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DROUGHT RISK EVALUATION USING REMOTE SENSING AND GIS : A CASE STUDY IN LOP BURI PROVINCE

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ABSTRACT: Drought disasters in Thailand have been occurring with increasing frequency in recent years. A drought is one weather hazard that is often underestimated for two reasons. (i) Droughts have a slow rate of onset and, (ii) They have less visual impact on us. However, the long term outcome of a drought can be widespread and very devastating.
This drought risk area evaluation study involved the intregration of Geographic Information Systems and Remote Sensing technology. JERS-1 OPS dry season data was acquired for 2 different years and was processed to detect vegetation condition change in response to drought.
Physical and meteorological factors were analysed and drought risk areas were identified based on the criteria of Ministry of Science, Technology and Environment (MOSTE) of Thailand. NDVI change between a normal year (1995) and drought year (1997) was analyzed for each drought risk area. It was found that the value of the NDVI is lower in high drought risk areas, which justifies the modified criteria of MOSTE.

1.INTRODUCTION

Drought disasters in Thailand have been occurring with increasing frequeency in recent years. The last droughts in Thailand occurred in the dry season several years ago, when the severest effects were seen in central, north eastern, eastern and southern regions.

Lop Buri is the one province which is critically affected by drought and water shortage events. Its main land use is agriculture, the primary crop being rice, which requires a lot of water for growth. Therefore drought hazard studying in this region is important for migration and agriculture planning.
This study has used remotely sensed data subject to a Normalized Difference Vegetation Index (NDVI) calculation in order to prove and support the modified criteria of drought risk areas evaluation developed by Ministry of Science, Technology and Environment (MOSTE).

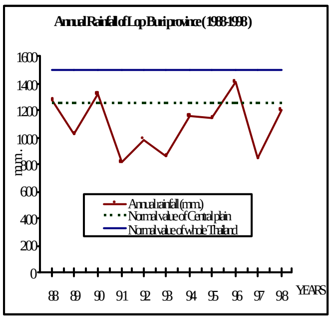
Evaluation of drought is one of the important items for the mitigation of its effects, but this evaluation is often difficult to obtain over large and remote areas. The Use of remote sensing and GIS is useful for drought evaluation to obtain up to date information that is difficult to collect by traditional methods such as field survey and sampling questionnaires.

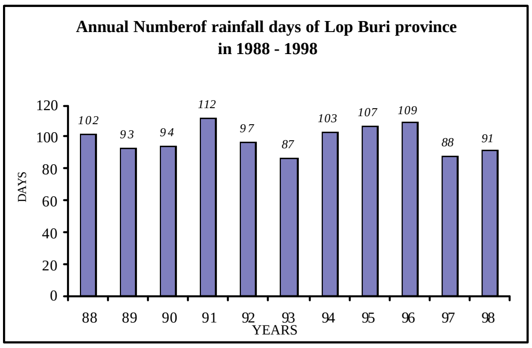
2.OBJECTIVES

The objective of this study was to evaluate the criteria for identifying drought risk areas, modified from MOSTE's criteria by investigating the decrease in Normalize Difference Vegetation Index (NDVI) evident in a drought year.

3.STUDY AREA

The study area is 2,942.38 Km^2, which covers 3 whole districts and partially covers 4 districts on the West of Lop Buri province in central plain region of Thailand. Its position is between latitude 14° 55′ - 15° 50′ N, longitude 100° 42′ - 101° 50′E. The predominant topography of area is flat, low lying terrain, around 25.6 meters above mean sea level. The north western part of the study area is occupied by some hilly terrain. Some areas in the central eastern region has similar slope complex. There are two main rivers; Lop Buri River and Bang Kham river. The average minimum temperature variation ranges from 23°C in winter to 33°C in summer. The average relative humidity fluctuates from a minimum of 52% to a maximum of 88% in April. Average annual rainfall was 1,092 mm between 1988-1998 and average annual of rainfall days is 95.5 days (Figure1)





Annual Numberof rainfall days
in 1988 - 1998

Figure1. Annual Rainfall and Numbers of Rainfall days of Lop Buri province in year 1988-1998
(source : Data processing sub-division, Climatology division, Meteorological department)

According to the annual rainfall report for Lop Buri province in 1988-1998, 1994 had a lower annual rainfall (1,151.8 mm) than the normal value for the central plain (1,250 mm) and the whole kingdom (1,500 mm). Thus the year 1994 was identified as a drought year and represented by a satellite image captured in January 1995. 1996, with an annual rainfall of 1401.5 mm was declared as a “normal” year and was represented by a satellite image captured in January 1997.

4.METHODOLOGY

4.1 Image processing

Two main processes were used in this study - Image processing and GIS. Image processing was necessary to derive land use classification and to calculate the Normalized Difference Vegetation Index (NDVI). Pre-processing, such as geometric and radiometric correction were necessary before the analysis, and were performed in order to reduce the radiometric distortion in the case of multi-date images. Land use maps were classified by the Maximum likelihood Method. NDVI calculation was performed to extract vegetation index values, which were used as the main indicator for determining drought impact under the concept that non-drought areas should show an NDVI correlating to dense vegetation.

$$NDVI = (NIR-VI)/ (NIR+VI) \qquad \text{(Equation 1)}$$

where: NIR,VI are Band 3, Band 2 in case of JERS-1 OPS image

For this study, a NDVI was calculated for each of the two images. The next step was to calculate the difference between the NDVI’s acquired for each year.
As already mentioned, the satellite images for 12 January 1995 and 29 January 1997, were considered as representative of years 1994 and 1996 respectively. The reason we assume this is because the criteria for estimating drought risk area uses average annual rainfall data. In January there is not any rainfall (the rainy season usually stretching from June to October). The satellite images for January 1995 and 1997 are considered as being an accurate representation of the conditions from the previous year.

The difference between the Normalized Difference Vegetation Index for 1994 and 1996 was calculated in order to detect NDVI change between normal and drought conditions, and was performed using the following equation:

$$\Delta NDVI = (NDVI\ time2) - (NDVI\ time1) \qquad \text{(Equation 2)}$$

where : time1 = Normal year in 1997, time2 = Drought year in 1995

4.2 Modified MOSTE drought risk area

A Linear Combination Weighting System and multi criteria assessment to determine drought risk areas for the Central Plain of Thailand were defined by relevant experts in meteorology, soil science and agriculture within MOSTE. Modification of some parameters was necessary as well as the adjustment of some weighting due to issues with the availability of data. With respect to this, two parameters which had the smallest score were cancelled. They were river density and catchments, which had scores of 2 and 1 respectively. A further modification was the inclusion of evaporation data to substitute the third sequence parameter (Table1). These modified criteria were applied to the study area and were compared to the results of the difference in NDVI between drought (1994) and normal (1996) conditions.

According to the purpose of the drought risk area evaluation, there are two main types of data input; (i) Meteorological data (including average annual rainfall, average annual number of rainfall days and average annual evaporation). This data used average normal values spanning from 1994 to 1998. (ii) Physical data (including irrigation area, ground water resource, topography and soil drainage characteristics)

Drought risk area can be calculated as a weighted linear combination of a set of input factors. Due to the fact that each of the factors have an influence on the drought condition, they can each be analyzed and implemented in the model. The expression used is as follows;

$$Wt = \Sigma W_i D_i \ \ldots \ W_n D_n \qquad \text{(Equation 3)}$$

Where Wt = Total weight, W_i = Weight value in each parameter i to n ,
D_i = Score value in each parameter i to n

The aggregate score from a linear combination factor model, obtained from the above expression were classed into four drought risk levels: 'very high drought risk area', 'high drought risk area', 'moderate drought risk area' and 'low drought risk area'

Table 1: Parameter and Weighting System for assess Drought Risk Area in Lop Buri province.

Score 7	**Score 6**	**Score 5**	**Weighting**
Annual rainfall average	Frequency of rainfall days	Annual Evapolation	
< 1,000 mm	< 60 days	>1900 mm	3
1,001-1,200 mm	61 - 70 days	1,801-1,900 mm	2.5
1,201-3,000 mm	71 - 80days	1,701-1,800 mm	2
1,301-1,400 mm	81 - 100days	1,601-1,700 mm	1.5
> 1,400 mm	> 100 days	<1,600 mm	1
Score 4	**Score 3**	**Score 2**	**Weighting**
Irrigation area	Ground water resource	Topography.	
Outside > 6 Km.	Rate < 5 M^3/hrs	Slope > 30%	3
Outside > 4 Km.	Rate 5-10 M^3/hrs	Slope 16-30%	2.5
Outside > 2 Km.	Rate 10-15 M^3/hrs	Slope 11-15%	2
Outside < 2 Km.	Rate 15-30 M^3/hrs	Slope 6-10%	1.5
Inside	Rate > 30 M^3/hrs	Slope 0-5%	1
Drought Levels	**Total Weight (Wt)**	**Score 1**	**Weighting**
		Soil Drainage	
Very high drought risk area	70-84	Well drained	3
High drought risk area	56-70	Moderately well drained	2.5
Moderate drought risk area	42-56	Somewhat well drained	2
Low drought risk area	28-42	Poorly drained	1.5
		Very poor drained	1

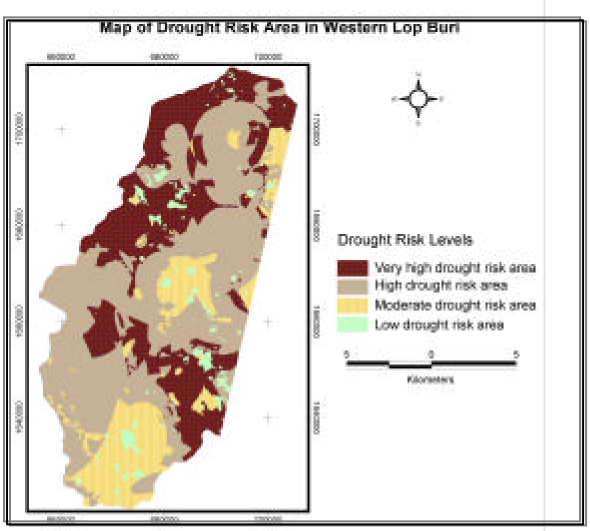
5. RESULT

5.1 Drought Risk Area

According to the map of drought risk in western Lop Buri (Figure2), the predominant condition is "high drought risk" comprising of approximately 1,504 sq.km. (51%) followed by the level of "very high", "moderate" and the least occurring condition is "low drought risk" (Figure3).

An analysis of drought risk in the district boundaries, shows that the largest of the very high drought risk areas is in King Amphoe Nong Muang district (249.58 sq.km.), a high drought risk area was found in Amphoe Kok Sumrong district (306.32 sq.km.). Moderate drought risk area was present in Amphoe Banmi district (345.80 sq.km.) as well as low drought risk area (212.99 sq.km.) located in this district.

With respect to landuse, very high drought risk areas are mostly located in the North, North-West, and South-West regions of the study area, where the major land uses are rainfed paddy fields, upland crops and deciduous forest.



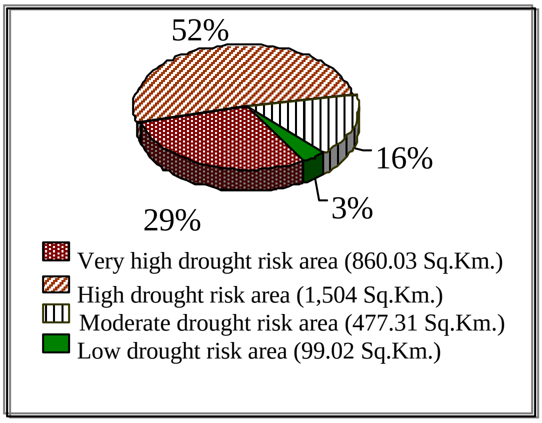
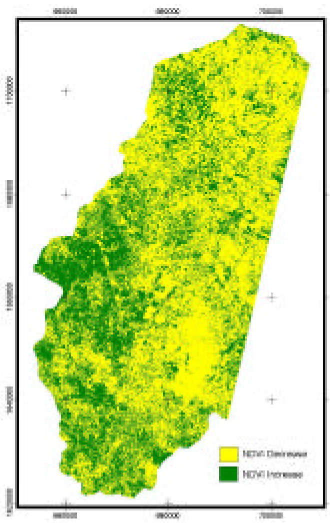


Figure 3: Drought risk area in each levels

Figure 2: Map of drought risk area in Western Lop Buri province.

5.2 Normalized Difference Vegetation Index change between drought year in 1995 and normal year in 1997

From the results of this calculation, it can be seen that over the whole study area, 67.28% of the land area experienced a decrease in NDVI, whereas 24.44% experienced an NDVI increase in the drought year (1995) when compared to the normal year (1997). The remaining 8.28% of land was within +/- 10% standard deviation of zero NDVI change, and therefore classified as not illustrating a significant change in NDVI in response to drought conditions. The decrease in NDVI is mostly evident in the northern, eastern and south-eastern locations, where the primary land cover types are paddy fields and upland crops. These are displayed below.



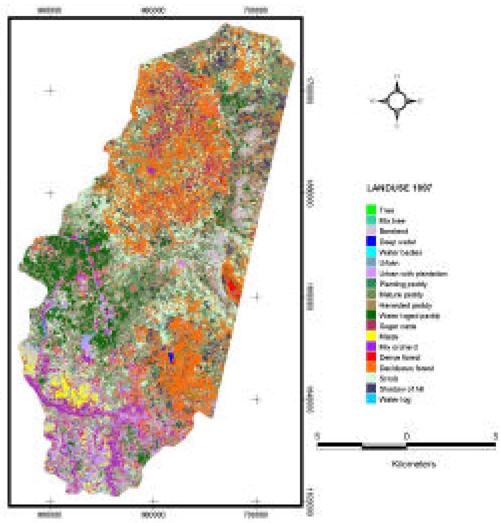


Figure 4: Map of NDVI change in Drought year (1995) and Normal year (1997)

Figure 5: Landuse map of Western Lop Buri in 1997

5.3 NDVI Change in three main land use type

The statistics show a decrease in NDVI for forest, paddy without water and upland crops (including sugar cane and maize). A comparison of the mean values of NDVI change revealed that forested areas experienced the highest decrease in NDVI, whereas upland crops and paddy fields illustrated a lower decrease in NDVI.

The degree of NDVI change is different across the different categories of drought risk level, as identified by the adapted criteria employed by MOSTE. The highest NDVI changes were witnessed in areas classified (by MOSTE) as being very high drought risk, high and moderate drought risk areas (with the exception of paddy fields) experienced a lower NDVI change than the very high drought risk areas, but higher than the level of NDVI change seen in the low drought risk areas (Figure 6)

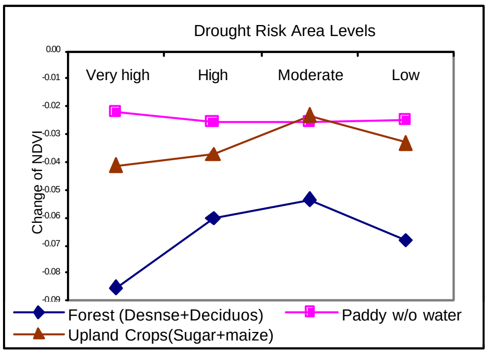


Figure 6: Mean of NDVI change of three landuse type in each drought risk area.

5.4 NDVI Change and Drought risk area

According to table 2, which describes area statistics of NDVI change, it can be seen that at every drought risk level a decreasing NDVI is evident. The results showed that the vegetation condition in January 1995 was affected by the dry spell and lack of rainfall in 1994. Thus it was shown that the image from 1995 could be related to the vegetation condition of 1994.

Table 2: NDVI change of Drought year (1995) and Normal year (1997) in Drought risk area

Drought Risk Levels	Area Sq.km.	Min	Max	Mean	Stdev.	NDVI Change (area%)	
						Decrease	Increase
1) Very high	860.03	-1.09	0.49	-0.03	0.07	67.20	22.06
2) High	1504.00	-1.09	0.49	-0.02	0.07	67.43	24.17
3) Morderate	477.31	-0.46	0.45	-0.02	0.06	63.04	29.06
4) Low	99.02	-0.38	0.31	-0.03	0.06	71.45	22.47

Source : Statistics from (NDVI1995)-(NDVI1997) in each drought risk area levels
Remarks : NDVI Decrease mean vegetation index value in drought year was lower than normal year.
(Decease value from '0' by <= -0.0064) where: 0.0064 is 10 percent of Average Stdev.
NDVI Increase mean vegetation index value in drought year was higher than normal year.
(Increase value from '0' by >= 0.0064) where: 0.0064 is 10 percent of Average Stdev.

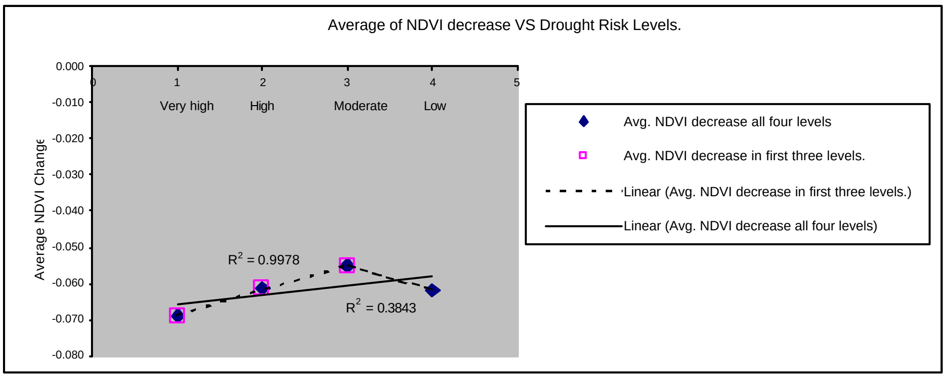


Figure 7: Relationship between average NDVI Change in each Drought risk levels.

Table 3. Average of decrease NDVI change value in each Drought risk levels.

Levels of Drought risk	Average NDVI decrease
1.Very high	-0.069
2.High	-0.061
3.Moderate	-0.055
4. Low	-0.062

5.5 Relationship between NDVI Change and Drought risk area

The relationship between NDVI change and drought risk level was calculated from the average NDVI change which was collected by masking each drought risk area. Correlation and regression analysis was performed using linear regression. The results show that the average decrease in NDVI shows a significant negative correlation with the first three drought risk levels (very high, high and moderate), the correlation coefficient is evaluated at 0.99. However, when a correlation is performed with all drought risk levels, the accuracy of the correlation is only 0.38.

6.CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The production of the drought risk area map for western Lop Buri province revealed the following information; (i) that the area experiences lower than normal, irregularly distributed rainfall., Average annual evaporation is also lower than normal. (ii) The area is located outside the boundaries of irrigated land. (iii) the ground water resource can produce a flow of less than 10 M^3 per hour. (iv) slope aspect is more than 16% (v) the area's soils are moderately well drained.

In total it was found that the largest drought risk category was the high drought risk category – which accounted for 52% of the land (1,504 sq. Km.)

The result of the Drought and NDVI study illustrates that vegetation condition can be used as an indicator for drought condition of an area. The results show a decrease in NDVI in January1995, which correlates to the reduced rainfall quantity during year 1994. Thus NDVI can be used as the main indicator to evaluate drought. On the other hand, we could also use the modified criteria of drought risk assessment by including vegetation and landuse data as well.
According to the results, the relationship between drought risk levels and NDVI change, can only be considered significant for the first three drought risk levels (very high, high and moderate).

The low significance of a correlation between NDVI change and drought risk when low drought risk is included in the analysis can be attributed to the fact that the areas identified as being low drought risk by MOSTE's adapted criteria illustrate a relatively high decrease in NDVI, where a low decrease would have been expected. This anomalous result may be explained by the fact that the low drought risk areas account for only 99 sq. Km (3% of the study area), and therefore may not comprise a statistically significant sample.

However, there are some limitations in that this study was unable to consider change in species, type, age and also characteristic of the vegetation. Similarly it was not possible to measure the social or human aspects involved, for example the farmer's calendar of planting, harvest etc. NDVI was measured only in terms of vegetation cover that can be referred to by drought risk levels.

6.2 Recommendation for further study

In order to obtain more accurate result, it is necessary to have more satellite images collected during different seasons during one year (such as on dry, rainy and summer). Therefore it will be better for comparing with GIS criteria which use annual climate data. On the other hand, it should be analyzed in individual season's criteria for GIS. The drought study was done as an overview of drought risk area, it would be an advantage to study drought resistant vegetation types within each vegetation cover type. It is preferable to consider the effects of excess moisture or flood condition which probably hav ethe effect of obscuring any vegetation change. Finally, the next study should consider the size of study area, which may be expanded or reduced base upon these considerations.

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