The Relationships between Standardized Precipitation Index and Vegetation Condition Index in Upper Chao Phraya River Basin

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Introduction

Drought is one of the most important natural disasters threatening of the human properties and lives. Droughts are commonly classified by type as meteorological, agricultural, hydrological and socio-economic droughts. Generally, it is the results from lower levels of precipitations than what is considered normal. Over the years, many drought indices were developed and used by meteorologists and climatologists around the world (WMO, 2012). The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales.

In Thailand, drought occurs on many parts of the country almost every year particularly in the upper Chao Praya river basin whereas is the main area of agricultural plantation. For agricultural drought, vegetation indices obtained from satellite data allow areas affected by droughts to be identified (Kogan, 1995, 1998).

Therefore, if we can look for some techniques to monitor drought with higher accuracy or the prediction of drought ahead then, it is advantage for planning to avoid or reduce any production losses from drought in the future.

Objective

To analyze the relationships between SPI and the effect of drought on the natural vegetations and agricultural crops in term of Vegetation Condition Index (VCI)

Study area

Along with the Upper Chao Phraya River basins consisted of Ping, Wang, Yom and Nan sub-basin as shown on Figure 1.

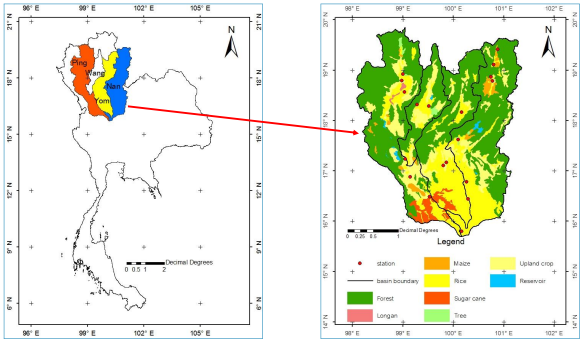

Figure 1 The location and land use map of the study area

Methodology

The procedures of implementation was defined as flowchart shown on Figure 2

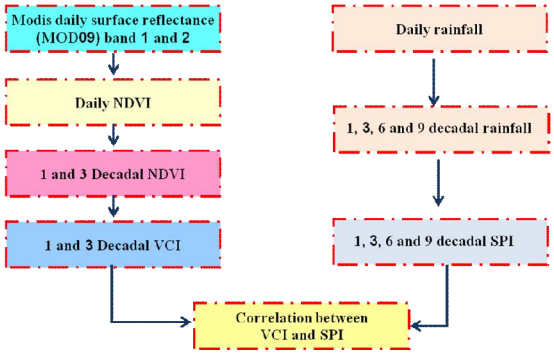

Figure 2 The methodology used in this study
Note: 1 decadal=10 days, 3 decadal=30 days, 6 decadal=60 days, 9 decadal= 90 days

1. Calculation of SPI

SPI was developed by McKee et al. (1993) and calculated by fitting the gamma probability density function to a given frequency distribution of precipitation totals for a station, and the resulting parameters are then used to find the cumulative probability of an observed precipitation event for the given time scale for the station. Then the cumulative probability was transformed to the standard random variable with the mean of zero and variance of one, which was defined as the value of the SPI.

The SPI could be calculated from rainfall data at different times scale. Therefore, the classification of drought intensities using resulting from the SPI was shown on the table 1. This study has been calculated SPI at different time scales, series of 1, 3, 6 and 9 decades (10, 30, 60 and 90 days) respectively using daily rainfall data from meteorological stations of the Thai Meteorological Department (TMD) during 1951-2012.

Table1 SPI value and drought classification

SPI Value	Drought Category
2.0 and above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
0.99 to -0.99	Near
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

2. Calculation of VCI

VCI was suggested by Kogan (1995). It shows how close the Normalized Difference Vegetation Index (NDVI) of the current month is to the minimum NDVI calculated from the long-term record. NDVI was first suggested by Tucker (1979) as an index of vegetation health and density.

$$NDVI = (\lambda_{NIR} - \lambda_{red})/(\lambda_{NIR} + \lambda_{red})$$

Where, λ_{NIR} and λ_{red} are the reflectance in the NIR and red bands, respectively. NDVI values range from -1 to +1, where vegetated area will typically have values greater than zero and negative values indicate non-vegetated surface features such as water, snow and cloud. VCI was defined as following:

$$VCI_j = \frac{(NDVI_j - NDVI_{\min})}{(NDVI_{\max} - NDVI_{\min})} \times 100$$

Where, $NDVI_{min}$ and $NDVI_{max}$ are multiyear minimum and maximum NDVI for specific time period and j is the index of the current time period. The condition of the ground vegetation presented by VCI is measured in percent. The VCI values around 50% reflect fair vegetation conditions. The VCI values between 50 and 100% indicate optimal or above normal conditions. The different degrees of a drought severity are indicated by VCI values below 50%.

In this study, the surface reflectance (MOD09) of band 1 and 2 (red and NIR) with spatial resolution 250 meters, geo-location (MOD03) and cloud mask (MOD35) products of the terra-MODIS over the period 2000-2012 were downloaded via access data from http://lpdaac.usgs.gov/. The satellite image processing procedure to derive VCI was shown on Figure 3.

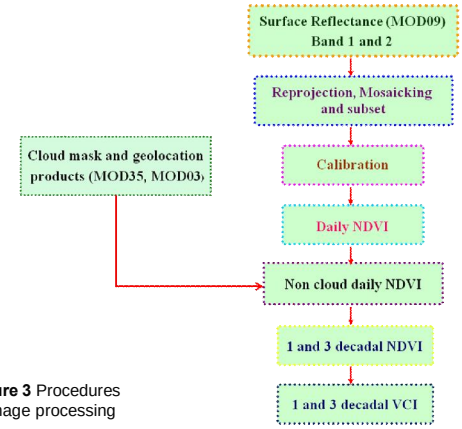

Figure 3 Procedures of image processing

3. Statistical relationship between SPI and VCI

The Pearson correlations were performed to determine the statistical relationship between SPI values with average pixel values of VCI in surrounding area of 3 kilometers radius at each of the meteorological station in several periods of time. The investigation has been not only at the same time scale of SPI and VCI but also at different time scale as shown on Figure 4. For the difference time scale, the relationships were determined only with the last decade of the time scale of SPI and VCI was the same decade.

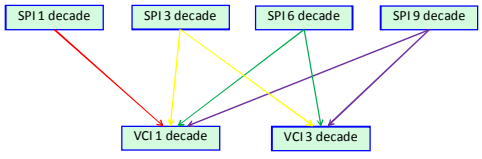

Figure 4 The Pairs of relationship between VCI and SPI in difference timescales

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Results

The examples of SPI value in each time scale with the last decade of time scale at 9th decade (21-31 March) of 2012 at some meteorological stations in the study area were shown on Table 2. Additionally, the average composited NDVI in 1 decade and moving 3 decade were produced from daily NDVI over 13 years period and then, the composited NDVI products were used to derive VCI. The examples of 3 decadal VCI image at the last 9th decade of 2012 (1-31 March 2012) with overlaid provincial boundaries was shown on Figure 5.

Table 2 The SPI in several time scales with the last decade of timescale at 9th decade of 2012

Station	SPI 1 decade (21-31 Mar)	SPI 3 decade (1-31 Mar)	SPI 6 decade (1 Feb-31 Mar)	SPI 9 decade (1 Jan-31 Mar)
Chiangmai	0.4	0	-0.3	-0.1
Lampang	-0.2	0.7	0.7	0.9
Lamphun	0.7	0.1	-0.1	-0.2
Phrae	-0.3	0.7	0.6	0.6
agromet	0.8	0.8	0.6	0.9
Uttaradit	-0.2	0.4	0.1	-0.1
Sisamrong agromet	-0.3	-0.5	-0.8	-1
Tak	1.2	0.6	0.5	0.3
Phitsanulok	-0.3	-0.4	-0.8	-0.8
Kamphaengphet	-0.7	-0.1	0.6	0.5

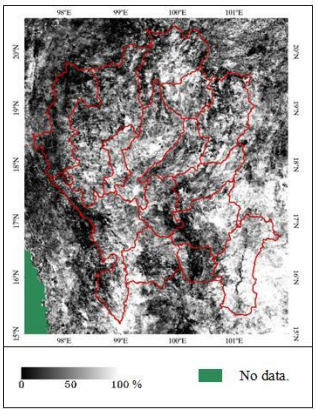

Figure 5 The 3 decadal VCI image at the last decade is 9th decade of 2012

The investigation of the relationships between SPI and average pixel values of VCI in surrounding area of 3 km radius at each of the meteorological station were performed at difference timescale. It was found that a numbers of significantly correlations in periods of 6 and 9 decade of SPI time scales would be much more than 1 and 3 decade of SPI timescales as well as the most of correlation coefficient (R value) are positive values and significantly correlations would be in the last decade of SPI time scales in winter and summer seasons during the 1st-13th and 32nd - 36th decades. There was a little number of significantly correlations in rainy season. Figure 6 show the example of scatter plot and regression line between 6 decadal SPI and 1 decadal VCI at Nan meteorological station at the last 9th decade of time scales.

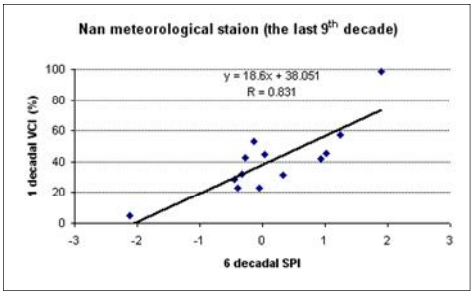

Figure 6 The relationship between SPI and VCI at Nan meteorological station at the last 9th decade of time scales.

Conclusions

This study intended to investigate the duration of rainfall deficiency that effected on the natural vegetation and agricultural crops. Then the relationship between SPI and VCI in term of correlation coefficients will perform in the sequential of meteorological drought (SPI) and agricultural drought (VCI) respectively. It was found that the properly period of time of SPI for monitoring and warning meteorological drought impact would be 6-9 decadal period. Therefore, the results will be increasing in better accuracy of monitoring, early warning and assessment drought impact in the future.

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Presentation of the outcomes via TMD Website

Finally, all appropriate results namely; the properly period of time of SPI for monitoring meteorological drought impact in 6-9 decadal periods will be performed for drought monitoring which disseminate via TMD website and will be updated on 1, 11 and 21 of each month as shown on Figure 7.
(http://www.arcims.tmd.go.th/dailydata/SPI_6dec.php)

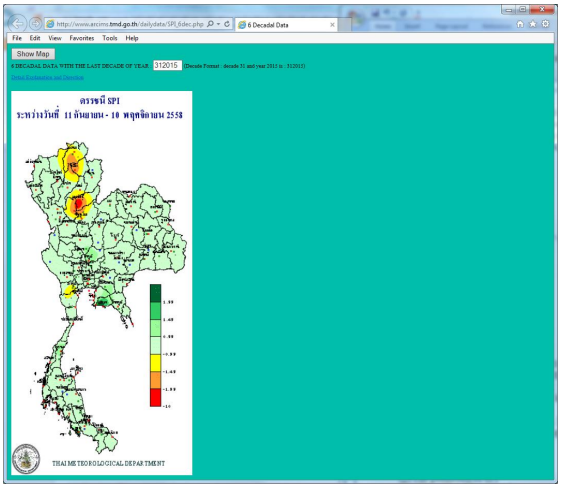

Figure 7 The webpage of SPI

Future plan

These techniques will be applied for drought impact prediction in the future within 3-4 months ahead by using numerical weather prediction (NWP) products accompany with observed rainfall as show on Figure 8. Therefore, the decision makers can use the products for advance planning in related activities as well.

Figure 8 Our Future Plan