Research Article

Geographic Information System for Drought Potential Areas in Kampar District

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Abstract: Drought is a natural disaster that has an impact on various sectors. Drought occurs during the dry season, which is from May to October. So that there is a need for spatial information in the Kampar Regency area for drought potential so that it can help overcome the problem of drought. The data consists of Landsat 8 OLI / TRIS images and rainfall data. The transformation method used is the Tasseled Cap Transformation to get the wetness and revision index and NDVI to get the vegetation index. The results of each index will be weighted and overlaid so that a map of the area with drought potential is obtained. The results of this study are Kampar District which has an area of 7% located in Tapung Hilir District, while 33% of Kampar District has a very low drought potential. In general, the Kampar Regency is classified as having moderate drought potential.

Keywords: rainfall, drought, NDVI, TCT, vegetation index

1. Introduction

Indonesia is a disaster-prone region. Indonesia's geographical location on the equator has the potential for various types of natural disasters, one of which is drought. Drought occurs during the dry season in areas that have low availability of water reserves. Drought is not a disaster that can be received directly, but a disaster that occurs slowly and has an impact on the future (Neritarani 2019).

One of the impacts caused by drought is the plantation sector, such as oil palm plantations. Drought can cause a decrease in the rate of CO2 absorption, a decrease in nutrient absorption, and a decrease in photosynthesis which results in a decrease in productivity (Darmosarkoro et al. 2001). According to (BPS 2019), the area of Kampar Regency is mostly used for development in the plantation sector, especially oil palm. The land area to date has reached an area of 226 085 Ha or around 20% of the total area of Kampar Regency. It is feared that this will reduce the level of productivity of oil palm in the event of drought, so it is necessary to organize a strategy to overcome the problem of drought in Kampar District.

Efforts can be made to overcome the problem of drought by understanding the characteristics of each climate in the region well. One of the main factors shaping climate characteristics is rainfall (Kumar 2009). Regional spatial information can be used for drought management. This information is in the form of land conditions and characteristics of an area as a step in planning regional development in the field of water resources and can determine the ability of regional surface flow so that it can affect the flow of rivers that are formed. With the advancement of remote sensing technology and geographic information systems (GIS), spatial information of an area can be done easily. (Raharjo 2019).

Research related to drought using remote sensing has been conducted by Jamil et al. (2013) who used Landsat 7ETM+ imagery to identify moisture conditions and surface vegetation density in the Klaten Regency area. The results of using Landsat 7ETM+ will be integrated with several factors that affect drought, such as rainfall, land use, and hydrogeology. To analyze the results obtained, interpretation techniques are used in the form of digital, weighting, and merging.

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The results of the study showed 5 classes with drought potential in Klaten Regency. Areas that have the highest drought potential are located in the southern and central parts of Klaten Regency. Another research was conducted by Inarossy et al. (2019) to detect drought areas using the spatial autocorrelation analysis method on the Normalized Difference Vegetation Index (NDVI) (G. Prayitno, et.al.2023, Y. Liang, et.al.2024, S. Dutta and A. K. Jha.2024, Vegetation Condition Index (VCI), Soil Adjusted Vegetation Index (SAVI), Vegetation Health Index (VHI), Temperature Condition Index (TCI), and rainfall using SPI method with IDW interpolation technique. The results of the analysis found that the observation area is in a class with normal drought potential.

Based on the explanation above, this study uses geographic information system techniques for image transformation methods that are different from previous studies in detecting drought potential, namely by using the Tasseled Cap Transform (TCT). According to Shifiyati et al. (2017), the values in TCT can be used in analyzing drought. Thus, this study uses indices that can be calculated from TCT, namely the wetness index and brightness index. This research aims to provide information on potential drought areas so that they can anticipate and reduce the impact of drought that results in losses in several sectors, especially the plantation sector in Kampar Regency.

2. Method

2.1 Research Data

The data used are Landsat 8 OLI/TRIS satellite images of the Kampar Regency area in July 2019 sourced from the United States Geological System (USGS) and can be downloaded on the website https://earthexplorer.usgs.gov. Digital map of Kampar Regency sourced from the Geospatial Information Agency (BIG) which is used for the administrative boundaries of Kampar Regency and each sub-district in Kampar Regency. The administrative boundary data can be downloaded on the website https://tanahair.indonesia.go.id/. Rainfall data of Kampar Regency in 2019 sourced from the Meteorology, Climatology and Geophysics Agency which is used to determine the amount of rainfall in Kampar Regency in 2019 (mm/year). As well as data on the area of Kampar Regency sourced from the Central Bureau of Statistics.

2.2 Research Stages

This research consists of several stages, namely processing Landsat images using TCT and NDVI (E. Roitberg and M. Shoshany. 2024, N. Jiang. 2023, A. Racoviteanu, et.al.2024) and rainfall data using the IDW interpolation method. The results of the data processing will be weighted and combined (weighted overlay), so that potential drought areas will be known. The research stages can be seen in Figure 1.

2.3 Tasseled Cap Transformation

Tasseled Cap Transformation (TCT) is a mathematical formula for calculating the brightness, greenness, and wetness indices of the digitized numbers in each band. The values of TCT can give an idea of drought (Shofiyati 2007). In this study, the brightness index and wetness index were used. The brightness index is a transformation that interprets the brightness of an object. This can be seen from the spectral value of the index results which show that the higher the spectral value, the brighter it is. The brightness of the object in the image shows the level of dryness. The following is the equation for finding the brightness index value (Baig et al. 2014). The brightness index equation is shown in Equation 1, while the Wetness index is shown in Equation 2.

$$\text{Brightness index} = \text{band2}\times 0.3029 + \text{band3}\times 0.2786 + \text{band4}\times 0.4733 + \text{band5}\times 0.5599 + \text{band6}\times 0.508 + \text{band7}\times 0.1872. \quad [1]$$

Moreover, The wetness index is a transformation that interprets the moisture level of an object. If the spectral value of the wetness index is higher, then the object will be more moist. The following is the equation for finding the wetness index value (Baig et al. 2014). Figure 1 is the Flowchart of this research in detail.

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Wetness index = band2×0.1511 + band3×0.1973 + band4×0.3283 +
  band5×0.3407 + band6×(-0.7117) + band7×(-0.4559). [2]
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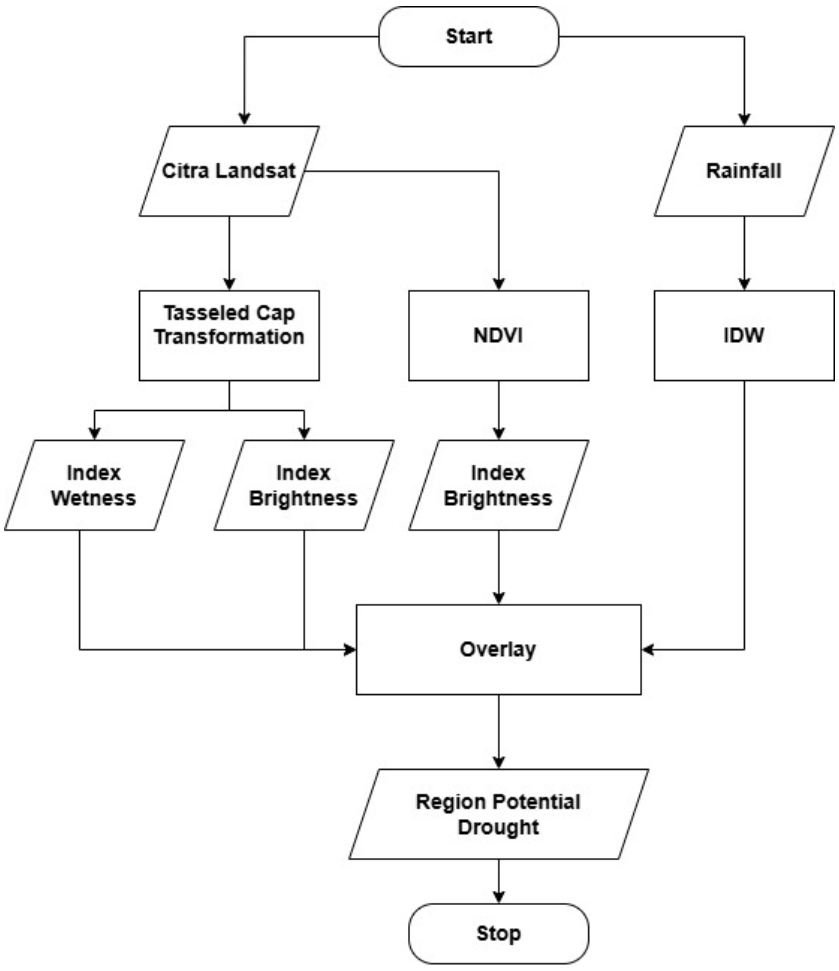

Figure 1. Research Stages

2.4 Normalized Difference Vegetation Index (NDVI)

NDVI or vegetation density index is one method to measure the greenness of vegetation by comparing the spectral between the NIR wave and the red wave The NDVI formula can be seen as follows (Ardiansyah 2015). NDVI dengan hubungan NIR ditunjukkan pada equation Where NIR is band 5 and Red is band 4.(E. A. Anggari, et.al. 2024, R. Lasaponara, et.al.2024, S. Desai, et.al.2024, S. Jain, et.al, 2024).

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NDVI = ((NIR-Red))/((NIR+Red)) [3]
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2.5 Inverse Distance Weighted (IDW)

This research uses the IDW method in interpolating rainfall in the Kampar Regency by estimating a value at an unsampled location based on data around the area. The IDW method directly implements the assumption that things that are close together will be more similar than those that are far apart. To estimate a value at each unmeasured location, IDW will use the size values surrounding the location to be estimated (Purnomo 2018).

2.6 Merging (Overlay)

This research uses a weighted overlay. The first step is to give weight to each parameter. Assuming that the weight of each parameter is the same, each weight is worth 25 which is the average of the overall weight results. The weight of each parameter can be seen in Table 1.

Table 1. Parameter Weight

No	Parameter	Weight
1	Brightness Index	25
2	Wetness Index	25
3	NDVI	25
4	Rainfall	25

The results of each weighting will be combined. Performing a weighted overlay can combine several thematic maps with the same location into one new map layer with unique values from each combined map so that potential drought areas can be identified.

3. Results and Discussion

The brightness index resulting from the TCT transformation process has spectral values in the interval 15 109 to 103 697. The spectral value is described in the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.12/Menhut-Ii/. The assumption used in this research is that the object will be drier if the spectral value is higher. Objects are said to be dry if they have high brightness.

The results of the brightness index are divided into 5 classes, namely very dark, dark, medium, bright, and very bright. From these results, the Kampar Regency area with a very dark class is only 5%, namely in the western area of Kampar Regency. The area of Kampar Regency is dominated by the medium brightness class, which is 50%. This means that Kampar Regency has a moderate brightness index. The results of the brightness index of Kampar Regency can be seen in Figure 2 and Table 2.

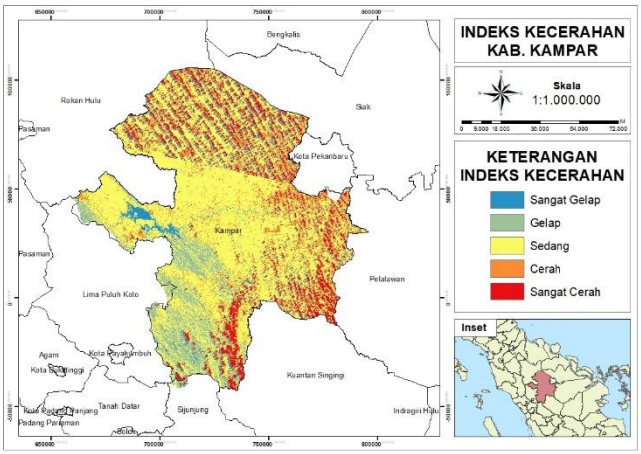

Figure 2. Brightness Index Class

Table 2. Area of Brightness Index

No.	Interval Spectral	Classification	Area (ha)	Percentage
1	15109 – 19500	Very Dark	55370	5%
2	19500 – 24000	Dark	183414	16%
3	24000 – 28500	Medium	617704	55%
4	28500 – 33000	Sunny or Bright	132062	12%
5	33000 – 103697	Very Bright	140378	12%

The wetness index has an interval between (<-30) – (>35). Rules regarding the spectral wetness index are contained in the Regulation of the Minister of Forestry of the Republic of Indonesia Number: P.12/Menhut-II/. The higher the level of wetness, the more humid the area is. The Wetness Index shows that the Kampar Regency area is dominated by very humid areas, which is around 70%. The results of the wetness index classification can be seen in Figure 3 and Table 3.

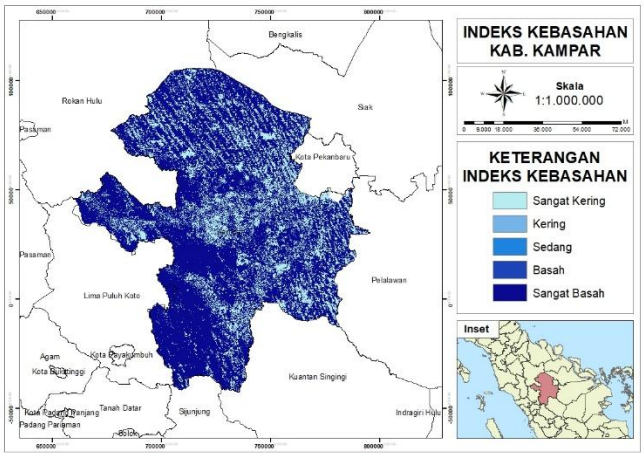

Figure 3. Wetness Index Class

Table 3. Area of Wettability Index

No	Interval Spectral	Classification	Area (ha)	Percentage
1	(<-30) – (-30)	Very Dry	290819	25,8%
2	(-30) – (-13)	Dry	3806	0,3%
3	(-13) – (10)	Medium	5309	0,5%
4	10 – 35	Wet	5951	0,5%
5	35 – (>35)	Very Wet	823042	72,9%

Furthermore, NDVI is also known as the vegetation index, which is used to determine the density of vegetation. This NDVI value can interpret drought potential. This is because, the higher the density of vegetation, the higher the water reserves in the area, so the area has very little drought potential. NDVI values range from -1 to 1. A positive NDVI value indicates that the area has a high vegetation density, while a negative value indicates a low vegetation density. There is only 1% of Kampar District that is not vegetated, indicating that the area is highly vegetated. The results of the NDVI of Kampar District can be seen in Figure 4 and Table 4.

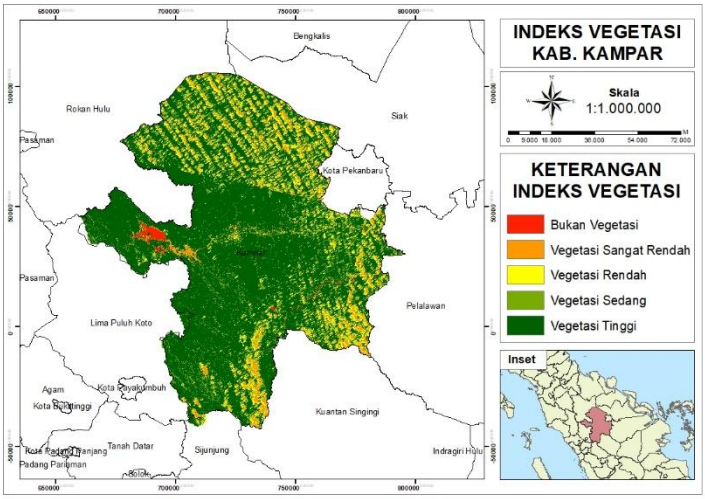

Figure 4. NDVI Index Class

Table 4. Area of NDVI Index

No	Interval Spectral	Classification	Area (ha)	Percentage
1	-1 – 0,03	Not Vegetation	6923	1%
2	-0,03 – 0,15	Very Low Vegetation	69350	6%
3	0,15 – 0,25	Low Vegetation	130678	12%
4	0,26 – 0,35	Medium Vegetation	138371	12%
5	0,35 – 1	High Vegetation	9	69%

Furthermore, Rainfall data from BMKG in 2019 shows that Kampar Regency has moderate rainfall with an average annual rainfall of 2089 mm/year. The relationship between rainfall and drought is that the higher the rainfall, the smaller the potential for drought. The results of rainfall interpolation using IDW interpolation can be seen in Figure 5 and Table 5.

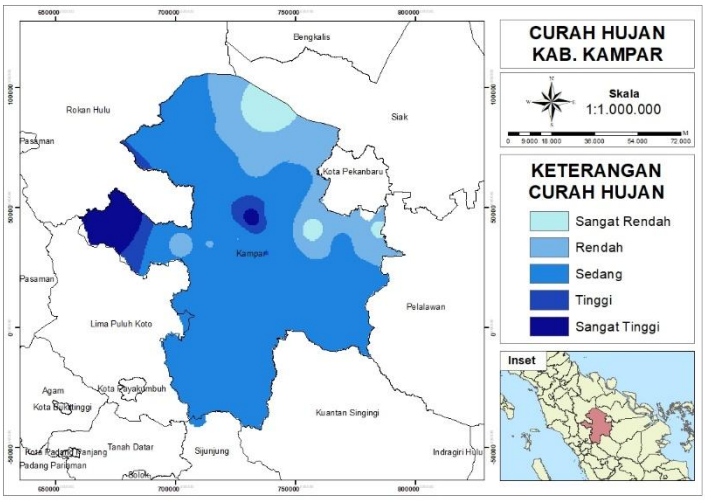

Figure 5. Rainfall Map

Table 5. Area Rainfall

No	Rainfall (mm/year)	Classification	Area (ha)	Percentage
1	< 1000 - 1000	Very Low	43847	4%
2	1000 - 2000	Low	205183	18%
3	2000- 3000	Medium	793477	70%
4	3000 - 4000	High	37033	3%
5	4000- 6400	Very High	49389	4%

Drought potential in Kampar Regency is divided into five classes of drought potential, namely very high, high, medium, low, and very low drought potential. The results of the weighting and overlay of the brightness index, wetness index, NDVI, and rainfall show that Kampar District has a moderate drought potential. The results of the weighting and overlay process can be seen in Figure 6 and Table 6.

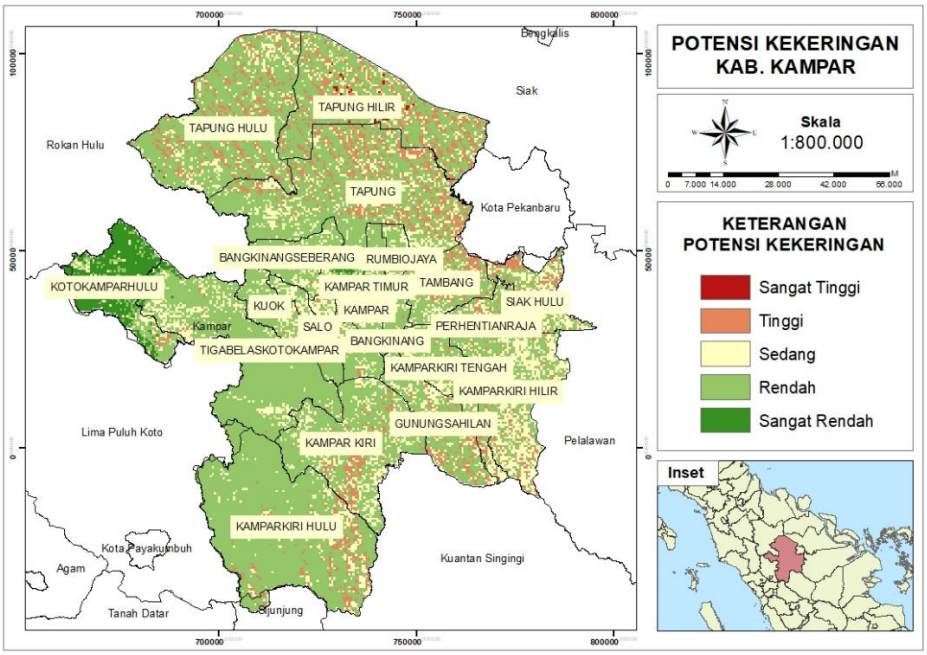

Figure 6. Drought Potential of Kampar District

Table 6. The extent of Potential Drought Area in Kampar Regency

Drought Classification	Area (ha)	Percentage
Very High	75262	7%
High	150524	13%
Medium	225786	20%
Low	301047	27%
Very Low	376309	33%

Areas with very high drought potential are found in the north, namely in Tapung Hilir Sub-district. This is due to several factors. This area has the smallest rainfall in the Kampar Regency. This area also has a low vegetation density, so the evaporation rate from water storage and surface temperature is small. Areas with high drought potential are located in Tapung Hulu, Tapung, Tambang, Siak Hulu, Gunung Sahilan, Kampar Kiri, and Kampar Kanan sub-districts. Meanwhile, the lowest drought potential is in the Koto Kampar Hulu sub-district. This is influenced by the high level of rainfall in the sub-district, which is 6370 mm/year. Other influencing factors are the vegetation index, brightness index, and wetness index. The higher the value of vegetation index, wetness index, and rainfall, the smaller the potential for drought. Overall, from the results obtained, Kampar Regency has a moderate level of drought.

4. Conclusions

The study of drought potential in Kampar District integrates remote sensing and geographic information system techniques. Remote sensing is used to interpret the brightness index, wetness index, and vegetation index that can be used to identify potential drought in the Kampar Regency area. Another parameter used for drought identification is rainfall. In Kampar Regency, 7% of the total area has drought potential.

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