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Space-based drought analysis to support agricultural insurance facing climate change

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Abstract. The long drought experienced in Indonesia in the past was identified as one of the main factors in the failure of rice production. The application of rice crop insurance was introduced since 2015 to help rice farmers who suffered from farm damage. The claim was increased year by year, with the highest in 2018-2019 (12,253 ha). The main problem associated with the insurance claim is the delay of inspection of the drought-affected land. Meanwhile, various satellite data can provide relevant information more quickly for those affected areas. The purpose of this study is to examine the potential use of satellite data to detect drought to support the rice crop insurance program. Daily and monthly rainfall data derived from the Tropical Rainfall Measuring Mission (TRMM), Global Satellite Mapping of Precipitation (GSMaP) and Multifunctional Transport Satellites (MTSAT) were analyzed to identify meteorological drought. Agricultural drought is studied through the character of several indices from Moderate Resolution Imaging Spectroradiometer (MODIS) data. Preliminary results showed that up to 89.45% of the analysis comformed with field conditions. Satellite data has its potential to be utilized in the identification of claims on agricultural insurance which requires information on land damage due to drought.

1. Introduction

Agricultural activities, especially rice crop is always confronted with a high risk of uncertainty, such as harvesting failure due to climate change caused by, for instance flood or drought leading to a considerable farmer’s loss. Global climate change is a disadvantage for farmers. In this regard, agricultural insurance is one of the policy instruments that could meet the farmer’s interests, a tool to prevent farmers from harvest failure and a program to educate the farmers on agricultural risk management. Insurance is one of the tools that farmers and other stakeholders can use to manage risks that are too large to manage on their own [1]. To this point, Dick and Wang [2] indicate that there was an increasing interest of both the private sector and the government in risk management and insurance to promote agricultural investments.

Drought is especially a strong threat to the rice crop. With previous experience on the negative impact of drought for farmers, the government, since 2015 applies rice crop insurance scheme (*Asuransi Usaha Tani Padi*/AUTP) to protect the farmers from farm damage caused by natural disasters. AUTP scheme is expected to help farmers from such uncertainty and ensure them to continue their activity on their farm field with sufficient initial capital obtained from an insurance claim.

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Under the AUTP scheme, risks to be covered are (a) flood, which is water inundation to rice farmland during the growth of rice plants over some time, causing crop damage; (b) drought, which is insufficient required water during the growth of rice plants, also causing damage; and (c) pests and disease, which are organisms that attack, damage, interfere with growth, or cause harvest failure. A claim is defined as damage to rice plants caused by insured perils, when equal to or more than 75% of the total acreage of any one rice plot is damaged. Upon completing the assessment on claim reports, the insurance company issues a letter of approval. Payment of claims will be made within 14 working days upon such approval. Site inspection is carried out by insured farmers and insurers, together with local agriculture officers. Damage is determined, based on which a claim report is prepared and submitted [3]. Obstacles frequently occurred during the site inspection period. It was experienced that many times the insurer represented by the company's loss adjuster and the agriculture officer did not well performed, shortage of available human resource has causing late site inspection which bring a disadvantage for the farmers. Therefore, the applied technology to help accelerate the inspection of the damage field is highly required.

Remote sensing technology offers a suitable solution for such a problem. With the ability to record a large region periodically and within a short period, this technology could be well applied to detect drought area at remote regions or sites with poor accessibility and difficult to reach by land. Phase identification of combined image of temporal and spatial high resolution could spot such drought regions.

There are several data and analyses to be used for this purpose. To analyze plants with drought impact, the satellite image of MODIS Terra could be used with high temporal resolution, namely daily that could be employed to detect larger area and integrated with high spatial resolution image, Landsat-8 (30 m). Meanwhile, drought analysis on the meteorology approach could use the daily and monthly rainfall data derived from TRMM and GSMap and MSTST [4].

This paper is intended to discuss the identification of drought using satellite imagery to help agricultural insurance stakeholders to detect drought field regions. More specifically, this paper also describes that this technology would be useful to identify damage farm area which is required in the claim mechanism of the crop insurance scheme. From a management point of view, this method would be very helpful in managing human resources and time spent an on-site visit for inspection purposes to allow a faster process of the insurance claim procedure.

2. Materials and methods

2.1. Study location

The study location is Java Island which astronomically laid between 113°48'10" to 113°48'26"E (Longitude) and 7°50'10" to 7°56'41"S (Latitude). It is positioned at an equatorial rain belt making this island has a tropical climate with high-level characteristics of rainfall, temperature and humidity. Two seasons are experienced by this island, which is rainy season which normally occurs from December to March and the dry season from May to October. Java is the main rice producer of more than 60% of the national production. The size of the wetland paddy area is about 3,473,396 ha or 46.54% of the total wetland paddy area in Indonesia [5].

Drought frequently occur in Java. Based on Meteorology, Climatology and Geophysical Agency (*Badan Meteorologi, Klimatologi, dan Geofisika*/BMKG) data, from September-October 2018 to February 2019, El-Nino was experienced by this region although it was categorized as weak to moderate level. However, even with the drought was in normal condition, its impact would spreading throughout the island, from Banten, West Java, Central Java, DI Yogyakarta to East Java Provinces. During the second week of August 2018, drought has been stricken in many regions in Indonesia. Several regions have experienced a condition without extreme rain or no rain for more than 60 days. A thousand hectares of wetland in several regions of East Java, Central Java, West Java and DI Yogyakarta were suffered from such drought led to harvest failure due to a shortage of water supply [6].

2.2. Data and methods

Droughts are generally classified into four categories, namely meteorological, agricultural, hydrological and socio-economic droughts [7]. In this paper, 2 types of drought were used, meteorological and agricultural droughts. This is because the two types are considered as the basis for determining drought in agricultural insurance.

Two sources of analysis data are used in this paper, namely (1) Monthly Drought Index Map of Satellite-based Drought Monitoring and Early Warning System - Indonesia obtained from University of Tokyo, Japan [8] and (2) Android-based National Monitoring System (*Sipandora*) from *Lembaga Penerbangan dan Antariksa Nasional* (LAPAN) [9]. The images used on Satellite-based Drought Monitoring and Early Warning System are MODIS images, MTSAT, GSMaP, while on *Sipandora* are Terra/MODIS images, rainfall data (CH) of Tropical Rainfall Measuring Mission/TRMM data [10] and Himawari-8 satellite data [11]. The consideration of using these data sources is that KBDI and SPI can identify the level of meteorological drought derived from satellite imagery. Meanwhile, VCI, VHI, TCI and EVI can identify agricultural drought.

The method used on Satellite-based Drought Monitoring and Early Warning System (University of Tokyo, Japan) [8] are:

- Meteorological droughts (daily in 4 km)
  - GSMaP SPI (calculated from rainfall data derived from satellite data)
  - MTSAT KBDI (obtained from rainfall + land surface temperature)
- Agricultural droughts (16 days in 250m)
  - MODIS VCI (vegetation index) associates with vegetation moisture condition. The formula referred to [12]:

$$VCI = 100x\frac{EVI - EVI_{min}}{EVI_{max} - EVI_{min}}$$

  - MODIS TCI (thermal index) associates with vegetation thermal condition [11]:

$$TCI = 100x\frac{LST_{max} - LST}{LST_{max} - LST_{min}}$$

  - MODIS VHI (vegetation + thermal index) represent overall vegetation health condition [13]:

$$VHI = 0.5(VCI + TCI)$$

Meanwhile for *Sipandora* (LAPAN), the method used are [9]:

- Enhanced Vegetation Index (EVI) related to the condition of the greenish of plants [13]:

$$EVI = Gx\frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + (C_1 x\rho_{red} - C_2\rho_{blue}) + L}$$

where: $\rho_{nir/red/blue}$ are atmospherically-corrected or partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectance, L is the canopy background adjustment that addresses non-linear, differential NIR and red radiant transfer through a canopy and C1, C2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. The coefficients adopted in the MODIS-EVI algorithm are; L=1, C1 = 6, C2 = 7.5 and G (gain factor) = 2.5.

- Processing of actual evapotranspiration value (ETa) is derived from EVI data and Land Surface Temperature/LST.
- The processing of land moisture value (KL) or ground water content is derived from reflectance of NIR and LST band.
- Information on drought insecurity of wetland area is obtained from the combination of meteorological drought (KM = CH/ETa), agricultural drought (KA = EVI/LST) and hydrological drought (KL).

3. Results and discussion

3.1. Drought event

Formally applied in 2015, rice crop insurance has been gradually accepted by the farmers. During the planting season when the crop insurance introduced and applied up to 2019/2020, the drought experienced by the farmers due to El-Nino was categorized as strong and weak, namely 2015/2016 (strong) and 2018/2019 and 2019/2020 (weak). Therefore, the drought analysis used in this paper is the image analyses of 2015, 2018, 2019 and 2020.

Table 1. El Nino and their intensities by year of events [13].

El Nino			
Weak-12	Moderate-7	Strong-5	Very Strong-3
1952-53	1951-52	1957-58	1982-83
1953-54	1963-64	1965-66	1997-98
1958-59	1968-69	1972-73	2015-16
1969-70	1986-87	1987-88	
1976-77	1994-95	1991-92	
1977-78	2002-03		
1979-80	2009-10		
2004-05			
2006-07			
2014-15			
2018-19			
2019-20			

Drought events based on data obtained from the Directorate of Plant Protection, Ministry of Agriculture are shown in figure 1 [14]. In 2015, there was a strong category of El Nino affecting drought condition of crops in a quite large size, i.e., 246,209 ha. Crop failure out of this figure was 80,665 ha. Meanwhile, in 2018 and 2019 weak category of El Nino was occurred. In 2018, El Nino has affected about 119,838 ha of crop land with crop failure around 22,085 ha. Similarly, in 2019, around 227,551 ha was affected by 80,180 ha of crop failure.

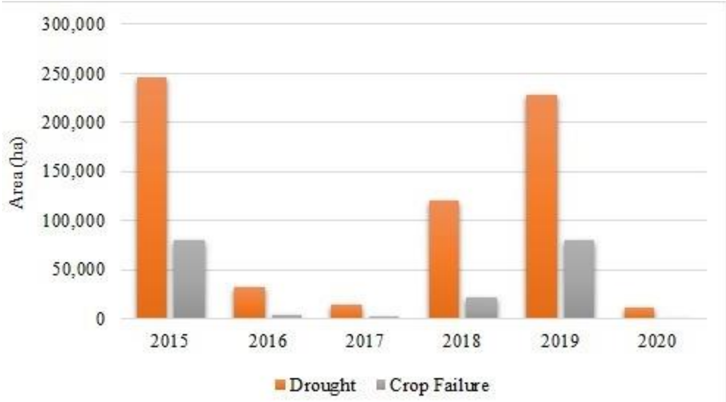

Figure 1. Area affected by drought, 2015 – 2020 [15].

3.2. Agricultural insurance

Based on claimed data of 2018 as illustrated in table 2, the strongest risk on crop field was performed by the drought as compared to flood and pest and disease infestations. The larger the area insured also indicate the larger area affected by the drought. In 2018, East Java Province and West Java Province showed such situation. The farmers of the two provinces also filed the highest claim from the occurrence of drought (44.33% in total). A similar situation also learned in 2019 where the crop was suffered from drought with farmer's claim up to 66.36% in total. However, the situation was different in 2020 with the attack of pests and disease was dominating the filed claim (64.60% in total).

Table 2. Agricultural area insured and claimed in 2015, 2018, 2019 and 2020 [16].

Province	Year	Wetland area insured	Flood	Drought	Pest and Disease	Total claimed
		-- (ha) --				
Banten	2018	4,968.84	103.90	143.98	121.69	369.57
West Java		131,376.55	191.38	648.08	590.37	1,429.82
Central Java		85,639.69	464.16	345.34	206.96	1,016.46
DI Yogyakarta		1,504.53	0.00	0.00	3.16	3.16
East Java		390,696.27	565.78	963.76	390.92	1,920.45
Total		614,185.88	1,325.21	2,101.16	1,313.08	4,739.45
Percentage (%)			27.96	44.33	27.71	100.00
Banten	2019	13,715.34	24.70	579.45	63.60	667.75
West Java		127,174.84	9.42	4,638.82	1,225.30	5,873.55
Central Java		59,847.97	673.79	1,353.60	163.94	2,191.33
DI Yogyakarta		2,532.42	599.18	0.00	0.00	599.18
East Java		488,000.06	480.87	1,031.34	614.11	2,126.32
Total		691,270.63	1,787.96	7,603.22	2,066.95	11,458.12
Percentage (%)			15.60	66.36	18.04	100.00
Banten	2020	2,252.80	20.95	0.00	74.85	95.80
West Java		66,855.85	600.28	58.37	606.33	1,264.98
Central Java		95,826.29	73.52	40.52	169.87	283.90
DI Yogyakarta		1,641.88	9.14	0.00	9.76	18.90
East Java		329,498.33	71.57	49.58	825.49	946.64
Total		496,075.15	775.45	148.47	1,686.30	2,610.22
Percentage (%)			29.71	5.69	64.60	100.00

The data shown in the table indicate that the drought event need to be thoroughly considered in the formulation of policy for farmers to adapt to such a condition. From the insurance point of view, to visit the scattered area of drought in each province would be a major problem. The insurance company need to have sufficient personnel to make spot inspection at each region hit by the drought to ensure the insured claim area. This would be more critical when the events occur at almost the same time. Therefore, the use of satellite data technology should ease the company to approve and set the claim and with a significantly shorter period. The insurance company may not need to hire more personnel as a field loss adjuster and similarly, the local government officer need not to visit the field only for such activity.

If the satellite technology would be applied to support agricultural insurance, specifically in monitoring the events (flood, drought, or pest and disease infestation) on the crop, a simpler procedure needs to be prepared. Socialization, promotion and advocation to use such technology along with hands-on practices in various training is highly suggested. The local agricultural officers may take the advantage to lead such activities and working closely with other stakeholders at the central level and local level.

3.3. Drought analysis

Remote sensing-based drought data used in this analysis was a meteorological drought or SPI and agricultural drought from *Sipandora* (LAPAN) [9]. Based on drought data as the result of image satellite analysis shown in table 3, it revealed that in 2020, the intensity of claim was 52.94% for the period of April-September occurred in Central Java, followed by West Java at 35.29% and East Java at 11.76%. This is supported by the data shown in figure 2, in which the meteorological drought was started to occur in the month of April 2020 in the Central Java region. In the West Java region, this was happened to start from May and from June for East Java. Moreover, as indicated by table 4, the meteorological drought occurred in a wide area each in East Java, Central Java and West Java.

Table 3. Claim intensity, 2018 - 2020 [16].

Year	Province	Claim Intensity				
		Total	Apr-Sep		Oct-Mar	
			Intensity	%	Intensity	%
2018	Banten	34	33	8.40	1	2.63
	West Java	163	141	35.88	22	57.89
	Central Java	57	43	10.94	14	36.84
	DI Yogyakarta	0.00	0.00	0.00	0.00	0.00
	East Java	177	176	44.78	1	2.63
		431	393	91.18**)	38	8.82**)
2019	Banten	170	166	12.87	4	8.16
	West Java	682	652	50.54	30	61.22
	Central Java	235	228	17.67	7	14.29
	DI Yogyakarta	0.00	0.00	0.00	0.00	0.00
	East Java	252	244	18.91	8	16.33
		1,339	1,290	96.34**)	49	3.66**)
2020*)	Banten	0.00	0.00	0.00	0.00	0.00
	West Java	12	12	35.29	0.00	0.00
	Central Java	20	18	52.94	2	50.00
	DI Yogyakarta	0.00	0.00	0.00	0.00	0.00
	East Java	6	4	11.76	2	50.00
		38	**34**	**89.47**)**	**4**	**10.53**)**

Notes: *) claim data up to 30 August 2020, **) Percentage of total claims

Table 4. Meteorological drought area in June 2020 based on remote sensing analysis.

Province	Strong	Moderate	Weak	Total
		-- (ha) --		
Banten		409	201,664	202,072
West Java		719,835	2,457,499	3,177,335
Central Java	36,365	1,269,322	2,085,618	3,391,304
DI Yogyakarta		56,299	254,491	310,790
East Java	1,629,165	2,775,810	207,703	4,612,678

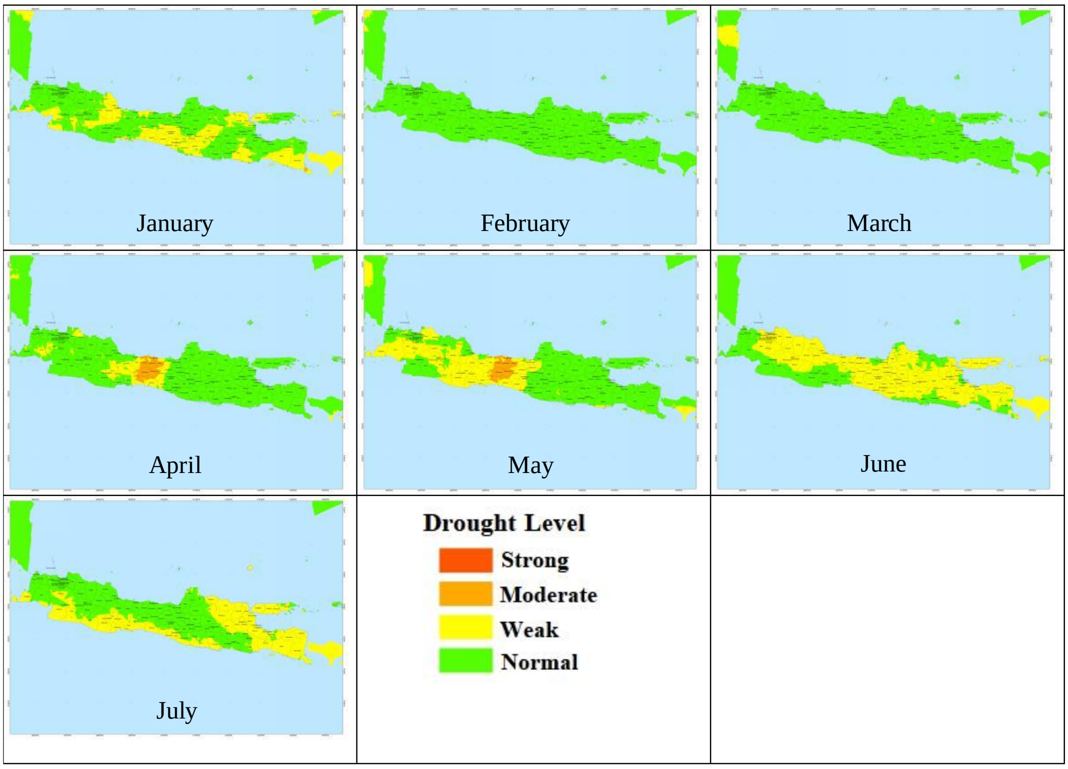

Figure 2. Dispersion of meteorological drought level in 2020 in Java based on SPI MODIS Terra data. [9]

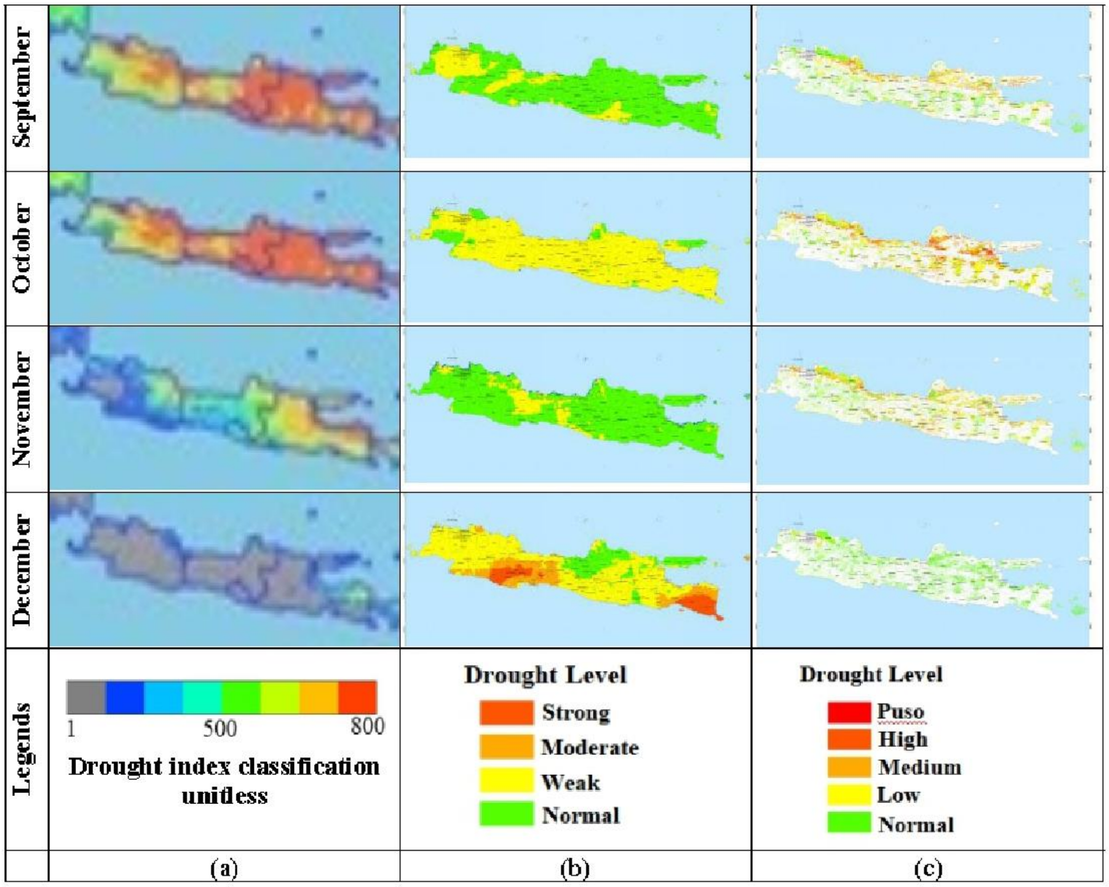

Figure 3. Comparison of meteorological drought level in 2018 in Java based on KBDI (a) [8] SPI (b) [9] and Agricultural drought level (c) [9].

Figure 3 shows the comparison of meteorological drought based on KBDI and SPI analysis and agricultural drought analysis in September 2018. Of the meteorological drought analysis, the area of agricultural land affected by the drought phenomenon could not be well-identified. This is because the meteorological drought is based on the rainfall events and, therefore another approach is required to identify drought affecting the plants, i.e., agriculture drought. MODIS Terra data with daily temporal resolution could be used to obtain those data. This information is required to be applied in agricultural insurance practices for specifically claim calculation. Figure 4 indicates agricultural drought analysis in April-September 2019. This information could be used to study the agricultural land area affected by drought within the April-September planting season which is 96.34% of agricultural insurance claims due to drought occurred in this period (table 3). Important to note that although meteorological drought may not suitable for indemnity-based agricultural insurance, however, such meteorological drought analysis could be well applied in an index-based agricultural insurance scheme.

The location affected by drought is taken based on administrative boundaries. The accuracy inspection of the truly affected land based on the drought analysis using satellite images was conducted on this location at which the claim is filed. The analysis would not be made based on the area planted because not all farmers apply the insurance product (not all land is insured). According to the accuracy assessment as shown in table 5, the result of drought image analysis at locations where farmers propose insurance claim show the accuracy up to 89.45%. Drought data sources utilize the data that is freely available on the website of the competent institution. The satellite data used prioritizes the high temporal resolution compared to spatial, such as MODIS. Since weather information requires data frequencies, low cost or free data is applied. The drought information is useful to learn certain areas affected by drought within a wider area. After knowing the drought-affected areas, further analysis is still needed for more detailed information using satellite imagery with higher spatial resolution, such as Landsat and Sentinel. To obtain better results, the position of the specified land must be accompanied by coordinates information (latitude, longitude) which can be taken from an open camera.

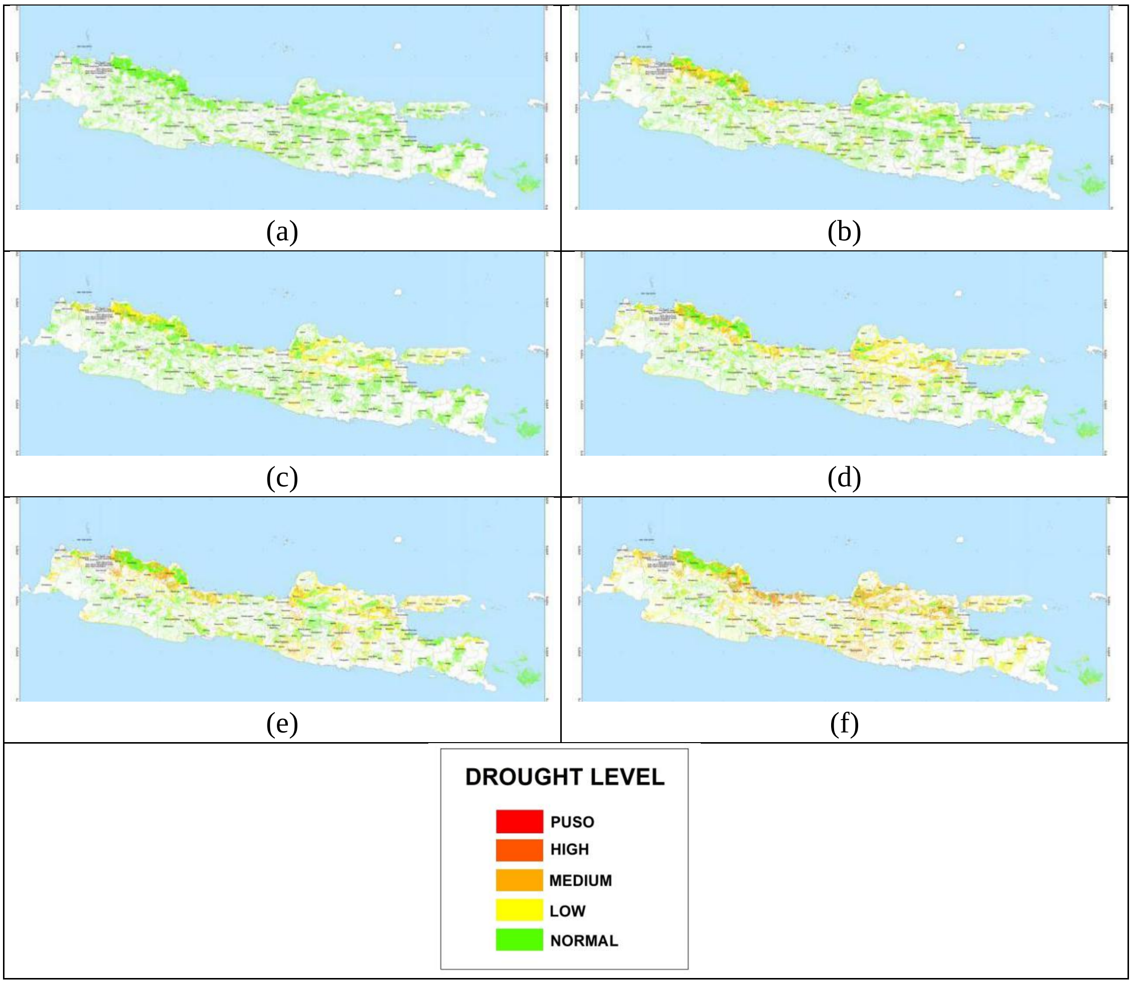

Figure 4. Agricultural drought in Java in 2019 derived from MODIS Terra data in April (a), May (b), June (c), July (d), August (e) and September (f) [9].

Table 5. Accuracy assessment image analysis results based on field data, 2018-2020.

Description	2018	2019	2020*
Total claim	393	1,339	38
Match with image analysis	276	1,199	25
Percentage (%)	70.23	89.54	65.79

Note: *) claim data up to 30 August 2020

4. Conclusions and policy implication

4.1. Conclusions

Drought is one of the unfavorable weather conditions when growing crop like paddy. Adaptation to this condition is required to maintain rice production. As staple food for most of Indonesian, response to prevent farmers from great loss due to harvest failure caused by drought is necessary. In this regard, rice crop insurance is applied to cover the crop risk of farm damage or harvest failure.

The remote sensing satellite data has the potential to be used in agricultural insurance practices. Its application is especially regarding to determination of land area damage for an insurance claim. On accuracy assessment, the satellite image data could provide the accuracy analysis up to 89.45%. Faster results obtained from such analysis could improve the claim mechanism of the insurance scheme, specifically on the determination and approval of filed claims that support the overall agricultural insurance program.

Several methods that could be used for the same objectives, as offered in website, namely global agricultural and meteorological drought information which could provide area affected by drought by regions. The closest information for practical use is agricultural drought information.

4.2. Policy implication

A more efficient way on field inspection within claim mechanism, a procedure to determine the area affected by drought or area of harvest failure with the stipulated value of risk to be paid to the farmers, is introduced through the use of satellite image data. The government and the insurance company are suggested to consider the use of this technology for application efficiency. Detail of application should be provided to support policy decisions made by relevant stakeholders.

The advantage of using this technology, mainly due to the concern of unavailability of human resource to visit the field for ground checking to determine the drought area affected or crop failure. Saving time using this procedure could be another advantage. Satellite images data could be well interpreted with high accuracy to determine the amount of payment of insurance claim. Payment for farmers could be faster as compared to the conventional procedure (physical field visit).

The satellite data to detect drought in support rice crop insurance program is now available. Although agronomical information is better for practical use, however, at this point, the daily and monthly rainfall data derived from TRMM and GSMaP, MTSAT and AMSR-E could be used to identify meteorological drought. Amid the global climate change, the use of satellite data is, therefore recommended to support crop insurance application. For practical use, increasing accuracy of the analysis is required by using a more detailed image resolution, both spatial and temporal, such as Landsat-8 and Sentinel-2 images. Further study on this issue is strongly suggested.

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