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REMOTE SENSING BASED DROUGHT MONITORING IN THE MIDDLE-PART OF NORTHEAST REGION OF THAILAND

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Abstract: Drought, one of natural phenomena, occurs so often especially in the northeast region of Thailand. Such of this drought affects severely agriculturists' farming. This study aims to develop drought monitoring of vegetation dynamics using satellite data in a case study conducted in the middle-part of northeast region of Thailand. Steps to study consisted of the MOD13Q1 data which is Normalized Difference Vegetation Index (NDVI) data set derived from MODIS/Terra Satellite during the past 3 years (2014 – 2016) that are analyzed to find a z-score and calculated to obtain Standardized Vegetation Index (SVI). After that, drought classes would be identified. The study results during the past 3 years revealed that the most severe drought occurred in 2014 which estimated to 97.72 percent or the area of 30,707.53 km^2. Furthermore, the result of SVI was used to find statistical correlation with rainfall from the rainfall measurement ground station with a simple linear regression model. The study results in the past 3 years indicated that SVI had high level of correlation with rainfall. It interpreted that this study contained reliability as SVI could be used to measure drought in the middle-part of northeast region of Thailand in both spatial and multi-temporal models.

Keywords: Remote sensing, drought monitoring, SVI

INTRODUCTION:

Drought is a natural disaster triggered by water shortage crisis that stems from dry spell or rain did not fall in the season. Drought affects the way of life and economic system that the world and Thailand pay attention to this crisis as drought has huge impact on economic, social and environmental systems. To measure drought accurately is highly challenging as drought is a natural disaster that gradually occurs. Severity of drought is different with imbalanced rainfall in a certain area and prolonged periods of no rainfall. Therefore, it is difficult to compare which periods experience more drought than the other (Laosuwan et al., 2016). Drought problem in Thailand is not a new issue but a repetitious problem especially in the northern part of Thailand. The drought stems majorly from the amount of rain falling in an area while drought crisis occurs yearly, in particular during winter through summer (Gomasathit et al., 2015). Water shortage has effects on plant growing. So, variation of plants can identify a degree of drought as well (Wattanakij and Mongkolsawat, 2008; Uttaruk and Laosuwan, 2017). The usability of data from meteorology only is not enough to monitor drought, in particular when data obtained is not up to date and frequency of data is insufficient while the data is incomplete. The adaptation of Remote Sensing Technology based on satellite data is another choice to be applied to different situations especially survey and inspection of areas affected by disasters such as drought, flood and storm (Byun and Wilhite, 1999; Stankevich et al., 2015; Laosuwan and Uttaruk, 2017). By the way, the use of satellite-based data to examine periods with unusual climatic conditions in an area affected by drought is a method that reflects vegetation dynamics (Tucker, 1979; Domenikiotis et al., 2004; Geerken, 2005; Fisher, 2006; Jiao, 2016).

Since satellite data can show details from repetition of data recording continually and be able to monitor areas in near real-time with multi-temporal diversity, process of some characteristics change can be monitored better. When satellite data are done with image processing with mathematic equation, they show more outstandingly what to study such as calculating NDVI which is calculated by determining the ratio of red and near infrared) (Dutta et al., 2015; Gao et al., 2016; Rimkus et al., 2017). The NDVI therefore provides a mean of monitoring vegetation dynamics in climatic conditions (Fensham and Holman, 1999; Bordi et al., 2009; Gebrehiwot et al., 2011).

Drought problem or drought crisis is a spatial problem. The use of satellite data to analyze areas being at risk of drought can increase efficiency in indicating problem conditions. This study aims to develop a method using remote sensing based drought monitoring of vegetation dynamics, during the past 3 years (2014, 2015 and 2016), in the middle-part of northeast region of Thailand having an area of 31,424.00 km^2.

MATERIALS AND METHODS:

Materials of this Study

Data from MODIS/Terra Satellite: MODIS/Terra Satellite is designed to monitor and examine natural resources data. The swath width is about 2,330 kilometers with 250 to 1,000 meters spatial resolution and 36 spectral bands. MODIS/Terra Satellite acquires global digital data within 2 days. Therefore,

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MODIS/Terra data are proper for monitoring spatial changes which are a large area. In this study the MOD13Q1 data are used through data gathering in each month of the year 2014, 2015 and 2016. The satellite data that range the middle-part of northeast region can be divided into 2 phases; h27v7 and h28v7. A mosaic image is made to connect data of two phases together so that it can cover all of the study areas. Next, geometric correction is made with WGS84-UTM zone 48N coordinate. Nearest Neighbor method is used to assess pixel locations and a subset of data from satellite is created to cover only the middle-part of northeast region.

Data from rainfall: The average monthly rainfall record of the year 2014, 2015 and 2016 from the rainfall measurement earth station of Thai Meteorological Department, totally 41 stations that cover the middle-part of northeast region.

Methods of this Study

Procedures of data analysis are determined in a logical order for analyzing drought in the middle-part of northeast region as shown below:

SVI Analysis: Since SVI value is developed from NDVI, the monthly MOD13Q1 (NDVI) data are used as they can be a useful indicator and widely used for monitoring and examining vegetation dynamics. The SVI value is based on calculation of a z-score for each pixel location of MOD13Q1 (NDVI) data. The standard score is a calculation of standard deviation from the mean in a unit of a standard deviation calculated from NDVI of each pixel location in each season. In this study the seasons are categorized in 3 periods (seasons in Thailand) namely, summer (17 February –16 May), rainy season (17 May –16 October) and winter (17 October –16 February). With respect to z-score analysis, the details are shown in the equation 1 (Peters et al., 2002).

$$Z_{ijk} = \frac{NDVI_{ijk} - \overline{NDVI_{ij}}}{\sigma_{ij}} \quad (1)$$

Where;

Z_{ijk} = the z-value for pixel i during week j for year k

$NDVI_{ijk}$ = the weekly NDVI value for pixel i during week j for year k

$\overline{NDVI_{ij}}$ = the mean NDVI for pixel i during week j over n years and

σ_{ij} = the standard deviation of pixel i during week j over n years

From the equation 1, the Z_{ijk} value is a hypothesis value to be consistent with a standard normal distribution with the mean of 0 and standard deviation of 1 to examine hypothesis from pixel locations in each season of the year 2014, 2015 and 2016. The probability value of SVI = P (Z_{ijk}) of the standard score of NDVI to reflect the probability of plant conditions. The SVI analysis can be seen in the equation 2 (Peters et al., 2002).

$$SVI = \frac{(Z_{ijk} - Z_{ijMIN})}{Z_{ijMAX} - Z_{ijMIN}} \quad (2)$$

Where;

Z_{ijk} = z-value for pixel i during week j for year k;

Z_{ijMAX} = maximum of z-value for pixel i during week j and

Z_{ijMIN} = minimum of z-value for pixel i during week j

From the equation 2, the probability of each pixel location will be shown in SVI value to recognize the greenness of plants in different seasons or different periods. The study is conducted over the 3 year periods (2014-2016) to indicate comparison of high level and low level of drought observed in the mentioned periods based on the seasons. It is an estimation of probability of current vegetation condition from previous vegetation condition. SVI value would lie above zero but lower than one (0 < SVI < 1) where 0 is the lowest standard score of NDVI value at a pixel location observed at a certain time of the 3 year periods and 1 is the highest standard score of NDVI value at a pixel location observed at a certain time of the 3 year periods.

Spatial Analysis of Drought: The spatial analysis of drought is a categorization based on a level of vegetation condition in each month of the year 2014, 2015 and 2016. The level of drought from the SVI in this study can be categorized into 5 levels (Table 1) where 0.00 – 0.05 mean the very low level of vegetation condition (droughts are most likely occur) to 0.95 – 1.00 mean the very high level of vegetation condition (droughts are least likely occur) (Wang et al., 2003; Wattanakij and Mongkolsawat, 2008; Laosuwan et al., 2016).

Tab. 1.
SVI level, Percentage of SVI and Drought level

SVI level	Percentage of SVI	Drought level
0.95 – 1.00 (very high vegetation)	96.0% - 100%	very low drought
0.75 – 0.95 (high vegetation)	76.0% - 95.0%	low drought
0.25 – 0.75	26.0% - 75.0%	moderate drought

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(moderate vegetation)		
0.05 – 0.25 (low vegetation)	6.0% - 25.0%	high drought
0.00 – 0.05 (very low vegetation)	0.0% - 5.0%	very high drought

Multi-temporal Drought Analysis: The multi-temporal drought analysis gives a clear picture as a whole of the 3 years study periods (2014 – 2016). In this study, the SVI analysis result is analyzed with the average monthly rainfall data in the year 2014, 2015 and 2016 obtained from rainfall measurement earth station, Meteorological department, totally 41 stations covering only the middle-part of northeast region of Thailand.

Statistical correlation analysis: The SVI analysis results from number 3.2 and rainfall data in the year 2013, 2014 and 2015 are brought to explain the statistical correlation with Linear Regression Analysis technique.

RESULTS

SVI analysis result: Regarding the SVI analysis result on a monthly basis of 3 seasons; summer, rainy season and winter, the average SVI value of the 3 years (2014- 2016) is shown in Fig. 1 and the graph lines indicate periodical and seasonal variability of SVI.

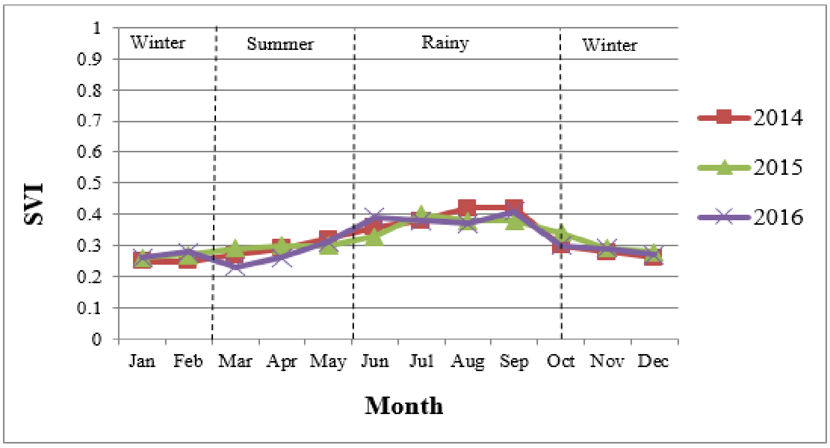

Fig. 1. The average SVI value of the 3 years in N-E Thailand; reduce the scale for SVI from 0.2 to 0.5

The SVI monthly analysis result of the year 2014 indicated different vegetation condition index that ranges from 0 to 1. The index followed the theory where the average gave an idea how the vegetation condition or drought is in each period and season. The highest average equaled to 0.42 in August and September which are in rainy season and the lowest average equaled to 0.25 in January which is in winter. The SVI monthly analysis result of the year 2014 is shown in Fig. 2.

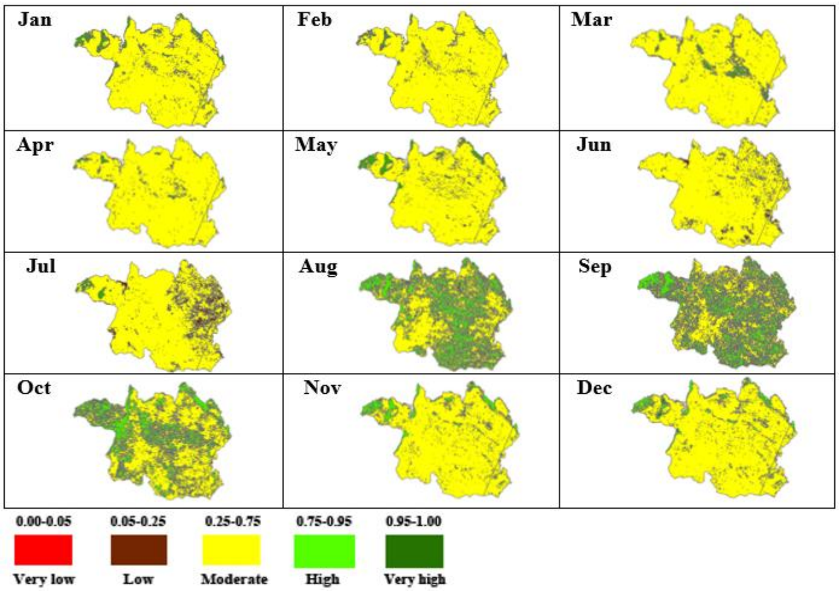

Fig. 2. The SVI monthly analysis result of the year 2014 in N-E Thailand

The SVI monthly analysis result for the year 2015 indicated different vegetation condition index that ranges from 0 to 1. The index followed the theory where the average gave an idea how the vegetation condition or drought is in each period and season. The highest average equaled to 0.40 July which is the beginning of rainy season and the lowest average equaled to 0.26 in January which is the beginning of winter. The SVI monthly analysis result of the year 2015 is shown in Fig. 3.

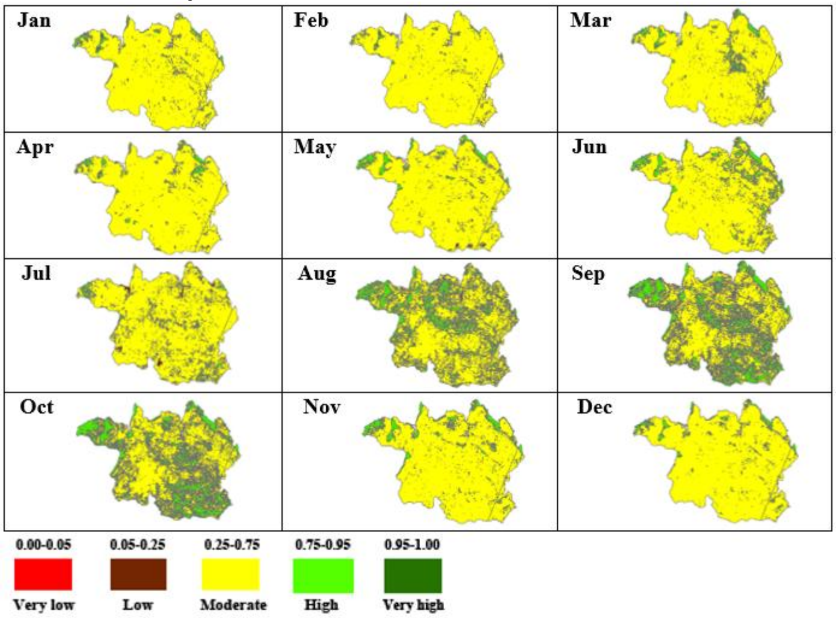

Fig. 3. The SVI monthly analysis result of the year 2015 in N-E Thailand

The SVI monthly analysis result for the year 2016 indicated different vegetation condition index that ranges from 0 to 1. The index followed the theory where the average gave an idea how the vegetation condition or drought is in each period and season. The highest average equaled to 0.41 in September which is the end of rainy season and the lowest average equaled to 0.23 in March which is in summer. The SVI monthly analysis result of the year 2016 is shown in Fig. 4.

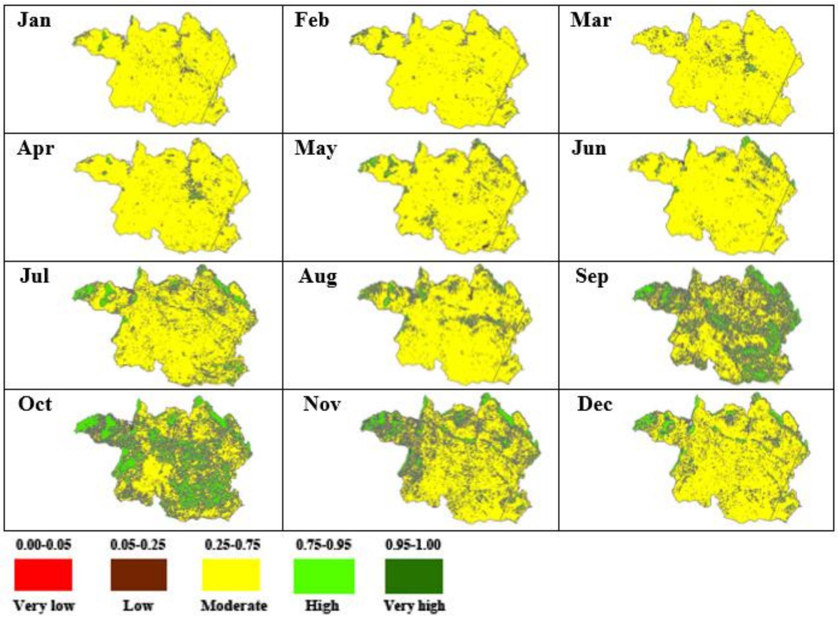

Fig. 4. The SVI monthly analysis result of the year 2016 in N-E Thailand

The SVI yearly analysis (Fig. 5) with an overlaying from monthly data reflects the spatial and multi-temporal drought more obviously than that the monthly analysis. From Figure 5, it can be seen that the most severe drought occurred in the year 2014 followed by 2016 and 2015.

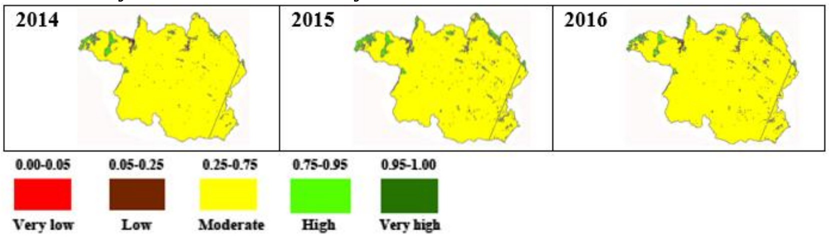

Fig. 5. The SVI yearly analysis

Temporal variations analysis result: The analysis of SVI and rainfall in this study reveal that the monthly temporal variations of SVI and rainfall are consistent all 3 years. It can be noticeable that when SVI increases, rainfall also increases. In contrast, when SVI decreases, rainfall also decreases. The analysis result of temporal variations can be seen in Fig. 6 and the results can be summarized as follow:

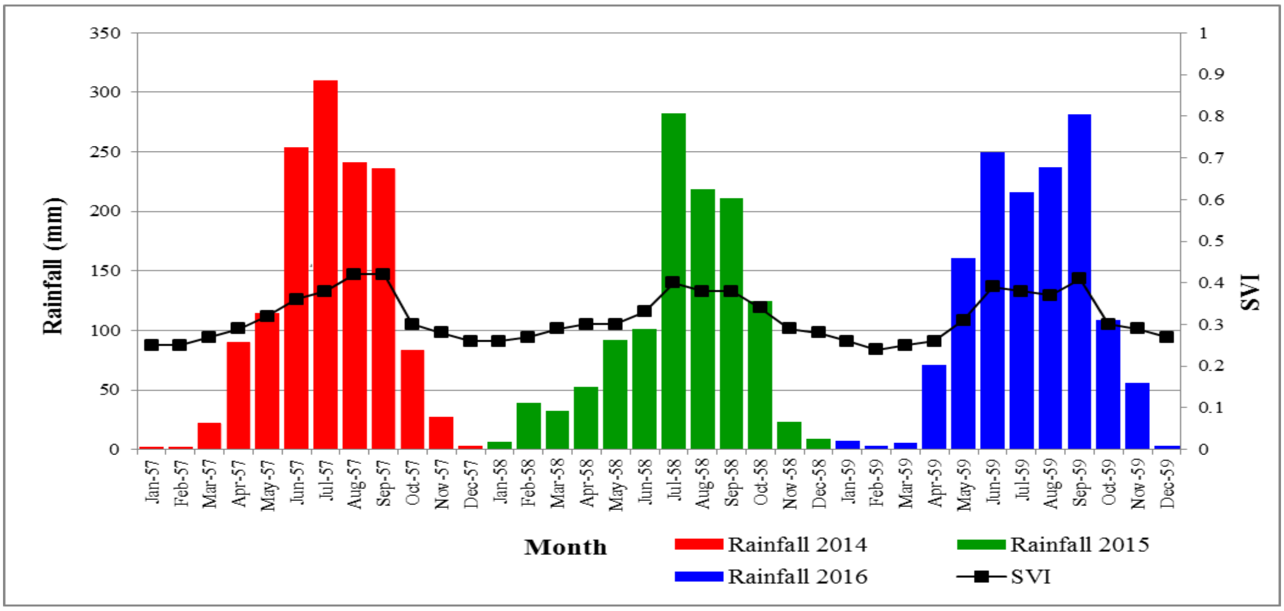

Fig. 6. Temporal variations analysis result

In 2014, rainfall variability during January and February was at the lowest and gradually increased to the highest level in July and decreased to the lowest level in December. In 2015, rain fall variability during January was at the lowest and gradually increased to the highest level in July and decreased to the lowest level in December. In 2016, rain fall variability during January was slightly high and decreased until March and gradually increased to the highest level in September and decreased to the lowest level in December. By the way, change in SVI is slightly slower than rainfall since plants gained development after provided with sufficient water for the growth or forming a bud.

Analysis result of statistical correlation: The results of statistical correlation analysis between SVI (independent variable) and rainfall (dependent variable) in 2014, 2015 and 2016 revealed that changes in SVI were consistent with rainfall. The analysis results were shown in Fig. 7 to Fig. 9. The correlation analysis between SVI and rainfall in 2014 brought about a correlation equation as y=1686.4x-418.65 and the coefficient of determination as R^2 = 0.87. The correlation analysis between SVI and rainfall in 2015 brought about a correlation equation as y=1909.6x-508.69 and the coefficient of determination as R^2 = 0.95. The correlation analysis between SVI and rainfall in 2016 brought about a correlation equation as y=1680.5x-406.73 and the coefficient of determination R^2 = 0.90.

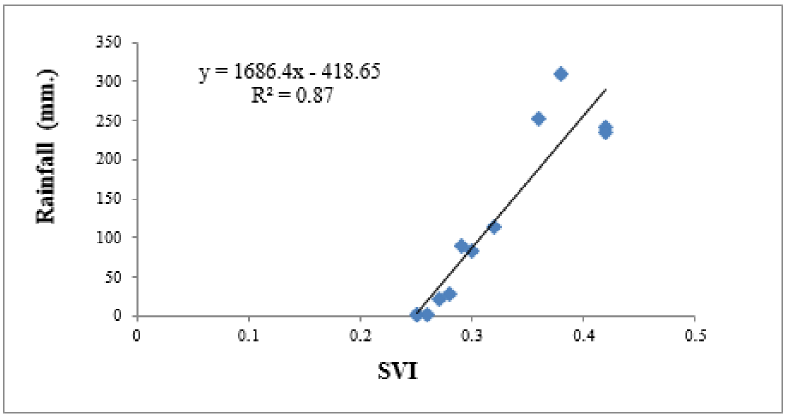

Fig. 7. Relationship of the statistical data between SVI and rainfall in 2014

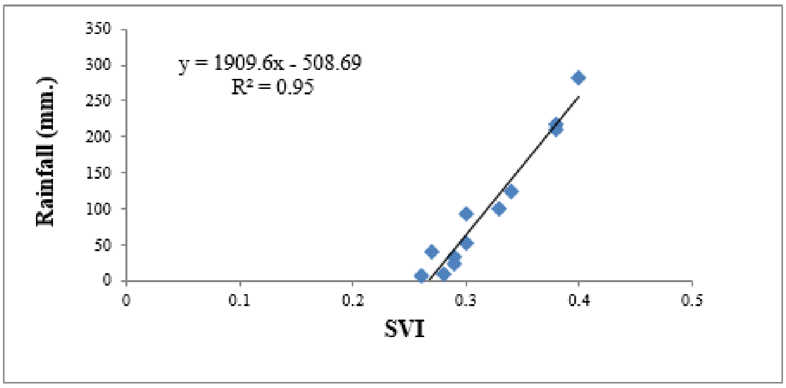

Fig. 8. Relationship of the statistical data between SVI and rainfall in 2015

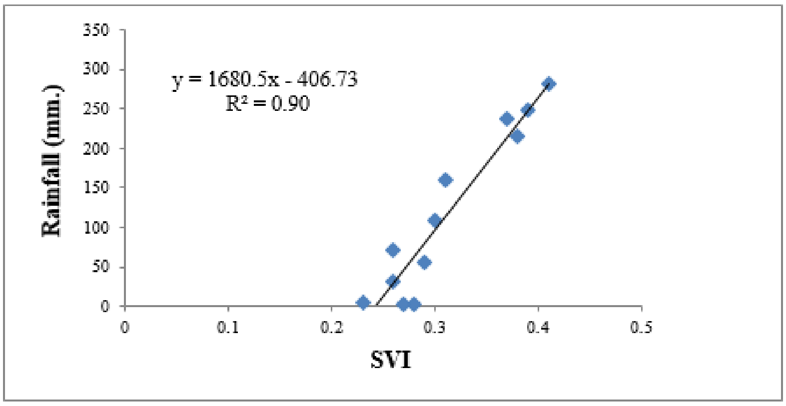

Fig. 9. Relationship of the statistical data between SVI and rainfall in 2016

CONCLUSIONS:

The SVI analysis of all 3 years found that 2014 was the period that drought most likely occurred and a level of drought was estimated to 97.72 percent or 30,707.53 Km^2. The second was the year 2016 which a level of drought was estimated to 95.60 percent or 30,041.34 Km^2 and the last one was the year 2015 which a level of drought was estimated to 93.15 percent or 29,271.45 Km^2. With regards to the analysis result of temporal variation between SVI and rainfall, it was found that the monthly average of SVI and rainfall were consistent with the 3 years study period and the comparison was shown in a standard curve as seen in Figure 6. It could be noticeable that the increase of SVI affects the increase of rainfall. In contrast, if SVI declined, rainfall would decline respectively. However, changes in SVI would be slightly slower than rainfall since plants gained development after provided with enough water for their growing. Furthermore, when SVI (independent variable) was analyzed the statistical correlation with monthly rainfall (dependent variable) of all 3 years (2014 – 2016) and in the year 2014 found that the coefficient of determination was $R^2 = 0.87$, in the year 2015, the coefficient of determination was $R^2 = 0.95$ and in the year 2016, the coefficient of determination was $R^2 = 0.90$. The coefficients of determination of all

3 years were close to 1 showing a high level of correlation.

The study also found that the result was in the same direction with other research such as: Drought Detection in Northeast Thailand using Standardized Vegetation Index of Multi-Temporal Satellite Data (Wattanakij and Mongkolsawat, 2014), Application of Remote Sensing Technology for Drought Monitoring in Mahasarakham Province, Thailand (Laosuwan et al., 2016), and Drought Detection by Application of Remote Sensing Technology and Vegetation Phenology (Uttaruk and Laosuwan, 2017). With respect to this study result, it probably can be used as criteria to determine drought areas of the middle-part of northeast region reasonably and for assessment of drought areas in a speedy and reliable manner. Related authorities can apply the mentioned methods to analyze areas having potential of drought occurrence and obtained results can be used to supplement preventive measures and relief plan to take in case of drought for other areas in Thailand sustainably in the future.

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