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Application of geo-informatics technology to study vegetation index and humidity: A case study of drought in the special economic Eastern region of Thailand

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Abstract Result showed the different changes in vegetation indicating the spatial-temporal pattern of drought. These factors represented the plant index (NDVI), humidity difference index (NDWI), and plant image index (EVI) values of spatial-temporal pattern image that being high values. It referred to the different areas among various vegetation covering. The NDVI and EVI showed a greater degree of NDWI that provided the difference in combination of vegetation covering and water contents. Finally, the map of severity for classifying the drought in the spatial-temporal pattern was performed. The spatial-temporal pattern of drought can be implied from the NDVI NDWI and EVI instead of using the meteorological data in case of inadequate coverage of climatic data.

Keywords: Geo-informatics technology, Drought, Normalized differential vegetation Index, Normalized difference water index, Enhanced vegetation Index

Introduction

Nowadays, the drought has damaged in many areas and obstructed development efforts in Thailand. The lack of water is shortage for domestic consumption and agriculture. The Eastern part of Thailand are mostly farmers waiting for rainfall precipatation but it is not enough drought stress The drought comes environment problems such as forest fires, no rain, low soil fertility, destroyed forestry and so on. Drought is a natural disaster that can happen anytime, and the drought problem is difficult to solove. It leads to imbalance ecosystem. Meteorological information may not enough that it is needed the satellite data to follow up drought occurrence. Even though drought is a complicated phenomenon, it can be analyzed by using remote information from the satellite, which would show the phase of abnormal dry air condition in the form of changes that happens to the plant covering and evaluating the severity, change of air, frequency and violence of the drought. The satellite

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image data are continuous and recordings repeated during periods of time. The information is continuous and covers a wide area. Many pieces of information indicate drought concern in plant growth, chlorophyll value in plants, quantity of water in plants, and soil types (Senate Committee on Agriculture and Cooperatives, 2006).

The special economic district in east of Thailand has shown many modern agriculture, industry and advanced petrochemicals. Statistics recorded on the special economic area including Chachoengsao, Chonburi and Rayong provinces revealed that the most severe drought crisis that happened in 2005, threatened the areas for 9 months, from January to September. The quantity of water in two areas in Rayong province (Dok Rai Reservation and Nong Pla Lai Reservation) reached16.70 cubic meters, that was not enough to meet the requirement for of agriculture and industry. It may be caused in the winter, summer and rainy seasons to drought that greatly affected for agricultural production and industry manioulation in this specific economic areas (Eastern Economic Corridor Policy Committee, 2019). Nowadays, the topographical technology has become a role to solove the problem.

The objectives were recoredthe data from geographic information system (GIS) and analyzed the areas at specific times, and to improve the information quality. The maps of the studied areas was gethered data and analyzed the the factors involving the influence of drought in the areas by using the plant index (NDVI), the humidity difference index (NDWI) and plant image index (EVI) to be located and catagorized the drought areas which severity in the identified areas (Steinberg and Steinberg, 2006).

Materials and methods

Vegetarian and humidity indexes were recorded in the drought stress areas in Eastern Thailand by MODIS satellite to record the changes in chlorophyll in the plants leaves in response to water shortage every month. The wave index was used for analysis as the index that reflects chlorophyll changes in the leaf. The quantity of water in the plants and in the ground were recorded as plant difference index (NDVI), humidity difference index (NDWI), and plant image index (EVI). Each index was monthly analysed from the equations: NDVI = (NIR–Red)/(NIR+Red) , NDWI = (NIR–SWIR)/(NIR+SWIR), EVI = 2.5(NIR–RED)/(NIR+6Red–7.5Blue+1) where Blue, Red, NIR and SWIR are digital number values of reflection in each phase as 0.469, 0.645, 0.857 and 1.65 micrometers, respectively. There were used many images reflecting NDVI, NDWI and EVI indexes in many phases to know the areas and time images of drought in the study area according to seasons. It was in response to the quantity of rain and the relationship to NDVI, NDWI and EVI indexes.

The changes in plants between seasons and during the year were recorded andv analyzed. The changes in area are monitored by using the change of index between images on different days following the method of Volcani *et al.* (2005). The change in area is analyzed from the difference in NDVI image according to the equation (Gitelson *et al*., 1996):-

dNDVI = NDVI1– NDVI2

The analysis is expanded to evaluate the change in area from the image difference technique for NDWI and EVI indexes by the same principle (Huete *et al*., 2002) as follows:-

dNDWI = NDWI1– NDWI2

dEVI = EVI1 – EVI2

NDVI1 index is NDVI image which taken in the first day. NDVI2 index is NDVI which taken in the second day. NDWI1 index is NDWI image which taken in the first day. NDWI2 index is NDWI image which taken in the second day. EVI1 index is EVI image which taken in the first day and EVI2 index is EVI image which taken in the second day. Then, it was recorded the NDVI difference (dNDVI Images), NDWI difference image (dNDWI Images), and the EVI difference image (dEVI Images).

The change level was analyzed by specifying threshold, which was one phase of standard deviation steps (SD Steps) from the average of the difference. The -1SD to +1SD showed "No change" and the next level was inform the size of the increasing changes in the positive and negative aspects (Figure 1).

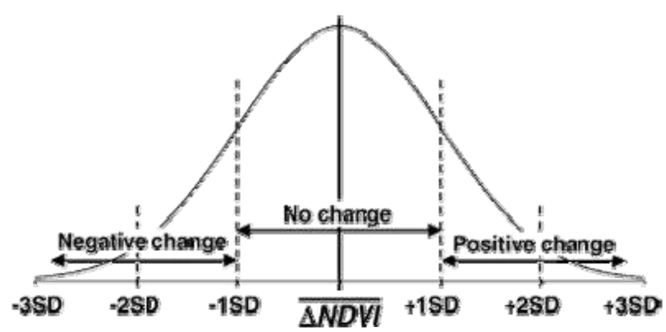

Figure 1. Histogram showing the changes in level arrangement by specifying threshold from the means (modified from Volcani *et al*., 2005)

Image comparison on different dates were recorded and analyzed for the changes in different dates and areas from reflection the image of the plant responded to the air condition or different images between two consecutive months during drought of the year, the monthly drought in the next year, the same month during rainy season in the next year, rainy season and drought in the same year (Table 1).

Table 1. Image comparison on different dates analyzed for studying change

Image pair used for studying the change		Remark
(Image1)	(Image2)	
January 2013	February 2013 February 2014	Same season, same year
January 2014	February 2015 February 2016	(drought)
January 2015	February 2017	
January 2016		
January 2017		
February 2013	February 2014 February 2015	Same month but different year
February 2014	February 2016 February 2017	(drought)
February 2015		
February 2016		
October 2013	October 2014 October 2015	Same month but different year
October 2014	October 2016 October 2017	(rainy season)
October 2015		
October 2016		
October 2013	January 2014	Different season in the same
October 2014	January 2015	year (rainy)
October 2015	January 2016	(Rainy-drought)
October 2016	January 2017	

The maps of drought status was done to determine the drought level that and was analyzed thge different of NDVI , NDWI and EVI images by specifying zero when there was no change (1-SD to +1SD). The size of changes were calculated the level of standard deviation. The map was made by different color levels along with the histogram of the change, percentage of area with change that was showed by graph (Figure 2).

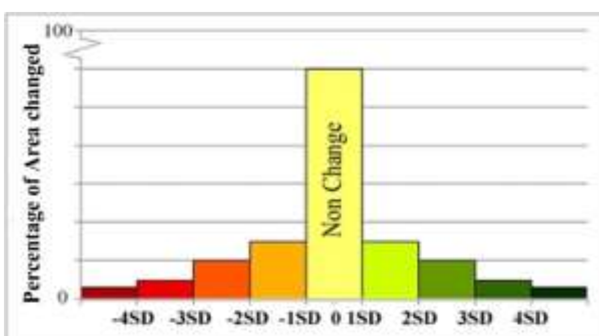

Figure 2. The level of change of the area according to the level of standard deviation shown as level of color (modified from Volcani *et al.*, 2005)

The severity level of drought was made through the map and analysed the differences of NDVI, NDWI and EVI indexes. It was made from the means of the differences in 5 years using the data means and distribution value or standard deviation (S.D.) to specify the range of each phase. Severity is categorized into four levels as follows:-

Area with no drought risk	$\bar{x} - S.D$
Area with low risk	$\bar{x}$
Area with average risk	$\bar{x} + S.D$
Area with high risk	$> \bar{x} + S.D$

The range analyzed value of each phase was categorized by the level of drought into four periods as follows:-1) During January - February 2013-2017, 2) During February - February 2013-2017, 3) During October - October 2013-2017 and 4) During October - January 2013-2017. The guidelines were prepared to solve the drought problem by sustainable way in the special economic area in the East of Thailand. The objective of reserch finding was applied Geo-informatics Technology to study vegetation index and humidity of the drought in the special economic Eastern region of Thailand.

Results

Result showed that the drought is analyzed by using image data from Terramo/Modis satellite in the year 2013-2017 revealed that the analysed variance according to the seasons of NDVI, NDWI and EVI indexes that obtained the plant condition, quantity of chlorophyll, amount of humidity in the plants, and soil humidity related to rainfall. It is showed that during rainy season, the plant uptaked high amount of water leading to well plant growth and high amount of chlorophyll. It demonstated that the NDVI, NDWI and EVI indexes appeared a high in the satellite images. It observed that the during drought, the quantity of rain is reduced dueto lack of water in the plants, then the NDVI, NDWI and EVI indexes appeared the low level in the satellite images.

The averaged yearly rain from 2013 to 2017 and the 5-years averaged rain quality revealed that the highest quantity year was 2017. The year with the lowest rain quantity was 2014, 2017-2016 which that lower than the mean of 5years means (Figure 3). The rainy seasons of 2013-2017 started in June that concerned to be no rain or decreased the rain during July-August, especially in July 2014 and 2015 (Figure 4). There was no rain or the rain was decreased and then the rainning quantity increased every year to be the highest in September-October. These two months were shown the rainning quantity for 1-3 years until November that the rainning quantity was greatly reduced before winter season. In winter season, the rain was lowest in December and no rain in January 2014. The monthly means of NDVI, NDWI and EVI indexes and year means were related to greenness and prosperity of the plants in the studied areas. A high NDVI index indicated the growing well plants but a low index showed plants were not grown well. The NDWI index indicated the water quantity in the plants and soil. The areas with high NDWI indedx showed a high humidity and the areas with low NDWI indexd indicated a low humidity around the plants. EVI index expressed the thickness of the plants in that areas.

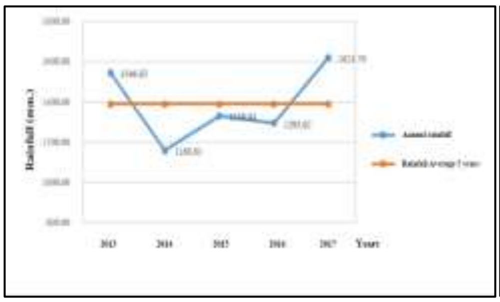

Figure 3. Average rainfall in 2013-2017

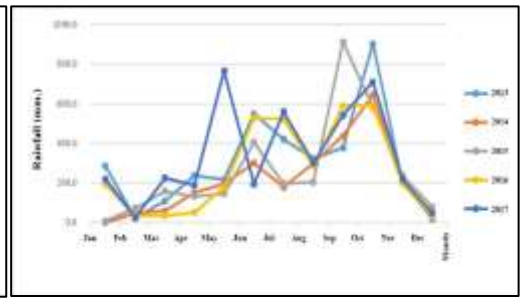

Figure 4. Means of 5-year monthly rainfall in 2013-2017

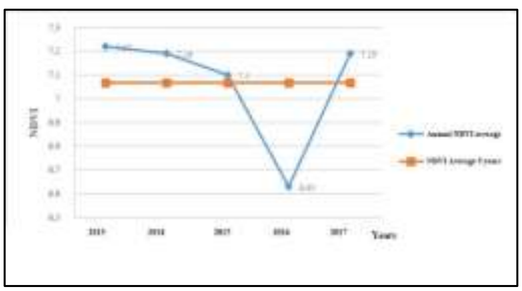

Figure 5. Yearly and monthly means of NDVI

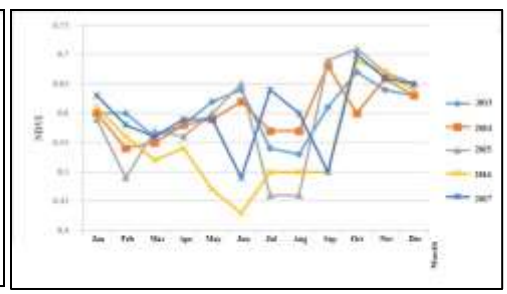

Figure 6. Monthly means of NDVI of 2013-2017

The yearly means of NDVI index was the highest in the year of 2013 and lowest in the year of 2016. It showed the means that lower than the total 5 year means (Figures 5, 6). The monthly means of NDVI index in comparison with the 5 years indicating that in February was low fluctuation and September-October was the highest variance**.**

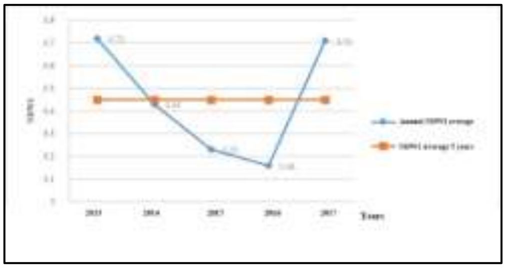

Figure 7. Yearly means of NDWI

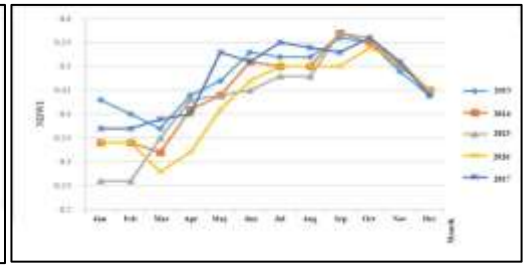

Figure 8. Monthly means of NDWI year 2013-2017

The yearly means of NDWI index in 2013-2017 was shown in Figures 7 and 8. It was found that the yearly means of NDWI index was the same direction of NDVI index means which the highest value in 2013 and the lowest in 2016. It was found that January to July had higher variance of NDWI index than NDVI index, and it was closedly related during August to December.

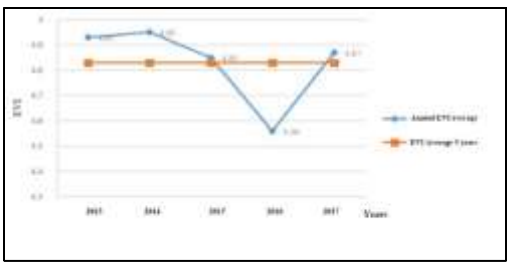

Figure 9. Monthly means of EVI

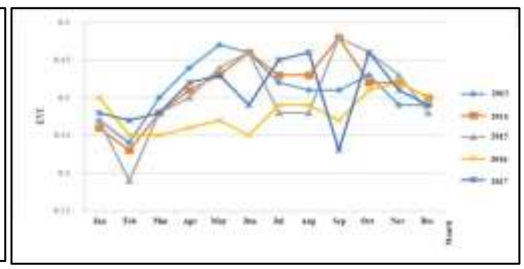

Figure 10. Monthly means of EVI of 2013-2017

The yearly means of EVI idex had lower than NDVI and NDWI indexes but they were in the same direction. It showed the lowest in 2016 which lower than the 5-year means. The monthly means of EVI showed the changed trend in every month. The lowest one was in February and it started to increase in May before decreased every with almost the same rates (Figures 9, 10).

The differences in NDVI, NDWI and EVI indexes in January, February and October of 2013-2017 found that NDVI index that received the data in January and February which no water or low rain. The special economic area in the East was categorized by NDVI indedx on the basis of rainning quantity. In each period, there would be differed in the amount of rain and plant growth. The areas with low NDVI index was appeared in January and February due to the drought period. NDVI index in January and February were not significantly differed because rainning quantity were the same. But the years of 2013 that rainning in February was lower than in January. It might be concerned from global warming. In October that during rainning season, the humidity was high due to heavy level of rain and the plants were growing well (Figures 11, 12).

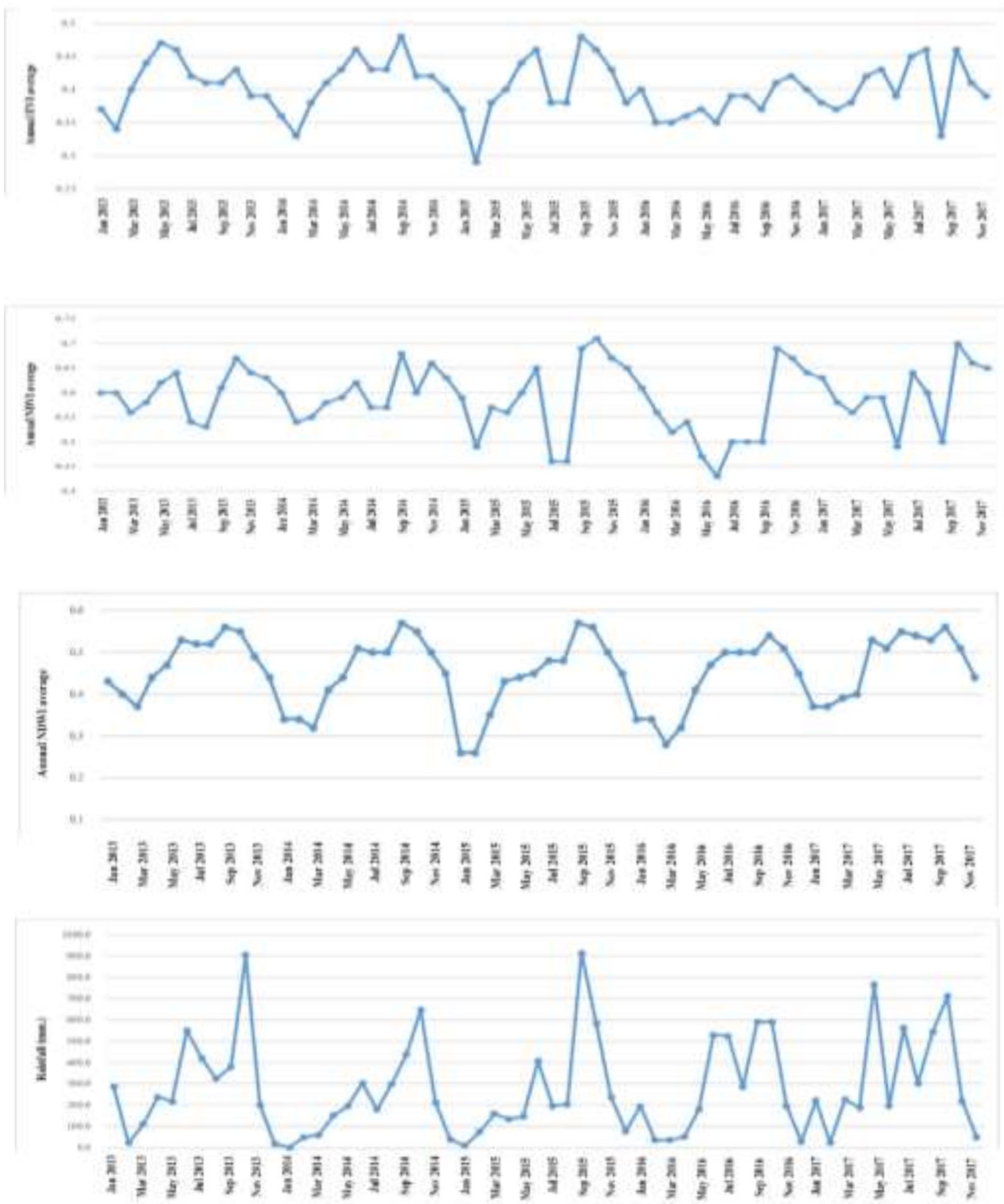

Figure 11. Monthly rain quantity and monthly means of NDVI, NDWI and EVI indexes

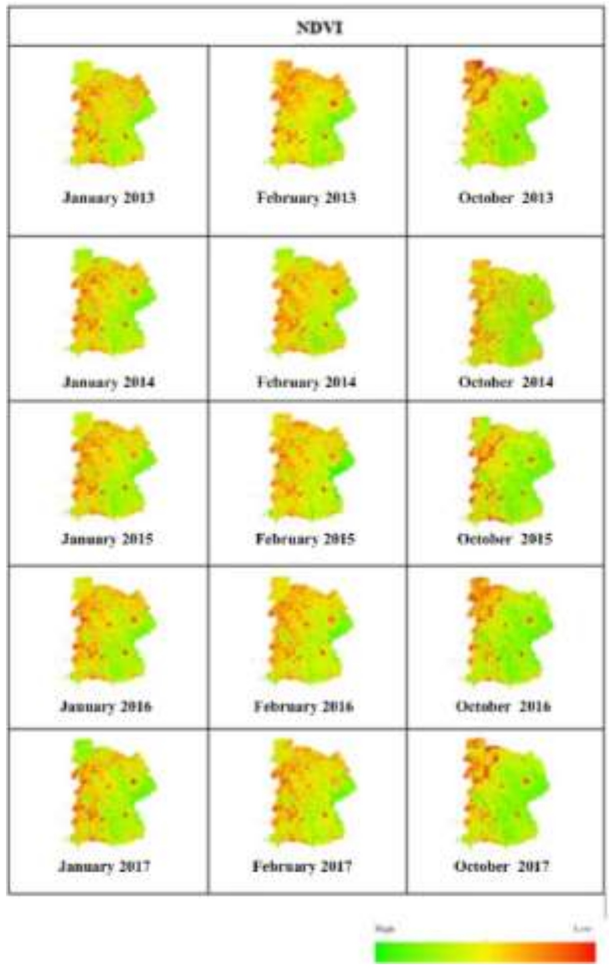

Figure 12. NDVI values in January, February, and October of 2013-2017 in Special Economic Eastern Region

The value or indexes received in October reflected that during rainning season, it was high humidity that related to NDVI image. It was found that NDWI inbdex had lower than NDVI index and also found that NDWI index was less than NDVI index in January and February which faced drought. Result was clearly shown in the areas faced the fast change. The reduced amount of rainfall leaed to reduce NDWI index due to the reaction to rain, and affecting to the plant growth and soil. It showed a clearly differences between drought area and the area of well growing plants whereas NDI index showed a minor difference (Figure 13).

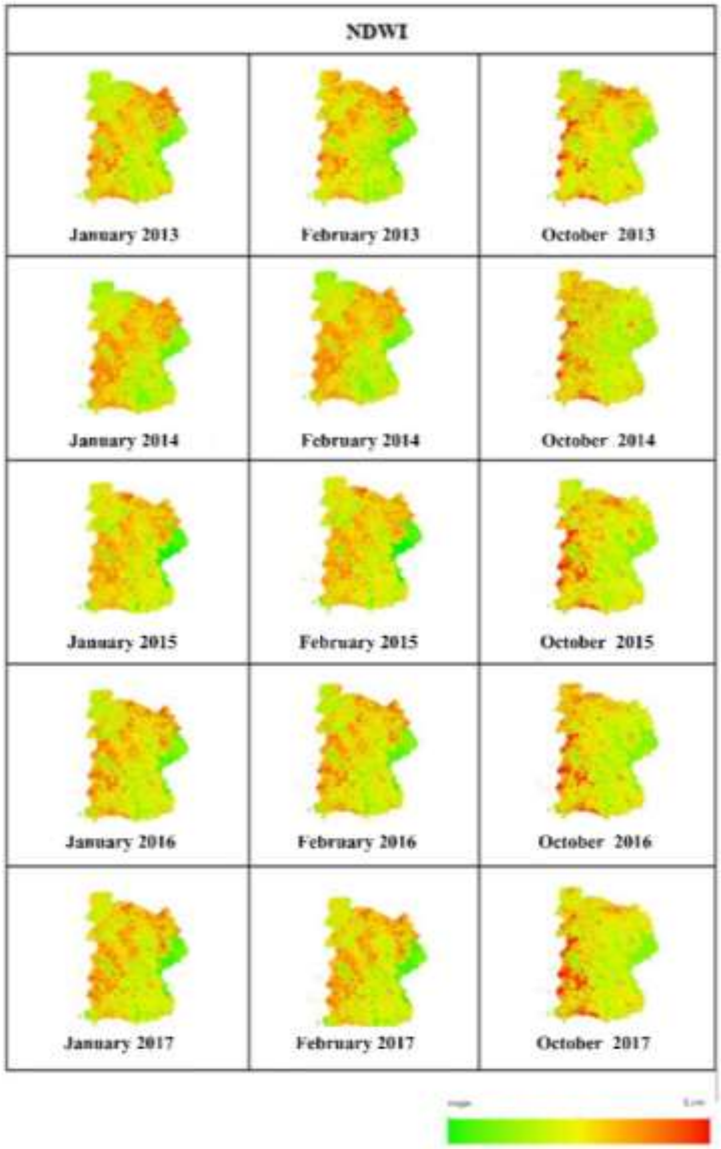

Figure 13. NDWI values in January, February and October of 2013-2017 in Special Economic Area in the East

The EVI index showed the width with lower value than NDVI and NDWI indexes, which was differed during the drying in January and February. It was found that in February 2013 faced a different drought situation which statred from January. It found that in October was high humidity, well growing plants that differed during January and February (Figure 14).

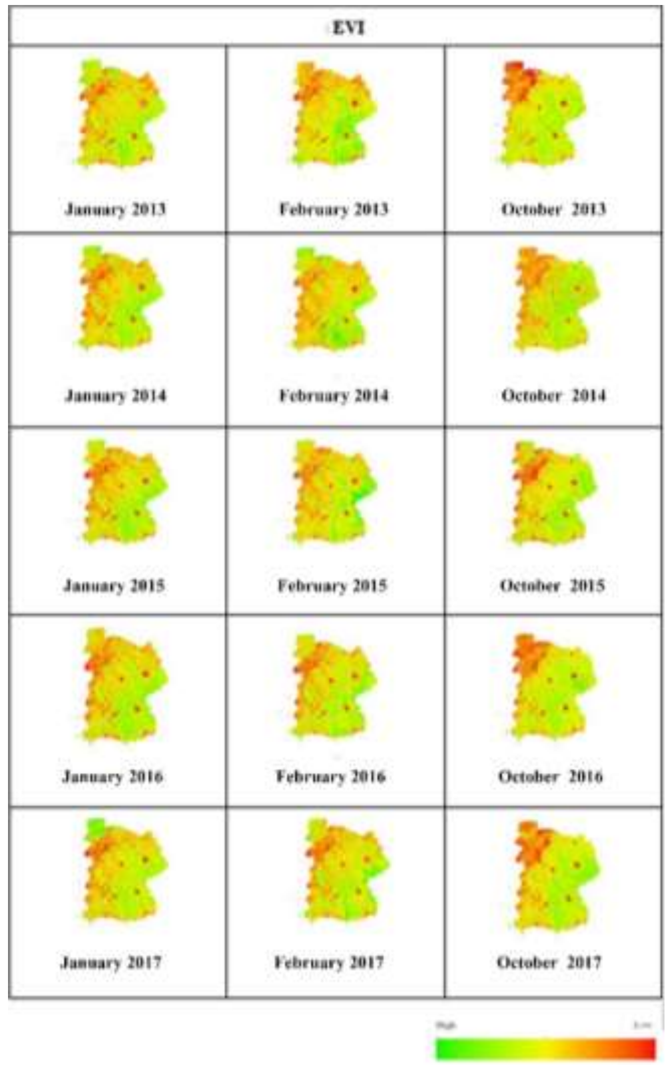

Figure 14. EVI values in January, February and October of 2013-2017, Special Economic Area in the East

The changes in areas from the differences in NDVI, NDWI and EVI indexes were recorded analyzed by using the technique of difference images which modified from the method of Volcani *et al.* (2005). Result showed that NDVI index showed the difference image when compared to the other two indexes of NDWI and EVI (Figure 15). It was based on the changes in index value of the image pairs in different date collection. The changes in the three mentioned indexes were found in different time periods of two consecutive months during the drought in the same year, the same month in the next year of drought, and during the next year of raining, and rainning and drought months.

The result can be seen in the images of dNDVI, dNDWI and dEVI. The analysis of the changes was done by specifying the means as the referenced points and the thresholds as the Standard Deviation Steps (SD Steps). Means of differences in positive and negative sense were expressed the direction and changing level. It showed a positive change in means that NDVI, NDWI and EVI images at the first day that higher than the second day. It indicated to decrease those indexes. The higher steps showed higher difference of -1SD to +1SD that explained as "there is no change".

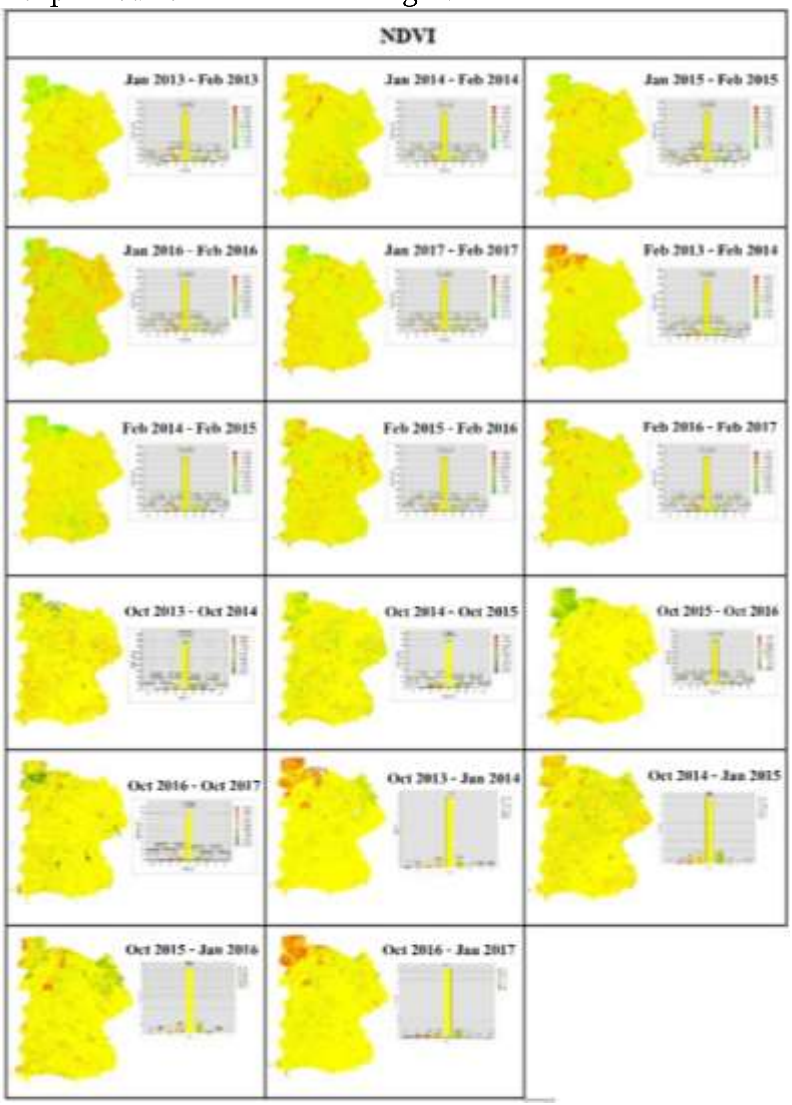

Figure 15. The difference image of NDVI and histogram shows changes in the Special Economic Area in the East

The difference of NDVI and histogram showed the change of the drought. The first period was same season and year faced the drought. It revealed that that the difference images between January and February was similar to the same year. The area was not changed and about 74.35 -76.14 per cent of the entire of the studied areas. The areas were mostly positive changed in January which NDVI index was higher than in February. The difference images in 2014 was no changed because low rainning quantity and leading to NDVI index in January was higher than in February or almost the same.

The second period of same months in different years of drought showed the difference images in February for the next year as the difference images of NDVI index had not changed from 75.07-76.42 per cent of the studied areas. It showed the positive and negative values due to variance and rainning quantity in each year. In February 2014 to February 2015, NDVI index of the first year was higher than the later year. It meaned that plant growth was high density. In February 2015, there was shown a negative change due to lower plant growth.

The third period in same month with different year of raining season was shown the difference images in October of the next year. The difference images of NDVI index showed the areas with no change from 77.06-81.82 per cent of the studied areas. The areas with no change showed the positive and negative values due to variance and quantity of rainning in each year. A comparison between October 2016 and October 2017 showed higher NDVI index in the later year. It meaned to be not changed in plant growth and density. On the other hand, in October 2016, there was negatively changed in plant growth but it was lower when compardeed to the later year.

The periods of four different seasons in the same year of raining and drought showed the difference images between October (raining season) and in January (drought) in the same year. The areas had no changed which 72.92-82.46 per cent of all the studied area and mostly they had negatively changed because the raining quantity shown in thein October was low. It was the period that plants did not uptaken much water and low growth. The NDVI value was lower than in January (drought). The rainning quantity was high humidity for the plant growth but low humidity had high NDVI index.

The difference images of NDWI and histogram showed changes in the drought areas was stated the first peroid in same season and year of drought (Figure 16). The difference images of NDWI index between in January and in February showed an area with no change of 73.17-76.43 poer cent of the studied area. The areas with no changes showed positive and negative due to variance and rainning quantity in each year. Mostly, in January was more dried than in February due to raining quantity of in the former year that higher than in the latter.The second period in the same month with different year of drought showed the difference images of NDWI index in February which no changed areas of 74.54-76.80% of the studied area that resulting as the same manner of the first year. In February was the drought month and low raining. The change was more clearly shown than NDVI index, but the level of changed variance in each one was higher level to change that less than the value of NDVI index.The third peroid in the same month with different years of rainy season showed the difference images of NDWI index in October that resulting as the same manner of the second year. In October, the areas were changed due to raining month. NDWI value and raining quantity were high humidity for the plant growth. NDWI value with change was more cleared than NDVI value. The fourth period of different season in the same year of raining and drought revealed the difference images of NDWI value in October and in January had no changeg of 71.11-76.00 per cent of the studied area that resulting as the same manner of the third year. The difference images in October and in February showed the different images and positive changed level. NDWI value in January showed the areas in a negative sense was clearly lower than in October due to low raining quantity in January which faced drought peroid and in October was raining.

The difference images of EVI index and histogram showed the change in drought areas. The first period in then same reason and year of drought expressed the difference images of EVI index between January and February revealed no change of 70.965-74.89 oer cent. The area with no change showed positive and negative senses of variance and raining quantity. The changes in areas was in the same direction of the difference images of NDVI and NDWI indexes, but higher changed than the NDVI and NDWI indexes.The second period in the same month and different years of drought differed image of EVI index in February that the area with no change (72.947-80.383 per cent) that resulting as the same manner of the first period. The areas had positive and negative values that higher changed than NDVI and NDWI indexes.The third period in the same month with different years of raining season showed the difference images of EVI index in October. It had no changed of 62.03-76.47 per cent that resulting as the same manner of the second period. The fourth period was the different seasons in the same year of raining and drought revealed that the difference images of EVI index in October and January had no changed of 70.36-81.93 per cent that resulting as the same manner of the second period.

The difference images in October and in February explained the difference images of NDVI index but the size of changes was high and the EVI index showed a negative change in January which higher than in October in all periods.

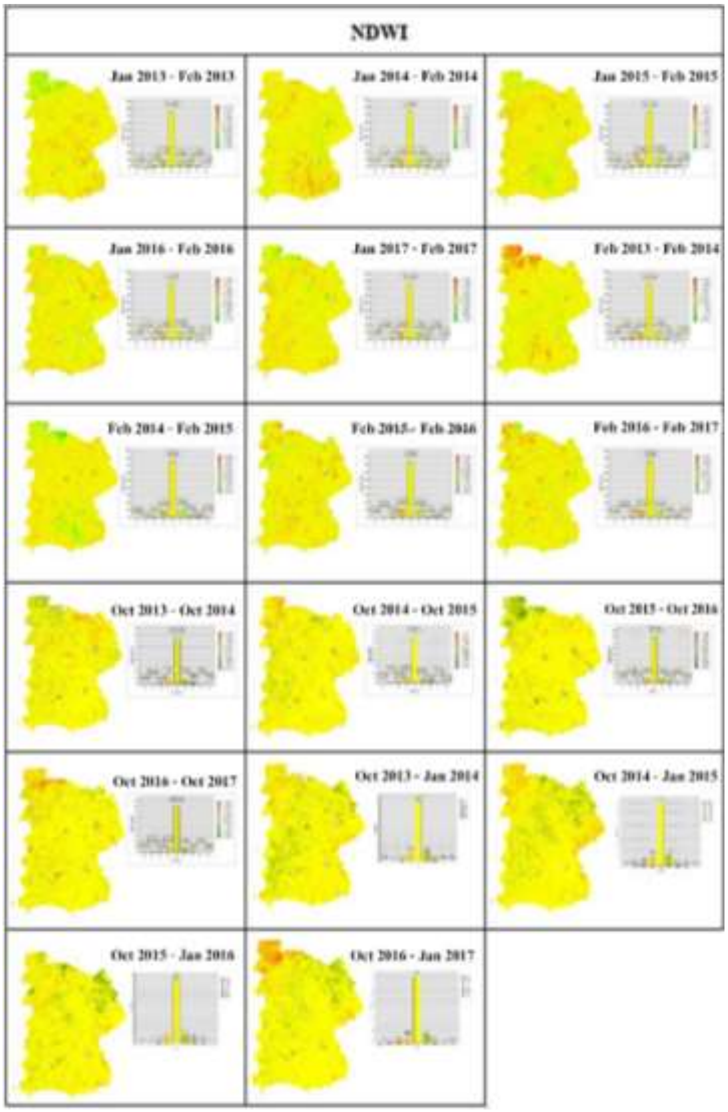

Figure 16. Difference image NDWI and histogram showing change in the Special Economic Area in the East

Categorization of drought levels in the special economic area in the East of Thailand found to be specifying the security level of drought by analyzing the difference images of NDVI, NDWI and EVI indexes. The means of the difference values of 5 years were recorded by using the averaged data and the distributed data for standard deviation S.D. to specify the range in each period (Table 2, Figure 17).

Figure 17. The difference image of EVI and Histogram shows the change in the Special Economic Area in the East

Table 2. The 5-year means of a plan in drought levels of the special economic area in the East of Thailand

5-year mean	NDVI		NDWI		EVI	
	Mean	SD	Mean	SD	Mean	SD
Jan-Feb	0.0488	0.1010	0.0683	0.0947	0.0033	0.0850
Feb-Feb	0.0030	0.0229	-0.0218	0.0978	-0.0154	0.0628
Oct-Oct	0.0305-	0.1202	-0.0063	0.1119	0.2853-	0.8814
Oct-Jan	-0.2624	1.9570	0.1028	1.8069	-0.2095	2.0450

The difference value of NDVI index was assessed the severity of drought in the special economic area in the East of Thailand (Figure 18).

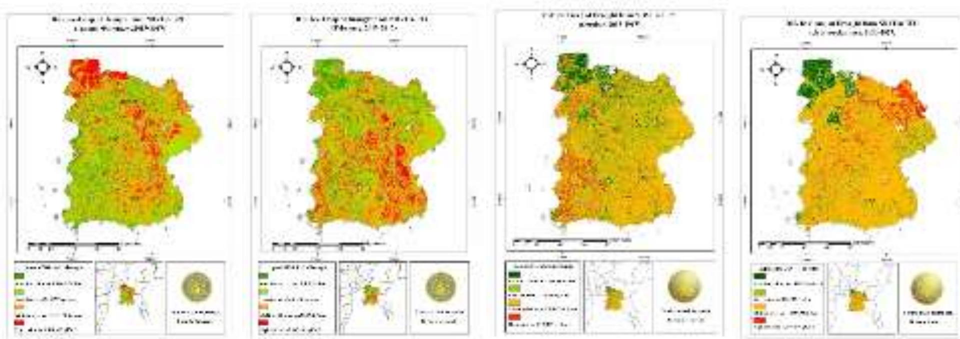

Figure 18. The map showing drought level from NDVI in the special economic area of the East during four time periods in 2013-2017

The second peroid in the same month and different years of drought (Figure 19).

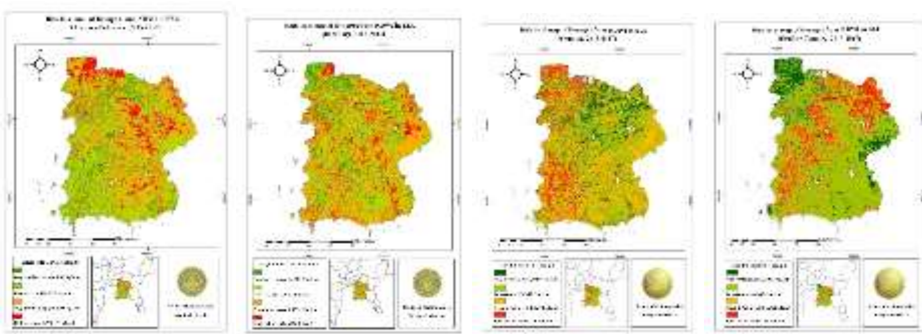

Figure 19. The map of drought levels from NDWI index in the special economic area in the East of Thailand during four periods of time between 2013 and 2017

The difference of EVI ides was assessed the severity of drought in the special economic area in the East of Thailand (Figure 20).

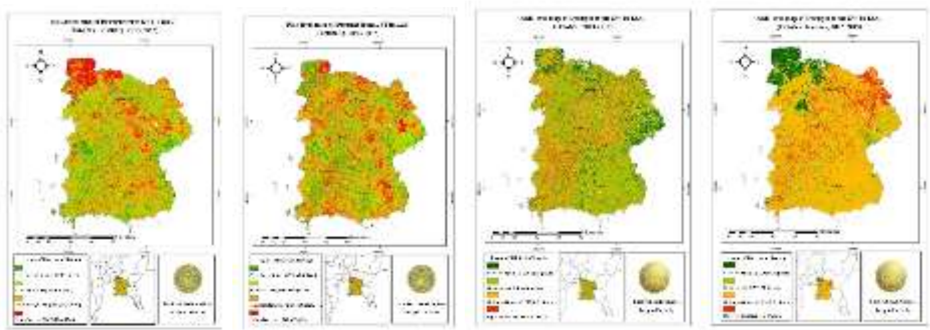

Figure 20. Map of index drought levels from EVI in the special economic area in the East of Thasiland in four periods between 2013 and2017

Discussion

The research finding was conducted from 2013 to 2017 to compare the different time periods of raining and drought seasons. The photographs in each time period were compared the impacts of the changes in NDVI, NDWI and EVI indexes. When considering the analyzed results of the drought levels, it was found that all provinces in the EEC areas, namely Chachoengsao, Chon Buri and Rayong are at high risk of drought about 1,503.03 sq. Km., equivalent to 12.77 percent. The drought level found in Thailand is moderate and does not cover the whole areas of the provinces. Many similar studies convinced Thailand is in the tropical climate, but the drought occurred in each area at each year is not as severe as other different countries of the same climate due to the fact that abnormal weather condition rarely occurs and a shortage of rainfall does not last for several months. Srikhao *et al.* (2014) investigated the Northeast provinces of Thailand and found that there was only 10 percent of the areas threatened by the moderate drought. Likewise, Nakthieng and Yimyuan (2015) analyzed the 4 Sub-districts in Ayudthaya, the central part of Thailand, and the study indicated that not all regions suffered a moderate drought. However, based on the total areas of the 3 provinces in the present study, 13,265 square kilometers, the area suffered from the drought problem is accounted for 12.77 percent only. However, it is considered minimal and can be manageable as the drought that occurred in Thailand is only a moderate drought (Meteorological Department, 2010).

To sum up, although Thailand is still geographically fortunate with an abundance of natural resources and no severe drought, any level of drought can still affect people's living conditions, agriculture and industries as such. If lacking good planning and management, the effects of drought can also be broadened, causing economic and social impacts (Socioeconomic Drought) when unable to manage enough water supplies to meet various needs (Wilhite and Glantz, 1985).

It is suggested that further study may be applied the index data from satellite images in order to measure drought in the cloudy and foggy areas during the rainy season and investigate the variance changes of the data values. The comparative study of satellite data should be carried out during the year to examine changes in the values of NDVI, NDWI and EVI indexes.

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