Assessment of agricultural drought in paddy field area using Vegetation Condition Index (VCI) in Sukaresmi District, Cianjur Regency

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Abstract. Drought is a phenomenon which happens in spatial and temporal scale. One of the sectors affected is agriculture. In August 2015, a severe drought happened in Sukaresmi Village of Sukaresmi District causing harvest failures. This study aims to analyze the distribution of agricultural drought level of severeness in Sukaresmi District during August 2013 until August 2017 from spatial and temporal aspect by using VCI (Vegetation Condition Index) method and finding the correlation between the drought extent and rainfall data as the expected cause. The monitoring of agricultural drought in this study was carried out by utilizing remote sensing derived VCI by Kogan (1995). This index obtained after the NDVI value of Landsat 8 imageries in the given period normalized for each pixel. VCI shows how close the vegetation condition compared to its best and worst condition within the period. The result shows an agricultural drought in Sukaresmi District occurred throughout the years. 2015 was the year with the greatest average extent of agricultural drought. There is also a negative and weak ($r = -0.212$) correlation between the extent of drought and rainfall variable which means the climate did not mainly cause the phenomenon.

1. Introduction
Drought is a phenomenon which we can see from many points of views, which occurred on the spatial and temporal scale, as various consequence sectors that depend on water resources are affected [1]. According to Dracup et al. [2] drought is “Lack of rainfall as great as so long continued to affect the plant and animal life of a place injuriously and to deplete water supplies both for domestic purposes and the operation of power plants especially in those regions where rainfall is normally sufficient for such purposes”. Agriculture is a sector in which water plays a significant role in its continuity along with temperature, soil condition, sunlight, and evapotranspiration process. Drought is one of many kinds of the hydrometeorological disaster which mainly caused by rainfall. Similar researches of the hydrometeorological disaster had been done in Cibanteng Village of Sukaresmi District discussing loss risk caused by a landslide [3], characteristic of settlement in landslide area [4], and three-dimensional mapping for the preparation a risk-reduction program of landslide disaster [5]. In August 2015, the drought began to expand in Sukaresmi village due to a long period without rain. Hence, farmers were experiencing harvest failure. Areas affected the most at the time was Kawunghuwuk, Ciwalen, and Cikancana. With the help of geospatial techniques, i.e., remote sensing, monitoring and assessing agricultural drought could be done more effectively. Satellite imagery provides the actual information in the form of spatial or temporal (Goward et al., 1985; Tucker et al., 1985; Peters et al.,1997) [6]. One
of the simplest, efficient, and often used index to assess drought is the Vegetation Condition Index or VCI [7] which directly related to one of the parameters of the drought. This research focuses on the assessment the agricultural drought severeness extent which occurred in paddy field areas within Sukaresmi District from August 2013-August 2017 by using multitemporal data from Landsat 8, as well as analyzing linkages between the extent with rainfall data.

2. Methodology

2.1 Research Variables

Variables used consists of drought variable and climatic variables (rainfall). Kogan (1995) classification of drought and Oldeman rainfall classification (Table 1) used in this research are as follows:

| Variables | Classification | Unit | Class     | Reference |
|-----------|----------------|------|-----------|-----------|
| Drought   | <10%           |      | Extreme Drought | [8]       |
|           | 10-20%         |      | Severe Drought  |
|           | 20-35%         | VCI  | Moderate Drought |
|           | 35-50%         |      | Normal       |
|           | >50%           |      | Wet          |
| Rainfall  | <100           | mm   | Dry         |
|           | 100-200        |      | Humid       |
|           | >200           |      | Wet         | [9]       |

2.2 Data Collection

Types of data used in this study consist of secondary data, primary data, and survey results. Secondary data obtained from the government in the form of maps, documents, and the results of image processing. These data include Landsat 8 imagery August 2013-August 2017 from USGS (United States Geological Survey), Shapefile of administrative boundaries, Landcover (BIG and Ministry of Environment and Forestry), Precipitation (Dinas PUPR Cianjur) from the government and geotagged photos of paddy fields landcover collected from the field survey.

2.3 Data Processing and Analysis

In this research, the radiometric correction was done to reduce interference from atmospheric conditions. In this case is the cloud. A simple mathematical formula [10] used for cloud correcting before moving on to the primary process.

2.3.1 Calculate NDVI

The formula used to calculate the value of NDVI (Kogan, 1995):

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]

NIR: Near-Infrared Band (band 5), RED: Red Band (band 4)

Values of NDVI varies from -1 to 1, when the value closer to 1 the better the condition of the vegetation.

2.3.2 Calculate VCI

After having the NDVI result, this equation is then used to get the VCI value[11].

\[
\text{VCI} = \frac{(\text{NDVI}_j - \text{NDVI}_{\text{min}})}{(\text{NDVI}_{\text{max}} - \text{NDVI}_{\text{min}})} * 100
\]

NDVI\text{max} and NDVI\text{min} are a representation of the largest and smallest pixel value of NDVI counted for each month. Variable j is the given month. VCI value is in percentage range from 1-100. The value is then classified based on classes of drought (table 1).
2.3.3 *The Correlation between VCI and Monthly Rainfall.*

The correlation between VCI and Monthly Rainfall using Spearman. VCI represented with a paddy field areas that have a level of drought severeness (moderate drought, severe drought, and extreme drought) based on the classification of Kogan. The early assumption was “VCI and rainfall have a negative correlation, which when the rainfall is low, then the drought extent increases, and vice versa.”

3. **Study Area**

Sukaresmi district located in the north of Cianjur Regency which administratively divided into 11 villages. The region has an area of 120.7 km² and the population amount of 83,053 inhabitants in the year 2016 [12] and a density of 688 people/km². Sukaresmi is a region of Plateau located in the hillside of Mount Gede, which altitude range from 249-1371 meters above sea level and range of slope 3-40% [13]. Hills and steep slopes dominate the topography. Most of its area used for agricultural purpose. Based on the statistical data, about 18% (22.3 km²) of the total area is paddy fields.

4. **Discussion**

4.1 *Annual Changes Of Drought*

Agricultural drought extent and distribution as a result of the VCI method describes vegetation health condition at any given moment compared to its best and worst condition throughout the period examined. The presence of diversity in the VCI value around a large area is showing the spatial variations regarding vegetation health conditions.

![Average Of Drought Extent](image)

**Figure 1.** Graph of the average extent of agricultural drought in paddy field areas shows the average extent increased gradually until 2015, then decreased gradually from 2015 to 2017.

As can be seen from Figure 1, above, the graph shows the average extent of drought every year. The drought extent that happened from 2013 to 2015 significantly increased. In the year 2013, the average drought extent in district Sukaresmi is 272.45 ha. This figure rose by the year 2014 covering 734.51 ha of drought area and expanded to 796.32 ha in 2015. 2015 was the year with the highest average extent of agricultural drought which also happened to be the year when El Nino phenomenon occurred in Indonesia. Meanwhile, in the next two years after 2015, the extent of drought gradually declined. The average drought extent in 2016 dropped to 541.61 ha and 296.72 ha in 2017. Figure 2. below shows the Map of Agricultural Drought in paddy fields area on June, August, and October.

Figure 2. below shows the spatial variations of the five classes of drought. In general, red, orange, and yellow color as the symbol of extreme, severe, and moderate drought respectively can see on the west and northeast part of the research area: Kawung Luwuk and Ciwalen Village located in this particular west part. As for the northeast part, there are Cikancana and Sukamahi village. From figure 2, we can also see that the most extreme drought tend to happen in June rather than August and October. The drought also supported by the fact that the broadest extent of extreme drought occurred in June 2014, while the least one occurred in August 2017. During the driest time (June 2014), the top four villages with the most extensive area of drought were Sukamahi (302.9 ha), Cikancana (197.9 ha), Ciwalen (151.6 ha), and Kawung Luwuk (132.9 ha).
Figure 2. Spatial Variation of Drought based on VCI value in Paddy Fields Area

The occurrence of drought continues to grow in some areas from 2013 to 2015. Whereas in the next two years the extent was decreasing. This temporal variation assumed to be due to the dynamics of rainfall in the research area. In order to find out which area is the most affected by this variable, the drought extent in June and August for each village calculated. June picked because the most extensive drought was happening in this month. And August picked because the least extensive drought was happening in this month, so the areas that are still affected during the expected least dry month could be known.
4.2 The Most Extensive Agricultural Drought
The most massive agricultural drought happened in June 2014. Around 1019.15 ha of paddy fields were experiencing drought from the total 2228.36 ha of paddy fields.

| Tahun | Cibadak | Cibanteng | Cikancana | Cikanyere | Cwaken | Kawung | Lawuk | Kubang | Paksan | Rawabelut | Sukamahi | Sukaresmi | Luas total |
|-------|---------|-----------|-----------|------------|--------|--------|-------|--------|--------|-----------|-----------|-----------|------------|
| 2014  | 76.3    | 29.9      | 197.9     | 41.0       | 151.6  | 132.9  | 108.5 | 62.6   | 2.9    | 202.9     | 12.6      | 1019.1    |            |
| 2015  | 72.4    | 33.6      | 34.5      | 54.7       | 247.1  | 140.7  | 73.4  | 83.9   | 11.2   | 109.8     | 8.1       | 869.3     |            |
| 2016  | 24.2    | 17.3      | 23.9      | 58.8       | 163.4  | 40.6   | 7.8   | 29.2   | 5.3    | 46.3      | 1.9       | 418.6     |            |
| 2017  | 16.5    | 16.8      | 18.3      | 30.6       | 62.7   | 32.4   | 55.4  | 23.8   | 11.3   | 61.0      | 6.1       | 334.7     |            |

Table 2. shows several villages suffered the worst drought, including Sukamahi, Cikancana, and Kawungluwuk. The most extensive area of extreme drought occurred Sukamahi village covering an area of around 71 ha which was approximately around 206.49% of the total area of paddy field in Sukamahi village.

4.3 The Least Extensive Agricultural Drought
The least extensive agricultural drought occurred in August 2017 with a total area of drought around 75.16 hectares, i.e., about 3% of the overall paddy field area.

| Tahun | Cibadak | Cibanteng | Cikancana | Cikanyere | Cwaken | Kawung | Lawuk | Kubang | Paksan | Rawabelut | Sukamahi | Sukaresmi | Luas total |
|-------|---------|-----------|-----------|------------|--------|--------|-------|--------|--------|-----------|-----------|-----------|------------|
| 2013  | 13.5    | 48.6      | 5.1       | 14.7       | 48.8   | 21.3   | 38.2  | 6.4    | 16.7   | 49.5      | 3.4       | 266.13    |            |
| 2014  | 94.8    | 61.8      | 51.1      | 66.0       | 217.1  | 90.7   | 137.3 | 46.3   | 30.9   | 148.9     | 33.7      | 978.61    |            |
| 2015  | 7.1     | 91.7      | 37.7      | 12.3       | 18.2   | 15.3   | 161.1 | 8.1    | 24.3   | 206.7     | 43.5      | 625.79    |            |
| 2016  | 29.4    | 49.9      | 36.3      | 2.7        | 37.9   | 28.6   | 46.8  | 29.3   | 20.8   | 79.8      | 3.6       | 365.08    |            |
| 2017  | 2.1     | 11.9      | 4.2       | 0.3        | 3.0    | 3.1    | 10.4  | 0.3    | 17.4   | 9.6       | 13.0      | 75.16     |            |

Table 3. shows how Sukamahi village also emerged as the village with the most extensive drought even in the expected least dry month. The most extensive area of drought in August occurred in 2015.

4.4 Correlation between Drought Extent area and Monthly Rainfall
Rainfall data used in this study is the monthly rainfall recorded by Kantor Balai Wilayah IV Station, Cabang Dinas Wil. IV Pacet. The result of the correlation between the percentage of drought extent area throughout Sukaresmi district and rainfall data shows that the two variables have a negative and weak correlation with the value of r = -0.212 (p 0.269). Which means when the amount of rainfall decreased, the drought area will be increasing, and vice versa. Despite the early assumption was right, the number is closer to 0 (zero) which also means the shortage of rainfall does not give a significant impact to the agricultural condition. There is a possibility of other reasons affecting drought more than rainfall, such as irrigation and land use system. However, to explain it, there needs to be further research. Qian, in 2016 [14] found there’s a higher correlation between VCI and temperature, as well as wind velocity.
5. Conclusion

VCI shows the vegetation condition at a particular time compared to its best and worst condition throughout a specified period. The result of this study shows June 2014 was the worst condition because during the month, a large part of paddy fields was experiencing drought. The temporal aspect shows 2015 was the year with the widest average of drought area, while the spatial aspect shows Sukamahi village frequently has the largest area of agricultural drought. However, the drought extent and rainfall data show a weak correlation which means despite the shortage of rainfall during dry months every year; rainfall is not the primary factor of drought occurred in a paddy field of Sukaresmi.

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