Identification of Dry Areas on Agricultural Land using Normalized Difference Drought Index in Magetan Regency

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Abstract. Indonesia is a country with vast agricultural lands. However, agricultural land production in Indonesia is threatened by climate change and land use change. One of phenomenon from climate change that threatened agricultural land is El Nino. El Nino can cause long-lasting drought. In 2018, Indonesia Ministry of Agriculture predicted that in the middle of 2019, El Nino would occur in Indonesia. Magetan Regency is one of the regencies in East Java Province that has a high level of vulnerability to drought. Magetan Regency ranked 36 in Indonesia as a Drought-Prone Regency. Drought in the agricultural sector is a drought which is one of the direct impacts of the climate change phenomenon. This research aims to identify dry areas in agricultural land using Normalized Difference Drought Index and Landsat 8 Imagery with acquisition month August 2017 (Normal Year) and 2019 (El Nino Year). The results of data processing revealed that the dry areas in 2019 are wider than dry areas in 2017 with extent area of 3350.26 ha in 2017 and 9237.28 ha in 2019.

1. Introduction

Indonesia had experienced several drought disasters caused by El Nino, for example El Nino 1997-1998 which caused the worst drought in the 21st century [1]. In 2015, Indonesia experienced a strong El-Nino phenomenon [2]. This caused the rainy season to arrive late. El-Nino in 2015 began to affect Indonesia in March 2015 and strengthened in July, and reached its peak in December 2015 [3]. BNPB said that El-Nino in 2015 caused 111,000 hectares of agricultural land got Puso (failed to be harvested). In October 2018, based on NOAA / NESDIS image, SST anomaly in Nino 3.4 experienced SST anomaly 0.62°C. Based on predictions by a number of state institutions, this caused weak El-Nino occurred in October 2018 to July 2019 [4]. Based on this phenomenon, Indonesia experienced a long dry season in 2019 due to El-Nino in the end of 2018 [5].

Agricultural drought is one of the direct impacts of crop damage due to climate change [6]. Drought that caused by climate change can cause agricultural crops to experience ‘Puso’. One of the affected areas is East Java Province. East Java is a province that has the largest agricultural land area and the largest agricultural production in Indonesia [7,8]. In 2012, the Ministry of Agriculture recorded the East Java region as the region with the highest crop failure rate with 996 hectares from 18,619 hectares experienced drought. According to the Drought Hazard Prone Index Map issued by BNPB in 2011, most of East Java regencies have high level of drought hazard. One area that has high drought prone risk is Magetan Regency. The level of drought prone in Magetan Regency is ranked 36 nationally and ranked 8 in East Java [9].
Vegetation index is one application of remote sensing technology that can be used to identify dry areas [10]. Using electromagnetic waves, satellite imagery can capture information about the condition of vegetation. Since 1980s, several vegetation indexes have been developed [11]. There are several IVs that can be used to identifying drought or dryness, such as NDVI, NDWI, NDDI, SAVI, etc. Combined IVs also have been developed such as Temperature Vegetation Dryness Index, that combine NDVI and LST (Land Surface Temperature) [12].

In this study, the index to be used is NDDI (Normal Difference Drought Index). Based on previous research by Du et al, (2018) NDDI is a vegetation index that has a high correlation with rainfall. Based on Abdi et al, 2018, NDDI has good accuracy reached 82% [13]. In this study writer compared dry areas in normal year (2017) and El Nino year (2019). Located below the foot of Mount Lawu, Magetan Regency has a diverse topographic area. These conditions cause Magetan Regency to have different physical conditions in the region. In areas with varying physical conditions, creating phenomena that also differ. One such phenomenon is the dry areas of agricultural land.

2. Methodology
Magetan Regency was chosen as the research area because it is one of the regencies in East Java that has a high vulnerability to drought and experiences drought during the dry season every year. The focus area of research was agricultural land, namely plantation, farm, irrigated rice field and rain-fed rice field. Drought level is obtained using vegetation index. In the study of vegetation index used is NDDI (Normalized Difference Drought Index). Based on the level of drought, the dry class would be chosen to be analyzed as a dry region. Dry areas obtained from Landsat 8 imageries with month of acquisition August (2017 and 2019).

NDDI is a vegetation index obtained from two other indices namely Normalized Difference Vegetation Index (NDVI) and Normalized Difference Wetness Index (NDWI). This Index was developed by Gu et al, 2007. To obtain NDDI values, Landsat 8 imageries should be calibrated and corrected. Radiometric calibration used is changing the DN value into the TOA reflectant. The following formula for obtaining NDVI and NDWI values [10]:

\[
\text{NDVI} = \frac{(\text{NIR}-\text{RED})}{(\text{NIR}+\text{RED})} \\
\text{NDWI} = \frac{(\text{NIR}-\text{SWIR1})}{(\text{NIR}+\text{SWIR1})}
\]

NIR = Near Infrared Band  
RED = Red Band  
SWIR1 = Short-wave Infrared Band

The clip process is carried out to separate the use of agricultural land (plantation, farm, irrigated rice field and rain-fed rice field) from non-agricultural land uses. Normalized Difference Drought Index (NDDI) is extracted using the formula below [14]:

\[
\text{NDDI} = \frac{\text{NDVI}-\text{NDWI}}{\text{NDVI}+\text{NDWI}}
\]

NDDI = Normalized Difference Drought Index  
NDVI = Normalized Difference Vegetation Index  
NDWI = Normalized Difference Wetness Index
Drought classification based on Normalized Difference Drought Index (NDDI) values can be seen in the Table 1.

**Table 1.** NDDI drought classification.

| NDDI Value | Dryness Level |
|------------|---------------|
| < 0.50     | Normal        |
| 0.50 – 1   | Rather Dry    |
| > 1        | Dry           |

Source: Gu et al, 2007

3. Result and Discussion

3.1. Dry Areas in August 2017

In August 2017, the Magetan Regency was dominated with normal conditions within area of 312885.22 ha or 73.18 % of agricultural land in Magetan. The areas under normal condition are found in the entire area of Magetan Regency. Meanwhile, the rather dry areas have areas of 111321.84 ha or 26.04 % of agricultural land in Magetan. Areas with rather dry conditions are quite widely spread throughout the regency, but there are many of them located in Parang District. The dry area is 3350.26 ha or 0.78 % of agricultural land in Magetan. Table 2 is the wide of area based on the dryness in 2017.

**Table 2.** Dryness area in Magetan regency (August, 2017).

| Dryness Level | Area (Ha) | Percentage (%) |
|---------------|-----------|----------------|
| Normal        | 312885.22 | 73.18          |
| Rather Dry    | 111321.84 | 26.04          |
| Dry           | 3350.26   | 0.78           |

Dry areas in August 2017 are spread throughout the regency, but the dry areas dominated in several districts, namely Parang, Bendo, Maospati, Karangrejo, Kawedanan and Sukomoro. Dry areas tend to happen within area that far from Lawu Mount that provide water for Magetan Regency. Area of dryness level in August 2017 can be seen in Figure 1.

**Figure 1.** Dryness level in August 2017.
Based on the results of data processing, the type of agricultural land that has the widest dry areas is irrigated rice field within area of 1585.95 ha or 47.34 % of dry areas in agricultural land. Dry conditions that occur in irrigated rice field caused by dry season. Although irrigated paddy field are generally well irrigated, in the dry season, river discharge for irrigation decreases so much caused land is not planted to prevent crop failure due to lack of water resources for irrigation. Whereas other agricultural land, rainfed rice field, has dry areas of 1066.22 ha or 31.83 % of dry areas in agricultural land, farm field has dry areas of 490.37 ha or 14.64 % of dry areas in agricultural land and plantation has dry areas of 207.7 ha or 6.20 % of dry areas in agricultural land. The table of dry areas in 2017 based on agricultural land can be seen in Table 3 and the map in Figure 2.

### Table 3. Dry areas based on agricultural land (August, 2017).

| Dryness Level          | Area (Ha) | Percentage (%) |
|------------------------|-----------|----------------|
| Farm                   | 490.37    | 14.64          |
| Plantation             | 207.7     | 6.20           |
| Irrigated Rice Field   | 1585.95   | 47.34          |
| Rain-fed Rice Field    | 1066.22   | 31.83          |

#### Figure 2. Dry areas in agricultural land (August 2017).

3.2. **Dry Areas in August 2019**

In August 2019, the Magetan Regency was dominated by normal conditions within area of 23816.99 ha or 51.82 % of agricultural land in Magetan. The areas under normal condition are found in the eastern and western part of Magetan Regency. Whereas, the rather dry areas have areas of 12909.71 ha or 28.09 % of agricultural land in Magetan. Areas with rather dry conditions are quite widely spread throughout the regency and close to area that in dry condition resemble of barrier between normal condition and dry condition. The area experiencing dry area is 9237.28 ha or 20.10 % of agricultural land in Magetan. 2019 is a year with weak El Nino condition. Table 4 is the region of overall dryness by 2019.
Table 4. Dryness area in Magetan regency (August, 2019).

| Dryness Level | Area (Ha)   | Percentage (%) |
|---------------|------------|----------------|
| Normal        | 23816.99   | 51.82          |
| Rather Dry    | 12909.71   | 28.09          |
| Dry           | 9237.28    | 20.10          |

Dry areas in August 2019 are dominated in central part of Magetan Regency. Most dry areas dominated in several districts, namely Parang, Magetan, Ngariboyo, Bendo, Maospati, , Kawedanan and Sukomoro. Dry areas tend to happen within area that far from Lawu Mount that provide water, mostly central part which dominated with soil type that come from limestone. In general, dry areas that happened in 2019 are wider than dry areas of 2017. Area of dryness level in August 2019 can be seen in Figure 3.

![Dryness Level in August 2019 Magetan Regency](image)

**Figure 3.** Dryness level in August 2019.

Based on the results of data processing, the type of agricultural land that has the widest dry areas is rainfed rice field within area of 3418.51 ha or 37.01 % of dry areas in agricultural land. In the dry season, rain-fed rice field are not watered and planted and left in a state of ‘bero’ that make the area dry. The land was left dry due to insufficient water resources to irrigate the area. Farmers do this to prevent production failure due to drought. Whereas other agricultural land, irrigated rainfed rice field, has dry areas of 2580.09 ha or 27.93 % of dry areas in agricultural land. Dry conditions in irrigated rice field occur after the area is harvested. In general, irrigated paddy field are left to dry before replanting in the specified planting season. This causes the region to experience dry. Another agricultural land, farm field has dry areas of 490.37 ha or 26.79 % of dry areas in agricultural land and plantation has dry areas of 207.7 ha or 8.27 % of dry areas in agricultural land. The table of dry areas in 2017 based on agricultural land can be seen in Table 5 and the map in Figure 4.
Table 5. Dry areas based on agricultural land

| Dryness Level         | Area (Ha) | Percentage (%) |
|-----------------------|-----------|---------------|
| Farm                  | 2474      | 26.79         |
| Plantation            | 763.84    | 8.27          |
| Irrigated Rice Field  | 2580.09   | 27.93         |
| Rain-fed Rice Field   | 3418.51   | 37.01         |

Figure 4. Dry areas in agricultural land (August 2019).

4. Conclusion
The conclusion that can be drawn from the results and discussion in this study is that the dry areas that occurred in 2019 (weak El Nino year) are wider than in 2017 (normal year) with dry areas of 9237.28 ha in August (2019) and 3350.26 ha in August (2017). Areas that are dominated by dry areas in 2017 and 2019 is Parang District, southern part of Magetan Regency. The types of agricultural land that have the widest dry areas are irrigated rice field and rain-fed rice field.

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References
[1] Shofiyati R., Takeuchi W., Darmawan S., Sofan P. 2014. An Effective Information System of Drought Impact on Rice Production Based on Remote Sensing. International Remote Sensing and Earth Science, 11 (2), 153-162.
[2] Badan Penanggulangan Bencana Nasional. 2015. Dampak EL-Nino Tahun 2015 terhadap Kekeringan di Indonesia. https://www.bnpb.go.id/dampak-el-nino-tahun-2015-terhadap-
kekeringan-di-indonesia accessed at October 30th, 2019.

[3] ACAPS. 2016. Dampak El-Niño/La Niña di Indonesia: Skenario. https://www.acaps.org/special-report/dampak-el-nino-la-nina-di-indonesia-skenario

[4] Kementerian Pertanian. 2019. Analisis dan Prediksi El-Nino dan La-Nina Tahun 2018/2019. Kementerian Pertanian: Sipetani.

[5] JRC European Comission. 2011. NDWI: Normalized Difference Water Index.

[6] Kementerian Pertanian. 2018. Petunjuk Teknis Pengamatan dan Pelaporan Organisme Pengganggu Tumbuhan dan Dampak Perubahan Iklim (OPT-DPI). Direktorat Jenderal Tanaman Pangan.

[7] Kementerian Pertanian. 2015. Rencana Strategis Kementrian Pertanian Tahun 2015-2019.

[8] Amalo, L. F., Hidayat, R., Sulma, S. 2018. Analysis of Agricultural Drought in East Java using Vegetation Health Index. AGRUVITA Journal of Agricultural Science, 40 (1), 63-73.

[9] Badan Nasional Penganggulangan Bencana. 2011. Indeks Rawan Bencana Indonesia.

[10] Du, T., Bui, D., Nguyen, M. Lee, H. 2018. Satellite-Based, Multi-Indices for Evaluation of Agricultural Droughts in a Highly Dynamic Tropical Catchment, Central Vietnam. Water, 10 (5), 659.

[11] AghaKouchak, A., A. Farahmand, F. S. Melton, J. Teixeira, M. C. Anderson, B. D. Wardlow, C. R. Hain . 2015. Remote sensing of drought: Progress, challenges and opportunities. Rev. Geophys., 53, 452–480.

[12] Putri, D. H., Taqyyudin, Saraswarti, R., Ash-Shidiq, I. P. 2019. Drought Potential of Paddy Field using Temperature Vegetation Dryness Index in Kuningan Regency. E3S Web Conference, 125.

[13] Abdi, S., Rahman, Fadli, Yuwono, D., Bambang. 2018. Pemanfaatan Teknologi Penginderaan Jauh untuk Deteksi Kekeringan Pertanian Menggunakan Metode Normalized Difference Drought Index di Kabupaten Kendal. Jurnal Geografi, 14 (2), 57-65.

[14] Renza, D., Martinez, E., Arquero, A., Sanchez, J. 2010. Drought estimation maps by means of multidate Landsat fused images. In Proceedings of the 30th EARSeL Symposium.