Drought Assessment Using GIS Technology in the Nam Choen Watershed, NE Thailand.

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Abstract: Drought is one of the natural disasters. It is a constant threat in one or another part of country like Thailand, where almost agricultural land is rain-fed. Drought is a recurring phenomenon that takes place every year especially in the Northeast Thailand. Then, we need to manage drought effectively using the new knowledge and technology. GIS technology offer great promise for natural disaster management with the ability to depict the spatial distribution of the extent and monitoring capability. Overlay analyst of ArcView GIS function developed by Khon Kaen University is applied to assess the drought risk areas in the Nam Choen watershed which is in the Northeastern part of Thailand. The seven data set considered to diagnose drought condition, are rainfall, stream density, slope, soil drainage, surface water and irrigation, sub-surface water and land use respectively. These data were used as input parameter in index overlay function to identify drought risk areas. The study result shows that the area of 2,520 square kilometers of the Nam Choen watershed, 39 % are of moderate risk areas which are located in the Northwest of watershed. These areas which are covered by hill evergreen forest. The 60 % are of severe risk areas that are found in the middle of the watershed and few area are of mild risk areas. When compared with NRD2C[1]/ villages on the item of availability of water for agriculture, only 60% of villages location of each water shortage class matches the drought class studied.
Key Words: GIS, Drought, Disasters

1. Introduction

Drought is one of the natural disasters. It is a constant threat in one or another part of country like Thailand, where almost agricultural land is rain-fed. Drought is a recurring phenomenon that takes place every year especially in the Northeast Thailand. Over 70% of the population is engaged in agriculture which is dominated by rain-fed production. At the present time, less than 6% of the cultivated land in the northeast is irrigated, leaving the majority of farmers operating in rain-fed conditions [7]. In addition, water shortage for domestic consumption is usually identified as the principal constraint for the people during the dry season. Lack of water or drought in the region has a profound impact that can be listed as economic, social and environmental. Drought risk areas, by nature, are a result of a variety of factors. Drought in general originates from less precipitation over an extended period of time. These include occurrence of no rain in the rainy season, number and amount of rainfall events and other climatic anomalies. Palmer (1965) identified monthly index values for past dry periods to yield an equation for calculating drought severity in four classes. In an operational definition of drought it identifies drought from impact data (i.e. crop damage). The drought pattern should be started with an assessment of rainfall. It is widely accepted that the combination of the physical nature of an area, amount of rainfall and water resource development leads to the identification of the drought pattern[5]. GIS technology offer great promise for natural disaster management with the ability to depict the spatial distribution of the extent and monitoring capability. The capability of GIS is to integrate multi disciplinary data that can be used to analyze drought risk area in time and space.

2. Objective

The objective is to assess the feasibility of utilizing index overlay function to analyze drought risk area.

3. Study area

The study area, Nam Choen watershed is located in Northeast Thailand. and covers an area of about 5120 sq.km. It lies between the latitudes of 16° and 17° N and the longitudes of 101° 24' and 102° 32' E (Fig 1). It is a part of upper Chi basin that is the one of third main basin in northeast region. It is consist of Nam Phom and Nam Choen catchment which Nam Phom river combine to Nam Choen river and ends at the Ubol Ratana Reservoir (Fig. 2). The

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[1]/ National rural development in village level.

Nam Choen watershed is established in the Korat plateau. Almost area is mountainous area in the west with evergreen forest and dry dipterocarp forest. The area is quite flat in the east which main land use is paddy field in the rainy season (during September-December) and becomes second crop in the dry season (during February-April). The foot slope area in the middle is a rolling topography which is used for rubber plantation and mixed orchard. Geologically, it is underlain by thick sequence of Mesozoic rock which mainly consists of sandstone which gave sandy soil in this area and limestone. In the lower plain it is composed of alluvial deposits of sand, silt and clay.

The climate in this area is influenced by the northeast and southwest monsoon. The mean annual rainfall is about 1,116 mm. and the average annual temperature is about 27 ^{0}C.

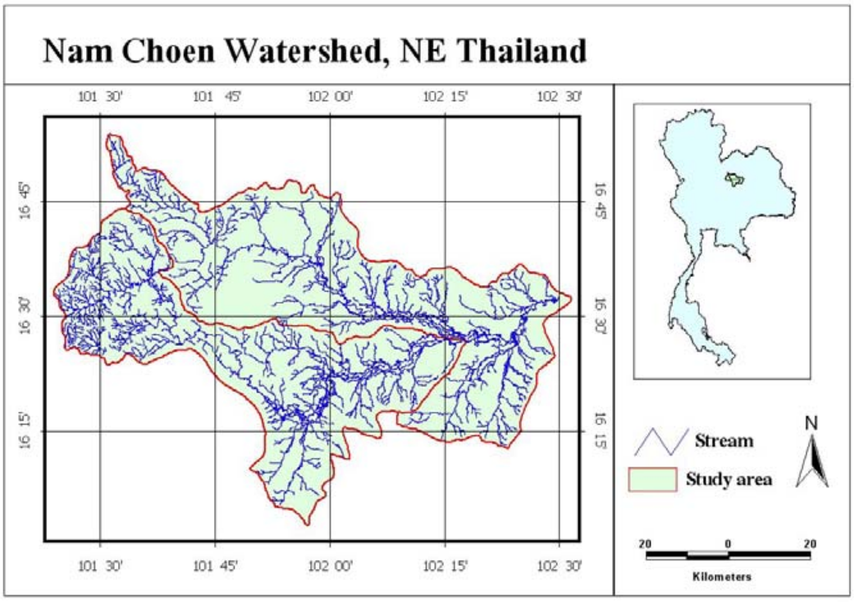

Fig. 1 Location of study area

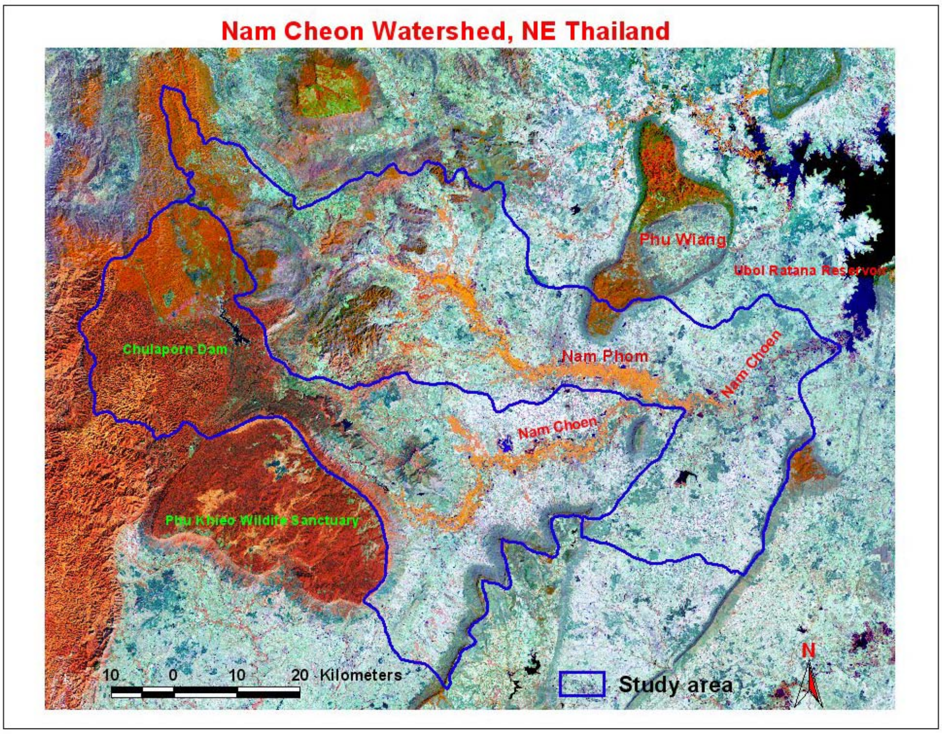

Fig. 2 The RGB (4,5,3) colour composite image of Landsat TM data acquired during December 2004- February 2005.

4. Methodology

1) Data collection

The data which are considered to cause drought risk area in this study, are rainfall, stream density, slope, soil drainage, surface water and irrigation, sub-surface water and land use. Those of data are both of primary data that are obtained from Landsat satellite data and existing data collected from other agencies as shown in Table 1.

Table 1 Data collection and source

Type of data	Themes	Source
Primary data	Surface water Land use	Landsat TM data acquired during December 2004-February 2005.
Secondary data	Rainfall Sub surface water Irrigated area Contour Soil Stream NRD2C	Meteorological Department Department of Mineral resource Royal Irrigation Department Topographic map at scale of 1:50000; Royal Thai Survey Department Soil map at scale of 1:50000; Land Development Department Topographic map at scale of 1:50000; Royal Thai Survey Department The National Economic and Social Development Board (NESDB) (National rural development in village level in 1994, 1996, 1999, 2003 and 2005)

2) Drought parameters analysis

Drought parameters which are identified to be used for drought risk analysis are rainfall, stream density, slope, soil drainage, surface water and irrigation, sub-surface water and land use. Parameter preparations are as fallows (Fig 3):

1. Rainfall analysis

Daily rainfall data from 41 stations in the study area and surrounding covering at least 15 years of record were compiled as a point database for analysis. Moving surface interpolation was performed to establish spatial mean annual rainfall (MAR) cover all the Nam Choen watershed. The range of annual rainfall was then identified using decile index to create the decile rainfall. The decile rainfall of 10 classes was grouped into 4 levels of drought severity, as shown in Table 2 and Fig 4.

Table 2 Decile rainfall

Decile-Range	**Decile Classifications**	Rainfall range (mm.)	Drought severity class
1 (lowest 20%)	much below normal	< 934.7868	4
2 (lowest 20%)	much below normal	>934.7868-1045.966	4
3 (next lowest 20%)	below normal	>1045.966-1130.065	3
4 (next lowest 20%	below normal	>1130.065-1204.470	3
5 (middle 20%)	near normal	>1204.470-1276.133	3
6 (middle 20%)	near normal	>1276.133-1349.867	2
7 (next highest 20%)	above normal	>1349.867-1431.076	2
8 (next highest 20%)	above normal	>1431.076-1529.169	1
9 (highest 20%)	much above normal	>1529.169-1670.497	1
10 (highest 20%)	much above normal	> 1670.497	1

Drought Severity : 1 = Very mild, 2 = Mild, 3 Moderate, 4 Severe

Source : modified from Charat et al, 2001 and Gibbs and Maher, 1967.

2. Hydrological analysis

There are four parameters in hydrological issue, surface water source, irrigated area, stream density in sub-watershed, and ground water yield and total dissolved solid. Surface water source was derived from 3 scenes of Landsat TM acquired during December 2004-February 2005 and irrigated area data collected by the project sites of the Royal Irrigation Department. Stream density was calculated from stream length within sub-watershed areas. groundwater yield and total dissolved solid at a scale of 1:100,000 are available from the Department of Mineral Resources. Those four parameters of hydrological data were categorized to drought severity class as illustrated in Table 3 and Fig. 4.

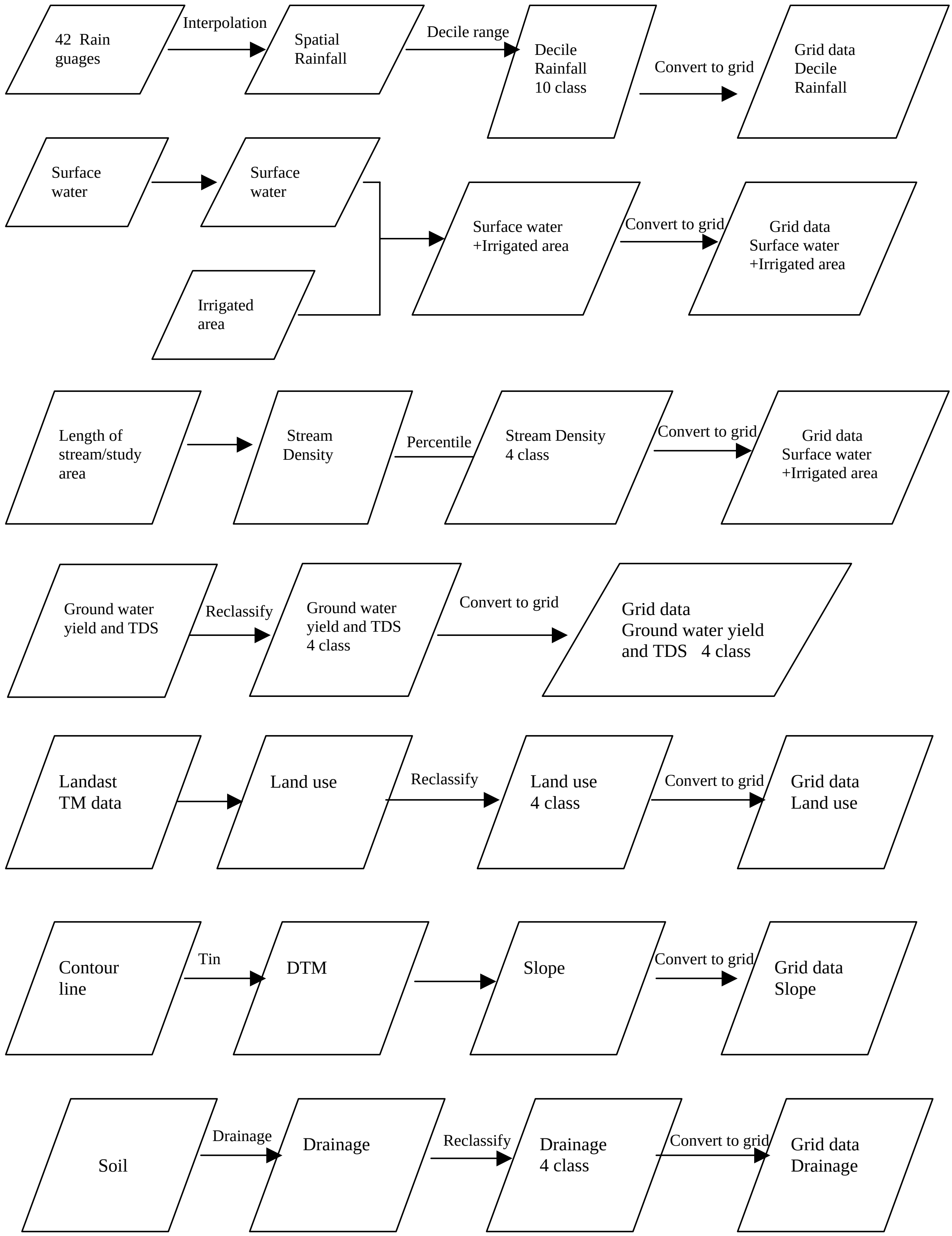

Fig 3 The procedure of parameter preparations

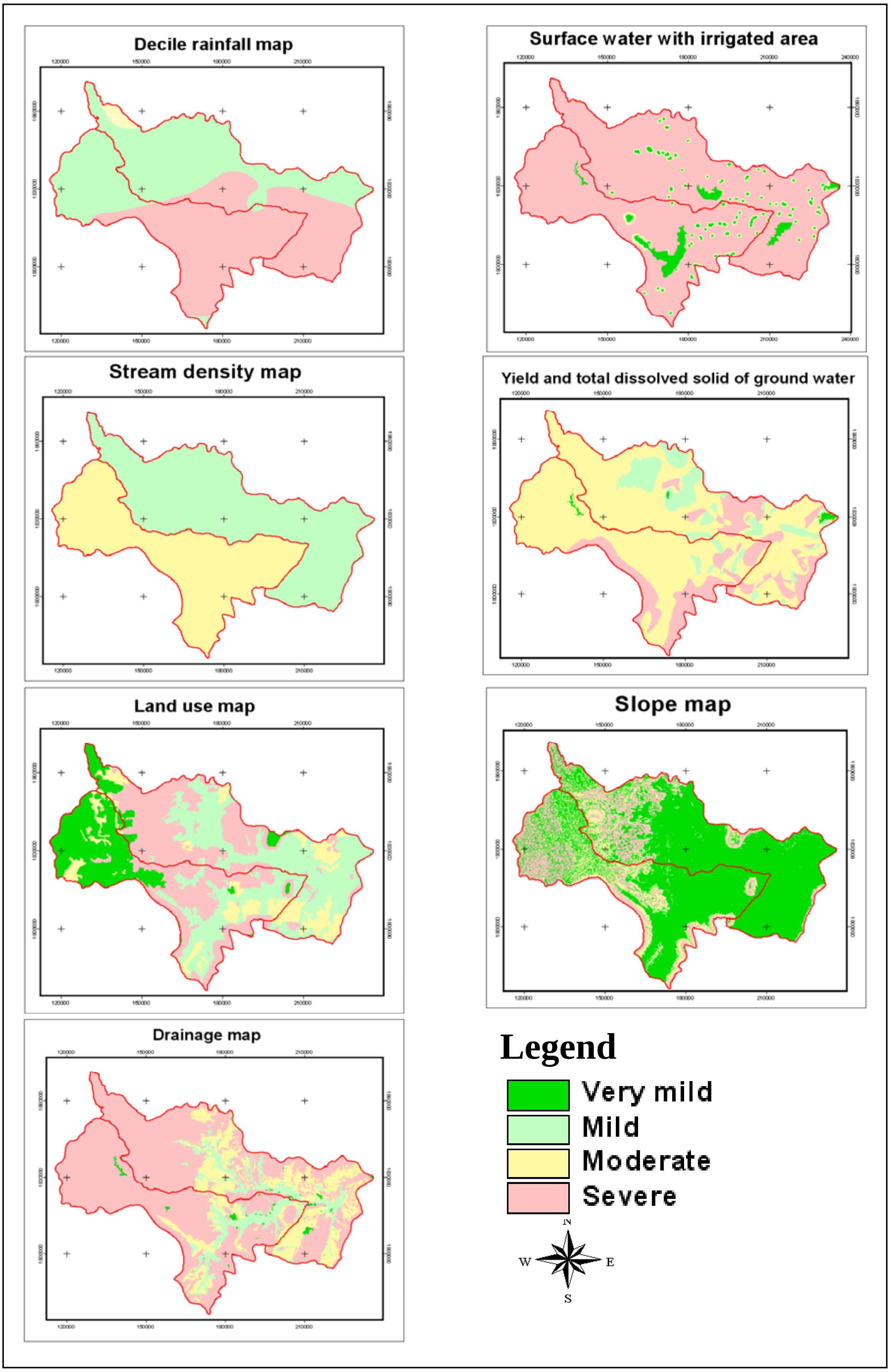

Fig 4 Seven drought parameters

3. Physical terrain analysis

Slope, Soil drainage condition and land use are input variables in term of **physical terrain.** Preparation of land use maps was carried out using the Landsat TM acquired as above. The drainage condition of study area was compiled from a soil properties prepared by the Land Development Department The Slope layer was derived from Digital Elevation Model made from contour line. The analysis and procedure were executed as shown in Fig. 3 with severity class in Table 3.

Table 3 Drought parameters and severity

Drought Component	Variables	Class	Drought severity
Meteorological data (Rainfall data)	**Mean annual rainfall** (Decile range)	< 1045.966 mm.	4
		> 1045.966 - 1276.133 mm	3
		> 1276.133 - 1431.076 mm.	2
		> 1431.076	1
Hydrological Data	**Water source**	Water source area of 0 - 0.5 km^2	
		Area beyond water source >0.75 km.	4
		Area beyond water source >0.5 - 0.75 km.	3
		Area beyond water source .0.25 - 0.5 km.	2
		Area beyond water source 0 - 0.25 km.	1
		Water source area of 0.5 - 5 km^2	
		Area beyond water source >1.5 km.	4
		Area beyond water source >1 – 1.5 km.	3
		Area beyond water source >0.5 – 1 km.	2
		Area beyond water source 0 - 0.5 km.	1
		Water source area of 5 –10 km^2	
		Area beyond water source >2.25 km.	4
		Area beyond water source >1.5 – 2.25 km.	3
		Area beyond water source >0.75 – 1.5 km.	2
		Area beyond water source 0 - 0.75 km.	1
		Area beyond water source 0 - 1 km.	1
	Irrigated Area	Area within irrigated area	1
	Groundwater yield and TDS. (TDS : Total dissolved solid)	3 m^3 / hr. & TDS. > 1500 mg/l	4
		2 - 10 m^3 / hr. & TDS. > 750 - 1500 mg/l	3
		10 –20 m^3 / hr. & TDS. <750 mg/l	2
		>20 m^3 / hr. & TDS. <750 mg/l	1
	Stream density	0.1 – 0.35 km/ km^2	4
		0.36 – 0.70 km/ km^2	3
		0.71 – 1 km/ km^2	2
		> 1 km/ km^2	1
Physical Terrain	**Land use**	Field crop / Deciduous forest / Village	4
		Mixed field crop / Forest and mixed crop	4
		Grass land / Shrub / non-use	3
		Mixed paddy / Mixed ever green forest	3
		Tree / Fruit tree / Swamp and other	2
		Paddy / Mixed fruit tree / ever green forest	2
		Water source / Riparian / Swamp	1
	Drainage condition	Excessively drained	4
		Moderately drained, Well drained	3
		Poorly drained, Somewhat poorly drained	2
		Very poorly drained	1
	Slope	> 30 %	4
		17-30 %	3
		2-17 %	2
		0-2 %	1

Drought Severity : 1 = Very mild, 2 = Mild, 3 Moderate, 4 Severe

Source : Modified from Charat, 2001.

3) Drought risk area analysis

The integration of drought components was analyzed using the index overlay. The seven of drought parameters were then input to index Overlay or weighting overlay function in Overlay Analyst Extension on ArcView GIS program to produce the drought risk area. Several trial analysis were done to identified the appropriated rating of each parameter (Table 4). The drought risk area represents the integration of meteorological data, hydrological data and physical terrain data which in turn are assigned according to the drought criteria studied (Fig 5 and Table 5) .

The function of index overlay is

$$P = (W1P1+W2P2+\ldots..+ WnPn)/(W1+W2+\ldots\ldots+Wn) \quad (1)$$

Where P = Output map
P1 = 1st Input parameter
P2 = 2nd Input parameter
Pn = nth Input parameter
W1 = Rating or weighting of 1st Input parameter
W2 = Rating or weighting of 2nd Input parameter
Wn = Rating or weighting of nth Input parameter.

Table 4 Rating of Drought Parameter.

Drought parameter	1st Trial Rating	2nd Trial Rating	3rd Trial Rating	4th Trial Rating	5th Trial Rating	6th Trial Rating
Deciles rainfall	7	6	7	4	6	6
Surface water &Irrigated area	6	7	6	1	7	5
Stream density	4	5	3	2	3	1
Ground water	5	4	5	3	2	2
Slope	1	3	4	7	5	4
Drainage of soil	2	2	2	5	4	3
Land use	3	1	1	6	1	7

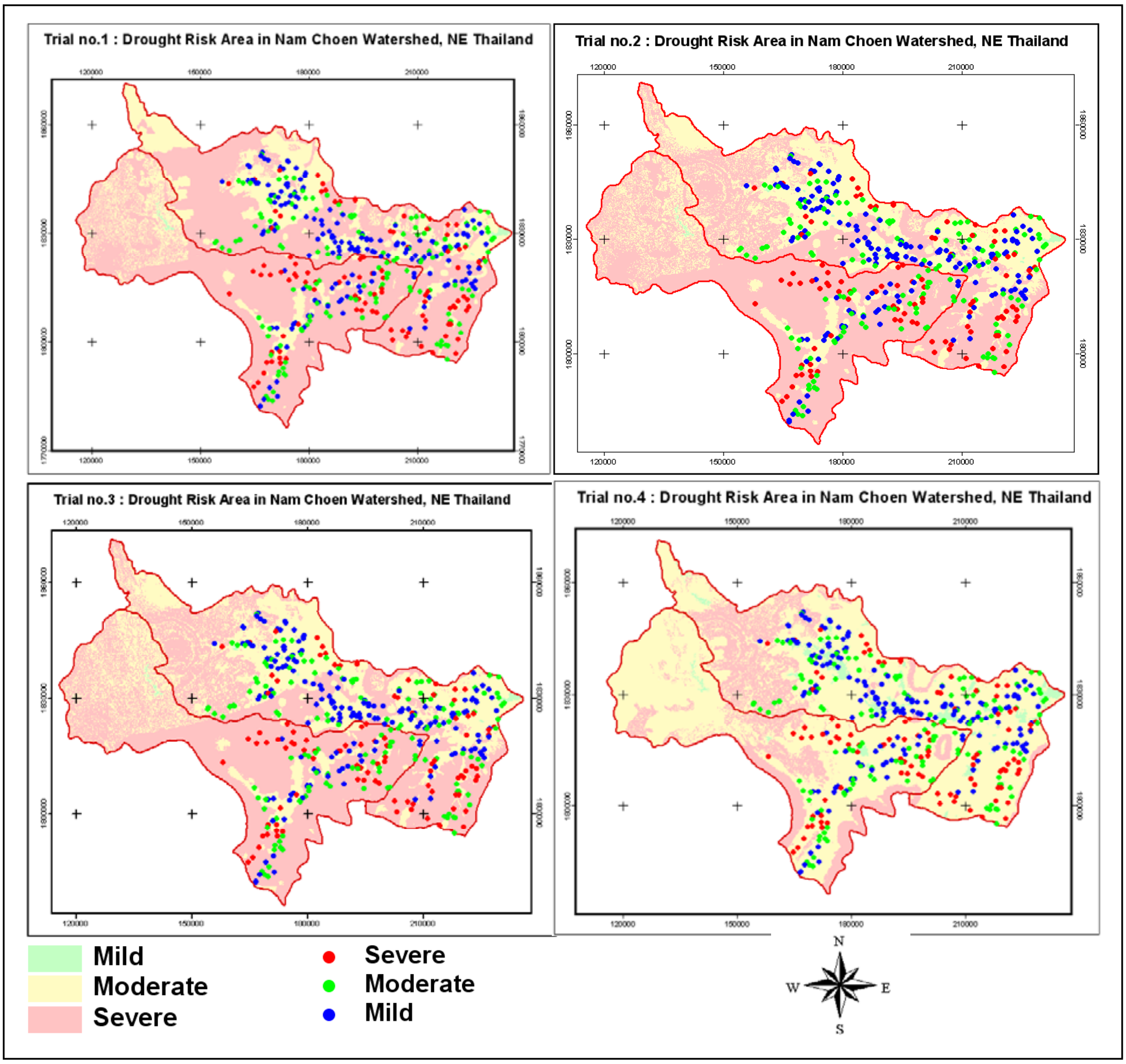

Fig. 5 Drought Risk Area obtained from each trial analysis

Table 5 Drought Risk Area in each trial analysis.

Drought class	Drought Risk Area											
	1st Trail		2nd Trail		3rd Trial		4th Trail		5th Trail		6th Trail	
	Sq.km.	%	Sq.km.	%	Sq.km.	%	Sq.km.	%	Sq.km.	%	Sq.km.	%
Mild	16.150	0.32	23.443	0.46	18.629	0.36	175.185	3.42	43.349	0.85	51.728	1.01
Moderate	1498.275	29.25	1921.847	37.52	2002.259	39.10	3883.637	75.83	2363.104	46.14	2919.262	57.00
Severe	3607.089	70.43	3176.225	62.02	3100.627	60.54	1062.693	20.75	2715.061	53.01	2150.525	41.99
Total	5121.515	100.00	5121.515	100.00	5121.515	100.00	5121.515	100.00	5121.515	100.00	5121.515	100.00

4) Drought risk area assessment

To assess the reliability of the resultant map the test areas were checked against NRD2C survey data surveyed by The National Economic and Social Development Board (NESDB). This survey is based on the shortage of water in villages for agricultural use. These data were used to identify the weighting of each drought parameter by matching the level of the shortage water and the class of drought risk as shown in Table 6 and Table 7.

Table 6 Comparison of number of villages with shortage of water for agricultural use and drought severity in 1st Trial and 2nd Trial

Drought severity	Number of villages with shortage of water for agricultural use/ Percentage					
	1st Trial			2nd Trial		
	Mild	Moderate	Severe	Mild	Moderate	Severe
Mild	2/1.17	-	1/1	4/2.24	-	1/1
Moderate	93/54.39	56/39.44	26/26	114/66.67	**63/55.63**	**38/38**
Severe	76/44.44	86/60.56	73/73	53/30.99	**79/44.37**	**61/61**

Table 7 Comparison of number of villages with shortage of water for agricultural use and drought severity in 3rd Trial and 4th Trial

Drought severity	Number of villages with shortage of water for agricultural use/ Percentage					
	3rd Trial			4th Trial		
	Mild	Moderate	Severe	Mild	Moderate	Severe
Mild	4/2.24	-	1/1	9/5.26	7/4.93	2/2
Moderate	114/66.67	**83/58.45**	**40/40**	156/91.23	133/99.66	96/96
Severe	53/30.99	**59/41.55**	**59/59**	6/3.51	2/1.41	2/2

5. Results and Discussion

Based on several trial analysis with difference rating of drought parameter, the result maps of drought risk area which are checked with the shortage of water in villages for agricultural use as shown in Table 6 and Table 7. It was found that the result maps of the second trial is similar to the third trial (Fig 5). However, the third trail is more reliable due to the percentage of the shortage water for agriculture use across the moderate and severe risk area are closely 60. Therefore, the result map obtained from the third trial is shown in Fig.6. with 4 categories: very mild, mild, moderate and severe. There are only 3 type of drought risk area in the study area. The severe overall drought area covers mainly the middle and the east of the region and approximately 60% of the Nam Choen watershed. The moderate drought risk area is found in the west in the mountainous area. Considering to land use and physiographic of the study area which is covered by evergreen forest, it should be very mild area. If we consider to rainfall data that is the most significant parameter., it is a moderate drought risk area. When it was analyzed by using index overlay which each parameter was multiplied by weighting and sum then was divided by sum of weighting. Then it becomes the moderate drought risk area covering about 39%. Few of the mild areas have occurred in the lower plain and water resource area. The areas occupied by the different kinds of the droughts are summarized in table 7.

Table 7 Drought Risk Area in Nam Choen Watershed.

Drought class	Drought risk area (sq.km.)	Drought risk area (%)
Mild	18.628	0.36
Moderate	2002.259	39.10
Severe	3100.627	60.54
Total	5121.515	100.00

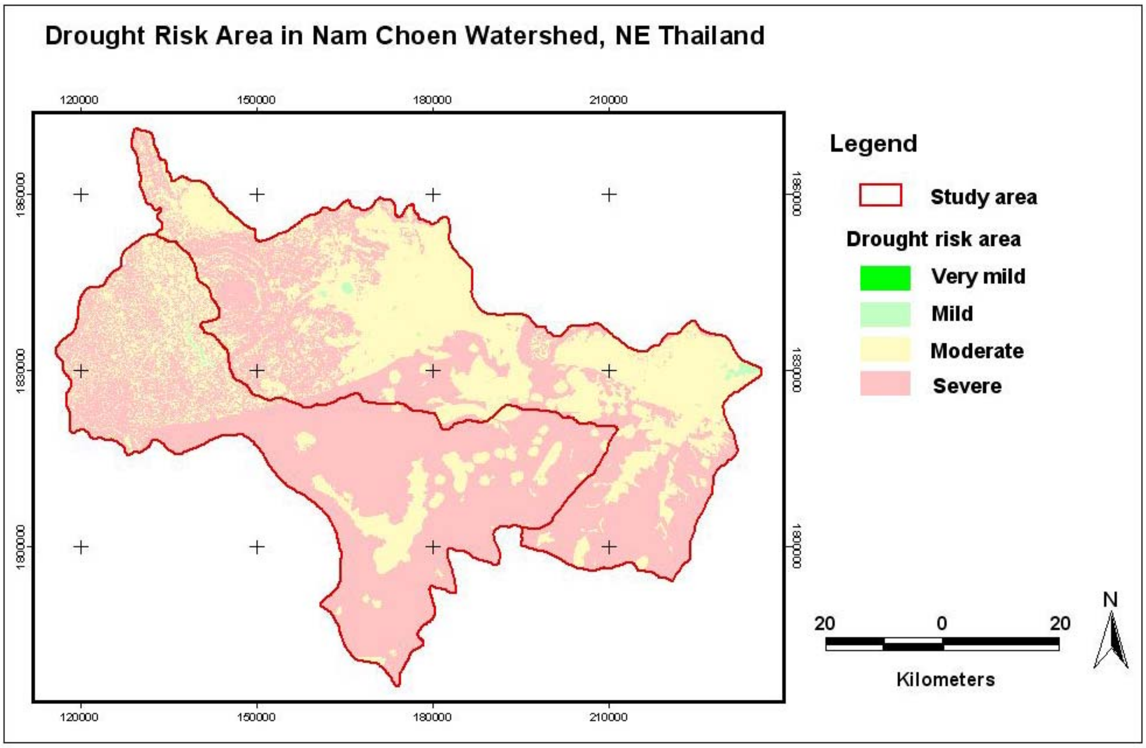

Fig. 6 Drought risk area in Nam Choen Watershed using index overlay function

6. Conclusion

In conclusion, the result obtained by using index overlay do not give much satisfy for drought risk analysis. The result maps from several trial analysis with difference rating of drought parameter show that when the rainfall data is higher weighting , the lager areas of severe drought are occurred. On the contrary, the moderate risk area will be increased when land use and other physical terrains have high weighting value.

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