

# Drought Vulnerability Mapping with Geomorphological Approach in Yogyakarta Special Region (DIY) and Central Java

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**Abstract.** This study aims to determine the level of vulnerability of the geomorphologic drought that occurred in Central Java and Yogyakarta Special Region. This study examines geomorphologic drought. Parameters used were slope, drainage, Available Water Capacity (AWC), permeability, landform, and land use. Landsat 8 and SRTM data were used for the extraction of physical parameters, such as slope, drainage, landform, and land use. The method used in this study is scoring and weighting. Query results were used for data classification by overlaying drought geomorphologic parameters. The expected outcome of this research is to map the geomorphologic drought vulnerability on Central Java and Yogyakarta Special Region. Drought vulnerability was divided into wet, normal and dry classes. Distribution of the dry class is frequent. Some of the dry classes are distributed on the steep till extremely steep slope region and on the structural and karsts landform. This was related to AWC value where region with high AWC contributed to the poor drainage of the soil, such as at Kulonprogo, Purworejo, Kebumen, Blora, Wonogiri, Purbalingga, Pekalongan, Jepara and Kudus regency. Normal classes are distributed on the sloping till steep slope, have moderate till well-drained soil and low AWC, such as at Gunung Kidul, Pati, Temanggung regency, and Magelang city. Wet classes are distributed on the flat or almost flat and sloping region. Most of the wet classes are distributed on volcanic hills and coastal area. Those regions are well-drained and the land uses are mostly for settlement and farming, such as at Sleman, Yogyakarta city, Klaten, Bantul, and Wonosobo regency.

**Keywords:** Geomorphology, Drought, Mapping, Landsat 8, SRTM

## 1. Preface

The recent change in global climate has become a new problem in Indonesia. The effect of that change in global climate also affects the micro climate, like the increase of drought locations. The drought areas in Java Island, especially in Central Java and DIY (Daerah Istimewa Yogyakarta – Yogyakarta Special Region) always increase every year. Both areas have static drought vulnerability areas per year, but the drought area increases by 30% in average, every year. As a result, the increase of drought area might aggravate the water crisis in those areas.

Drought might be caused by meteorological or geomorphological factor. In Indonesia, meteorological drought happens more often than geomorphological drought. Since researches about



geomorphological drought are scarce, this research is trying to assess the geomorphological drought that is caused by physical factors, such as topography and non-water-absorbing rocks [6]. Geomorphological approach used in this research studies the slope, geology (stone), types of soil, hydrology, and vegetation cover.

The advancement of remote sensing technology today made various researches with wide coverage easier. One of the easiness is the availability of Landsat 8 Image / LDCM (Landsat Data Continuity Mission) which is available for free. The supremacy of Landsat 8 can be utilized for various studies and applications, such as drought assessment. In the other hand, Landsat 8 Image also available multitemporal, so it is highly possible to perform an analysis with sequential time order. Physical parameters and geomorphological information which support the drought vulnerability research could also be extracted from the image. Afterwards, the mapping of drought vulnerability zone is done with Geographic Information System. Reinterpretation and research input are then presented according to Cartographical Rule.

## 2. Formulation of the problem

The formulation of the problem in this research is:

- How is the level of geomorphological drought vulnerability in DIY and Mid-Java Province?

## 3. Objective

The objective of this research is to:

- Analyse the vulnerability of geomorphological drought in Yogyakarta Special Region and Central Java Province.

## 4. Benefits of research

The benefits of this research are:

- a) Providing information about the distribution of drought areas in Yogyakarta Special Region and Central Java Province.
- b) Development of Geographical Information System and Remote Sensing science and technology in case study field applications.
- c) As a reference for land regulation, farming, and vegetation choosing, which are appropriate to the land geomorphology.

## 5. Research methodology

This research is done in several stages. The data gathering and selection stage includes literature study, material procurement, and data selection. Afterwards, the selected data are converted to digital form.

The next stage is the digital image processing. In this stage, there are geometric and radiometric image correction, composite forming, multispectral classification, and parameter extraction which are used to determine the drought vulnerability form Landsat 8 image. An Image Processing Software is used to aid the processing of remote sensing satellite image data.

The derivative data which is used in this research is processed after geometric corrections. The function of the correction is to produce data which has appropriate special position with the coordinates on the field. Geomorphological data processing is done by scoring and weighting for classification. The scoring and weighting for each parameter isn't equal. The dominant drought parameters are given wider range of values than minor parameters. First class rating shows that the parameter affects drought highly, whereas the last rating shows that it has less effect on drought. The used parameters in research are slope, drainage condition, Available Water Capacity (AWC), permeability, landform and land usage. The landform classification is appropriate with the [7] classification and the result of land usage classification is according to Landsat 8 interpretation. The interpretation is done with seven interpretation elements.

The value of drought vulnerability can be collected from drought index calculation. The formula used to calculate the drought index is:

$$\Sigma\{(R_i \times B_i)G\}$$

Note:

- R<sub>i</sub> : Rating  
 W<sub>i</sub> : Weight  
 G : Number of Parameter

The used parameters, classes, and dignity in research are shown at Table 1:

**Table 1.** Drought Vulnerability Parameter Class and Weight

| Parameter  | Class                                    | Rating (R <sub>i</sub> ) | Weight (B <sub>i</sub> ) |
|--|--|--------------------------|--------------------------|
| Slope<br>(R1 x B1)<br><br>Weight = 2                         | • Flat                                   | 1                        | 2                        |
|  | • Fairly Sloping                         | 2                        | 4                        |
|  | • Sloping                                | 3                        | 6                        |
|  | • Fairly Steep                           | 4                        | 8                        |
|  | • Steep                                  | 5                        | 10                       |
|  | • Very Steep                             | 6                        | 12                       |
|  | • Sheer                                  | 7                        | 14                       |
| Drainage<br>(R2 x B2)<br><br>Weight = 2                      | • Good                                   | 1                        | 2                        |
|  | • Average                                | 2                        | 4                        |
|  | • Bad                                    | 3                        | 6                        |
|  | • Very Bad                               | 4                        | 8                        |
| Available Water Capacity<br>(AWC)<br>(R3 x B3)<br>Weight = 4 | • 100 mm/m                               | 1                        | 4                        |
|  | • 150 mm/m                               | 2,5                      | 10                       |
|  | • 200 mm/m                               | 4                        | 16                       |
|  | • 250mm/m                                | 5,5                      | 22                       |
|  | • 300 mm/m                               | 7                        | 28                       |
| Permeability<br>(R4 x B4)<br><br>Weight = 4                  | • Medium Grain Sandstone                 | 7                        | 21                       |
|  | • Limestone                              | 7                        | 21                       |
|  | • Schist                                 | 7                        | 21                       |
|  | • Tuff                                   | 7                        | 21                       |
|  | • Weathered Gabbro                       | 7                        | 21                       |
|  | • Weathered Granite                      | 7                        | 21                       |
|  | • Clay                                   | 7                        | 21                       |
|  | • Basalt                                 | 7                        | 21                       |
|  | • Slate Stone                            | 4                        | 12                       |
|  | Permeability (R4 x B4)<br><br>Weight = 3 | • Fine Sand              | 4                        |
| • Dust   |  | 4                        | 12                       |
| • Fine Grain Sandstone                                       |  | 1                        | 3                        |
| • Rough Gravel   |  | 1                        | 3                        |
| • Medium Gravel  |  | 1                        | 3                        |
| • Fine Gravel  |  | 1                        | 3                        |
| • Rough Sand   |  | 1                        | 3                        |
| • Medium Sand  |  | 1                        | 3                        |
| • Sand Dunes   |  | 1                        | 3                        |
| • Turf   |  | 1                        | 3                        |
| Landform (R5 x B5)<br><br>Weight = 2                         |  | • Volcanic (V)           |                          |
|  | - V1 Volcanic Mountains                  | 4                        | 8                        |
|  | - V2 Volcanic Hills                      | 3                        | 6                        |

|                         |   |   |    |
|-------------------------|---|---|----|
|                         | - V3 Volcanic Plains                            | 2 | 4  |
|                         | • Denudasional (D)                              |   |    |
|                         | - D2 Denudasional Hills                         | 7 | 14 |
|                         | • Fluvial (F)                                   |   |    |
|                         | - F Fluvial Plains                              | 1 | 2  |
|                         | • Karst   |   |    |
|                         | - K1 Southern Java Karst Hills                  | 6 | 12 |
|                         | - K2 Northern Java Karst Hills                  | 6 | 12 |
|                         | • Marin   |   |    |
|                         | - M1 North Beach Plains                         | 5 | 10 |
|                         | - M2 South Beach Plains                         | 4 | 8  |
|                         | • Structural                                    |   |    |
|                         | - S1 Mountains                                  | 5 | 10 |
|                         | - S2 Hills                                      | 5 | 10 |
|                         | - S3 Structural Plains                          | 5 | 10 |
| Land Usage<br>(R6 x B6) | • Body of Water                                 | 1 | 2  |
|                         | • Forest, Mixed Farms, Plantations,<br>Fishpond | 4 | 4  |
|                         | • Settlement, Bushes                            | 6 | 6  |
| Weight = 2              | • Dry Land Farming, Moor, Field                 | 5 | 8  |
|                         | • Open Land, Built Land                         | 7 | 10 |

Source: [1, 2, 3, 4, 5]

The calculation of scoring result is done using the Geographic Information System Query. In this method, there are tabular and spatial data calculations. Data is processed digitally, so it is done faster and easier with many parameters. The resulting drought index is then classified into three classes; Dry, Normal, and Wet.

## 6. Research outcome

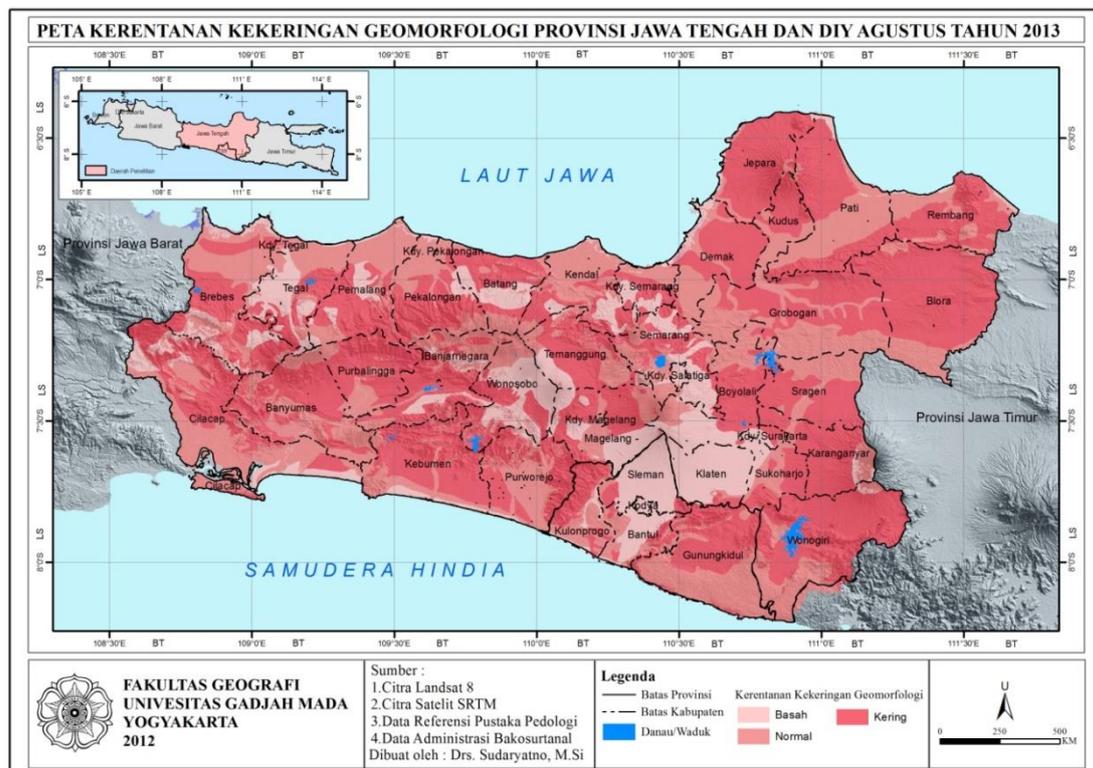
The geomorphological drought in August had wider coverage than it is during wet and normal conditions. These conditions are triggered by landform and the soil ability to store or let water flow. Geomorphological Drought Map in Yogyakarta Special Region and Central Java in 2013 is provided in Figure 1.

The research shows that the distribution of geomorphological drought vulnerability with similar dry class in every regent within Yogyakarta Special Region and Central Java. The drought vulnerability level is the result of interaction of slope, drainage condition, Available Water Capacity (AWC), permeability, landform and land usage factors in an area.

**Table 2.** Land Drought Vulnerability in Yogyakarta Special Region and Central Java (in Hectare)

| Regency      | Low    | Normal | High    | Area (Ha) |
|--------------|--------|--------|---------|-----------|
| Banjarnegara | 13.046 | 40.761 | 61.138  | 115.464   |
| Bantul       | 25.273 | 16.952 | 9.863   | 54.003    |
| Banyumas     | 798    | 61.250 | 76.813  | 139.423   |
| Batang       | 21.687 | 20.216 | 45.304  | 87.636    |
| Blora        | 131    | 32.555 | 159.468 | 195.904   |
| Boyolali     | 30.328 | 36.543 | 45.734  | 113.171   |
| Brebes       | 29.034 | 68.427 | 77.623  | 177.438   |

|                  |         |          |          |           |
|------------------|---------|----------|----------|-----------|
| Cilacap          | 30.962  | 107.875  | 90.004   | 241.174   |
| Demak            | 8.311   | 31.896   | 59.352   | 100.309   |
| Grobogan         | 1.080   | 97.344   | 102.523  | 202.052   |
| Gunungkidul      | 225     | 76.261   | 71.748   | 149.090   |
| Jepara           | 1.894   | 6.700    | 88.371   | 97.782    |
| Karanganyar      | 3.695   | 11.399   | 62.936   | 79.006    |
| Kebumen          | 8.362   | 31.826   | 92.044   | 134.093   |
| Kendal           | 15.570  | 54.756   | 29.953   | 100.911   |
| Klaten           | 63.130  | 2.430    | 4.374    | 70.284    |
| Kodya Magelang   | -       | 1.683    | 163      | 45.166    |
| Kodya Pekalongan | 284     | 3.335    | 1.052    | 57.782    |
| Kodya Salatiga   | 3.924   | 852      |          | 111.756   |
| Kodya Semarang   | 10.469  | 13.346   | 14.661   | 1.855     |
| Kodya Surakarta  | 1.723   | 311      | 2.676    | 159.044   |
| Kodya Tegal      | 638     | 2.366    | 697      | 87.834    |
| Kodya Yogyakarta | 3.287   |          |          | 4.693     |
| Kudus            | 62      | 16.968   | 27.907   | 113.984   |
| Kulon Progo      | 5.968   | 22.611   | 28.908   | 81.160    |
| Magelang         | 36.811  | 25.264   | 49.138   | 10.7864   |
| Pati             | 3.931   | 65.919   | 88.387   | 10.3842   |
| Pekalongan       | 5007    | 32.082   | 50.350   | 4.801     |
| Pemalang         | 16.322  | 44.490   | 52.681   | 102.354   |
| Purbalingga      | 622     | 20.426   | 59.764   | 38.844    |
| Purworejo        | 3.937   | 47.346   | 55.283   | 5.7847    |
| Rembang          | 2.553   | 31.570   | 69.141   | 99.952    |
| Semarang         | 36.424  | 31.135   | 34.286   | 50.973    |
| Sleman           | 47.465  | 2.509    | 7.588    | 4.734     |
| Sragen           | 206     | 37.341   | 61.133   | 98.747    |
| Sukoharjo        | 9.635   | 15.693   | 25.388   | 3.715     |
| Tegal            | 35.007  | 34.968   | 28.373   | 87.488    |
| Temanggung       | 12.688  | 25.817   | 48.560   | 194.719   |
| Wonogiri         | 1369    | 51.531   | 138.189  | 101.203   |
| Wonosobo         | 43.867  | 21.940   | 34.922   | 3303      |
| Total            | 535.725 | 124.6691 | 195.6497 | 3.781.402 |



**Figure 1:** Geomorphological Drought Vulnerability Map in DIY and Central of Java in August 2013

Wet classes lie on some areas within Sleman, Klaten, Boyolali, Bantul, Magelang, Wonosobo, Kendal, Temanggung, Batang, Tegal, Kodya Semarang, Demak coast, and small parts of Pemalang Regency. Normal classes are distributed on the southern part of Mid-Java, which are some of the areas of Gunungkidul regency, Cilacap, Wonogiri, Kulonprogo, and Purworejo Regency, and northern parts of Mid-Java, which covers some of Pati regency, Kendal, Rembang, Pekalongan, Tegal, Pemalang, Brebes, Kodya Tegal, Kodya Semarang, and Kodya Pekalongan.

Normal classes are also available on some parts of Blora regency, Grobogan, Purbalingga, Sragen, Boyolali, Temanggung, Magelang, Banyumas, Banjarnegara, and Wonosobo.

Regencies that mostly included in the dry class are Wonogiri, Karanganyar, Sragen, Blora, Rembang, Pati, Jepara, Kudus, Grobogan, Temanggung, Magelang, Kulonprogo, Kebumen, Purbalingga, Demak, Pemalang, Banjarnegara, Brebes, Banyumas, Cilacap, and Pekalongan.

Wet area distributions are narrower than dry and normal areas. This condition is caused by different permeability conditions. The permeability on wet areas is composed of fine sand, rough sand, and sand dunes. The permeability of sand is very good since it allows water flows well. Dry areas are mostly composed of materials which let water flows poorly, such as clay, which let water flows slowly. Clay also tends to absorb water to its pores, which cause water to be saturated. On wet conditions, soil on clay areas would be clayey and harder to pass. However on dry season, the condition tilted; water evaporate so the soil contracts and cracking. This condition is what called as drought.

The most affective factor from geomorphological drought is the soil condition. This soil data is then derived to AWC data, permeability, and drainage. That soil condition, added with topography and landform factors, resulting in the identifier of soil condition which determine its vulnerability to water. For example, regosol soil which consists of clay in plains would absorb water. In different condition such as escarpment, water would flow downwards, slowly.

Slope variation causes the variation of the surface quantity and runoff speed; land with steeper slope will have greater runoff speed than those with less steep slope, causing non-maximum rainwater infiltration and surface water supply.

Land texture and structure are the primary factors in determining the value of Available Water Capacity. Land with clayey texture has a very high level of AWC, while sandy land has a very low AWC level. Rooting depth is also a significant factor which also determines the value of AWC. Research result shows that the high level of AWC on each type of soil is proportional to the high level of geomorphological drought in Mid-Java and DIY, indicating that AWC is also a dominant parameter in determining geomorphological drought level.

Good permeability exists on land used as rice field, settlement, dryland farming, moor, and bushes. If associated with slope factor, good permeability exists on volcanic hills, volcanic plains, alluvial plains, and marin plains. There also exist spring belts on the buckling hillsides. This indicates a very good concentration of land water. Flat to fairly sloping slopes exist on areas with fluvial plains landform.

The studied research areas had good, average, bad, and very bad drainage classes, and are affected by the landform of an area. In the other hand, fluvial landform also has good drainage, because it is close to water source, so that water can flow and not saturate and sediment in an area

Another affective parameter in drought vulnerability is the land use. Dry class areas vulnerable to geomorphological drought had land utilized as forest, mixed farms, plantations, and fishpond. This is related to the land ability which the land and water crisis able to absorb water for a long time. Normal and wet class areas vulnerable to geomorphological drought mostly consist of body of water, settlement, bushes, dryland farming, moor, and rice field. This is related to the water availability and wet land condition, hence the soil tend to be fertile.

## **7. Conclusion**

- a) The distribution of dry class is more prevalent than other classes. Most of the dry class are distributed in steep to sheer slopes and have structural and karst landform. This is related to the type of land on those areas which affect high level of AWC, so that the drainage became bad. The examples are Kulonprogo, Blora, Purworejo, Kebumen, Wonogiri, Purbalingga, Pekalongan, Jepara, and Kudus regencies.
- b) Normal classes are distributed at scarps to gentle slope. This class had average drainage to good, so that the AWC level is low. The examples are Gunung Kidul, Pati, Temanggung regencies, and Magelang city.
- c) Wet classes are distributed at gentle slope to plains. Mostly distributed at middle and down slopes to coast, this class had good drainage so that most of the land uses are settlement and farming. The examples are Sleman, Klaten, Bantul, Wonosobo regencies and Yogyakarta city.

## References

- [1] Adi P and Subhakti 2011 *Agihan Tingkat Kerentanan Kekeringan di Provinsi Daerah Istimewa Yogyakarta Menggunakan Parameter - parameter Geomorfologi dan Meteorologi (Skripsi)* (Yogyakarta Fakultas Geografi UGM)
- [2] Anisa T and Miranti 2011 *Identifikasi Lahan Pertanian Rawan Kekeringan dengan Metode Sistem Informasi Geografi Studi Kasus Kabupaten Indramayu Provinsi Jawa Barat. Karya Tulis* (Bogor IPB)
- [3] Darmawijaya M Isa 1997 *Klasifikasi Tanah Dasar Teori Bagi Peneliti Tanah dan Pelaksana Pertanian di Indonesia* (Gadjah Mada University Press Fakultas Pertanian UGM)
- [4] Dudal R and M Soeprtohardjo 1957 *Soil Classification in Indonesia* (Bogor Pusat Penelitian Tanah dan Agroklimatologi)
- [5] Soeprtohardjo, M 1976 *Jenis Tanah di Indonesia. Seri 3C. Klasifikasi Tanah. Training Pemetaan Tanah* (Bogor)
- [6] Suyono 2007 *Kajian Kekeringan dan Banjir dengan Pendekatan Geografi di satuan Wilayah Sungai Pemali - Comal Provinsi Jawa Tengah. Laporan Penelitian* (Yogyakarta Fakultas Geografi UGM)
- [7] Zuidam, Van a Zuidam-Cancelado 1979 *Aerial photo - interpretation in terrain analysis and geomorphologic mappin* (The International Institute for Aerospace Survey and Earth Sciences (ITC))