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Drought monitoring using LISAT (LAPAN-IPB Satellite) and Landsat 8 Satellite Imagery in Pakisjaya District, West Java

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Abstract. Drought is a natural hazard indicated by the decreasing of rainfall and water storage in the region and impacting agricultural sector. Recently, satellites data are widely used for calculating the drought indices. Since 2010, Bogor Agricultural University (IPB) and the National Institute of Aeronautics and Space of Indonesia (LAPAN) had launched satellite, called “LISAT” LAPAN-IPB Satellite. The objectives of the research are (1) to compare NDVI values from two different satellites –LISAT and Landsat (2) to analyzed the relationship between climate variability using spatial rainfall data with NDVI values over Pakisjaya District in specific time of study, (3) to validate NDVI derived from LISAT data with field observation. The study area will focus in Pakisjaya District, Karawang, West Java, one of Java agricultural production center. The biggest potentials in Pakisjaya district are agriculture, plantations and fish ponds. Therefore, the identification of drought in Cirebon is expected to be used as an early warning of drought and mitigation measures to reduce the impact of drought on agricultural sustainability. The results showed drought occurrence in 2017 was caused by the shifting of wet season. Wet season that should occurred in January, but from rainfall estimation using CMORPHs, wet season was delayed to April. It is associated with NDVI data derived from LISAT and Landsat 8 results. Highest NDVI was found in April, and the lowest NDVI was found in January. Nevertheless, NDVI value derived from LISAT were low than literature, but generally from the pattern, it can differentiate well different land used observed. Overall, this study can be used as drought mitigation, particularly for the agricultural farmers, so that they can arrange the suitable planting time.

1. Introduction

Drought is a natural hazard indicated by the decreasing of rainfall and water storage in the region and impacting agricultural sector. Drought assessment has been used to monitor agricultural sustainability. Drought indices are commonly used for drought assessment. Recently, satellites data are widely used for calculating the drought indices. Satellite data is an easy, quick, and inexpensive tools in monitoring drought in the regional scale compared to weather data observations.

In this study, Normalized Difference Vegetation Index (NDVI) were conducted to identify drought. Drought can be measured by vegetation condition, whether the vegetation is healthy or unhealthy – suffered from drought. NDVI is calculated by using Near Infrared and red band from LISAT (LAPAN-IPB Satellite) and Landsat 8 Satellite imagery. Lower NDVI indicates healthy vegetation and higher NDVI reflects unhealthy vegetation. Moreover, satellite data then will be compared with climate data (Rainfall) to see the compatibility between satellite and climate data.



The objectives of the research are (1) to compare NDVI values from two different satellites as LISAT is a new launched-satellite, while Landsat is well-established and developed satellite which has been widely used for many scientific researches, (2) to analyzed the relationship between climate variability using spatial rainfall data with NDVI values over Pakisjaya District in specific time of study, (3) to validate NDVI derived from LISAT data with field observation.

2. Methods

2.1. Study site

Pakisjaya district is located at $107^{\circ}05'E - 107^{\circ}E$ and $5.938^{\circ}S - 6.07^{\circ}S$ (figure 1) and have an areal extent of 57,79 km² which covers 8 sub-districts, namely Talagajaya, Telukbuyung, Tanahbaru, Solokan, Tanjungbungin, Tanjungmekar, Tanjungpakis, and Telukjaya sub-districts [1]. The wet season mostly occurs from November to February, while dry season occurs from June to October. The mean annual rainfall over Pakisjaya is about 1806 mm.

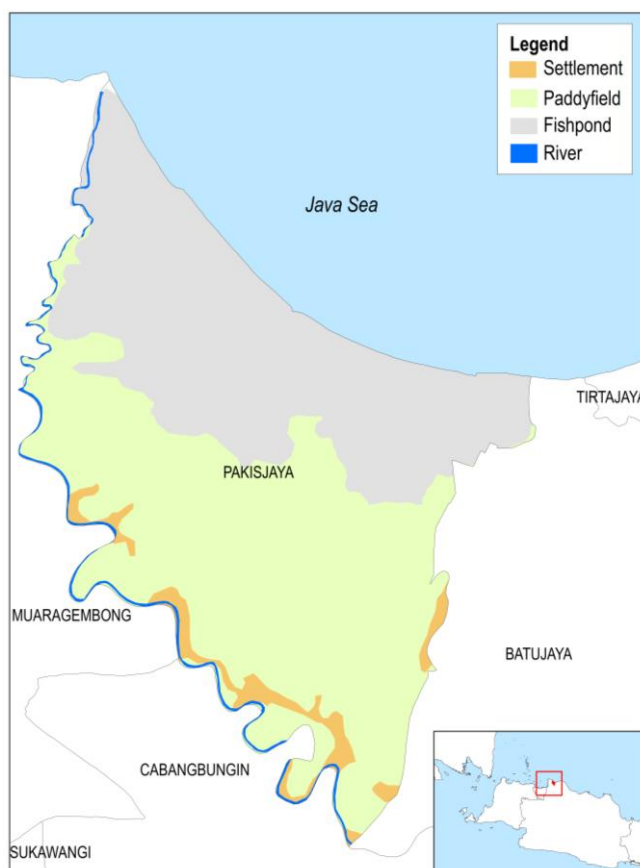


Figure 1. Study area.

2.2. Data background and processing

The LAPAN-A3 satellite, also known as LAPAN-IPB, is a third-generation satellite created by LAPAN as a successor of two previous satellites, LAPAN-A2 (LAPAN-Orari) and LAPAN-A1 (LAPAN-Tubsat) were launched on June 22, 2016, from the Institute of Aeronautics and Space Satish Dhawan Sriharikota, India. This satellite has a weight of about 115 kg, so it can be categorized as a mini satellite because it weights between 100 kg to 1000 kg [2]. The specification of LAPAN-A3 spectral bands are presented in table 1.

Table 1. LAPAN A3/LAPAN-IPB Satellite (LISAT) Spectral Bands.

Bands	Wavelength (micrometers)	Resolution
Band 1 - Near Infrared (NIR)	0.77 – 0.9	18
Band 2 - Red	0.63 – 0.7	18
Band 3 - Green	0.51 – 0.58	18
Band 4 – Blue	0.41 – 0.49	18

Source: Metadata LISAT.

The Landsat 8 mission objective is to provide timely, high-quality visible and infrared images of all landmass and near-coastal areas on the Earth, continually refreshing an existing Landsat database. The specification of LANDSAT 8 TIRS/OLI spectral bands are presented in table 2.

Table 2. LANDSAT 8 TIRS/OLI Spectral Bands.

Landsat 8	Bands	Wavelength (micrometers)	Resolution
Operational Land Imager (OLI)	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
	Band 2 - Blue	0.452 - 0.512	30
	Band 3 - Green	0.533 - 0.590	30
	Band 4 - Red	0.636 - 0.673	30
	Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
	Band 8 - Panchromatic	0.503 - 0.676	15
	Band 9 - Cirrus	1.363 - 1.384	30
Thermal Infrared Sensor (TIRS)	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

Source: <https://landsat.usgs.gov/what-are-band-designations-landsat-satellites>.

NDVI in this study was calculated from radiance value from satellite data [3] and from corrected reflectance value with sun angle. NDVI then calculated using following equation (equation 1)

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red}) \quad (1)$$

CMORPH (CPC MORPHing technique) produces global precipitation analyses at very high spatial and temporal resolution. This technique uses rainfall estimates that have been derived from low orbiter satellite microwave observations exclusively, and whose features are transported via spatial propagation information that is obtained entirely from geostationary satellite IR data [4].

CMORPH data is a high resolution precipitation data provides an overview of estimated precipitation globally so that cropping is needed to obtain data at certain points in accordance with the study area. The estimated rainfall from the global scale CMORPH allows this data to be used directly on a regional scale to estimate local rainfall estimates. Furthermore, rainfall data is interpreted in January, April, September and October in Pakisjaya District and analyzed the influence of climate parameters, namely rainfall. The estimated value of rainfall obtained then will be related to the drought condition from NDVI value derived from LISAT and Landsat 8 satellite data. Research flow is presented in figure 2.

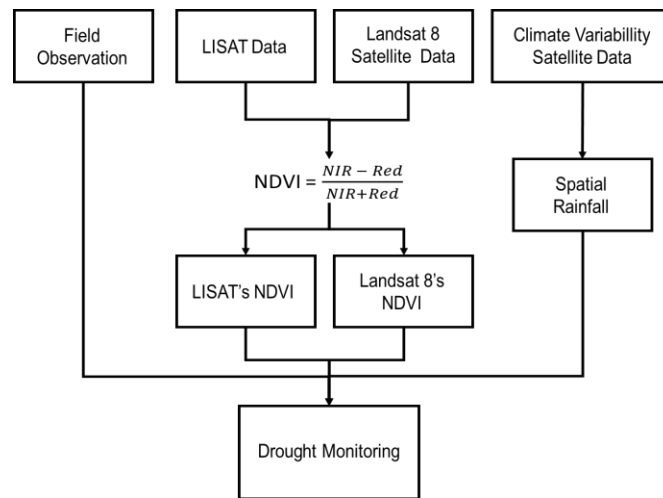


Figure 2. Research flow

3. Result and discussion

3.1. Normalized Difference Vegetation Index

NDVI calculation had been done for drought monitoring. It is important to see if LISAT data result is similar with LANDSAT 8 which there were numerous study using LANDSAT imagery for calculating NDVI [5][6]. NDVI itself can be used as drought monitoring as it is can define the healthiness of vegetation. Low value means unhealthy vegetation which is drought might be occurring, while high value represents healthy vegetation (no drought occurrence). The results showed, generally NDVI from both Landsat 8 and LISAT satellite data had similar spatial data map pattern except in April, LISAT data had low NDVI value in the center of Pakisjaya District compare to Landsat 8 (figure 4). Relatively the value range of NDVI of all months were not too different. On January, the value was ranging between -0.15 to 0.48 and -0.7 to 0.39, for Landsat 8 and LISAT data respectively. Based on the map (figure 3), NDVI for both data satellite was relatively the same. Mainly, NDVI data on January was low in entire Pakisjaya District.

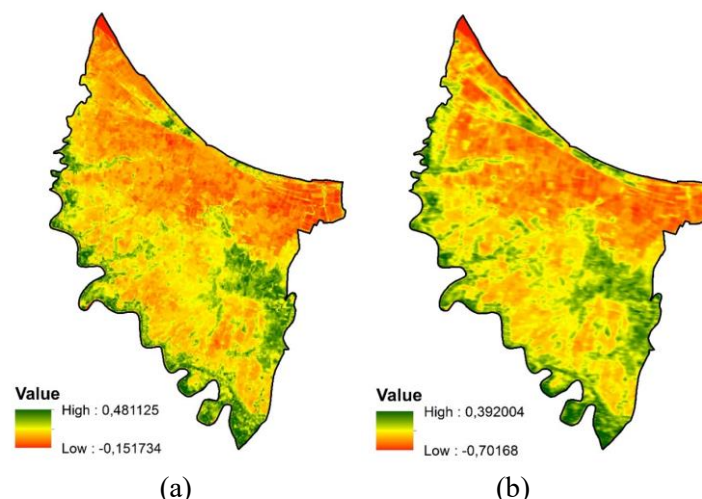


Figure 3. Map of NDVI derived from (a) Landsat 8 on January 24th 2017 and (b) LISAT on January 31st 2017.

While NDVI on April 2017 was showed different value from January. Mostly, both Maps from Landsat 8 and LISAT appeared to have higher NDVI value than January 2017. The paddy field area also had high NDVI value reached 0.54 and 0.51, from Landsat 8 and LISAT respectively. Paddy field area

that affected by drought before (January 2017), were seen unaffected drought (Area was covered with green color). The difference between Landsat and LISAT data, was that Landsat 8 had more green area compared to LISAT (figure 4). Gap of acquisition time could be the reason, where acquisition time for Landsat 8 was April 30th 2017, while LISAT April 4th 2017.

NDVI value on October 2017 generally had lower NDVI value than April 2017. The value was ranging between -0.097 to 0.467 and -0.666 to 0.406 for Landsat 8 and LISAT respectively (figure 5). On October, the spatial maps are also showing similar pattern of NDVI value. Only NDVI derived from Landsat 8 data which had area affected by drought in paddy field area in West part of Pakisjaya District.

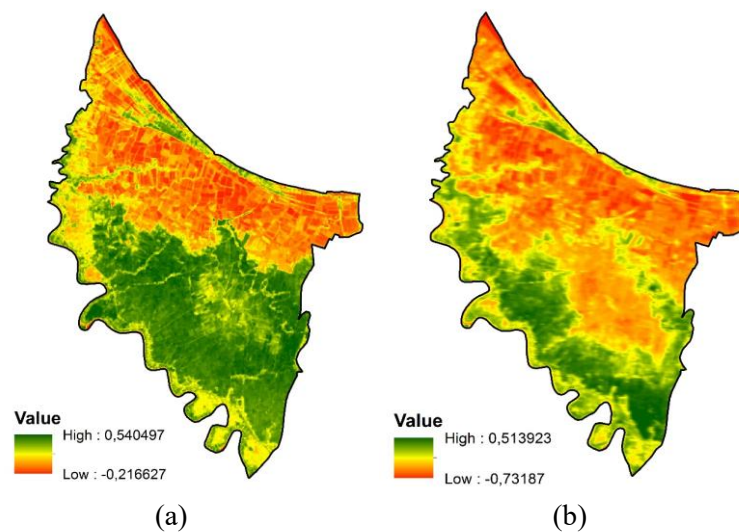


Figure 4. Map of NDVI derived from (a) Landsat 8 on April 30th 2017 and (b) LISAT on April 4th 2017.

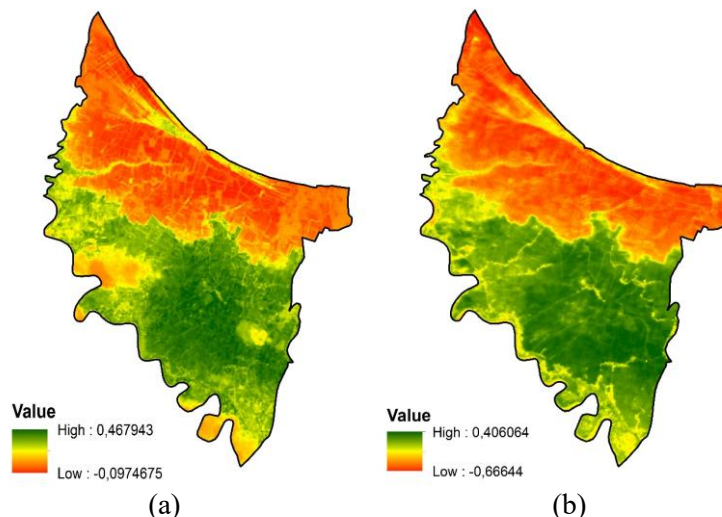


Figure 5. Map of NDVI derived from (a) Landsat 8 on April 30th 2017 and (b) LISAT on October 11th 2017.

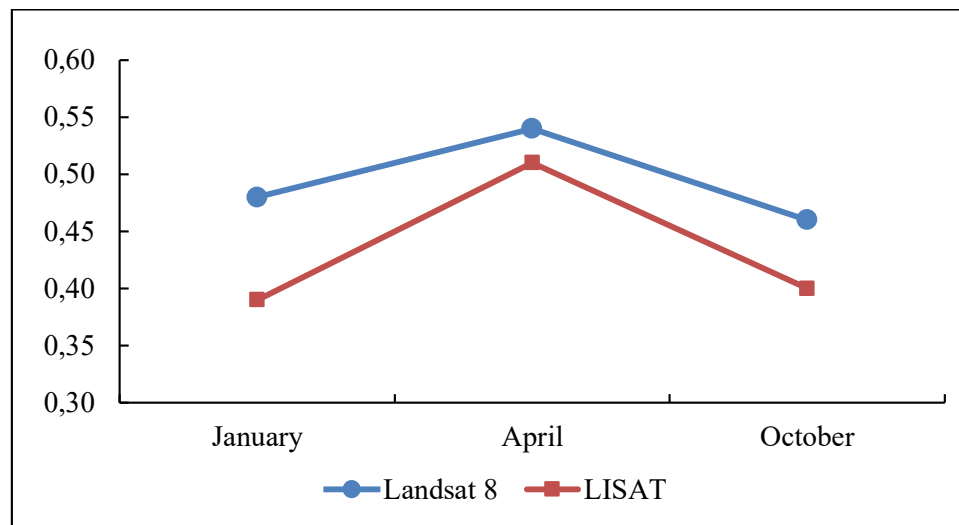


Figure 6. NDVI Value on January, April, and October derived from Landsat 8 and LISAT.

The graph above (figure 6), summarizes NDVI Value derived from Landsat 8 and LISAT on January, April, and October 2017. From January to April, both NDVI value from Landsat 8 and LISAT had increased, and slightly decreased from April to October.

3.2. Climate Study in Pakisjaya District

CMORPH data obtained from research was downsampled to Java Island and will focus on studying the Pakisjaya District. The time study is taken in December and January which represent wet season, April which represents the transition season from rainy to dry season, while September and October represents the transition of dry to wet season.

In January, the result of CMORHP model showed rainfall average of 4 mm/day where this value is classified as low rainfall and quite dry where usually January has high rainfall (figure 10a). But this result associated with NDVI value from satellite data (figure 3) which has lower ranges of NDVI value than other month.

While in April, which categorized as transition season, was showing a rainfall value amounted as 5 mm/day obtained from the estimated CMORPH (figure 7c). From literature, this month should have transitioned from wet season to dry season but from the estimated rainfall, it showed higher rainfall value compared to January. Rainfall had been shifted starting into April not January. In September and October, the value of rainfall had been decreased into 3 mm/day (figure 7d and 7e). This is also in accordance with the drought occurrence from October's NDVI value of Landsat 8 and LISAT which produced a smaller value than the other months (figure 5).

3.3. Data Validation

Observation was done to validate data produced by satellite imagery with field observation. Table 3 presents observation condition and its NDVI value to see the likeness between NDVI derived from LISAT and field condition. LISAT data was used for the validation because still few users to study about LISAT, therefore, validation is important to analyzed if LISAT data was accurate to the real condition. Observation was done in September 2018. Land in Pakisjaya mostly covered by Paddy field and Fishpond area, therefore, for this observation we classified three different types of land use, namely Paddy field –wet and dry condition and fishpond (figure 8).

NDVI values from LISAT data from observation points were categorized as low NDVI (0.1 or less) [6]. Although all value was low, but from the pattern, it can differentiate well different land used observed. Namely, wet paddy field had the highest NDVI among other land cover, then dry paddy field,

and lastly fishpond. Dry paddy field and fish pond had no literally green leaf, therefore, NDVI value were very low (for water in NDVI reach minus value).

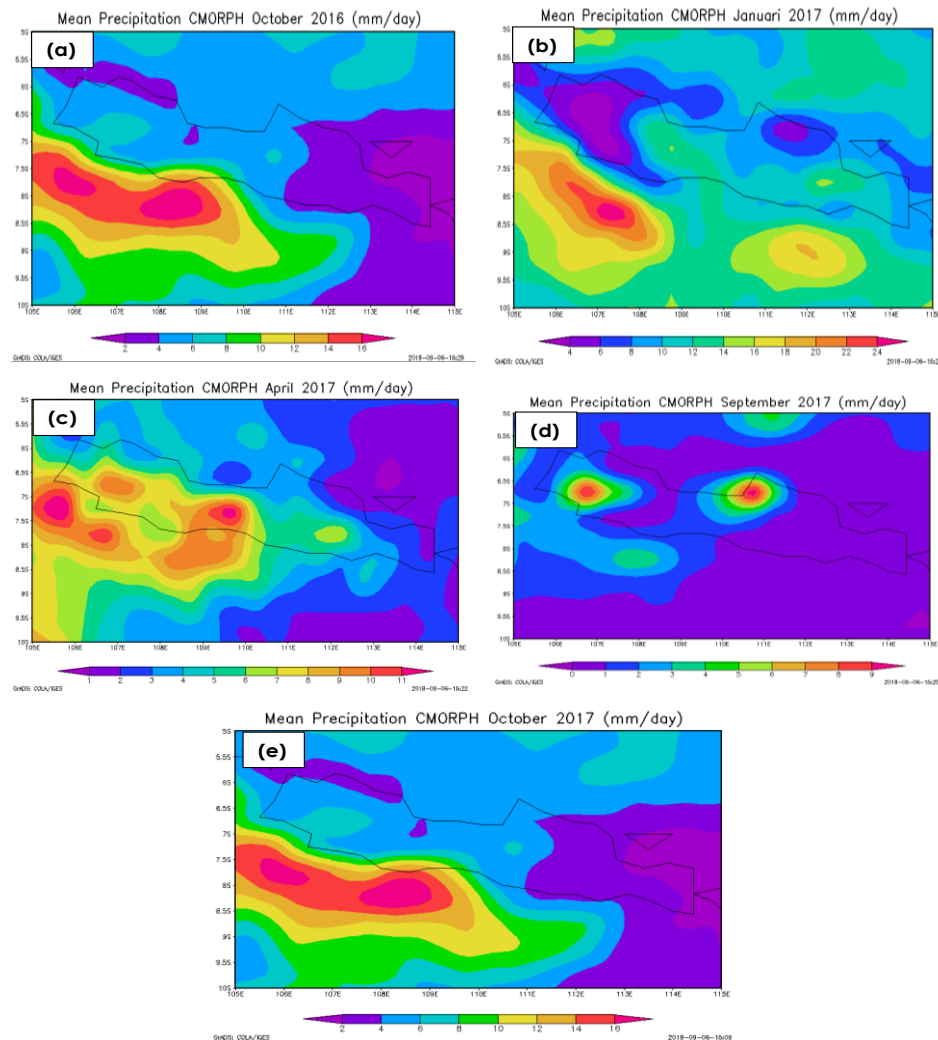


Figure 7. Mean Precipitation Spatial Data in Java Island.

Table 3. Field observation condition in October 2018 and LISAT's NDVI Value.

Latitude	Longitude	Observation Condition	NDVI Value
-6.010340438	107.098665722	Wet Paddy field	-0.088251
-5.9862225	107.0881031	Wet Paddy field	-0.099926
-5.9906387	107.0870436	Wet Paddy field	-0.090636
-5.983281	107.101246	Dry Paddy field	-0.26043
-5.983426	107.1009	Dry Paddy field	-0.263816
-5.9827391	107.09824	Fishpond	-0.258054
-5.9826783	107.1009137	Fishpond	-0.256523

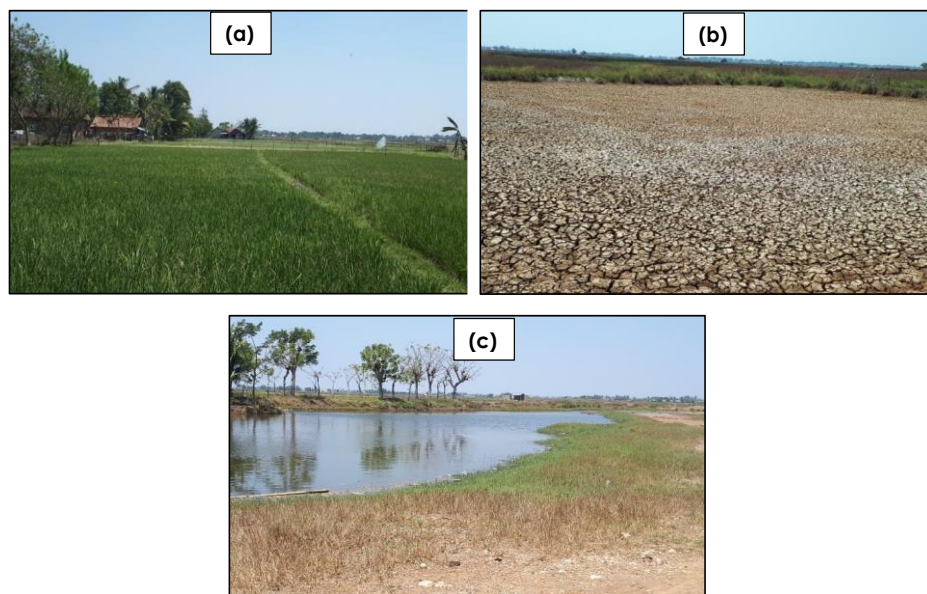


Figure 8. Field condition in Pakisjaya District (a) Wet Paddy field, (b) Dry Paddy Field, (c) Fishpond

4. Conclusion

Drought occurrence in 2017, from the study results, was caused by the shifting of wet season. Wet season that should occurred in January, but from rainfall estimation using CMORPHs, wet season was delayed to April. It is associated with NDVI data derived from LISAT and Landsat 8 results. Highest NDVI was found in April, and the lowest NDVI was found in January. Nevertheless, NDVI value derived from LISAT were low than literature, but generally from the pattern, it can differentiate well different land used observed. Therefore, normalization on LISAT imagery is needed for further study to increase the accuracy. Overall, this study can be used as drought mitigation, particularly for the agricultural farmers, so that they can arrange the suitable planting time.

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