Application of vegetation health index (VHI) to identify distribution of agricultural drought in Indramayu Regency, West Java Province

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Abstract. The drought that occurred in Indramayu Regency was caused by a shift of the beginning season and a long dry season which affected the availability of water storage for plants. Indramayu Regency is one of the rice centers in West Java with 56% of its area is rice fields. But in recent years rice productivity has been reduced due to drought. The Indramayu District Agriculture Office noted that in 2012, 2015 and 2018 paddy fields. The purpose of this study was to determine the distribution of 2012, 2015 and 2018 wetland agricultural drought areas and their relationship with rainfall in Indramayu Regency. The VHI drought index (Vegetation Health Index) is used to determine the pattern of distribution of the drought area of agricultural land. VHI is a combination of VCI (Vegetation Condition Index) and TCI (Temperature Condition Index) derived from NDVI data processing (Normalized Difference Vegetation Index), LST (Land Surface Temperature) of Landsat 7 and 8 images. The processing results of the VHI index show the distribution of drought levels no drought to extreme drought, where in 2012, 2015 and 2018 the distribution of drought in agricultural land has the same pattern, which is dominated by the coastal areas of Indramayu Regency due to the influence of less rainfall. While the level of mild drought is in the western and center regions of Indramayu Regency.

1. Introduction
Drought is a normal part of the climate which is included in an extreme climate or as a natural disaster [1]. The indications of climate change in Indonesia are caused by rising sea surface temperature from the Hindian ocean and Pacific Ocean. The rising of sea surface temperature caused a shift at the beginning of the season and the duration of the rainy season which affects the availability water for plants. El Nino which caused by Indonesia condition territorial waters, will reduce the amount of rainfall in Indonesia when the seawater temperature is relatively cold [2]. Drought means natural phenomenon when precipitation is significantly below normal recorded levels causing hydrological imbalances that adversely affect land resource production systems. There are three causes of drought, including precipitation, type of soil and plants. When the precipitation and soil moisture is less than average causing the amount of water is insufficient. Heavy rain shows the intensity of very large rainfall which can cause floods, landslides and other disasters. Otherwise, reduced amount of rainfall causes a lack of water supply for living needs to be vulnerable to drought. Rainfall patterns in Indonesia are influenced by several factors, i.e. the shape of the terrain or topography, the direction of the terrain, the direction of the wind parallel to the coastline and the distance of wind gusts above the plain [3].

Indramayu Regency, West Java is one of the rice centers with national rice contribution is 2.03%, but until 2015, the harvested area and rice productivity tended to decrease -3.3% and 0.4%. the long dry season occurs in Indramayu region, especially in July, August, and September, where rainfall is 30-
70% from normal conditions (per 1°C increase in sea surface temperature anomalies in Nino region - 3.4) [4]. Indramayu District Agricultural Service noted that in 2012, 2015 and 2018 paddy field experienced crop failures. The condition of climate change can potentially reduce agricultural production, especially rice in Indramayu. Agricultural drought is related to land surface temperature and vegetation index. A drought index is a major tool for detecting, monitoring and evaluating drought events which can be known by using remote sensing satellites. Landsat 7 and 8 imagery can detect spatial and temporal patterns because of its high resolution to detect large areas.

This research of identification agricultural drought was assessed using VHI (Vegetation Health Index) method which is a combination of vegetation index (NDVI) and land surface temperature index (LST) [5]. This research aims to determine the spatial and temporal distribution of agricultural drought on 2012, 2015 and 2018.

2. Materials and Methods

2.1. Study Area

Indramayu Regency, as shown on Figure 1, is located on the north coast of West Java Province with 107° 52’ – 108° 36’ east longitude and 6° 15’ – 6° 40’ south latitude and elevation ranges 0 to 287 meters. Indramayu Regency has the highest annual average rainfall of 3046 mm/year in 2018 and the lowest annual rainfall average 2147 mm/year in 2015 (figure 2). Most of the lowest rainfall occurs from June to September. Alluvial and hydromorphic soil types are the main soil types. The production of rice fields in Indramayu Regency is one of the West Java rice barns, which is related to the paddy field area is 56% of the Indramayu Regency’s total area. Agriculture land spreads throughout the sub-district are divided into irrigated crop covering 80.96% and rainfed crop covering 22.20%. The northern coastal region and parts of the southern coast consists of ponds and mangrove forests. The southern region consists of gardens, fields, and settlements. The source of irrigation in paddy fields of
Indramayu comes from the local dam in Indramayu Regency, Jatigede dam in Majalengka Regency, and Jatiluhur dam in Sumedang Regency.

Figure 2. (a) Elevation; (b) Slope; (c) Average monthly rainfall

2.2. Data sets
In this study, the Landsat 7 and 8 multispectral satellite data were obtained from USGS website with recording date on 7 July 2015, 15 July 2018 and 8 September 2012. Each year was taken in the dry season, i.e. July and September. Landsat images had a high-resolution satellite imagery with 30 m spatial resolution.
2.3. Methodology

![Methodology flowchart for VHI calculation](image)

**Figure 3.** Methodology flowchart for VHI calculation

### 2.3.1. NDVI
Vegetation index value is calculated from the ratio between measured reflections from red band (R) and near-infrared bands. NDVI value range between -1 and 1 shows non-vegetation land use, low to high vegetation density. NDVI is calculated by using the following formula:

$$ NDVI = \frac{(NIR\ Band - Red\ Band)}{(NIR\ Band + Red\ Band)} $$  \hspace{1cm} (1)

### 2.3.2. LST
Land surface temperature can reflect the temperature/heat on healthy vegetation. High temperatures and low soil moisture cause plant stress. The thermal band used is band 6 for Landsat 7 and band 10 or 11 for Landsat 8. DN (Digital Numbers) on Landsat needs to be changed to a spectral radiance value with the following formula:

$$ L = M \times QCAL + A $$ \hspace{1cm} (2)

The spectral value of radians is then calculated by the following formula [5]:

$$ T = \frac{K2}{\ln(N/V1 + 1)} $$ \hspace{1cm} (3)

T values in Kelvin units are changed to Celsius units with the following formula:

$$ T_{Celsius} = T_{Kelvin} - 273 $$ \hspace{1cm} (4)

### 2.3.3 VCI, TCI and VHI
The vegetation condition index, temperature condition index and vegetation health index are calculated using the following equations [6]:

$$ VCI = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100 $$ \hspace{1cm} (5)

$$ TCI = \frac{LST_{max} - LST_i}{LST_{max} - LST_{min}} \times 100 $$ \hspace{1cm} (6)
\[
VHI = 0.5 \times TCI + 0.5 \times VCI
\] (7)

Where:

VCI and TCI value shows scale from 0 to 100 represent environmental conditions of vegetation and temperature. The VCI and TCI indices have an inverse relationship where the higher the VCI value the lower the TCI value. The combination of VCI and TCI values with the same weight will produce VHI values. The results of the VHI equation will produce a range of values from 0 to 40 which are classified into 5 classes of level of drought that is not drought, mild, moderate, severe and extreme drought [7] as shown on Table 1.

Table 1. Classification of the VHI values in term of drought

| Drought  | Values |
|----------|--------|
| Extreme  | 0 - 10 |
| Severe   | 10 - 20|
| Moderate | 20 - 30|
| Mild     | 30 - 40|
| No drought | >40    |

3. Results and Discussion

Table 2. Extent of Agricultural Drought in 2012, 2015 and 2018.

| Level of Drought | 2012 (hectares) | 2015 (hectares) | 2018 (hectares) |
|------------------|-----------------|-----------------|-----------------|
| No drought       | 15132           | 25355           | 40322           |
| Mild             | 34758           | 21166           | 32834           |
| Moderate         | 38362           | 24609           | 23158           |
| Severe           | 13774           | 27603           | 17722           |
| Extreme          | 14733           | 16162           | 4427            |

Based on Table 2, the area of which has not experienced a drought has increased since 2012. Extreme drought experienced an increase in area in 2015 then declined dramatically in 2018. Figure 4 shows that 2012 was dominated by moderate drought area of 38362 hectares or 32.86% of the total area distributed from the middle to the east including the Losaran District, Lelea, Widasari, Bangodua, Tukdana, Sliyeg, Kertasemaya, Sukagumiwang, Karangampel district. The area of extreme drought area is 12,834 hectares or 12.62% of the total area. The area of extreme drought area is 12,834 hectares or 12.62% of the total area. The level of extreme drought distributed in the western and southern areas of Indramayu Regency including the Haurgeulis, Gantar, Kroya, Gabus Wetan, Terisi, Cikedung, Bangodua and Tukdana districts. The extreme class drought area of 2012 is at an altitude of 0 - 50 meters above sea level and the slope is flat. Areas of severe and extreme drought predominance in dark gray alluvial soil types and yellow podzolic and gray hydromorphic associations. This can be due to the two types of land dominating the Indramayu Regency. The texture of the hydromorphic is gray, which is the texture of sand and is rather light so the ability to absorb water is very low. While the texture of alluvial and podzolic soil has a texture of dust to clay so that the ability to absorb water is good. However, the distribution of severe and extreme drought in areas of alluvial and podzolic soil types can be due to the condition of rice fields during the harvest so that the soil is left dry by farmers.
Most of the puso-affected rice fields are technical irrigation rice fields and the rest are rain-fed rice fields. Drought has been very heavy during the last seven years, most occurred in 2012 for the Districts of Cikpapan, Bangodua, Tukdana, and Gabus Wetan caused by low precipitation during the season so that the water supply needed for rice plants is reduced.

Severe drought on 2015 spread along the coast of the north and east and the south of Indramayu district includes Pasekan, Sindang, Balongan, Juntinyuat and Karangampel districts. Area of extreme drought is 16,162 hectares or 13.95% of the total area. There are about 25 districts experiencing extreme drought spread in the west to the south Indramayu includes the District of Haurgeulis, Gantar, Kroya, Gabus Wetan, Cikedung, Terisi, Lelea, Kertasemaya, Sukagumiwang, Krangkeng, Karangampel, Kedokan Bunder, Juntinyuat, Sliyeg, Jatibarang, Balongan, Indramayu, Sindang, Cantigi, Pasekan, Lohbener, Arah, Losarang, Kandanghaur and Bongas districts. Area of extreme drought is 16,162 hectares or 13.95% of the total area. There are about 25 districts experiencing extreme drought spread in the west to the south Indramayu includes the District of Haurgeulis, Gantar, Kroya, Gabus Wetan, Cikedung, Terisi, Lelea, Kertasemaya, Sukagumiwang, Krangkeng, Karangampel, Kedokan Bunder, Juntinyuat, Sliyeg, Jatibarang, Balongan, Indramayu, Sindang, Cantigi, Pasekan, Lohbener, Arah, Losarang, Kandanghaur and Bongas districts. During 2012 to 2018, 2015 was a year with a large dry season duration. The existence of the El Nino phenomenon occurred in 2015 led to climate irregularities. The lowest average monthly rainfall in 2015 in the class 30-80 mm is spread in the west, north coast and south part of Indramayu Regency. The distribution of the low average rainfall is partly experienced by severe and extreme drought. Extreme drought is also in the low-class altitude region which can affect high land surface temperatures and higher wind speeds compared to high altitude class areas. So that rainfall does not fall in large numbers compared to areas far from the coast. Based on the type of soil, heavy and very heavy drought is distributed in all types of soil except for complex soil types grumusol, regosol and mediteranian. Mediterranean soil types have a rather heavy texture or high-water absorption, so heavy drought dan very heavy tends not to occur in these soil types. The effect of low vegetation density and high land surface temperature in several sub-districts in the southern, central and coastal areas can be a factor in the drought that is included in the class of severe and extreme drought. Some of the rice fields on the east and north coasts of Indramayu Regency are ponds that are likely to supply brackish water. So that farmers tend to plant rice with a fairly low vegetation density in the hope that there will be no substantial crop failure. The extreme drought which is spread almost in all districts in Indramayu Regency due to lack of water supply from rainfall.

Paddy fields in 2018 have a large area of land that does not experience drought with an area of 40322 ha or 34.04% of the total paddy fields in Indramayu Regency which are spread in the east to south and some in the western part including Karangampel, Kedokanbunder, Kertasemaya, Tukdana, Bangodua, Sliyeg, Jatibarang, Arah, Lohbener, Losarang, Bongas and a small part in Anjatan, Haurgeulis and Sukagumiwang districts. The average annual rainfall in 2018 which is higher than other years can affect the extent of non-drought in high agricultural land. The level of extreme drought and severe is spread in the area of the average rainfall above the low class in the range of 50 - 150 mm. Reduction in the area of heavy and very heavy drought has decreased since 2015, where the phenomenon has a relationship with average minimum and maximum rainfall greater than in 2012 and 2015. In addition, the number of dry months in 2018 was the least compared to other years, so areas tend to be wetter.

Based on altitude and slope, severe and extreme drought is in the low altitude region (<7 meters) and the slope is very flat and flat. As in the previous year's period, severe and extreme droughts tend to spread over flat elevations and flat slopes. The altitude and slope conditions affect the amount of land surface temperature that is higher in the region of low altitude and flat slopes. Alluvial soil types dominate in areas of severe and extreme drought in Indramayu Regency. This is supported by the type of soil in Indramayu Regency which is dominated by alluvial soil type which is 60.1 percent clay texture. Water absorption is increasing from the texture of the clay to dust. Thus, alluvial soil types have ability to store water well. However, drought can occur in alluvial soil types due to the influence of the condition of rice fields that are in the harvest period so that the fields are still in dry conditions.
4. Conclusions
The distribution of agricultural drought in Indramayu Regency which uses the Vegetation Health Index (VHI) equation is divided into classes not drought, mild drought, moderate drought, severe drought and extreme drought. The distribution of agricultural drought in the extreme category during 2012 to 2018 has the same pattern, which is dominated by the coastal and southern regions of Indramayu Regency due to less rainfall, among others in parts of Kandanghaur District, Losarang, Balongan, Indramayu, Sindang, Cantigi, Pasekan, Juntinyuat, Karangampel, Krangkeng, Gantar, Kroya and Terisi. The mild drought level category is in the northern and central western regions covering Anjatan, Bongas, Jatibarang, Sliyeg, Widasari, Kertasemaya, Kedokanbunder and Sukagumiwang sub-districts. The highest severe drought occurred in 2015 covering an area of 16,162...
hectares which was spread almost in all districts in Indramayu Regency due to the influence of rainfall. While mild droughts occur in 2018, most of which are in the central western region.

5. References
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