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FORECASTING TIME SERIES CHANGE OF THE AVERAGE ENHANCED VEGETATION INDEX TO MONITORING DROUGHT CONDITION BY USING TERRA/MODIS DATA

SUMMARY

Drought condition is a natural disaster that has caused economic and social damages considerably including a shortage of consuming water, and has been a hindrance to the agricultural production and industrial development. Currently, the drought condition tends to be more severe in Yasothon Province of Thailand, thus affecting plantation in the area. The purpose of this study was to monitor the drought condition of Yasothon Province, which is located in the Northeastern region of Thailand, by using Enhanced Vegetation Index (EVI) data during 2010 – 2019 obtained from Terra/Modis Satellite, and by studying the change in time series from the average EVI during 2010 – 2019, for the forecast in 2020 – 2022 by using moving averages method and exponential smoothing method in order to compare the differences between the original data of average EVI and the data of average EVI adjusted by smoothing algorithm using RMMEH method. Statistics used in examining the forecasting accuracy were MAD and MAPE. It was found from the study that MAD and MAPE of the forecast of the original average EVI and the average EVI adjusted by using RMMEH method were slightly different in that the average EVI adjusted by using RMMEH method and forecasted by moving averages method was best accurate. In addition, according to the time series change forecast of EVI, it was found that the original average EVI and the EVI which was smoothed by RMMEH method of the forecasting year during 2020 – 2022 by using moving average method and exponential smoothing method were very low in each year, indicating that the drought would occur in the future.

Keywords: Enhanced Vegetation Index (EVI), Remote Sensing, Drought, RMMEH method

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INTRODUCTION

Drought condition is a natural disaster found in many areas and has caused huge damage and had greatly hindered the national development of Thailand. The areas affected by drought condition often face a shortage of consuming water and water supply used for farming which relies heavily on rainwater (Laosuwan, et al., 2016). When there is insufficient amount of water, the agricultural yields decrease, thus causing a lack of agricultural products and processed products for domestic consumption and for exporting. The drought condition in the Northeastern region of Thailand has long been taking place and has been considered as the serious problem mainly due to a shortage of rainfall, and other factors including the soil water retention, underground water source, and the use of land.

The drought is caused by a lack of rainfall during rainy season and the irregularity of raining time between June to July (Rotjanakusol & Laosuwan, 2018). In addition, according to the analysis into rainfall pattern in terms of space and time, it was found that there would be no rain after the latter half of September as well since the area cannot be accessed by the Southwestern monsoon; and if in any year there is no tropical cyclone moving through such area, the drought would turn out to be more serious. Main consequences from the drought include a lack of consuming water, water supply used in various activities especially in farming. Farming is the main career of people living in Northeastern region; therefore, a lack of water does cause substantial impact on the cultivation thus decreasing the crop yields leading to the economic, social, and environmental problems, as well as health issue such as the epidemic disease that occurs during the dry season (Rotjanakusol & Laosuwan, 2019a).

The severity of drought condition depends on many factors including physical factor, ecological factor, and human activities factor. Therefore, the rainfall is regarded as the significant factor to be used when finding the relationship pattern with the spectral index and to study the duration of rainwater that affects plantation (Mongkolsawat et al., 2001; Dutta, et al., 2015; Gomasathit et al., 2015). The relationship between the rainfall and the spectral index is a key variable used to determine the drying area (Thavorntam et al., 2015; Lines et al., 2017; Nistor et al., 2018). The phenological change of plants in dry area could appear as the reflection of electromagnetic wave differently that could be seen by satellite data (Tucker, 1979; Peters et al., 2012; Seekaw et al., 2014; Uttarak & Laosuwan, 2018). However, in studying drought condition, data have to be adjusted for the suitability of use and for the increased efficiency in showing more clearly whatever being studied. The data adjustment of this sort is called Index (Vrieling et al., 2014; Klisch & Atzberger, 2016; Uttarak & Laosuwan, 2017; Rotjanakusol & Laosuwan, 2019b). The spectral index which is associated with the physical characteristics of plants and amount of water in plants and in soil can identify the drought condition (Kogan, 2001; Fan et al., 2015; Li et al., 2015; Uttarak & Laosuwan, 2020a) for example, in the calculation for Enhanced Vegetation Index (EVI), the results of such can identify the growth and fertility of

plants in each climatic condition duration (Season) very well (Holben & Justice, 1981; Matsushita et al., 2007). Currently, the study of natural resources is performed by using remote sensing technology used with the application of satellite data in the study. The aim to apply this technology is to reduce time spent in physical exploration in the actual area. Nowadays, a lot of satellite data, both low and high spatial resolution, are used (Uttaruk & Laosuwan, 2020b; Prohmdirek et al., 2020; Auntarin et al., 2021; Piamdee & Laosuwan, 2021). The study of time series forecast is to study the changing pattern of data that have occurred from the past until the present time (Gu, 2007) the extent of data change depends on the pattern of data to be studied (Furtuna et al., 2015), which is the same as natural resources data. Therefore, in studying the time series forecast of EVI, it is to make quantitative comparison; the time series forecast is a quantitative forecast where there are both linear and non-linear methods each of which has its own limitation. The study of change in EVI data to be used in time series forecast is performed using linear method (Li et al., 2014).

Consequently, in this study, EVI was used to study the drought condition together with the time series forecast, by studying the change from the average EVI obtained from Terra/Modis Satellite during 2010 – 2019, in forecasting for 2020 – 2012. In this forecast, the average EVI data adjusted by smoothing algorithm method was used by using RMMEH method (Jin et al., 2013) from Terra/Modis satellite data to be used in the forecast, by applying Moving Averages Method and Exponential Smoothing Methods

MATERIAL AND METHODS

Moving Averages Method

The moving average is a smoothing tool for the convenience in monitoring the trend. Basically, the average would help spread the abnormalities out of the moving averages data used to predict the future. The moving averages method pattern is as shown in Equation 1.

$$Y_{t+1} = \frac{Y_t + Y_{t-1} + Y_{t-2} + \dots + Y_{t-N+1}}{N} \quad (1)$$

Where;

- Y_{t+1} = prediction value over time $t + 1$
- Y_t = data value in the current period (t)
- N = number of data used to mean

Exponential Moving Average

This is the method for data forecast with the same principle as the weighed moving average which is quite complicated; the error occurring from the forecast is used to adjust the next average for more accuracy, however, it is easily applied. The pattern of exponential moving average is as shown in Equation 2.

$$\hat{Y}_{t+1} = aY_t + (1-a)\hat{Y}_t \quad (2)$$

Where;

- \hat{Y}_{t+1} = the new smoothing or the value for the next forecast
- a = the constant smoothing modifier ($0 < a < 1$)
- Y_t = the new data value or the actual value of the time series t
- \hat{Y}_t = the old smoothing or forecast period t

Enhanced Vegetation Index (EVI)

This is the method for solve the problem of the response of light reflection from soil and climate. It is reported that EVI is more associated with the spatial index of leaves surface than normalized differences vegetation index. And according to the past study, it was found that EVI is more sensitive to parameters in area where there is more density of leaves than Normalized Difference Vegetation Index (NDVI). The pattern of EVI is as shown in Equation 3.

$$EVI = G \times \frac{NIR - RED}{NIR + (C_1 \times RED - C_2 \times BLUE) + L} \quad (3)$$

Where;

- EVI = Enhanced Vegetation Index
- G = Gain Factor
- NIR = percentage of reflection in the near infrared spectrum
- RED = percentage reflection in the visible red spectrum
- BLUE = percentage reflection in the visible blue spectrum
- $C_1 C_2$ = coefficient for dust particles in the atmosphere
- L = correction factor for the soil

Adjusting EVI data by smoothing algorithm

This is the technique in adjusting data by smoothing algorithm, which is called RMMEH to be used in adjusting EVI from Terra/ Modis Satellite; the procedures are as follows: (1) Finding M_t is to find the average EVI of the selected year. The pattern in finding M_t is as shown in Equation 4; (2) finding R_t or the median from 5 periods of time which are in close proximity. The pattern in finding M_t is shown as in Equation 5, and (3) finding $EVI_{RMM,t}$ is to find maximum value from EVI, M_t , and R_t of EVI of the studied year. The pattern in finding $EVI_{RMM,t}$ is as shown in Equation 6.

$$M_t = \frac{(EVI_{t-1} + EVI_{t+1})}{2} \quad (4)$$

Where;

- M_t = mean of the EVI over time t
 EVI_{t-1} = previous year's EVI of the period t
 EVI_{t+1} = next year's EVI of the period t

$$R_t = RM_5(EVI_{t-2}, EVI_{t-1}, EVI_t, EVI_{t+1}, EVI_{t+2}) \quad (5)$$

Where;

- R_t = median of all 5 EVI values of time t
 RM_5 = median of the EVI value of time t
 EVI_{t-1} = previous year's EVI of the period t
 EVI_{t-2} = EVI of the previous 2 years of the period t
 EVI_{t+1} = next year's EVI of the period t
 EVI_{t+2} = EVI of the next 2 years of the period t

$$EVI_{RMM_t} = MAX(EVI_t, M_t, R_t) \quad (6)$$

Where;

- EVI_{RMM_t} = EVI of the period t
 M_t = mean of the interval t
 R_t = median of the period t

Checking for forecast accuracy

This is the checking for forecast accuracy of moving averages method and exponential smoothing method was performed. In this study, the accuracy was measured in the following ways: (1) mean absolute deviation (MAD): it is to check for the mean absolute deviation of the forecast, which is very useful for the analysis where deviation in the same unit with the original time series data was to be examined. The pattern in finding MAD is shown as in Equation 7; and (2) mean absolute percentage error (MAPE): this can be calculated by taking the actual error in each period to be divided by actual data in such period and then averaging the actual error in percentage. The pattern in finding MAPE is shown as in Equation 8.

$$MAD = \frac{\sum |\text{actual values} - \text{Forecast}|}{n} \quad (7)$$

Where;

- actual values = observation at a particular time
 Forecast = forecast value at a particular time
 n = number of comparative data

$$\text{MAPE} = \left[\frac{\sum |\text{Actual values} - \text{Forecast}| \div \text{Actual values}}{n} \right] \times 100 \quad (8)$$

Where;

- actual values = observation at a particular time
 Forecast = forecast value at a particular time
 n = number of comparative data

The Study area

The study area in this study is Yasothon Province, located at the Northeastern region of Thailand (Figure 1), at the latitude of 15 – 16 °N and longitude of 104 – 105 °E, 128 meters above sea level, with the area of about 4,161.44 km², or equal to 0.81 % of total area of the country. Yasothon area is characterized by slope from the west side down to the east side; much of the soil is sandy and salty. At the upper part of the Province, much of it is high plain area alternated by undulating area, and some areas consist of forests and small mountains.

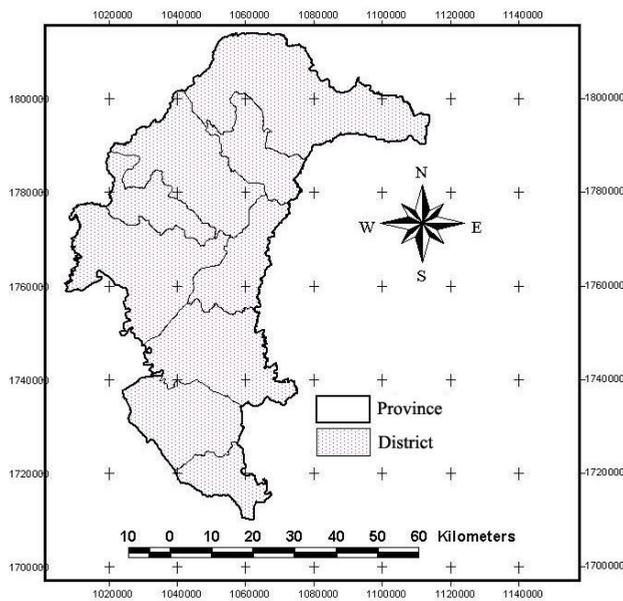


Figure 1. Yasothon Province

Data from satellite

Terra/ Modis Satellite is designed with the aim to follow and monitor natural resources data with swatch of about 2,330 km, with spatial resolution of 250 m to 1000 m, with 36 band recording system, and data from areas all over the world can be recorded within 2 days. In this study, MOD13Q1 product was used to cover the studied area during 2010 – 2019.

Methodology

For the benefit of brevity of the presentation of methodology used in this study, the conclusion was made by using research framework as shown in Figure 2 with the brief procedures as follows: (1) analyze EVI from Terra/ Modis Satellite data in the year of 2010 – 2019, and the average EVI could be analyzed and found by using Equation 3; (2) adjust the average EVI by using smoothing algorithm using RMMEH method from Equation 4, 5, and 6, respectively; (3) predict the land use in terms of time of EVI and EVI index where smoothing algorithm was applied already by using RMMEH method and by using moving averages method and exponential smoothing method; and (4) check for accuracy and compare the results of the study.

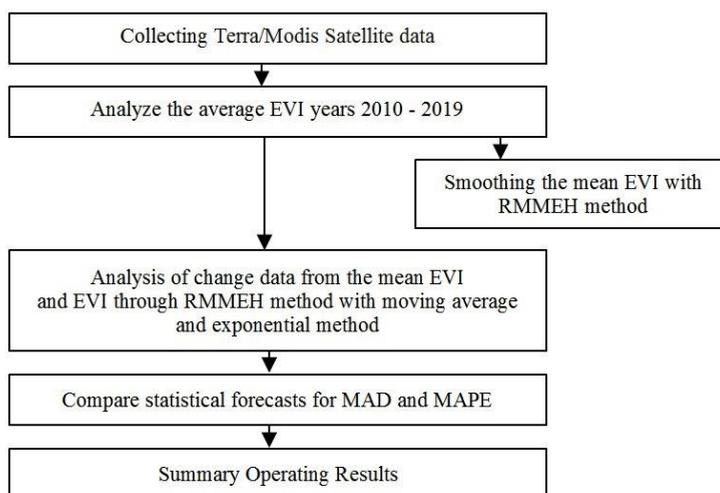


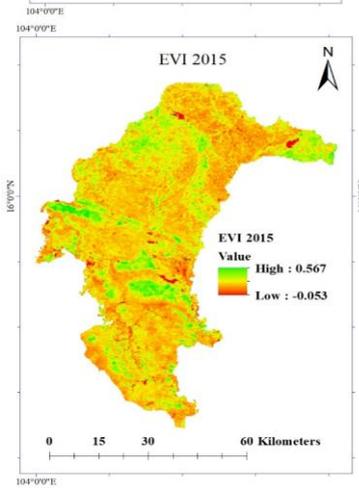
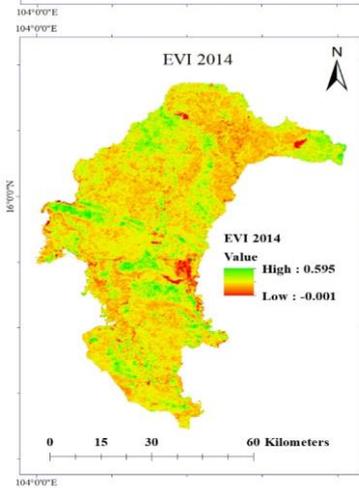
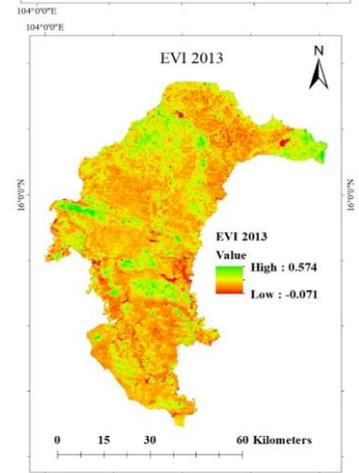
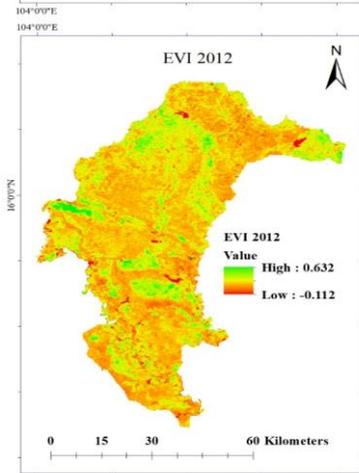
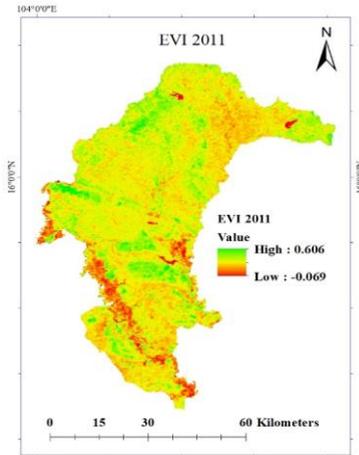
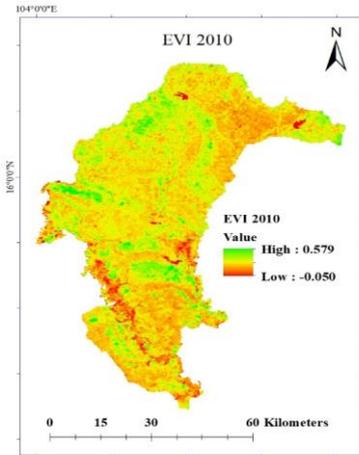
Figure 2. Research framework

RESULTS AND DISCUSSION

In time series change forecast of the average EVI to examine the drought condition from Terra/Modis Satellite data during 10 years (2010 – 2019) in Yasothon Province, the results of the study were as follows:

Result from finding EVI

According to the study during 10 years (2010 – 2019) (Figure 3 and Table 1), it was possible to identify the differences of quantity and fertility of plants in the area; EVI was -1 to 1. Generally, green plants would have EVI of 0.2 – 0.8. According to Table 1, it could be concluded that the maximum value, the minimum value, means, and standard deviation of EVI during 2010 – 2019 in each period revealed different EVI between -1 to 1; such figure was consistent with the theory. The means could identify the condition of plants in the area or the drought condition in each period of time; the minimum means was 0.120 in 2011, and the maximum means was 0.139 in 2016.



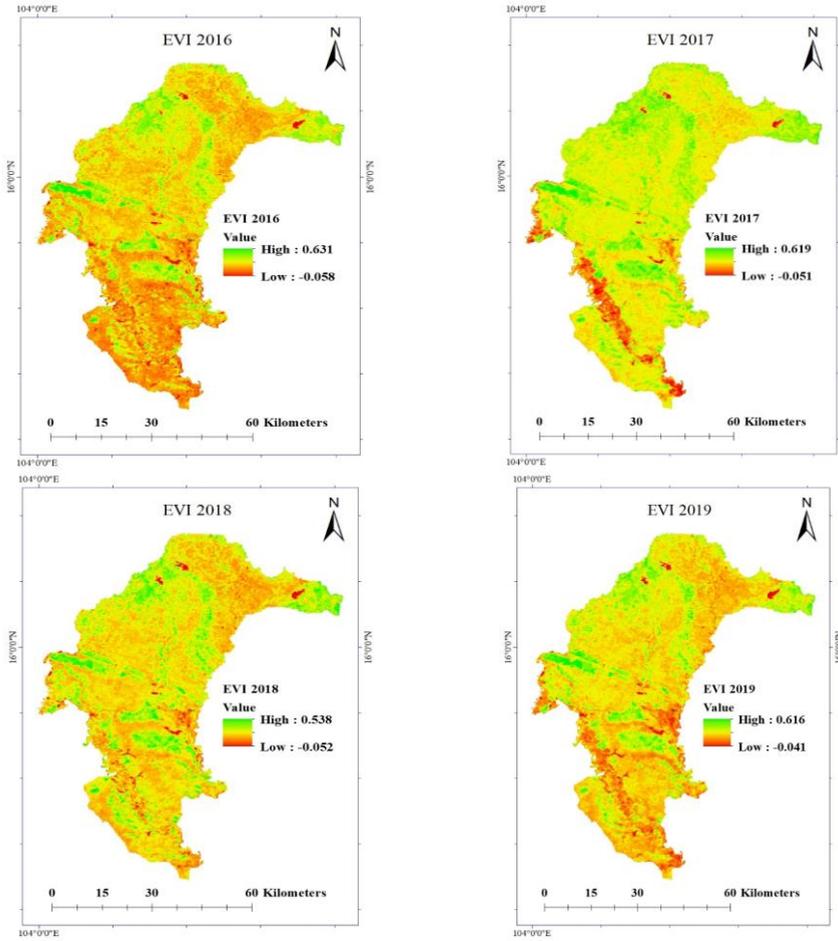


Figure 3. Spatial analysis of EVI during 10 years

Table 1. Minimum, Maximum, Mean, Standard Deviation of EVI

Year	Minimum	Maximum	Mean	Standard Deviation
2010	-0.050	0.579	0.123	0.155
2011	-0.069	0.606	0.120	0.154
2012	-0.112	0.632	0.133	0.168
2013	-0.071	0.574	0.125	0.158
2014	-0.001	0.595	0.130	0.164
2015	-0.053	0.567	0.131	0.165
2016	-0.058	0.631	0.139	0.176
2017	-0.051	0.619	0.130	0.166
2018	-0.052	0.538	0.123	0.157
2019	-0.041	0.616	0.138	0.176

Result from time series change analysis

For the results of the analysis into the average EVI from Terra/ Modis Satellite data with smoothing algorithm by using RMMEH method, EVI , M_t , R_t , and EVI_{RMM_t} of the average EVI during 2010 – 2019 could be shown as in Table 2.

Table 2. the average EVI with smoothing algorithm using RMMEH method

Year	EVI	M_t	R_t	EVI_{RMM_t}
2010	0.123	0.124	0.124	0.124
2011	0.120	0.128	0.124	0.128
2012	0.133	0.122	0.128	0.133
2013	0.125	0.131	0.128	0.131
2014	0.130	0.128	0.130	0.130
2015	0.131	0.134	0.131	0.134
2016	0.139	0.130	0.130	0.139
2017	0.130	0.131	0.130	0.131
2018	0.123	0.130	0.130	0.130
2019	0.138	0.126	0.130	0.138

The result of time series forecast from the original average EVI that had Smoothing Algorithm by RMMEH method

The results of time series forecast from the original average EVI that had Smoothing Algorithm by RMMEH method were shown in Table 3 and Table 4. It was found that the original average EVIs of the forecasted years which were in 2020 – 2022 by using moving averages method were 0.130, 0.130, and 0.132, respectively, and by using the exponential smoothing method, were 0.126, 0.126, and 0.126, respectively.

Table 3. The time series forecast from the original average EVI

Year	EVI	Moving Average	Exponential Smoothing
2010	0.123		
2011	0.120		0.123
2012	0.133		0.122
2013	0.125	0.125	0.123
2014	0.130	0.126	0.123
2015	0.131	0.129	0.124
2016	0.139	0.128	0.124
2017	0.130	0.133	0.125
2018	0.123	0.133	0.125
2019	0.138	0.130	0.125
2020		0.130	0.126
2021		0.130	0.126
2022		0.132	0.126

Table 4. The time series forecast from the average EVI pass Smoothing Algorithm by RMMEH method

Year	EVI_{RMM_t}	Moving Average	Exponential Smoothing
2010	0.124		
2011	0.128		0.124
2012	0.133		0.124
2013	0.131	0.128	0.125
2014	0.130	0.130	0.125
2015	0.134	0.131	0.125
2016	0.139	0.132	0.126
2017	0.131	0.134	0.126
2018	0.130	0.134	0.126
2019	0.138	0.133	0.127
2020		0.133	0.128
2021		0.134	0.128
2022		0.135	0.128

Besides, it was found that the average EVI that had smoothing algorithm by using RMMEH method of the forecasted years which were 2020 – 2022 by using moving averages method were 0.133, 0.134, and 0.135, respectively, and by using exponential smoothing method, were 0.128, 0.128, and 0.128, respectively. From the forecast of the original average EVI that the moving averages method was closer to the original average EVI than the exponential smoothing method. The results of forecast of the average EVI that had smoothing algorithm by using RMMEH method were found that the moving average was closer to the EVI that had smoothing algorithm by RMMEH method than the exponential smoothing method.

Checking for accuracy of the forecast

The results from checking for the accuracy of the forecast by both methods to see which forecasting techniques were of least errors, from 1) MAD and 2) MAPE; the less MAD and MAPE, the better the forecast. The results from checking for the accuracy of the forecast as mentioned could be shown in Table 5. Table 5 showed that errors from both methods were very little and in close proximity. It was found from the forecast that data that passed smooth algorithm by RMMEH method using moving average were best accurate and better than by using the original average EVI.

Table 5. The results from checking for the accuracy

Methods	EVI		RMMEH	
	Moving Average	Exponential Smoothing	Moving Average	Exponential Smoothing
MAD	0.00542	0.00722	0.00357	0.00733
MAPE	4.107 %	5.420 %	2.650 %	5.472 %

According to results of time series change forecast of the average EVI from Terra/Modis Satellite data to examine the drought condition during 10 years (2010 – 2019) in Yasothon Province and by comparing the results between the original EVI and data that passed smoothing algorithm by RMMEH method, with the use of both methods including moving average method and exponential smoothing method, it could be concluded as follows:

(1) To classify the level of drought conditions from EVI during 10-year period, in each year it was possible to make a comparison; if EVI is lower than the means which is 0 to -1, it means that the drought condition is highly severe; if EVI is approaching near 1, it means the vegetation is fertile thus no occurrence of drought condition or little drought condition. According to this study, it can be seen that during 10-year period, the average EVI in each year was very low, suggesting clearly that there was the occurrence of drought condition in the area. And it was found that in 2011, the drought condition was higher than that in other years in the 10-year period since the average EVI was equal to 0.120 which was very close to 0.

(2) From the analysis of Table 2 showing RMMEH method used in adjusting the average EVI, it was found that the average EVI adjusted by RMMEH method was higher than the original EVI, suggesting that RMMEH method could reduce the variable of primary data suitably.

(3) It was found from the comparison of the forecast by checking for accuracy of forecast using MAD and MAPE, it was found that the MAD and MAPE of the forecast of the original average EVI and the average EVI adjusted by RMMEH method were slightly different, and the average EVI adjusted by RMMEH method with the forecast by moving average was best accurate.

(4) It was found from the time-series change forecast of EVI that the original EVI and the EVI that had smoothing algorithm by RMMEH in the forecasted years during 2020 – 2022 by using moving average and exponential smoothing had very low means in each year, suggesting that the drought condition will occur in the future.

Many researchers have applied satellite data in combination with vegetation indices such as NDVI SVI and EVI to monitor drought. For example, the study titled “Performance of Smoothing Methods for Reconstructing NDVI Time-Series and Estimating Vegetation Phenology from MODIS Data” by (Cai *et al.*, 2017), the study titled “Remote Sensing Based Drought Monitoring in the Middle-part of Northeast Region of Thailand” by (Rotjanakusol & Laosuwan, 2018), the study titled “An Investigation of Drought around Chi Watershed during Ten-year Period using Terra/Modis Data” by (Rotjanakusol & Laosuwan, 2019). All three researches mentioned above can be concluded that using satellite data together with vegetation indices can effectively monitor drought.

Additionally, in this study similarly found that the result was in the same direction with other research such as A Novel Compound Smoother—RMMEH to Reconstruct MODIS NDVI Time Series (Jin & Xu, 2013), Normalized Difference Vegetation Index Times Series Change Forecasting Using. Moving

Averages Method and Exponential Smoothing Methods (Sangpradit, 2017). Both studies concluded that when applying the data of average EVI adjusted by smoothing algorithm using RMMEH method, the results were more accurate.

CONCLUSIONS

Drought in Thailand straight affects the agriculture and water source since Thailand is the country where the people do farming particularly growing rice; moreover, Thailand is classified as one of the largest field of rice production in the world. Regularly, the drought in Yasothon Province that straight affects agriculture happens in rainy season where the rainfall is missing for an extended period of time. In this research, the focus was on forecasting time series change of the average enhanced vegetation index to monitoring drought condition by using Terra/MODIS data. From this study it can be concluded that the adjustment by smoothing the average EVI using RMMEH method can be applied with other methods also. The adjustment of the average EVI by RMMEH could help decrease the variance of data; and the map of level of drought condition created by using EVI data of Yasothon Province of Thailand during 10-year period showed clearly the drought areas. Therefore, if the plan is prepared in advanced before the situation, it will efficiently help alleviate and handle the impact from the drought.

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