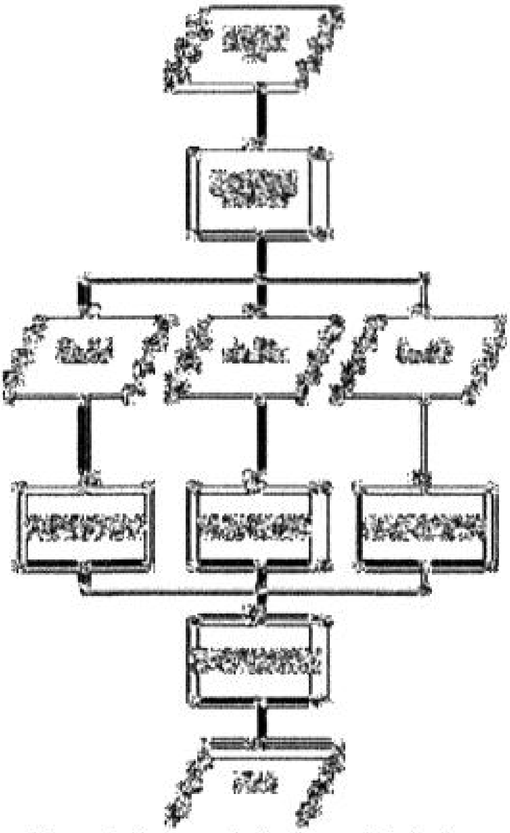

Figure 1. Framework for Research Activities

2.1. Study location

Maros watershed is a parallel type watershed, located at 4° 58' 37"S - 5° 12' 5" S and 119° 28' 34"E - 119° 54' 53"E with the main river length about 65,625 km and has an area about 676,543 km^2. The direction of the main river flows from east to west, where the upstream is in the Tombolo Pao District, Gowa Regency, and empties into the Makassar Strait so that the Maros watershed is a cross-regency watershed. It is one of the watersheds that has contributed to water availability in Makassar, so it is essential to consider, both in terms of ecology and social-economic aspects.

Maros watershed has unique characteristics; in that part of the territory is a karst area. It is a non-renewable natural resource and one of the essential ecosystems for several species of flora and fauna. Karst also has a vital role in the hydrological cycle because it functions as a store and regulator of water systems. Karst area in the Maros watershed is a type of karst tower [10]. Maros watershed boundaries were obtained from hydrological analysis using DEM. It is shown in figure 2.

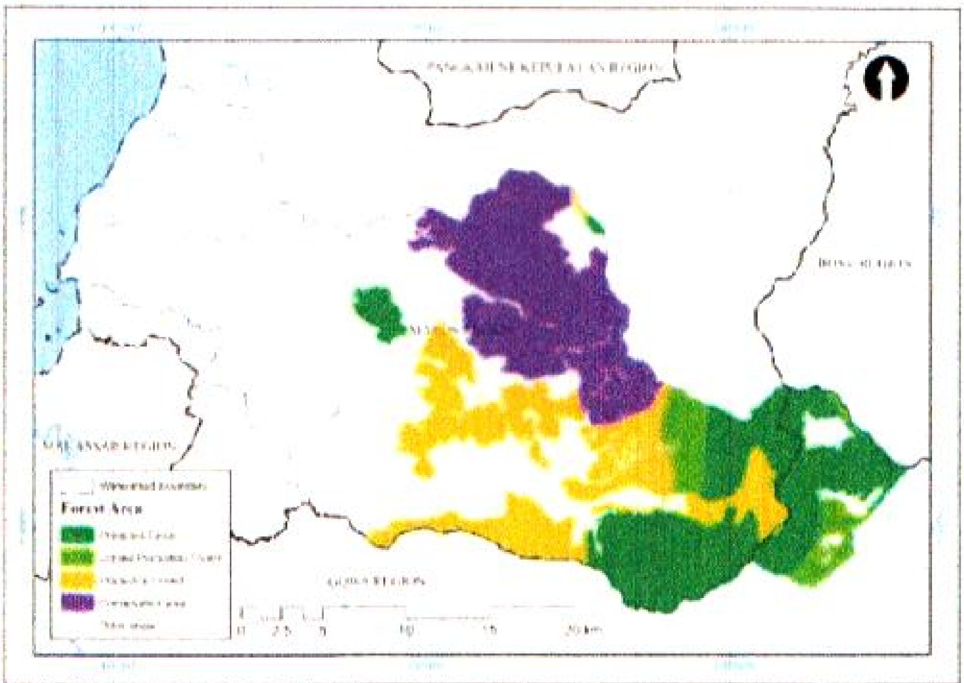

Figure 2. Maros watershed boundaries

2.2. Data Correction

A radiometric correction was performed using the Fast Line of Sight Atmospheric Analysis of Hypercubes (FLAASH) method. FLAASH is an atmospheric correction method by correcting infrared wavelengths and short waves up to 3μm. The method also includes a radiative transfer code model based on the Modtran4 model [11]. Modtran4 can reduce water vapor and aerosol information directly from the image using sensor viewpoint, elevation angle, and average surface height. Other parameters, such as visibility, can be derived directly from the image. The result of the reflectance value from the corrected image is a minimum of 0 and a maximum value of 1. Still, if it does not meet the value, the algorithm is entered using the calculated statistics with equations [12].

$$\rho = (\text{b1 le 0}) * 0 + (\text{b1 ge 10000}) * 1 + (\text{b1 gt 0 and b1 lt 10000}) * \text{float(b1/10000.0)}$$

where ρ is image reflectance, and b1 is the band to be corrected. Histogram of the reflectance values is shown in figure 3 and figure 4.

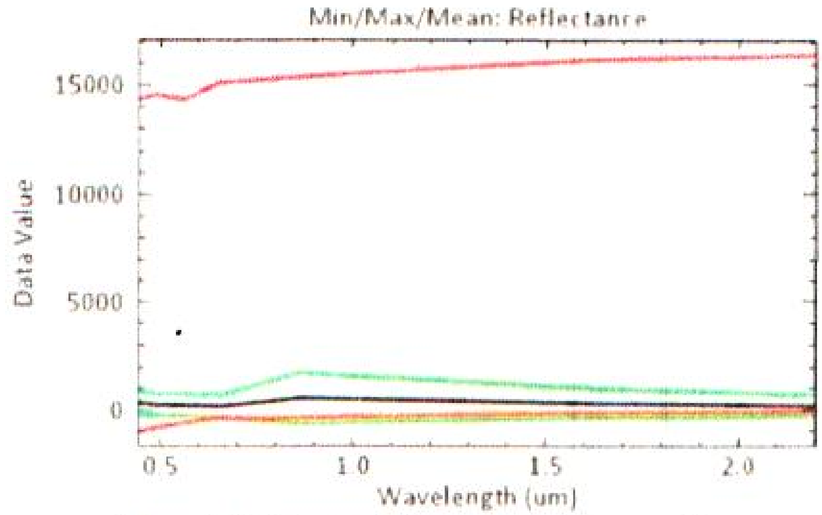

Figure 3. Histogram reflectance value before corrected

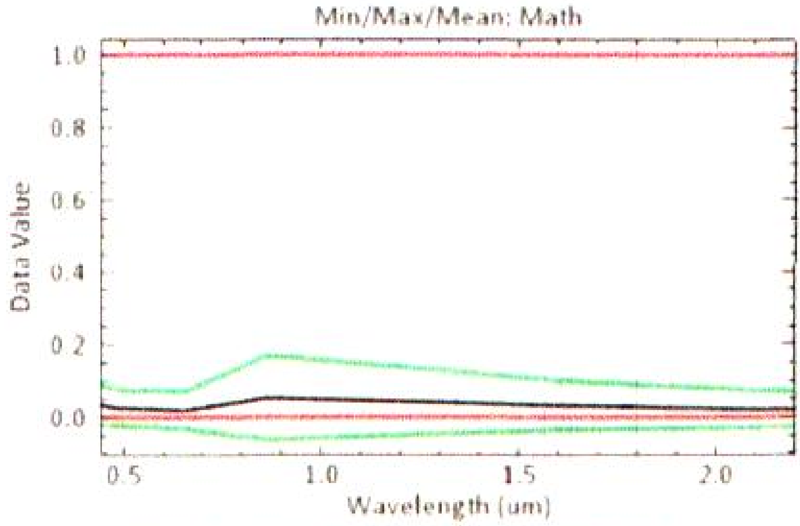

Figure 4. Histogram reflectance value after correction

Figure 3 shows a maximum reflectance value of more than one and a minimum reflectance value of less than 0. In contrast, figure 4 shows that the maximum reflectance value is one, and the minimum reflectance value is 0. Statistical comparison can be seen in table 1 and table 2.

Table 1. Statistical reflectance values before being corrected

Basic Stats	Min	Max	Mean	StdDev
Band 1	-999	14332	343.161	538.971
Band 2	-805	14570	254.906	492.254
Band 3	-556	14330	236.248	505.203
Band 4	-371	15130	186.795	504.039
Band 5	-371	15376	526.408	1156.749
Band 6	-129	16178	316.075	673.872
Band 7	-65	16393	199.122	480.771

Table 2. Statistical reflectance values after being corrected

Basic Stats	Min	Max	Mean	StdDev
Band 1	0	1	0.034	0.054
Band 2	0	1	0.026	0.049
Band 3	0	1	0.024	0.051
Band 4	0	1	0.019	0.050
Band 5	0	1	0.053	0.116
Band 6	0	1	0.032	0.067
Band 7	0	1	0.020	0.048

In Table 1 and Table 2, the comparison of the maximal reflectance value and the minimum reflectance value is obvious, the maximum reflectance value of table 1 is above one, and the minimum reflectance value is below 0. The standard deviation value in table 2 is also lower than table 1.

2.3. NDLI

The interpretation of latent heat is obtained by calculating NDLI. To calculated NDLI, three spectral bands are used, band 3-green, band, 4-red, band 6-SWIR. Band 3 represents the chlorophyll content in vegetation and also in water. Band 4 is spectral, which shows the absorption of pigmentation, where healthy vegetation has strong pigmentation absorption. Band 6 is spectral that is sensitive to water content, both in vegetation and in soil. Reaction band six will be decreased at high water content. Furthermore, band 6 is also able to distinguish dry land from land built that is waterproof. GIS model builder calculates NDLI analysis; the model builder chart is shown in Figure 5.

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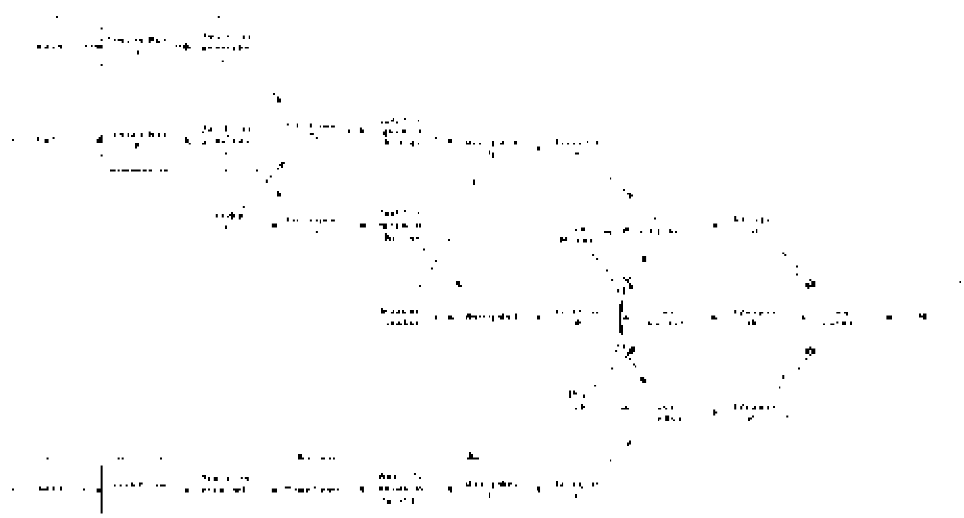

Figure 5. NDLI's model builder chart

Figure 5 shows the workflow to get NDLI values by remote sensing analysis. After radiometric correction and geometric correction, NDLI is calculated on raster calculations with an equation [7]

$$NDLI = \frac{\rho\,Band\ 3 - \rho\,Band\ 4}{\rho\,Band\ 3 + \rho\,Band\ 4 + \rho\,Band\ 6}$$

Where ρ is image reflectance, while the reflectance value is obtained by the equation [13]

$$\rho = \frac{\pi\ x\ L_\lambda\ x\ d^2}{E_{sun,\lambda}\ x \sin\theta}$$

Where L_λ is spectral radiation, d is Earth-Sun distance in astronomical units, $E_{sun,\lambda}$ is atmospheric solar radiation, and θ is sun elevation

After the NDLI value is obtained, the drought value is adjusted to the classification of the drought level. The drought level classification using the SPEI table with modifications. SPEI SPEI was developed by combining the sensitivity of the Palmer Drought Severity Index (PDSI) to change values evaporation and the multi-temporal nature values of the Standardized Precipitation Index (SPI). SPEI drought index has seven categories, as in table 3.

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Table 3. SPEI drought index

Range Index		Class
1		Extremely Wet
0.5	0.99	Very Wet
0.1	0.49	Moderately Wet
0	0.1	Mildly Wet
-0.1	0	Mild Drought
-0.49	-0.1	Moderately Drought
-0.99	-0.5	Severe Drought
	-1	Extremely Drought

Source: [14]with modification

A positive (or negative) value indicates an increase (or decrease) trend. A high positive value means getting wet (negative value means drier).

3. Result and discussion

The results of data processing and analysis obtained NDLI values in the Maros watershed from Landsat 8 OLI multiband calculations, where the study locus has been adjusted to the hydrological boundary of Maros watershed. NDLI is used as an indicator to determine the area of water supply crisis or drought. NDLI values range from +1 to -1, but in the study area, NDLI values only range from 0.37 to -0.25. Figure 6 shows the spatial distribution of NDLI in Maros watershed.

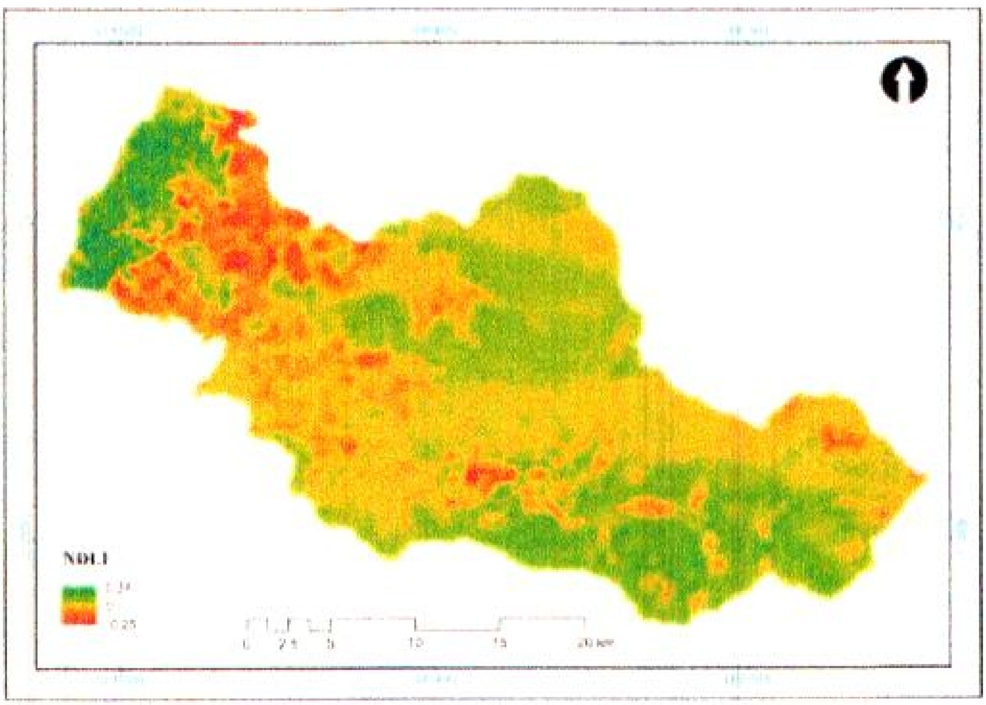

Figure 6. NDLI spatial distribution in Maros watershed

Figure 6 shows that NDLI is acceptable to presenting information on water availability. It is demonstrated by contrasting the distribution of wet areas and other areas, where a positive value indicates a space containing water because the spectral reflectance of the band - green is higher than the band - red.

Based on drought level class shown in Table 3, Maros watershed has drought levels from moderately wet to moderately drought. The distribution of drought levels in the Maros watershed is shown in table 4.

Table 4. Drought level classification distribution in Maros watershed

Range index		Class	Area (ha)	Percentage (%)
1		Extremely Wet	0	0.00
0.5	0.99	Very Wet	0	0.00
0.1	0.49	Moderately Wet	6,548.24	9.05
0	0.1	Mildly Wet	58,583.28	80.98
-0.1	0	Mild Drought	7,129.85	9.86
-0.49	-0.1	Moderately Drought	81.30	0.11
-0.99	-0.5	Severe Drought	0.00	0.00
	-1	Extremely Drought	0.00	0.00

There are four classes of drought, which the mildly wet is the largest area, with an area of 58,583.28 ha, which means 80.98 percent of total Maros watershed area. Otherwise, moderately drought is the narrowest area of 81.30 ha or 0.11 percent of the total Maros watershed area. It shows that in Maros watershed, there has been a drought even though it has not reached to severe stage. These results are almost the same as other studies, where the Maros watershed is experiencing drought. Maros watershed experience hydrological drought-related water discharge, and anthropogenic drought-related human activity [15].

4. Conclusion

Maros watershed is an area with high human activity. It disrupts the hydrological cycle, namely drought. NDLI is one index related to water and can be used to identify drought. NDLI results show that 9.97 percent of the Maros watershed is experiencing drought, with mild to moderately drought. Most drought occurs in other land areas, while most of the areas that did not experience drought were conservation areas and protected forests.

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