# AN EFFECTIVE INFORMATION SYSTEM OF DROUGHT IMPACT ON RICE PRODUCTION BASED ON REMOTE SENSING

**Rizatus Shofiyati[1]*, Wataru Takeuchi[2], Soni Darmawan[3], and Parwati Sofan[3]**
[1] Indonesian Center for Agricultural Land Resources Research and Development (ICALRD)
[2] University of Tokyo, Japan
[3] Indonesian National Institute of Aeronautics and Space (LAPAN)
*e-mail: rshofiyati@litbang.deptan.go.id or rshofiyati@yahoo.com

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**Abstract.** Long droughts experienced in the past are identified as one of the main factors in the failure of rice production. In this regard, special attention to monitor the condition is encouraged to reduce the damage. Currently, various satellite data and approaches can withdraw valuable information for monitoring and anticipating drought hazards. MODIS, MTSAT, AMSR-E, TRMM and GSMaP have been used in this activity. Meteorological drought index (SPI) of the daily and monthly rainfall data from TRMM and GSMaP have analyzed for last 10-year period. While, agronomic drought index has been studied by observing the character of some indices (EVI, VCI, VHI, LST, and NDVI) of sixteen-day and monthly MODIS, MTSAT, and AMSR-E data at a period of 4 years. Network for satellite data transfer has been built between LAPAN (data provider), ICALRD (implementer), IAARD Cloud Computing, University of Tokyo (technical supporter), and NASA. Two information system have been developed: 1) agricultural drought using the model developed by LAPAN, and 2) meteorological drought developed by Takeuchi (University of Tokyo).The accuracy study using quantitative method for LAPAN model uses VHI is 60% (Kappa 0,44), while that of for University of Tokyo model uses qualitative model with KBDI value 500-600 shows an early indication of drought for paddy field. This will help the government or field officers in rapid management actions for the indicated drought area.This paper describes the implementation and dissemination of drought impact monitoring model on the area of rice production center using an integrated information system satellite based model. The two developed information systems are effective for spatially dissemination of drought information.

Keywords: *Drought, Rice production, Satellite remote sensing, Information system*

## 1 INTRODUCTION

Historical record of precipitation shows that Indonesia have been occured frequentlyby drought disater in recent years. As recorded, droughts have occurred in 1997, caused by the El Niño (Puterbaugh, 1997), also in 1987 (Pusat Penelitian Tanah, 1989), and 1972, 1977, 1982, 1987, 1991 and 1994 (Pasandaran and Hermanto, 1997). The 1997-1998 El Niño was the strongest in this century, and during this period Indonesia experienced a serious drought as reported by the World Meteorological Organization (Gathara *et al.*, 2006; FAO-The United Nation, 1998). Boer and Subbiah (2005) reported that since 1844 to 2009, there have been 47 El-Nino events cause droughts. This happens more often since 2002, specifically in every two years (Makmur, 2009), as possibly due to impact of climate change. As reported by BNPB (2013), from year 2000 to 2007, drought occured 960 times.

Amount of rainfall and its distribution, through its contribution to the availability of water in the soil, greatly affect the growth and production of crops. Crop failure as a result of climate change, may occur. The decline in production due to the planting schedule backwards or do not fit as usual. Most areas retreated to the dry season, many areas experiencing water scarcity, crop failures can lead to prolonged which also causes food supplies become very uncertain. Effect on agriculture, specifically rice production in Asia can take large toll due to drought impact if appropriate and timely actions are not planned. In 2011, in Indonesia agricultural area that suffered by drought is around 1,624,260 ha.Long drought in 1997/98 resulted in a decrease of 6.5% rice production resulted government forcing to import 3 million tons of rice in 1998 (BPS, 1998). Analysis based on ground rainfall data (BMKG, 2012) and crop calendar analysis (IAARD, 2012) showed that in 2012 the drought 74 out of 118 districts in Java Island had high to severe drought vulnerability. According to the data of Directorate General of Food Crops, Ministry of Agriculture, the drought in 2012 had affected almost all of the paddy fields in Java Island. In this 2012, the widest drought suffered West Java area of 18,619 ha with 111 ha of harvest failure, followed by East Java area of 11,155 ha with 996 ha of harvest failure, Central Java drought level reached 7,568 ha with area of 23 ha of harvest failure level. Based on Statistic data year 1993 – 2012 provided by BPS (2013), actual planting area of paddy in 2012 is 1.53 million ha in Wet Season (WS) and 1.02 million ha in 1st Dry Season (DS).

Though drought is a gradual disaster, drought can cause devastating effects on agriculture and water supplies, but monitoring and forecasting can allow people to take necessary action to avert possible destruction. In this regard, an early warning of onset of a drought would be very useful in the planning of agricultural development settings. To this point, monitoring techniques using appropriate tools, such as space based technologies to find out actual ground surface information in relatively short time are very important. Further, analysis of such data and information would be incorporated in the current agricultural development planning to reduce possible risks on crops. Web-GIS based system is usefull to deliver the information of drought.

This paper is explain assessment of the use of satellite data for monitoring the drought condition of rice field in near real time and disseminate the drought information to decision makers (such as BPS, local government, etc) and to the farmer through extension workers or field officers. It also describes the implementation and dissemination of drought impact monitoring model on the area of rice production center using an integrated information system satellite based model that are effective for spatially dissemination of drought information.This paper is the development of its earlier version titled “Assessment of drought impact on rice production in indonesia by satellite remote sensing and dissemination with web-gis” published in Proceedings of Asian Conference of Remote Sensing (ACRS) 2013.

## 2 MATERIALS AND METHODS

### 2.1 Study area and data used

Many kind of Satellite data have been used to analyse drought condition as listed in Table 2-1. Date of acquisition of satellite data are from 2009 to 2013.

Table 2-1: Satellite data used

| Satellite data | Application |
|---|---|
| AMSER-E | LSWC |
| MODIS | TCI, VCI, VHI |
| MTSAT | KBDI |
| GSMap | Daily rainfall data |

Secondary data used are 1) crop yield at district level, 2) crop calendar, and 3) rainfall data. Field data has been collected from Indramayu and Subang Districts of West Java Province, Center Java and DI Yogyakarta Prov, Barito

Kuala (Batola) of South Kalimantan Prov., and South Sulawesi Prov. Data verification has been conducted in duration of June, July, August 2012, August and September 2013.

## 2.2 Method

The information system used in this study consisted by two types, namely 1) agricultural drought using the model developed by LAPAN, and 2) meteorological drought developed by Takeuchi (University of Tokyo). These two information systems use the integration of several remote sensing-based methods or models.Some indices used to obtain indicator to get drought condition. Meteorological and agricultural drought have been used in the calculation of drought level.

Meteorological drought:

- Keetch-Byram Drought Index (KBDI) formulated by Keetch and Byram (1968):

$$dQ = \frac{(800 - Q)(0.968\exp(0.0486) - 8.30)dr}{1 + 10.88\exp(-0.0441R)} x10^{-3} \qquad (2\text{-}1)$$

It also known as the Cumulative Severity Index (CSI) is a continuous reference scale for estimating the dryness of the soil and duff layers. This system is based primarily on recent rainfall patterns. It is a measure of meteorological drought; it reflects water gain or loss within the soil.KBDI is a soil/duff drought index that ranges from 0 (no drought) to 800 (extreme drought) and is based on the soil capacity in 20 cm of water. The depth of soil required to hold 20 cm of moisture varies.

- *Land Surface Water Content* (LSWC) was derived by Takeuchi and Gonzales (2009) :

$$LSWC = 100.0 / (1 + 241.9 * \exp(-80.0 * NDPI) \qquad (2\text{-}2)$$

LSWC providesthe fraction of a land surface covered by water.

- Normalized Polarization Index (NDPI) :

$$NDPI = (36.5V - 36.5H) / (36.5V + 36.5H) \qquad (2\text{-}3)$$

Agricultural drought condition :

- *Enhanced Vegetation Index* (EVI) to observe anomalies (Liu and Huete, 1995) :

$$EVI = Gx\frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + (C_1 x\rho_{red} - C_2\rho_{blue}) + L} \qquad (2\text{-}4)$$

*L* is a soil adjustment factor, and *C1* and *C2* are coefficients used to correct aerosol scattering in the red band by the use of the blue band. The $\rho_{blue}$, $\rho_{red}$, and $\rho_{nir}$ represent reflectance at the blue (0.45-0.52μm), red (0.6-0.7μm), and Near-Infrared (NIR) wavelengths (0.7-1.1μm), respectively. In general, *G*=2.5, *C1*=6.0, *C2*=7.5, and *L*=1.

- *Vegetation Condition Index* (VCI) which is related to vegetation moisture (Kogan, 1987, and Kogan, 1990):

$$VCI = 100x\frac{EVI - EVI_{\min}}{EVI_{\max} - EVI_{\min}} \qquad (2\text{-}5)$$

- *Temperature Condition Index* (TCI) by Kogan (1990) which is related to vegetation thermal condition:

$$TCI = 100x\frac{LST_{\max} - LST}{LST_{\max} - LST_{\min}} \qquad (2\text{-}6)$$

- *Vegetation Health Index* (VHI) can reflect vegetation healthiness, by Kogan (1990):

$$VHI = 0.5(VCI + TCI) \qquad (2\text{-}7)$$

Figure 2-1 shows existing method to predict season by using ground rainfall data, and this will be integrated with satellite data to get drought information. The information could facilitate farmers to plan planting time, and local government to determine regional planning especially in agricultural field.

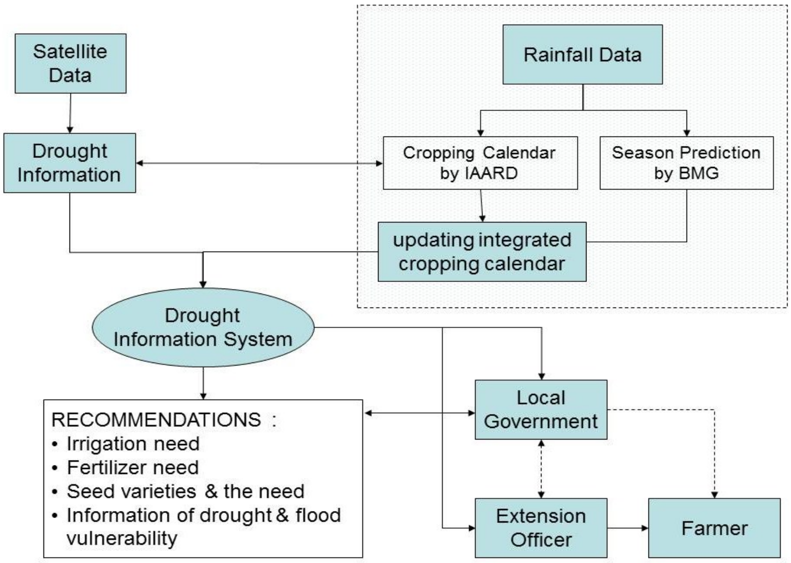



Figure 2-1: Flow Chart of Analysis and Information Provision

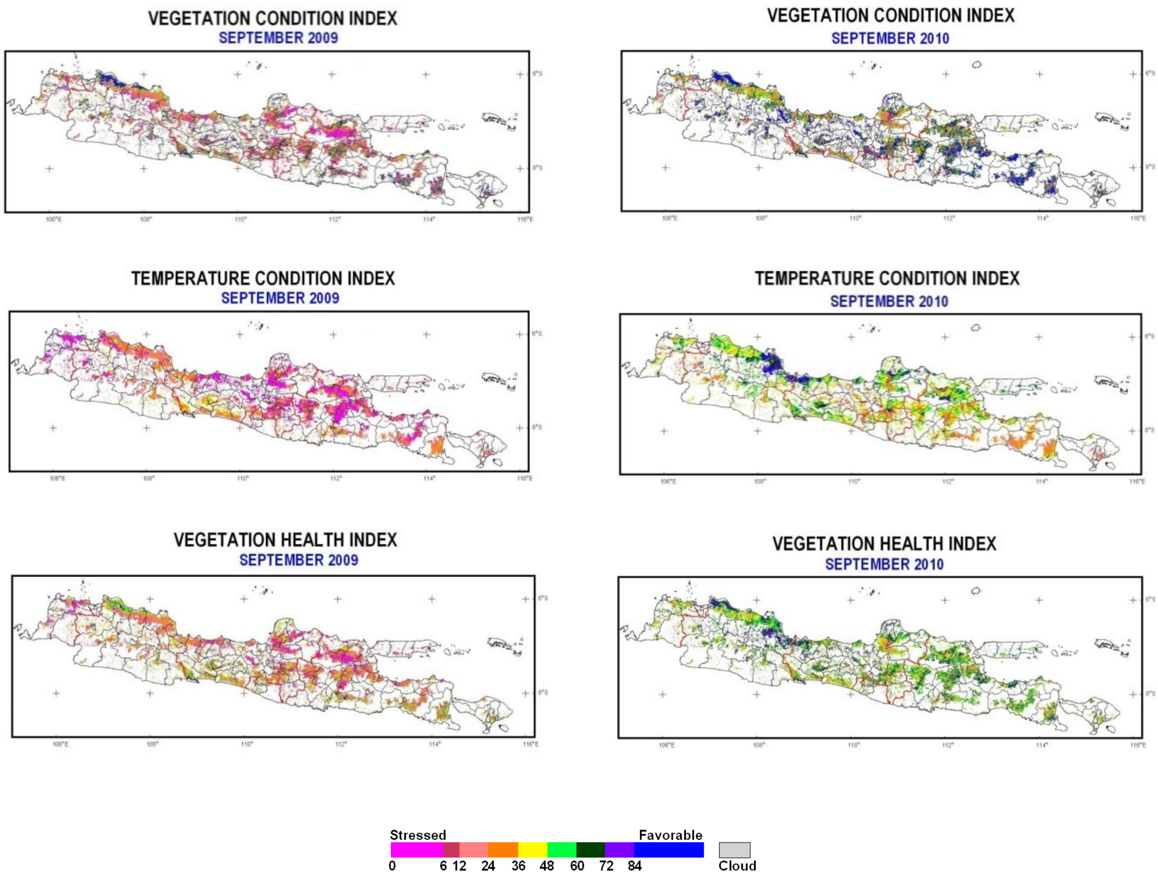



Figure 3-1: VCI, TCI and VHI of MODIS in Java Island September 2009 and 2010

## 3 RESULTS AND DISCUSSION

### Drought condition of rice field

Drought conditions was analized from VCI, TCI, and VHI of MODIS data 250 m resolution as provided in Figure 3-1.

While drough anomalies has been derived from daily rainfall of GSMaP and KBDI of MTSAT data showed at Figure 3-2. The result shows as follows

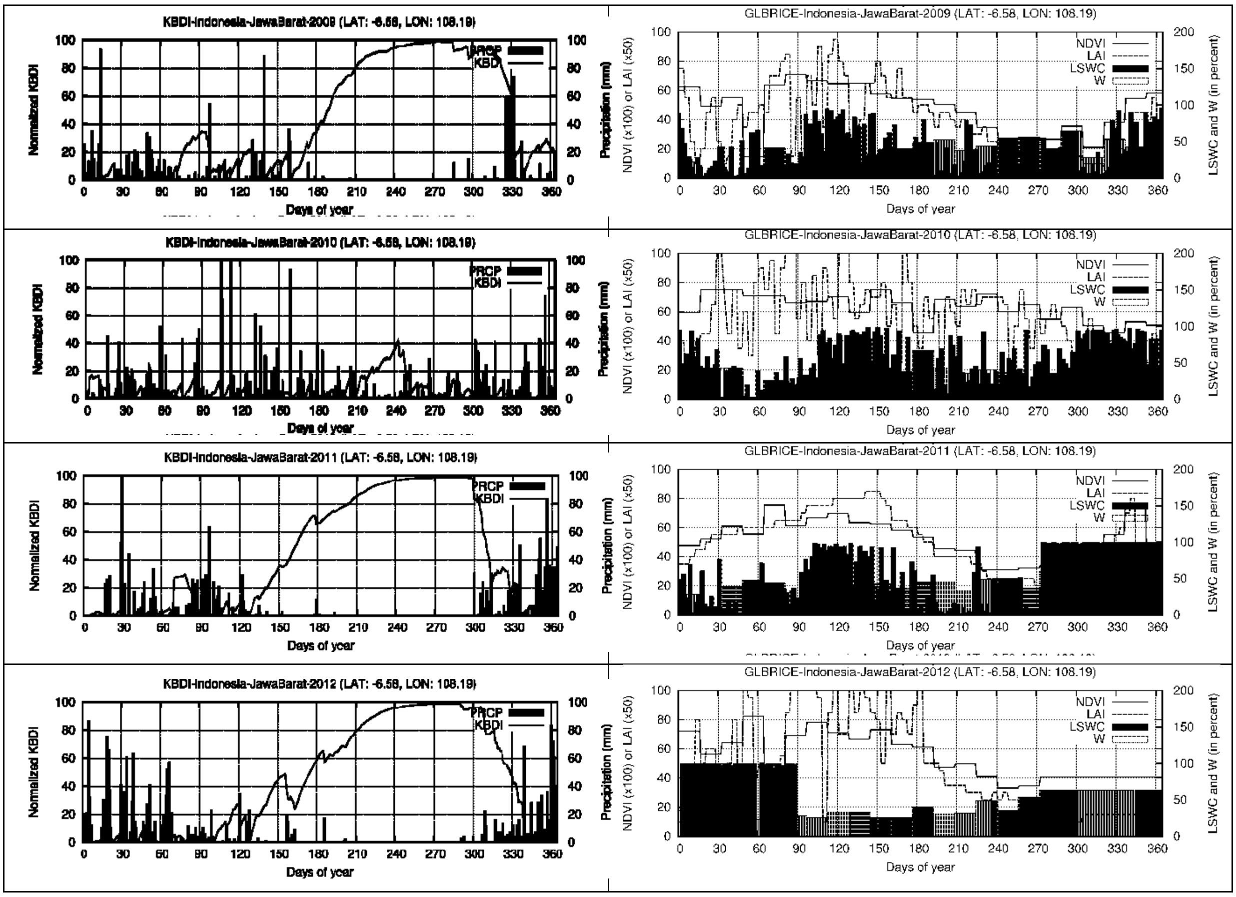



Figure 3-2: KBDI, LSWC, and Precipitation 2009-2012 of West Java

For area has no vegetation, the index has characterized by surface conditions. Figures explain that in September 2009 most of paddy field area in Java Island was suffered by severe drought. Comparing with September 2010, most area of paddy field has favourable VCI. Eventhough, the TCI is moderate, and infuence the VHI to be moderate or fair drought.

Considering from precipitation data obtained from GSMaps presented in Figure 3-2, in 2009 has low rainfall from July to November, and the KBDI analysis shows drought anomaly. The condition is different in year 2010, which is no drought anomaly based on KBDI analyzes. As reported by Indonesian Agency of Meteorology, Climatology, and Geophysics, in 2012 Java Island had suffered by drought with vulnerability status high to severe. Data of Directorate General of Food Crops, Ministry of Agriculture, and drought in 2012 occurred in almost of paddy fields in Java Island. In this year, the widest drought suffered West Java area of 18,619 ha, followed by East Java area of 11,155 ha, Central Java drought level reached 7,568 ha. Based on the report, the results of the analysis using the KBDI and VCI shows the corresponding results. In 2012, Value of normalized KBDI showed increased since the month of May until November 2012. Area of drought onset in 2009 and 2010 ilustrated in Figure 3-2. It describe that based on KBDI analysis, Indramayu area affected by drought in 2009, while in 2010 the area has not experienced drought.

The accuracy assessment using quantitative method for LAPAN model is 60% (Kappa 0,44) while that of for University of Tokyo model uses qualitative model with KBDI value 500-600 shows an early indication of drought for paddy field.

**Impact of drought to paddy productivity and harvested area**

Based on the predictions of the Consortium for Research and Development Climate Change (KP3I-MoA, 2009) Agency for Agricultural Research in Las *et al.* (2011), the national rice planting area is threatened by drought due to El-Nino increased from 0.3 to 1.4% to 3.1 to 7.8%, while areas that had dried up due to drought increased from 0.04 - 0.41% to 0.04 to 1.87%.

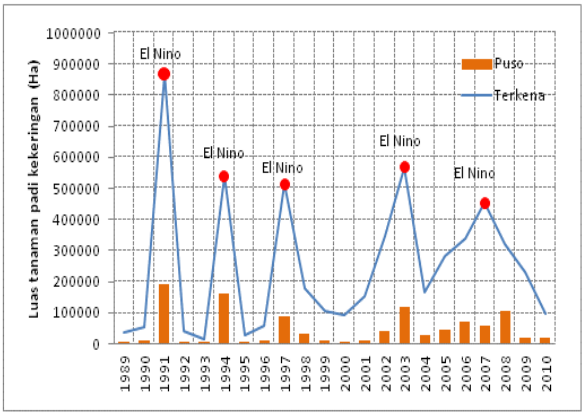



Figure 3-3: Rice plant area affected by drought (Directorate for Food Crop Protection ofIndonesian Agency of Agricultural Research and Development, 2011)

BPS report (2013) are presented in Figure 3-3 shows that until 2012, the national rice production reached 69.05 million tons, an increase of 5.00% from the previous year, while rice production in 2011 will decline by 1.07 % or as much as 0.71 million tons compared to 2010. This decrease is thought to occur because of a decline in harvested area reached an area of 49.81 thousand hectares (0.37 percent) with a productivity level of 0.35 quintal/ hectare, or 0.69%. Decline in rice production in 2011 occurred in the period May to August in which several national rice production centers experiencing the dry season, so the water deficit. Decline in rice production in 2011 occurred in Java amounted to 2.22 million tons, while outside Java, an increase of 1.14 million tons.

Based on Figure 3-4 shows a decrease in harvested area on El Nino in 1994, 1997, and 2003. Decline in production and productivity there is a decrease in one year thereafter. While the El Nino of 2007 was not a decline in harvested area, production and productivity of the acreage except in Prov. Bali and Central Java.

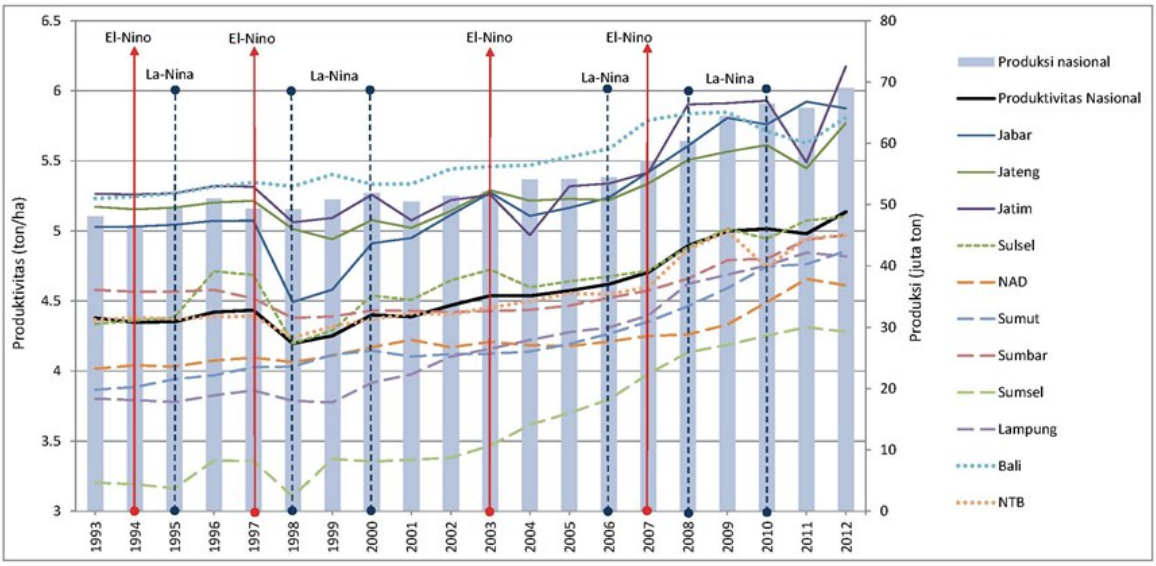



Figure 3-4: Harvested area of paddy in Java in 1993 – 2012 (BPS, 2013)

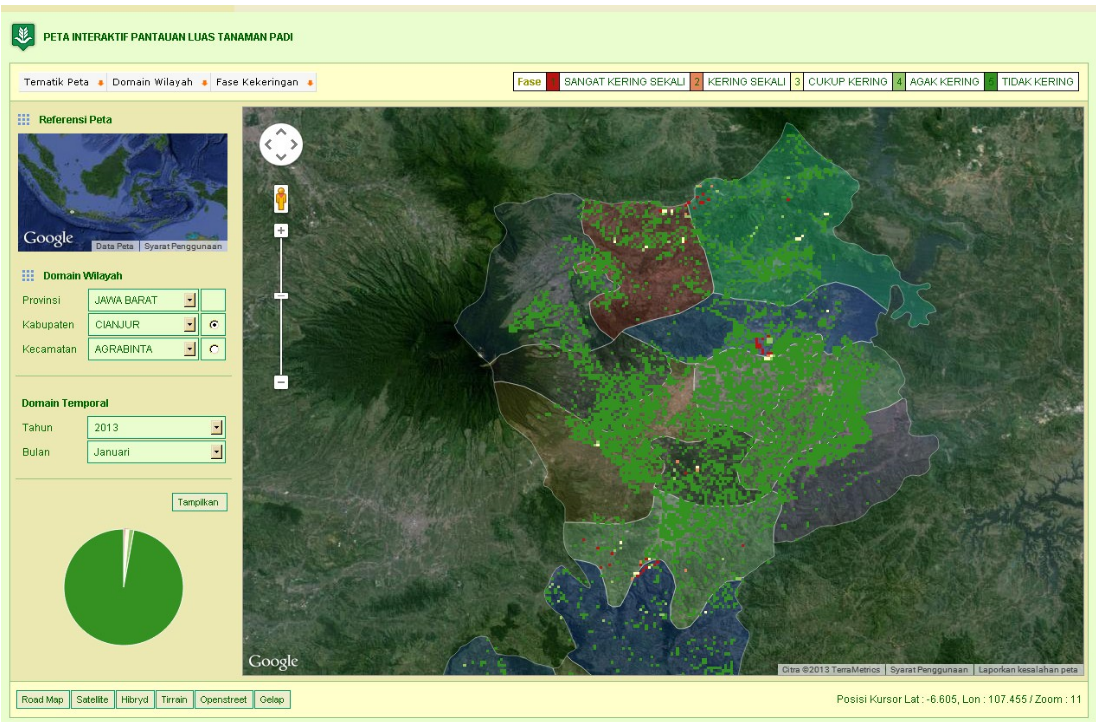
**Dissemination Using Web-GIS**

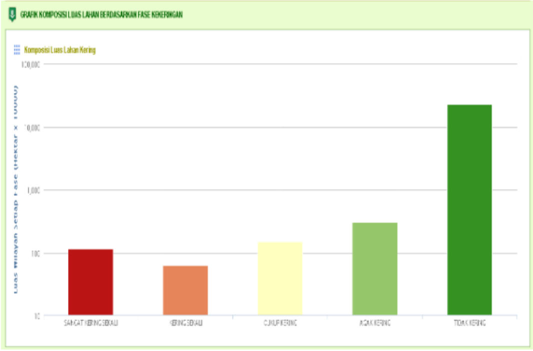
As mentioned in previous chapter there are two types of information systems in this study, namely 1) agricultural drought using the model developed by LAPAN, and 2) meteorological drought developed by Takeuchi (University of Tokyo). The information system is Web-GIS based system to disseminate drought information has been developed in two versions, in English for global used and in Indonesian for local used. It need to develop to meet a more interactive and integrated Web-GIS. Indonesian version has been posted in ICALRD server and cloud computing of IAARD (Figure 3-5), while English version in University of Tokyo portal (Figure 3-6).

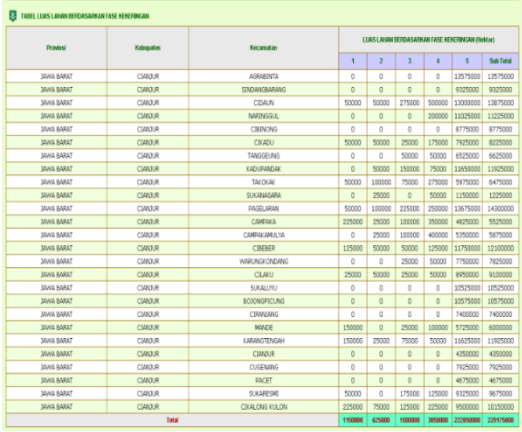
Indonesian version has six main menus: (1) info, (2) Interactive Map, (3) Static Map, (4) Drought information system, (5) contact, and (6) Help. Information provided is level of drought, location, and acreage each drought level.

Meteorological drought information system covers global drought information for whole Indonesia area. It uses for climate monitoring. Level of drought shows in scale bar colour degradation. Agricultural drought provides more detail information of drought impat on agriculture area. Level of drought provides in five levels, i.e. no drought, mild drought, moderate drought, severe drought , and extreme drought. The information presented in agricultural drought is in table and graphic consisted information of area affected by droght per level in sub district level. Meteorological drought presents graphic of KBDI based on rainfall condition.

The information of drought can be used by government or field officers to give more attention to area affected by allocating water irrigation need. The officer also plan crop types that tolarable to drought condition for the area. Recommendation on rapid management actions for the indicated drought area can be done based on the drought information systems.







TABEL LUAS LAHAN BERDASARKAN FASE KEKERINGAN

| Provinsi | Kabupaten | Kecamatan | LUAS LAHAN BERDASARKAN FASE KEKERINGAN (Hektar) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | Sub Total |
| JAWA BARAT | CIANJUR | AGRABINTA | 0 | 0 | 0 | 0 | 13575000 | 13575000 |
| JAWA BARAT | CIANJUR | SINDANGBARANG | 0 | 0 | 0 | 0 | 9325000 | 9325000 |
| JAWA BARAT | CIANJUR | CIDAUN | 50000 | 50000 | 275000 | 500000 | 13000000 | 13875000 |
| JAWA BARAT | CIANJUR | NARINGGUL | 0 | 0 | 0 | 200000 | 11025000 | 11225000 |
| JAWA BARAT | CIANJUR | CIBINONG | 0 | 0 | 0 | 0 | 8775000 | 8775000 |
| JAWA BARAT | CIANJUR | CIKADU | 50000 | 50000 | 25000 | 175000 | 7925000 | 8225000 |
| JAWA BARAT | CIANJUR | TANGGEUNG | 0 | 0 | 50000 | 50000 | 6525000 | 6625000 |
| JAWA BARAT | CIANJUR | KADUPANDAK | 0 | 50000 | 150000 | 75000 | 11650000 | 11925000 |
| JAWA BARAT | CIANJUR | TAKOKAK | 50000 | 100000 | 75000 | 275000 | 5975000 | 6475000 |
| JAWA BARAT | CIANJUR | SUKANAGARA | 0 | 25000 | 0 | 50000 | 1150000 | 1225000 |
| JAWA BARAT | CIANJUR | PAGELARAN | 50000 | 100000 | 225000 | 250000 | 13675000 | 14300000 |
| JAWA BARAT | CIANJUR | CAMPAKA | 225000 | 25000 | 100000 | 350000 | 4825000 | 5525000 |
| JAWA BARAT | CIANJUR | CAMPAKAMULYA | 0 | 25000 | 100000 | 400000 | 5350000 | 5875000 |
| JAWA BARAT | CIANJUR | CIBEBER | 125000 | 50000 | 50000 | 125000 | 11750000 | 12100000 |
| JAWA BARAT | CIANJUR | WARUNGKONDANG | 0 | 0 | 25000 | 50000 | 7750000 | 7825000 |
| JAWA BARAT | CIANJUR | CILAKU | 25000 | 50000 | 25000 | 50000 | 8950000 | 9100000 |
| JAWA BARAT | CIANJUR | SUKALUYU | 0 | 0 | 0 | 0 | 10525000 | 10525000 |
| JAWA BARAT | CIANJUR | BOJONGPICUNG | 0 | 0 | 0 | 0 | 10575000 | 10575000 |
| JAWA BARAT | CIANJUR | CIRANJANG | 0 | 0 | 0 | 0 | 7400000 | 7400000 |
| JAWA BARAT | CIANJUR | MANDE | 150000 | 0 | 25000 | 100000 | 5725000 | 6000000 |
| JAWA BARAT | CIANJUR | KARANGTENGAH | 150000 | 25000 | 75000 | 50000 | 11625000 | 11925000 |
| JAWA BARAT | CIANJUR | CIANJUR | 0 | 0 | 0 | 0 | 4350000 | 4350000 |
| JAWA BARAT | CIANJUR | CUGENANG | 0 | 0 | 0 | 0 | 7925000 | 7925000 |
| JAWA BARAT | CIANJUR | PACET | 0 | 0 | 0 | 0 | 4675000 | 4675000 |
| JAWA BARAT | CIANJUR | SUKARESMI | 50000 | 0 | 175000 | 125000 | 9325000 | 9675000 |
| JAWA BARAT | CIANJUR | CIKALONG KULON | 225000 | 75000 | 125000 | 225000 | 9500000 | 10150000 |
| Total | | | 1150000 | 625000 | 1500000 | 3050000 | 222050000 | 229175000 |

Figure 3-5: Web-GIS of Indonesia Crop Monitoring in Indonesian at ICALRD's Portal

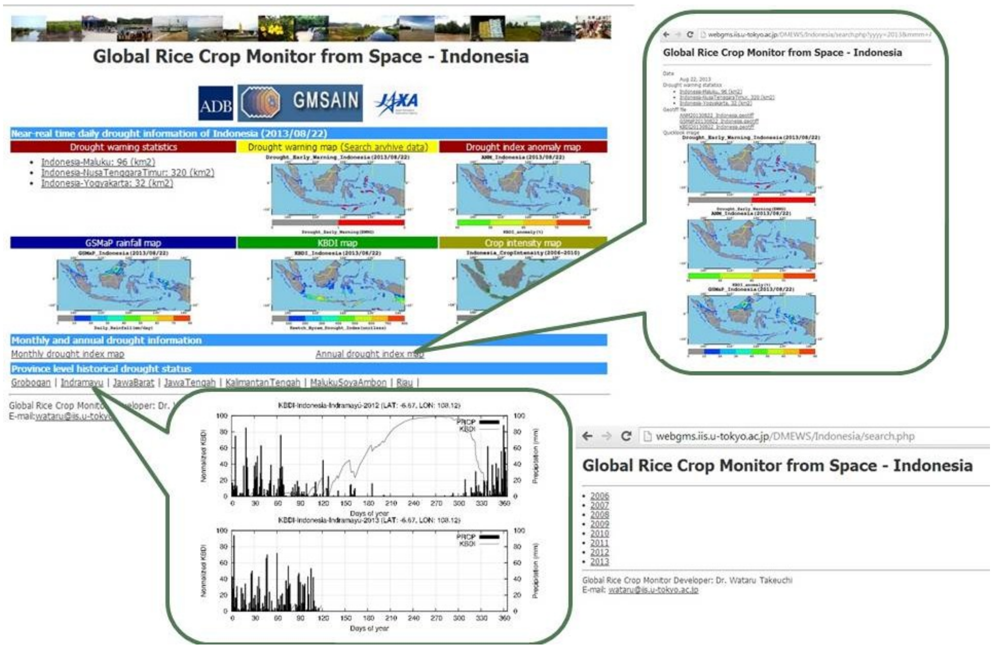



Figure 3-6: Web-GIS of Indonesia Crop Monitoring in English Version at Univ of Tokyo's Portal

**Framework for Operational Used of Drought Monitoring**

Number institutions are involved in this project. The Prototyping executor is the Indonesian Center for Agricultural Land Resources Research and Development (ICALRD) of Indonesian Agency for Agricultural Research and Development (IAARD) - Ministry of Agriculture (MoA), Indonesia. Technical support is provided by University of Tokyo, and Geoinformatics Center (GIC) - Asian Institute of Technology (AIT). JAXA provides MODIS, MTSAT, AMSR-E and ALOS data, University of Tokyo supports with drought index from MODIS, MTSAT and AMSR-E, Future - AMSR-2, and LAPAN for Agricultural drought index, and IAARD for cropping calendar data and rainfall data. End users are Indonesian local government unit and farmers through extension officers. The results will be introduced and disseminated through workshops and seminars, as well as through a Web Portal. To facilitate the activity, satellite data network for data download or data transfer between IAARD, ICALRD, LAPAN, and the University of Tokyo has been build as presented in Figure 3-7. Framework for operational used of crop monitoring to deliver drought information presented in Figure 3-8.

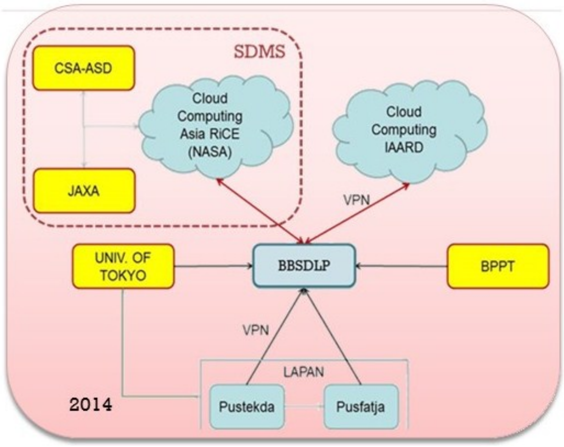


Figure 3-7: Transfer data connection facility

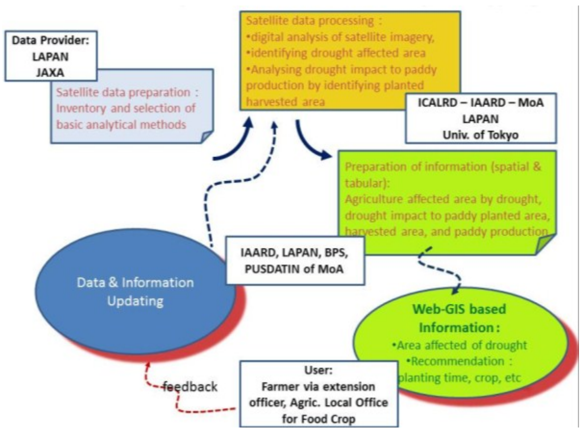


Figure 3-8: Framework for operational used of Crop Monitoring

## 4 CONCLUSION

Method using KBDI and LSWC derived from AMSER-E and GMaps satellite data has been developed and can represent precipitation anomaly and well capture a drought onset day. While crop monitoring model by using VCI, TCI, HVI of MODIS data 250 meter resolution can provide good capability to achieve spatially distributed information over wide area coverage and multi-temporal to give sufficient information for agricultural monitoring. Harvested area and production of paddy is affected in the year of drought (1997, 2003, 2005, 2009, and 2011) in Java Island. Based on MODIS, MTSAT and AMSER-E data, Java Island was suffered by drought in 2009. However, accuracy assessment needs to be done to strengthen the model. It has prospect to be used for operationally to identify drough estimate yield. The accuracy of analysis is 60% (Kappa 0.44) for VHI of agricultural information, and an early indication of drought for paddy field is500-600of KBDI value.

Web-GIS based system to disseminate drought information has been developed in two versions, in English for global used and in Indonesian for local used.The two developed information systems are effective for spatially dissemination of drought information. This will help the government or field officers in rapid management actions for the indicated drought area.

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