Development of Drought Information System at Remote Sensing Application Center, National Institute of Aeronautics and Space (LAPAN)

J T Nugroho¹, S Sulma¹, K I N Rahmi¹ and S Harini¹

¹ Remote Sensing Application Center, National Institute of Aeronautics and Space (LAPAN), Indonesia

Email: imeljalu@yahoo.com

Abstract. National Earth Monitoring System (SPBN) is a natural resource and disaster information system developed by Remote Sensing Application Center, National Institute of Aeronautics and Space (LAPAN), Indonesia. Drought information system is one of the SPBN disaster information products, consisting of Standardized Precipitation Index (SPI), Vegetation Greenness Level (TKV), and monthly accumulation of rainfall information. The quality of information products are improved towards data processing automation as well as provision of user-oriented products. The purpose of our research is to report the existing of drought information products at SPBN-LAPAN, to present briefly the automation process and also to analyze the result of the products. In this study, the “new” drought index information, which developed by blended of two datasets (TKV dataset that characterized agricultural drought and monthly rainfall dataset that characterized meteorological drought), using threshold method has introduced. The level of drought index is divided into five classes, namely cloud/water, severely dry, dry and normal.

1. Introduction

The National Disaster Management Agency (BNPB) noted that during the period January to June 2019, the number of disasters in Indonesia had reached more than 2,000 incidents with a death toll of around 360 people [1]. BNPB claimed that 98% of these disasters were hydrometeorological disasters caused by weather factors such as flood, drought, landslide, and tornado. This condition poses a challenge for Indonesia to create an industrial center for disaster management. The enactment of Act No.21 of 2013 concerning space, apart from carrying out classification processing and detection of geo-bio-physical parameters, as the responsibility of National Institute of Aeronautics and Space (LAPAN).

LAPAN also has the task of determining the dissemination of remote sensing information [2]. This mandate is stated in one of the points of the vision and mission of the Remote Sensing Application Center, LAPAN to implement and manage the National Earth Monitoring System (SPBN). The SPBN information service is located at https://spbn.pusfatja.lapan.go.id and https://sipandora.lapan.go.id/ which also available for mobile application. SPBN consists the information of Natural Disaster Mitigation Information System (abbreviated as SIMBA) and the Natural Resources Monitoring Information System (abbreviated as SIPANDA). This information continues to be improved, including the development of a service automation system, so that user access to remote sensing-based disaster...
information becomes more accessible, faster and more accurate and also to develop the user-oriented information products. Figure 1 illustrates the mapping of information services available in the SPBN, LAPAN.

![Figure 1. Mapping of SPBN LAPAN information system.](image)

The potential for drought is one of the information content for SIMBA Disaster Early Warning, which consists of three pieces of information, namely the Standardized Precipitation Index (SPI), the monthly accumulated rainfall, and the Vegetation Greenness Level (TKV). SPI is an index used to characterize meteorological drought [3,4]. TKV information was derived from EVI (Enhanced Vegetation Index) data representing agricultural/vegetation drought [5]. EVI is an optimization of NDVI (Normalized Difference Vegetation Index), which is designed to increase vegetation signal by increasing sensitivity in areas of high biomass and reducing atmospheric influence [6,7]. The processing modeler is a model that is built for automatic data processing. This process utilizes an interface to simplify a sequential workflow [8,9].

As it is known, drought can be divided into, among other things, meteorological drought and agricultural drought. An area is said to be experiencing drought not only in terms of its meteorological drought conditions but also from agricultural drought. For this reason, it is deemed necessary to introduce a drought index that is expected to characterize the two types of drought so that they can represent the actual conditions. The purpose of our research is to report the existing of drought information products at SPBN-LAPAN, to present briefly the automation process and also to analyze the result related to drought conditions for several regions in Indonesia. In this study, the “new” drought index information, which developed by blended of two datasets (TKV dataset that characterized agricultural drought and monthly rainfall dataset that characterized meteorological drought), using threshold method has introduced. The information products developed are expected to be used as supporting data and can be used as recommendations in decision making.

2. Data and Method

2.1 Data

Table 1 summarizes the data that used in this project. There are Enhanced Vegetation Index (EVI) from MODIS satellite data and Himawari-8 data, which source from Remote Sensing Technology and Data Center (Pustekdata), LAPAN, and also CHIRPS monthly rainfall data from Climate Hazards Center (CHC).
Table 1. Data list that used in the project.

| No. | Data                  | Spatial Resolution | Period          |
|-----|-----------------------|--------------------|-----------------|
| 1.  | EVI-MODIS monthly     | 250 m              | Jan 2018 - now  |
| 2.  | CHIRPS monthly        | 5.5 km             | Jan 1989 - now  |
| 3.  | Himawari-8 monthly accumulated | 4 km              | Jan 2019 - now  |

2.2 Method

The method that we use in this work is summarized in Table 2. We use a statistical method to calculate Standardized Precipitation Index (SPI) and monthly accumulated rainfall information. We use band reflectance ratio and reclassing method to extract Vegetation Greenness Level (TKV) information. The processing modeler for automation processing and the analytical hierarchy process method was also applied to estimate potential groundwater as a future project.

Table 2. The method implemented in this project.

| No. | Method                  | Purpose                                         |
|-----|-------------------------|-------------------------------------------------|
| 1.  | Statistical             | SPI and monthly accumulated calculation         |
| 2.  | Band reflectance ratio and reclassing | Vegetation Greenness Level calculation         |
| 3.  | Processing modeler      | Automation process                              |
| 4.  | Analytical Hierarchy Process | Groundwater Potential Zone Estimation |

The SPI is a meteorological drought index calculated based on the amount of rainfall. This index uses monthly rainfall data for at least 30 years and actual monthly rainfall data. SPI is obtained from comparing the selection of monthly average rainfall data and the actual monthly rainfall and is divided by the standard deviation for 30 years. The formula of SPI was shown as below:

\[
SPI = \frac{x_a - \bar{x}}{\sigma}
\]  

(1)

Where \(x_a\) = actual rainfall (mm/month), \(\bar{x}\) = rainfall average for 30 years and \(\sigma\) = standard deviation (McKee et al., 1993). Mathematically, EVI is calculated using the following formula:

\[
EVI = Gx \frac{(NIR - RED)}{NIR + C1xRED - C2xBLUE + L}
\]  

(2)

Where NIR, Red, and Blue are atmospheric-corrected (Rayleigh and ozone absorption) surface reflectance of near infrared, red and blue bands, L is canopy background adjustment that addresses nonlinear (L=1), C1 and C2 are the coefficient of the aerosol term (C1= 6, C2=7.5), G is gain factor (G=2.5) (Huete et al. 2002). In general, the TKV area is calculated using the equation:
\[ L(hA) = \frac{[\text{count}] \times 62500}{10000} \]  

(3)

Where \( L(hA) \) is the area of TKV in units of hA, [count] and 62500 are the number and area of pixels, respectively, and 10000 are the unit conversion factors. The percentage of the TKV area is calculated using the equation:

\[ L(\%) = \frac{L(hA)}{L(t)} \times 100 \]  

(4)

Where \( L(\%) \) is the area of TKV in (%), and \( L(t) \) is the area of the inner province (hA). \( L(t) \) is obtained from statistical calculations that are automatically generated by the model.

The processing modeler is a model built by applying visual-based programming to develop a series of workflow sequences into single processing with input, output data, and the selection of algorithmic functions that can be dynamically managed. The development phase of the semi-automation model begins with the preprocessing stage, which is to classify TKV classes based on pixel values in the EVI image. In the second stage, the constructing of a semi-automated model for calculating the TKV area was carried out for each province throughout Indonesia. At this stage, automating calculation of several workflow series includes determining the boundaries of the area, calculating the area, and the percentage of TKV classes for each province in Indonesia. The last stage is the finalization stage, namely making the TKV area table and map layout.

In the flowchart diagram, we can see that all data processing has done by an automatic process with the final information product are SPI information, Vegetation Greenness Level information, and monthly accumulated rainfall information.

\[ \text{Figure 2. Flowchart of drought information system.} \]
3. Result and Discussion

3.1 Automation process for SPI

The automation process to calculate SPI is shown in Figure 3. We use 30 years of monthly data, and using python script to calculate SPI and clipped for the Indonesia region directly. Then we upload the information to the SPBN information system so users can access the information by the website or mobile application.

![Automation Process of Standardized Precipitation Index (SPI)](image)

**Figure 3.** Automation process in SPI calculation.

3.2 Processing Modeler for Area and Percentage of TKV Calculation

In stage 1, from the monthly EVI data, the TKV parameters can be derived which are classified into five classes, namely very low (0.2 < TKV < 0.4), low (0.4 < TKV < 0.5), moderate (0.5 < TKV < 0.7), high (0.7 < TKV < 0.8) and very high (0.8 < TKV < 0.9). Classes with a TKV value <0.2 are classified as cloud and/or water objects. EVI monthly data that has gone through the classification process will then become input for the model to be built and after this referred to as TKV data. Table 3 summarizes the TKV classes derived from the EVI MODIS data.

| Class         | Pixel Value EVI (scale factor 10000) | TKV          |
|---------------|-------------------------------------|--------------|
| Cloud/water   | < 2000                              | TKV < 0.2    |
| Very low      | 2000 – 4000                         | 0.2 < TKV < 0.4 |
| Low           | 4000 – 5000                         | 0.4 < TKV < 0.5 |
| Moderate      | 5000 – 7000                         | 0.5 < TKV < 0.7 |
| High          | 7000 – 8000                         | 0.7 < TKV < 0.8 |
| Very high     | > 8000                              | 0.8 < TKV < 0.9 |
The construction of the semi-automation model begins with the process of cutting (clip) TKV data using provinces boundary data issued by the Geospatial Information Agency (BIG). The workflow sequence was carried out in calculating the area and percentage for each TKV class and for 34 provinces in Indonesia. The addition of table attributes is required to store the calculation results of the area and the percentage of TKV. The workflow series process is carried out automatically until the calculation is complete for 34 provinces in Indonesia.

In the finalization stage, a table of the TKV area for all provinces in Indonesia was prepared and layout the TKV information map. The process carried out at this stage is done manually, but it does not rule out the development of a complete automation model. The two results, namely the TKV information map and the TKV area table are merged into the SPNB so that users can take advantage of disaster information services. An illustrative example of the semi-automation model interface for calculating the area and percentage of TKV is shown in Figure 4.

![Diagram](image)

**Figure 4. Illustration of semi-automation model interface for calculating area and percentage of TKV.**

The results of the calculation of the area and percentage of TKV for provinces in the Sumatra Island region in May 2019 are shown in Table 4. By ignoring the cloud/water class, it can be calculated that the TKV class, in general, is still dominated by the medium class with a percentage of 30.1% and is followed by the high class, with a percentage of 18.4%. These results indicate that, in general the weather conditions in the Sumatra Island region are in the normal category (not experiencing drought).

In contrast to the previous results, the calculation of the area and percentage of TKV for provinces in the Java Island region, from the calculation it was found that the TKV class, in general, was in the very high category with a percentage reaching 26.6% and followed by high and medium classes, each with a percentage. Amounted to 24.1% and 21.3%. Table 5 summarizes the results of calculating the area and percentage of TKV for provinces in the Java Island region.
Table 4. Area and percentage of TKV in May 2019 in Sumatra Island region.

| Province          | Very low | Low  | Moderate | High   | Very High |
|-------------------|----------|------|----------|--------|-----------|
|                    | Area (Ha) | %    | Area (Ha) | %      | Area (Ha) | %         |
| Aceh              | 153343.7  | 2.7  | 162843.7  | 2.9    | 1025231.2 | 18.3      |
| North Sumatera    | 240937.5  | 3.4  | 242937.7  | 3.4    | 1626250.0 | 22.8      |
| Riau              | 364862.5  | 4.1  | 344350.0  | 3.9    | 2981850.0 | 33.6      |
| West Sumatera     | 156268.7  | 3.7  | 155900.0  | 3.7    | 1208600.0 | 28.9      |
| Jambi             | 161875.0  | 3.4  | 178306.2  | 3.2    | 534125.0  | 26.9      |
| Bengkulu          | 48437.5   | 2.4  | 63981.2   | 3.2    | 471000.0  | 23.7      |
| South Sumatera    | 398856.2  | 4.7  | 423237.5  | 4.9    | 197925.0  | 24.0      |
| Lampung           | 227962.5  | 6.9  | 237500.0  | 7.1    | 1183675.0 | 35.6      |
| Riau Island       | 38143.7   | 4.6  | 47087.5   | 5.7    | 1266037.5 | 26.4      |
| Bangka Belitung   | 72112.5   | 4.4  | 89718.7   | 5.4    | 743375.0  | 28.1      |

On the islands of Kalimantan and Sulawesi, from the calculation of the area and the percentage of TKV, it is known that the TKV class is in the medium and high categories, respectively 34.5% and 30.2% for TKV on the island of Kalimantan and 31.0% and 23.7% for TKV class in Sulawesi Island.

Table 5. Area and percentage of TKV in May 2019 in Java Island region.

| Province     | Very low | Low  | Moderate | High   |
|--------------|----------|------|----------|--------|
|              | Area (Ha) | %    | Area (Ha) | %      |
| Banten       | 72425.0   | 7.8  | 54837.5  | 5.9    |
| West Jawa    | 273500.0  | 7.4  | 220568.7 | 6.0    |
| D K I Jakarta| 32837.5   | 49.9 | 56812.8  | 8.6    |
| Central Jawa | 105681.2  | 3.1  | 142750.0 | 4.2    |
| D I Yogyakarta| 4437.5  | 1.4  | 8300.0   | 2.6    |
| East Jawa    | 158112.5  | 3.3  | 201968.7 | 4.2    |

Table 6. Area and percentage of TKV in May 2019 in Kalimantan Island region.

| Province       | Very low | Low  | Moderate | High   | Very High |
|----------------|----------|------|----------|--------|-----------|
|                | Area (Ha) | %    | Area (Ha) | %      | Area (Ha) | %         |
| West Kalimantan| 418731.2  | 2.9  | 462500.0  | 3.2    | 4525825.0 | 31.2      |
| South Kalimantan| 194437.5 | 5.3  | 215725.0  | 5.9    | 1368506.2 | 37.3      |
| Central Kalimantan| 425675.0| 3.1  | 536656.2  | 3.5    | 4854931.2 | 32.1      |
| North Kalimantan| 190881.2| 2.8  | 211168.7  | 3.1    | 2354287.5 | 34.5      |
| East Kalimantan  | 391662.5 | 3.1  | 452168.7  | 3.6    | 4704450.0 | 37.3      |
Table 7. Area and percentage of TKV in May 2019 in Sulawesi Island region.

| Province     | Very low | Low   | Moderate | High    | Very High |
|--------------|----------|-------|----------|---------|-----------|
|              | Area (Ha) | %     | Area (Ha) | %       | Area (Ha) | %         | Area (Ha) | %         |
| West Sulawesi| 76143.7  | 4.6   | 73343.7  | 4.4     | 398262.5 | 24.1      | 355656.2  | 21.5      |
| Central Sulawesi| 209212.5 | 3.5   | 239656.2 | 4.0     | 1613012.5| 26.7      | 1405193.7 | 23.2      |
| South Sulawesi| 344893.7 | 7.8   | 330018.7 | 7.5     | 1612250.0| 36.7      | 979200.0  | 22.3      |
| Southeast Sulawesi| 147568.7 | 4.1   | 189743.7 | 5.3     | 1320131.2| 36.7      | 888787.5 | 24.7      |
| North Sulawesi| 40431.2  | 2.8   | 46112.5  | 3.2     | 400075.0 | 28.0      | 365912.5 | 25.6      |
| Gorontalo    | 45200.0  | 3.8   | 69543.7  | 5.8     | 403250.0 | 33.8      | 292531.2 | 24.5      |

From the calculation of the area and the percentage of TKV in the Indonesian territory, it is known that the Indonesian territory is still in a normal condition and has not experienced drought. This can be seen from the TKV class, which is in the medium and high category.

If it is reviewed using multi-temporal TKV data from January to May 2019, it can be analyzed in general the changes in TKV for each province. Figures 5 to Figure 10 show the variation of TKV classes during the January to May 2019 period for the six provinces in Java Island. Symbols A, SR, R, T, and ST respectively represent the TKV class as follows: Water/Cloud, Very Low, Low, Medium, High, and Very High, while symbol A represents cloud and/or water objects. The preliminary analysis can be seen for the DKI Jakarta area in period that the TKV conditions are relatively very low, which indicates relatively dry conditions. Figure 5 shows the temporal variation of TKV during the period January to May 2019.

![Figure 5. TKV temporal variations during January - May 2019 period for DKI Jakarta.](image1)

![Figure 6. TKV temporal variations during January - May 2019 period for Banten.](image2)
Figure 7. TKV temporal variations during January - May 2019 period for West Java.

Figure 8. TKV temporal variations during January - May 2019 period for Central Java.

Figure 9. TKV temporal variations during January - May 2019 period for D. I Yogyakarta.

Figure 10. TKV temporal variations during January - May 2019 period for East Java.
The results obtained for DKI Jakarta province (Figure 5) are different from the pattern of TKV variation for other provinces in Java Island, as shown in Figures 6 to 10, which each explain the temporal variation of TKV for Banten, West Java, Central Java, DI Yogyakarta, and East Java. Compared to the TKV data processing using a manual method with the semi-automation model built, the result is that the construction of a semi-automation model for TKV processing using the processing modeler model has shortened the data processing time from about 170 minutes to 20 minutes for all provinces in Indonesia. Besides shortening the data processing time, the application of this semi-automation model is also expected to minimize errors, especially human factors, during the process.

3.3 Drought Index
And furthermore, this is drought index information as our invention as we know that there is some kinds of drought, such as meteorological drought and agricultural drought. In this work, we use monthly accumulated rainfall data to characterize of meteorological drought and vegetation greenness level data as characterizes agricultural drought to produce the new drought index. By using a threshold method, we build algorithm to combine and blended the two data to produce the drought index information. Figure 11 shows the illustration of drought index data processing. Figure 12 shows the layout of drought index information. A drought index model based on blended data has been built where the level of drought is divided into five classes, namely cloud/water, severe dry, dry, and normal.

![Figure 11. Illustration of drought index data processing.](image1.png)

![Figure 12. The layout of drought index information.](image2.png)
For the future work, we plan to complement the vegetation greenness level information based on land use classes and also to estimate the potential groundwater in some regions in Indonesia. This information is essential for water dropping management in the event of a drought disaster.

4. Conclusion
The application of a processing modeler-based semi-automation model can shorten the TKV data processing time for all provinces in Indonesia to around 20 minutes. From the calculation, it is known that the TKV class of Sumatra Island, in general, is still dominated by the middle class (30.1%) and high (18.4%). For Java Island, the TKV class in general is in the very high (26.6%) and high (24.1%) categories. On the Kalimantan island, the TKV class was in the medium and high categories, respectively 34.5% and 30.2%. For Sulawesi Island, the TKV class was in the medium (31.0%) and high (23.7%) category. Model development towards full automation is needed to improve services to users. It is deemed necessary to introduce a drought index which is expected to characterize the two types of drought so that they can represent the real conditions.

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