Identification of potential drought in Lamongan Regency

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Abstract. Drought will affect almost every aspect of human life. The impact of drought hazards is often slow but certain, so that if not monitored continuously it will result in the loss of food due to crops and dead livestock, farmers losing their livelihoods and others. Lamongan regency is one of the districts with drought level in very high risk class. At IRBI BNPB in 2011, Lamongan Regency is 2nd ranked of all regencies in Indonesia. By interpreting remote sensing data we will be obtained parameters such as ground surface temperature, vegetation density with EVI transformation, wetness index, brightness index, and land use. These parameters and accompanied by secondary data which is rainfall can be used to identify the drought potential in Lamongan because each parameter has properties that can be associated with its vulnerability to drought potential. Performed by weighting technique and overlay process on these parameters can produce the identified areas with very high drought potential which is 14.171 hectares or 0.009% of total area and dominated in Paciran Sub-District. And the identified areas with very low drought potential which is 20979.626 hectares with a percentage 13.222% of total area and dominated in Karangbinangun Sub-District, Kalitengah Sub-District, Turi Sub-District and Deket Sub-District.

1. Introduction
Drought will have an impact on all aspects of human life. The impact of this drought is often slow, so that if it is not monitored continuously it will result in disasters in the form of loss of food due to food crops and dead livestock, farmers losing their livelihoods and others. The first indication of drought is monitoring the level of rainfall [1]. The level of rainfall from the Province of East Java itself has a lower level than other provinces on the island of Java. One of the regencies in East Java Province is Lamongan Regency. Lamongan Regency is a regency located in East Java Province. Based on the Indonesian Disaster Risk Index BNPB (IRBI BNPB), Lamongan Regency is one of the districts with a drought level in a very high risk class. Even in the 2011 BNPB IRBI output, Lamongan Regency was ranked 2 of all districts in Indonesia. The lack of map data containing information on potential drought-hit areas also plays a role as one of the factors that inhibits the resolution of drought problems, so that these maps are currently very much needed considering that drought is a problem that has serious impacts on all sectors of life. Making georefined maps can use Remote Sensing (Inderaja) and Geographic Information Systems (GIS) techniques [2].

The purpose of this study is to identify areas that have potential drought in Lamongan Regency. By knowing areas that are prone to drought, specific data analysis can be done to overcome the problems that exist in Lamongan Regency, East Java Province.
2. Methodology
The research location is in Lamongan Regency, East Java Province. Astronomically, Lamongan lies 6º 51 '54" - 7º 23 '6" LS and between 112º 4' 41 '' - 112º 33 '' 12 'BT. The administrative boundaries of the Lamongan Regency are shown as follows:

- North is bordered by the Java Sea
- East is bordered by Gresik District
- South is bordered by Jombang and Mojokerto District
- West is bordered by Bojonegoro District

![Map of the research location, Lamongan Regency, East Java, Indonesia.](image)

Data types of the research:
- Landsat 8 L1T path / row 119065 satellite imagery with data acquisition on 15 August 2017
- Digital Topographic Map (RBI map) of Lamongan Regency Scale 1: 25,000 consisting of 13 thematic maps.
- Lamongan Regency administrative boundary with GIS format
- Lamongan District Monthly Rainfall Data 2017
- The coordinates of the sample training points obtained from the field survey

The stages of data processing for this study are as follows [3]:

2.1. Pre-processing
There are several data that must be collected in this study, namely Landsat 8 L1T path / row 119065 satellite imagery with the acquisition of 15 August 2017, RBI Map scale 1: 25000 Lamongan Regency, Rainfall Data of Lamongan Regency in 2017 and Data of Lamongan Regency administrative boundary.

2.2. Geometric correction
Geometric correction is the rectification of images geometrically so that map projections and coordinate systems are used in accordance with the real world. Geometric corrections were performed using the Image to Map rectification method using a digital RBI Map of Lamongan Regency scale of 1: 25000. The digital RBI map used consists of 13 maps of the RBI.
2.3. Radiometric correction
Radiometric correction which aims to improve image quality and conversion of Digital Number (DN) to reflectants that will be used in subsequent data processing. Atmospheric correction of Landsat 8 images in this study using the Second Simulation of Satellite Signal method in The Solar Spectrum (6SV).

2.4. Image processing
There are 3 image processing that must be done, namely:

- LST (Land Surface Temperature) calculation is done to get the surface temperature using band 10 and band 11 Landsat Image 8. The following is the equation used for this LST algorithm [4].
  \[
  \text{LST} = \text{BT10} + (2.946 \times (\text{BT10} - \text{BT11})) - 0.038
  \]
  Where the BT value is obtained from:
  \[
  \text{BT} = \frac{K2}{\ln\left(\frac{K1}{L_{\lambda}} + 1\right)} - 273
  \]
  \[L_{\lambda}\]: Spectral radiance (W/m*m*ster*µm)
  \[K1\]: Thermal conversion constant for the band (K1_CONSTANT_BAND_n from the metadata)
  \[K2\]: Thermal conversion constant for the band (K2_CONSTANT_BAND_n from the metadata)

- Tasseled Cap transformation is done to get wetness index and brightness index which will be used to determine the humidity of a land. Following are the equations used for this TCT algorithm.
  \[
  \text{Brightness} = 0.3029B2 + 0.2786B3 + 0.4733B4 + 0.5599B5 + 0.508B6 + 0.1872B7
  \]
  \[
  \text{Wetness} = 0.1511B2 + 0.1973B3 + 0.328B4 + 0.3407B5 - 0.7117B6 - 0.4559B7
  \]

- Enhanced Vegetation Index (EVI) is carried out to get canopy density values from vegetation. The following is the equation of EVI.
  \[
  \text{EVI} = \frac{(G \times (\rho_{\text{NIR}} - \rho_{\text{RED}}))}{(\rho_{\text{NIR}} + C1\rho_{\text{RED}} - C2\rho_{\text{BLUE}} + L)}
  \]
  The variables C1 and C2 in equation (4) are weighting factors to overcome aerosols, while the L variable is the canopy and soil effect calibration factor, while G is the scale factor so that the EVI value is in the range between -1 to 1. The variable values L, C1, C2, and G are usually given values of 1, 6, 7.5 and 2.5 respectively.

2.5. Classification of Landsat 8 L1T Imagery
Supervised classification is done on the image that has been cut to get land cover in Lamongan Regency. This classification process uses the Supervised Classification: Maximum Likelihood method [5].

2.6. Accuracy test
The accuracy of the classification results is carried out to test the accuracy of the use map produced from the digital classification process with the test sample from the results of fieldwork. The method used to calculate classification accuracy by using an error matrix or confusion matrix / error matrix.

2.7. Rainfall data interpolation
Rainfall data used in this study consisted of 10 rainfall posts spread in Lamongan Regency and the data were in the form of monthly data. The process of making rainfall maps is done using the IDW Interpolation (Inverse Distance Weighted) method.
2.8. Scoring / weighting of each parameter

Scoring method is giving value or score to each parameter used. Giving a score or price is based on how much influence it has on vulnerability. The more influential the greater the score or value given.

2.9. Final overlay and weighting

Overlay is done for all parameters using the Intersect method. Overlay in this study will produce 5 classes. Where the intervals of each class can be determined using the following formula:

\[
\text{Class interval} = \frac{\text{max. Value} - \text{min. Value}}{\text{class Number}}
\]  

(5)

From the interval calculation for each class, the range of values for each class is 0.714, so the classification results are as follows:

| Class | Range   | Interval value |
|-------|---------|----------------|
| 1     | lowest  | 1.360 – 2.074  |
| 2     | low     | 2.075 – 2.789  |
| 3     | medium  | 2.790 – 3.504  |
| 4     | high    | 3.505 – 4.219  |
| 5     | highest | >4.20          |

3. Results and discussion

3.1. Land surface temperature classification map

Map of land surface temperature classification obtained by the calculation process using the LST formula for bands 10 and 11 Landsat Image 8 with the acquisition date of August 15, 2017. The surface temperature is used as a parameter to identify potential drought because the surface temperature of the soil can show that the higher the surface temperature of the soil, the vulnerability the drought will be higher, and vice versa the lower the surface temperature of the land, the lower the susceptibility to drought. The following are the results of the Ground Surface Temperature Classification Map shown in Figure 2.
Based on the results of the Soil Surface Temperature classification, classes with a temperature category of 32-36 °C dominate with an area of 69677.86151 ha with a percentage of 43.664%. And for classes that have high temperatures more are found in Brondong sub-district, Paciran sub-district and Solokuro sub-district. The area identified has a fairly high temperature because these areas are in the coastal region.

3.2. Canopy density map using EVI transformation
The results of EVI values in this study have a range of values between -1 and 1. Canopy density can be used as a parameter of identification of drought potential values of canopy density with this transformation. vulnerability to drought will be even higher, and vice versa. The following are the results of the Density Map with the EVI Transform shown in Figure 3.
Based on the calculation of area and percentage of canopy density with EVI transformation, the level of vegetation density rarely dominates more than half of the total area with an area of 101855.7058 ha with a percentage of 63.802%. When viewed with observations made in the field, the level of canopy density obtained from the EVI process is forestry or plantation areas or areas used for agricultural land.

3.3. Map of wetness index

The wetness index map is obtained from calculations with the TCT algorithm. The greater the value of the wetness index, the more wet the level of vulnerability to drought will be smaller, and vice versa, the smaller the value of the index of lust, the drier the area so that the vulnerability to drought will be higher. The following are the results of the Headline Density Map with the EVI transformation shown in Figure 4.

![Figure 4. Map of wetness index. (analysis result).](image)

| Class | wetness class | Area (Ha)   | %    |
|-------|---------------|-------------|------|
| 1     | very dry      | 5409.668877 | 3.389 |
| 2     | dry           | 21216.98997 | 13.290 |
| 3     | moist         | 40246.51433 | 25.210 |
| 4     | wet           | 55267.20839 | 34.619 |
| 5     | very wet      | 37505.38367 | 23.493 |

Based on the calculation of area and percentage of wetness index, the classification of wetlands is more dominant with an area of 55267.20839 ha with a percentage of 34.619%. Wetland areas dominate Kalitengah sub-district, Karangbinangun sub-district, Turi sub-district, and Ceket sub-district. The area can be identified as a wet category because the area is dominated by agricultural land or rice fields where there is irrigation. In addition there are also areas that are areas of water bodies namely reservoirs or swamps.
3.4. Map of brightness index

Brightness index maps are obtained from calculations using the TCT algorithm. The greater the value of the brightness index, the object dries so that the level of vulnerability to drought will be even greater, and vice versa the smaller the brightness index value, the drier the area so that the vulnerability to drought will be lower. Following are the results of the Brightness Index Map shown in Figure 5.

![Map of brightness index](image)

Figure 5. Map of brightness indexes.

| Class | Classification | Area (Ha)        | %    |
|-------|----------------|------------------|------|
| 1     | darkness       | 10141.98565      | 6.353|
| 2     | dark           | 59567.71422      | 37.313|
| 3     | rather bright  | 75209.57594      | 47.111|
| 4     | bright         | 14178.42104      | 8.881|
| 5     | more bright    | 545.563016       | 0.342|

Table 5. Area of brightness index (analysis result)

Based on the calculation of the area and percentage of the brightness index, the classification of the rather bright area dominates with an area of 75209.57594 ha with a percentage of 47.111%.

3.5. Land cover map

Land cover map is obtained from visual interpretation using the Supervised Classification: Maximum Likelihood method [5]. The classification process in this study was divided into 5 classes. Namely the shrub class, water bodies, forests / plantations, dry land agriculture and the built environment. The class division is based on SNI 7645: 2010 rules on a scale of 1: 50,000. Following are the results of data processing from the Land Cover classification shown in Figure 6.
Figure 6. Land cover map (analysis result).

Table 6. Area of land cover classified map (analysis result).

| class         | classified result  | Area (Ha)       | %     |
|---------------|--------------------|-----------------|-------|
| 1             | Rice field         | 26934.98561     | 16.882|
| 2             | water body         | 1704.861136     | 1.069 |
| 3             | forest,garden      | 52071.74902     | 32.637|
| 4             | dryland agriculture| 34159.10704     | 21.410|
| 5             | settlements        | 44676.796       | 28.002|

Based on the results of land use classifications, the class with bush category dominates with an area of 52071.74902 ha with a percentage of 32.637%. In accordance with Perka BIG No. 15 of 2014 that for land cover must have an accuracy of 85% with field conditions. Therefore an accuracy test was carried out with a confusion matrix with 207 field sample points.

Table 7. Accuracy test.

| Classified data       | Reference data | Total | User Accuracy (%) |
|-----------------------|----------------|-------|-------------------|
|                       | a  b  c  d  e |       |                   |
| Settlement            | 84  5  5  3  0 | 97    | 86.598            |
| Dryland agriculture   | 2   28 1  0  0 | 31    | 90.323            |
| Forest,garden         | 4   2  30 4  0 | 40    | 75                |
| Rice field            | 1   0  30 1  32| 32    | 93.75             |
| Water body            | 1   0  0  6  7 | 7     | 85.714            |
| Total                 | 92  35 36 37  7 | 207   |                   |

Overall accuracy = 85.990%
Indexes Kappa = 80.100% = 0.801
From the accuracy test process, the overall accuracy result is 85.99% and the kappa index is 0.801. The kappa index value is stated to be good because it is in the range of 0.61-0.80 [6]. So that the results of this land cover can be declared true.

3.6. Rainfall map
Rainfall map is obtained from 2017 monthly rainfall data from 10 rainfall posts spread in Lamongan Regency. This process is carried out using the IDW (Inverse Distance Weighted) method. This rainfall data is then classified according to its effect on drought, where the lower the rainfall, the vulnerability to drought will be higher, and vice versa, if rainfall in the region is recorded high, then the vulnerability to drought will also be low. The following are the results of the rainfall class map shown in Figure 7.

| Class | Rainfall (mm/month) | Area (Ha)     | %    |
|-------|---------------------|---------------|------|
| 1     | 0 - 3               | 3738.723462   | 2.325|
| 2     | 4 - 7               | 117606.151    | 73.151|
| 3     | 8 - 11              | 25434.35134   | 15.820|
| 4     | 12 - 15             | 13572.01151   | 8.442|
| 5     | >=16                | 420.968018    | 0.262|

Based on the calculation of area and percentage of the division of rainfall classes, classes with rainfall of 1500 - <2000 mm/year dominate more than half of the total area with an area of 117606.151 ha with a percentage of 73.343%. And there are 2 sub-districts that have very low rainfall with ranges below 1500 mm/year, namely Paciran sub-district and Karangbinangun sub-district.

3.7. Drought potential map
Drought potential map obtained from the Overlay process of 6 maps used as parameters in this study. The six maps are the Ground Surface Temperature Map, Head Density Map, Wetness Index Map, Brightness Index Map, Land Use Map, and Rainfall Map [7]. Overlay is done using the Intersect method.
The following are the results of the Drought Potential Map of Kab. Lamongan in 2017 is shown in Figure 8.

![Drought Potential Map of Kab. Lamongan in 2017](image)

**Figure 8.** Map of drought potential in Lamongan regency.

**Table 9.** Area of level of drought potential.

| Class | Drought level | Area (Ha)     | %    |
|-------|---------------|---------------|------|
| 1     | lowest        | 20979.62645   | 13.221 |
| 2     | low           | 64518.23813   | 40.658 |
| 3     | medium        | 55776.07249   | 35.149 |
| 4     | high          | 17396.66531   | 10.963 |
| 5     | Highest       | 14.171776     | 0.009 |

Based on the drought potential map along with its area and percentage calculation, the area identified as having the potential to be affected by drought is very high which has a low percentage of 0.009% dominated in Paciran District. This sub-district is located in coastal areas where the surface temperature is quite high so that the potential for drought is even higher.

And the areas identified as having the potential to be affected by drought are very low which have a percentage of 13.221% dominated in Karangbinangun District, Kalitengah District, Turi District and Deket District. These sub-districts are areas that are dominated by agricultural land or rice fields that have a high degree of wetness so that the potential for drought is very small.

**4. Conclusion**

Based on research on the Identification of Drought Potential Using Remote Sensing and Geographic Information Systems (Case Study: Lamongan District, East Java Province), several final conclusions are obtained, namely:

- In this study there are 6 parameters obtained from the interpretation of remote sensing data, namely: ground surface temperature, crown density with EVI transformation, wetness index,
brightness index, land use, and from secondary data, namely rainfall. These parameters can be used for the process of identifying the existence of drought because each parameter has properties that can be associated with its vulnerability to the potential for drought.

- Remote sensing and geographic information systems capable of detecting potential drought. The role of remote sensing in the study of potential drought is to identify surface conditions. Whereas geographical information systems are able to classify the potential level of drought in the study area with a technique of rating, weighting and overlaying.

- Drought potential identification is done by overlay method and obtained 5 classes, namely very high potential, high potential, moderate potential, low potential and very low potential. With classes that dominate are areas that have the potential to experience low drought with an area of 63122.683 ha with an area of 39.639%. Which is dominated in Karangbinangun District, Kalitengah District, Turi District and Deket District. For areas prone to drought with high and very high potentials, an area of 29934.259 ha and 192.023 ha is obtained with a percentage of 18.798% and 0.121%. The area is the area that is in the coastal area and downtown area because the downtown area is a built environment dominated by settlements.

5. References

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