Assessment of Drought Risk Area in Thung Kula Rong Hai using Geographic Information Systems and Analytical Hierarchy Process

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Abstract
Thung Kula Rong Hai has encountered a drought that affects consumptive and agricultural life of local people. In finding some ways to prevent and monitor a potential drought, the researcher studied Thung Kula Rong Hai area by applying Analytical Hierarchy Process (AHP) to assess and identify drought risk areas. Five factors including Land use, Water body, Groundwater volume, Soil drainage, and Rainfall quantity were in this study. The results drought-prone areas in Thung Kula Rong Hai could be identified and categorized into four sub-areas high risk zone, medium risk zone, low risk zone, and insignificant risk zone. The main cause of drought is the uneven distribution of rainfall.

1. Introduction

It has been widely accepted that natural disaster can cause enormous loss of life and individual and public property damage. Both government and people lose a lot of resources. However, the amount of loss from potential natural disaster could be minimized if natural disaster management would be more effective. Previously, the way to manage natural disaster has mainly focused on helping victims and reconstruction of affected areas (Aodngam, 2000 and Viratjandr, 2007, 2010). The prevention or mitigation of natural disaster damage requires preparation of Risk Mapping that represents areas susceptible to natural disaster. Risk Mapping is used to warn local people about potential natural disaster so that they are more aware of the prevention and mitigation of disaster impact and are ready to face disaster (Jeyaseelan, 1999, Suwanwerakumtorn, 2000, Feizizadeh et al., 2013 and Usha et al., 2014). It also is useful information for related organization to make a supportive plan to mitigate or eliminate the damage. Besides, Risk Mapping would be applied by private and public agencies as a decision-making tool about physical infrastructure (Moktari, 2005, Chopra, 2006 and Iglesias et al., 2009). Analytic Hierarchy Process or AHP is a method to simplify and analyze complex problems or decisions by imitating human behavior. The decision problem is decomposed into a hierarchy of more easily comprehended sub-components. Each component of a problem then can be analyzed independently and compared one other. Finally, a decision maker will get his/her desired choice. In this study, AHP was applied to identify drought risk area by determining physical factors of Thung Kula Rong Hai area in 2012. Weights reflect the relative importance of each decision criterion. Therefore, the application of AHP to this study would improve the decision making process and operating performance (Alphonce, 1997, Kulapramote, 1999, Tunsirikongkhon, 1999, Santanu and Chattopadhyay, 2003, Ngai and Chan, 2005, Kwak and Kondoh, 2008, Berritella et al., 2007, Vidal et al., 2010, Zhao et al., 2012, Feizizadeh et al., 2013, Dagnachew et al., 2014 and Usha et al., 2014).

2. Objective

To study the physical condition of drought risk area in Thung Kula Rong Hai and apply Analytic Hierarchy Process (AHP) to identify drought risk area in such location.

3. Areas of Study and Methodology

3.1 Areas of Study

Thung Kula Rong Hai is located in northeast region of Thailand. Its area has size around 3,000 square

kilometers, covering Mun and Chi Rivers. Its southern boundary is near Mun River.
It has been commonly known that during the rainy season, the area is flooded and then expose to drought.

North: covers Patumrat, Kasetwisai, and Suvarnabhumi districts of Roi-Et.
South: covers Chumpolburi and Tatum districts of Surin.
West: covers Bhudtaisong district of Buriram and Mahachanachai district of Yasothon.
East: covers Phayakkhaphum Phisai Disctrict of Maha Sarakham.

The area of Thung Kula Rong Hai (Table 1) is a largest plateau in northeastern (Isan) region of Thailand. Its area size is around 2,107,691rais. It covers five provinces namely Roi Et, Surin, Maha Sarakham, Sisaket, and Yasothon. The longest area of Thung Kula Rong Hai starts from Phayakkhaphum Phisai Disctrict, Maha Sarakham Province to eastern part onwards. The widest area is in Patumrat, Kasetwisai, Suvarnabhumi, and Ponsai districts, consisting of 847,000 rais. The rice field named Thung Kula Rong Hai is located in Kasetwisai and Suvarnabumi districts of Roi-Et and Tatum and Chumpolburi districts of Surin.

3.2 Determining Variables of Interest
The variables of interest include:
3.2.1 Rainfall quantity (Rain Fall)
3.2.2 Water body distance (Water body)
3.2.3 Groundwater volume (Gwav)
3.2.4 Soil drainage (Soil) and
3.2.5 Land Use

This study used weighting scale to weight or prioritizes five factors (Subongkhot, 1993, Amatayakul, 1993 and Kulapramote, 1999) and then conducted factors rating to analyze drought risk area through the calculation of the weighted sum of scores from the equation (1) below:

$$\sum_{n}^{i=1} Wi.Ri=W1.R1+ W2.R2+ W3.R3+\ldots+Wn.Rn$$

Equation 1

3.3 Methodology
The figure 1 represents the diagram for analyzing factors affecting drought risk area.

Table 1: The area of Thung Kula Rong Hai

Province	District	Area	
		Rai	%
Roiet	Kaset Wisai Pathum Rat Phon Sai Suwanapoom	986,807	46.8
Surin	Tha Tum Chumphon Buri	575,993	27.3
Sisaket	Rasi Salai	287,000	13.6
Maha Sarakham	Phayakkhaphum Phisai	193,890	9.2
Yasothon	Maha Chana Chai Kho Wang	64,000	3.1
sum		2,107,690	100.00

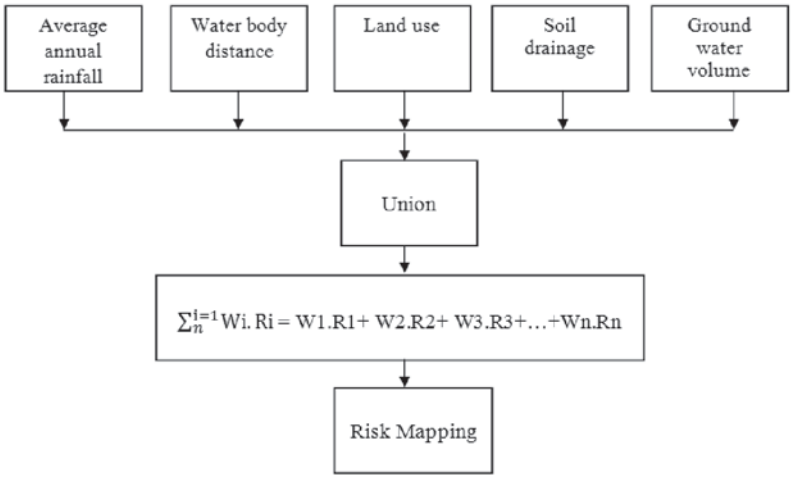

Figure 1: Diagram for analyzing factors affecting drought risk area

3.3.1 Data of average annual rainfall (Rainfall)
Average annual and monthly rainfall data from meteorological stations were spatially interpolated. Such rainfall data was classified into 4 levels of risk:

1) High level (<1,000 mm of rainfall)
2) Medium level (1000-1100 mm of rainfall)
3) Low level (1100-1200 mm of rainfall) and
4) Insignificant level (>1,200 mm of rainfall)

3.3.2 Data of water body distance (Water body)
This study determined an area with a shortest distance to water as an area with lowest risk of drought. The distance to water body as categorized into four levels of risk:

1) High risk (4,000 meters)
2) Medium risk (3,000 meters)
3) Low risk (2,000 meters) and
4) Insignificant risk (<1,000 meters)

3.3.3 Data of groundwater volume (Gwav)
Gwav is characterized by groundwater reserve. An area where groundwater volume is small is more likely to have water scarcity. Smallest volume of groundwater is related to highest risk of drought. The volume of groundwater (Gwav) is categorized into four levels of risk:

1) High risk (Flow rate <2 m^3/hr., TDS> 1500 mg/ m^3)
2) Medium risk (Flow rate 2-10 m^3/hr., TDS 750-1500 mg/ m^3)
3) Low risk (Flow rate >10-20 m^3/hr., TDS<750 mg/ m^3) and
4) Insignificant risk (Flow rate <20 m^3/hr. ,TDS< 750 mg/ m^3).

3.3.4 Data of soil drainage (Soil)
A level of soil drainage is associated with drought. Soil with good drainage such as sandy soil is related to the drought because it is coarse and won't absorb water. So, soils with good drainage are more likely to associate with high risk of drought. Four levels of drought risk were categorized based on different levels of soil drainage:

1) High risk (good soil drainage)
2) Medium risk (fair soil drainage)
3) Low risk (bad soil drainage) and
4) Insignificant risk (very bad soil drainage)

3.3.5 Data of land use (Land use)
Different characteristics of land use can result in the drought. To identify the characteristic of land use, this study considered various types of areas and their plants. Land use was categorized into four types of land based on relative drought risk level:

1) High risk (farmland, crop field, fruit farm, perennial plant farm and other agricultural areas)
2) Medium risk (Irrigation canals, fish / shrimp ponds, water resource)
3) Low risk (roads, wilderness, non-agricultural areas) and
4) Insignificant risk (Riverine Forests and forests)

4. Results

4.1 Determination of Weighting Score and Rating Score

This study considered five factors affecting drought risk area in Thung Kula Rong Hai. This study also used a method to determine weighting score and rating score of such factors. The results of determining weighting score to identify drought risk area in Thung Kula Rong Hai or results of AHP through pairwise comparison were shown in table 2. Eigen vector was used as weighting score from AHP. By doing so, the author gained correct weighting score as follows:

1) Rainfall (w1) had weighting score of 0.55
2) Water body (w2) had weighting score of 0.18
3) Land Use (w3) had weighting score of 0.11
4) Soil (w4) had weighting score of 0.08 and
5) Gwav (w5) had weighting score of 0.08

Then, data from 4.1.1 was analyzed by multiplying each factor's weighting score by its rating score (table 3).

4.2 The results of Data Analysis through GIS
4.2.1 Assigning level of drought risk to each factor
1) Rainfall was used as a criterion to classify drought risk area into different levels. Based on analyzing rainfall data, four sub-areas that are susceptible to drought were classified and identified as shown in table 4.

2) Water body distance was used as a criterion to classify drought risk area into different levels. Based on analyzing water body data, four sub-areas that are susceptible to drought were classified and identified as shown in table 5.

3) Land use was used as a criterion to classify drought risk area into different levels. Based on analyzing land use data, four sub-areas that are susceptible to drought were classified and identified as shown in table 6.

4) Soil drainage was used as a criterion to classify drought risk area into different levels. Based on analyzing soil drainage data, four sub-areas that are susceptible to drought were classified and identified as shown in table 7.

5) Groundwater volume was used as a criterion to classify drought risk area into different levels. Based on analyzing Groundwater volume data, four sub-areas that are susceptible to drought were classified and identified as shown in table 8.

Table 2: Pairwise comparison matrix

Factor	Average annual rainfall	Water body distance	Land use	Soil drainage	Ground water volume
Average annual rainfall	1	3	5	7	7
Water body distance	0.33	1	1.67	2.33	2.33
Land use	0.2	0.6	1	1.4	1.4
Soil drainage	0.14	0.43	0.71	1	1
Groundwater volume	0.14	0.43	0.71	1	1
Sum	1.81	5.46	9.09	12.73	12.73

Table 3: Class intervals of probabilities of drought risk area in Thung Kula Rong Hai

Rating score	Weighting score
1.00 – 1.78	1
1.79 – 2.56	2
2.57 – 3.34	3
3.35 – 4.12	4

Table 4: Areas classified according to risk level of average annual rainfall

District	Risk level (areas : Square kilometers)			
	High risk (4)	Medium risk (3)	Low risk (2)	Insignificant risk(1)
Suwanapoom	2,436.28	1,827.21	1,218.14	609.07
Pathum Rat	785.18	588.88	392.59	196.29
Kaset Wisai	1,276.22	957.16	638.11	319.50
Phon Sai	474.87	356.15	237.43	118.71
Chumphon Buri	1,450.68	1,088.01	725.34	362.67
Tha Tum	1,594.36	1,195.77	797.18	398.59
Phutthaisong	1,435.94	1,076.95	717.97	358.98
Phayakkhaphum Phisai	901.51	676.13	450.75	225.37
Sum	7,975.5	7,766.26	5,177.51	2,588.73

Table 5: Areas classified according to risk level of water body distance

District	Risk level (areas : Square kilometers)			
	High risk (4)	Medium risk (3)	Low risk (2)	Insignificant risk(1)
Suwanapoom	797.32	597.99	398.66	199.33
Pathum Rat	256.96	192.72	128.48	64.24
Kaset Wisai	417.67	313.25	208.83	104.41
Phon Sai	155.41	116.55	77.70	38.85
Chumphon Buri	474.76	356.07	237.38	118.69
Tha Tum	521.79	391.34	260.89	130.44
Phutthaisong	469.94	352.45	234.79	117.48
Phayakkhaphum Phisai	295.04	221.28	147.52	73.76
Sum	3,388.89	2,541.65	1,694.34	8,70.96

Table 6: Areas classified according to risk level of Land use

District	Risk level (areas : Square kilometers)			
	High risk (4)	Medium risk (3)	Low risk (2)	Insignificant risk(1)
Suwanapoom	487.25	365.44	243.62	121.81
Pathum Rat	157.03	117.77	78.05	39.25
Kaset Wisai	255.24	191.43	127.62	63.81
Phon Sai	94.97	71.30	47.48	23.74
Chumphon Buri	290.13	217.60	145.06	72.53
Tha Tum	318.87	239.15	159.43	79.71
Phutthaisong	287.18	215.39	143.59	71.79
Phayakkhaphum Phisai	180.30	135.22	90.15	45.07
Sum	2,070.97	1,553.3	1,035.45	517.71

Table 7: Areas classified according to risk level of soil drainage

District	Risk level (areas : Square kilometers)			
	High risk (4)	Medium risk (3)	Low risk (2)	Insignificant risk(1)
Suwanapoom	354.36	265.77	177.18	88.54
Pathum Rat	114.20	85.65	57.10	28.55
Kaset Wisai	185.63	139.22	92.81	46.40
Phon Sai	69.07	51.80	34.53	17.26
Chumphon Buri	211.00	158.25	105.50	52.75
Tha Tum	231.90	173.93	115.95	57.97
Phutthaisong	208.86	156.64	104.43	52.21
Phayakkhaphum Phisai	131.12	98.34	65.56	32.78
Sum	1,506.14	1,129.6	753.06	376.51

Table 8: Show areas classified according to risk level of groundwater volume

District	Risk level (areas : Square kilometers)			
	High risk (4)	Medium risk (3)	Low risk (2)	Insignificant risk(1)
Suwanapoom	350.56	255.17	185.88	89.45
Pathum Rat	117.10	84.55	77.22	35.16
Kaset Wisai	157.40	148.12	95.13	48.10
Phon Sai	70.70	62.71	41.65	19.22
Chumphon Buri	220.15	161.23	110.00	55.50
Tha Tum	243.41	169.58	121.79	59.17
Phutthaisong	212.55	151.22	108.96	60.54
Phayakkhaphum Phisai	143.57	101.77	75.67	41.39
Sum	1,515.44	1,134.35	816.30	408.53

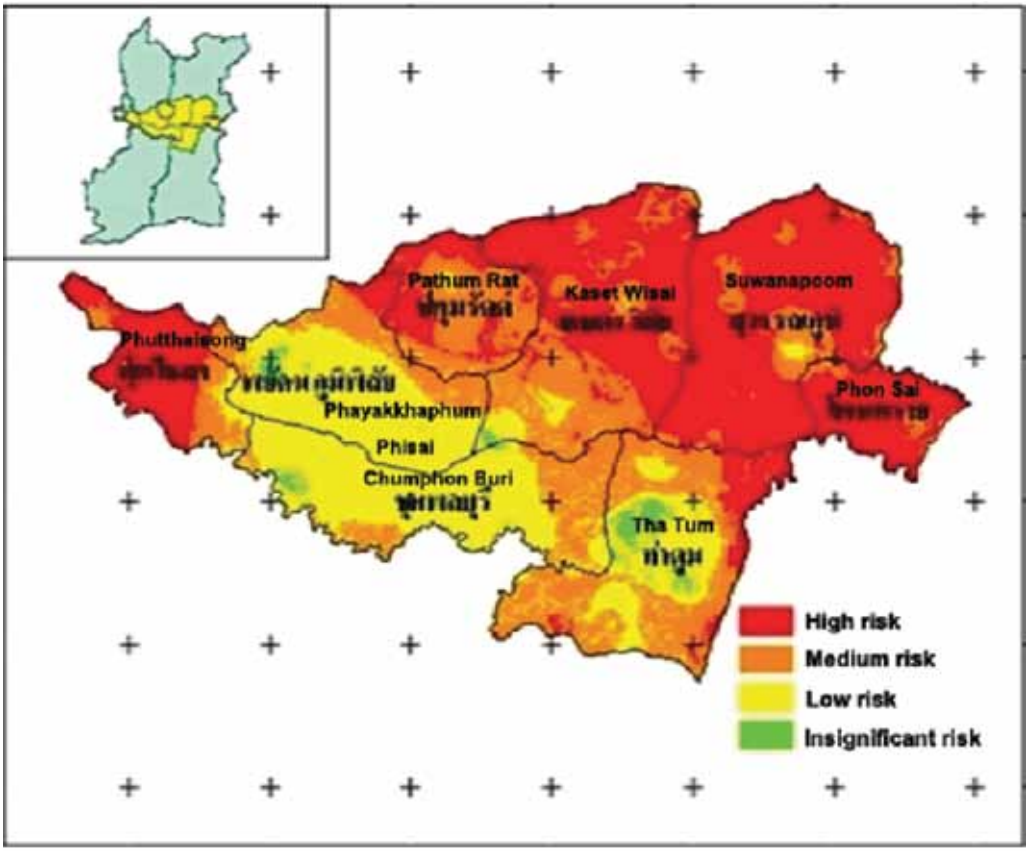

Figure 2: Drought risk areas of Thung Kula Rong Hai

4.2.2 Analysis of overlaying data
Data was analyzed by AHP and the overlaying of five factors was analyzed based on the equation (2) below:

[S = (0.55*CW_RAIN)+(0.18*CW_WATER)+ (0.11*CW_LANDUSE)+(0.08*CW_SOIL)+ (0.08*CW_GWAV)]

Equation 2

Where;
S = Sum of all factors affecting drought risk area
W1 = Rainfall with weight score of 0.55
W2 = Water body with weight score of 0.18
W3 = Land use with weight score of 0.11
W4 = Soil drainage with weight score of 0.08 and
W5 = Gwav with weight score of 0.08.

There were four levels of drought risk including High, Medium, Low, and Insignificant risk as shown in figure 2.

5. Conclusion and Discussion
The study of applying AHP to assess drought risk area in Thung Kula Rong Hai in 2012 by considering five factors including Rainfall, Water body, Land use, Soil, and Gwav could be discussed as follows.

5.1 Influential factors
The assessment of drought risk area in this study determined four levels of drought risk namely, High risk, Medium risk, Low risk and insignificant risk. Overall average annual rainfall (Rainfall) was a factor affecting drought as shown in figure 2. The cause of drought was uneven distribution of rainfall. The areas of study mostly are farmland and agricultural areas, which need proper rainfall. It was found that farmland became very dry after harvest period. Such area encountered water scarcity for agriculture and consumption.

5.2 Physical Assessment of Drought Risk Areas
5.2.1 *High-level:* drought risk areas were characterized by areas having severe rainfall deficiency or drought, sandy soils or sandy loams, fine textured soil, soils with very bad water absorption, outside irrigated areas, or small volume of groundwater

5.2.2 *Medium-level:* drought risk areas were characterized by areas having rainfall deficiency or drought, soils with bad water absorption, loose soils or sandy loams, outside irrigated areas, or medium volume of groundwater

5.2.3 *Low-level:* drought risk areas were characterized by areas having moderate rain, soils with bad water absorption, loose soils or sandy loams, outside irrigated areas, or medium volume of groundwater. Some areas of study were in the drought zone where soils could absorb water at moderate or high level as well as groundwater volume was at moderate level.

5.2.4 *Insignificant-level*: drought risk areas were characterized by areas having heavy or moderate rainfall, soils with good water absorption, clays or clay loams, inside irrigated areas, or large volume of groundwater.

5.3 Agricultural Drought Risk Assessment
The overlay analysis of each factor represented that the size of drought risk area was 1,975.95 km^2, or accounted for 41.98% of total area of study. Also it was found that such area had soil drainage from moderate to good levels. In terms of land use, such area was utilized for farmland and crop farms. Most of them were in Suwanapoom, Tatum, and Chumphon Buri districts. On the other hand, areas that were insusceptible to drought covered 409.78 km^2, or accounted for 8.70% of total area of study. Such area had soil drainage from bad to very bad levels. In terms of land use, such area was utilized for riverine forest and forests.

5.4 Assessment of Land use
This study utilized the maximum-likelihood decision rule, assessment of classification accuracy, field study, and assessment of land use accuracy. After conducting field study, geographic coordinates data was recorded through random sampling of 164 area points of interest. Such random sampling was divided into 9 types. Data then was analyzed through assessment of land use classification accuracy. In terms of land use classification based on the maximum-likelihood decision rule, producer's accuracy showed as followed: Forests(F1) had 50% of producer's accuracy; Riverine forests(F2) had 100%; Community forest(F3) had 88.89%; Village (U) had 50%: paddy field, well-developed vegetation (A1) had 0%; paddy field, sparse vegetation(A2) had 87.50%; water body(W1) had 58.82%; water body(W2) had 60.87%.

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