LANDSLIDE HAZARD ZONATION USING MULTIPLE CRITERIA ANALYSIS WITH GIS AND REMOTE SENSING TECHNIQUE

PhattarapornSangrawee[1], Yootthapoom Potiracha [2]and Chaowalit Silpathong[3]

Geo-informatics and Space Technology Development Agency (Public Organization)
120 The Government Complex Commemorating His Majesty The King's 80 th Birthday Anniversary,
5th December, B.E. 2550 (2007) Building B 6th and 7th Floor, Chaeng Wattana Road, Lak Si Bangkok 10210,
Thailand; Tel: (662)141-4551; Fax:(662)143-9605;
Email: phatporn@gistda.or.th[1], ypoti@gistda.or.th[2] and chaow@gistda.or.th[3]

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ABSTRACT: Landslide is a geological phenomenon and occurred when the stability of slope changes from stable to unstable condition. Case south of Thailand had heavy rainfall to landslide occurred render school, village and households were damaged by landslide devastating and many people are homeless. The study is aimed to develop landslide hazard map using Multiple Criteria Analysis **(**MCA**)** together with remote sensing and geographical information system (GIS**)**.The key in landslide hazard mapping is the assessment and ranking of risk. Magnitudes of existing landslide of selected study area was evaluated by techniques in GIS and compared with existing landslide hazard map from Department of Mineral Resources (DMR) and then analyze correlation with parameters used by DMR for re-weighing value of these parameters. There are 9 considering factors used in MCA; i.e. elevation, household, slope, soil, land use, drainage, geology, magnitude of landslide and rainfall. The re-defined landslide hazard map was divide to 4 susceptibility zone around intermountain plateau in south of Thailand. Landslide susceptible map can be used for predict the occurrence and severity of the landslide and also planning developmental activities in this intermountain plateau.

1. INTRODUCTION

Landslide is the most costly and damaging natural hazard in the mountainous region. This year in southern part of Thailand has long rain season on March which the rainfall are over than all past(Royal Irrigation Department, 2011) and there is the first time influence of landslide occurrence. Especially in various district of Nakhon Si Thammarat province were damaged by landslide devastating on 31stMarch 2001, sample at Nop Phi Tam district the most violent landslide. However landslide occurs without any prior indication but the method prevention and reduces of risk landslide is important. Landslide hazard map mostly done by weighting factor method. Various factors that indicated landslide potential were considered in the analyses then landslide hazard zonation map aims to identifying the landslide potential zone and ranking of correlation factor and landslide area for search the most important cause.

2. STUDY AREA

Nop Phi Tam district locate at the south of Thailand and bounded is 99˚30'57.6" and 99˚52'4.8" East longitude and 8˚35'34.8" and 8˚55'44.4" North latitude. It has an area of approximately 721.69Sq.km. This area is mostly used for evergreen forest 57.26%, Para rubber 35.62%, plantation 3.24%, and urban area 1.94%. There are two season because of influencing from southwest monsoon and northeast monsoon. Summer is from February to April. Rainy season is from May to January and average temperature is 27˚-28˚ C˚. The boundary of study area is show in Figure 1.

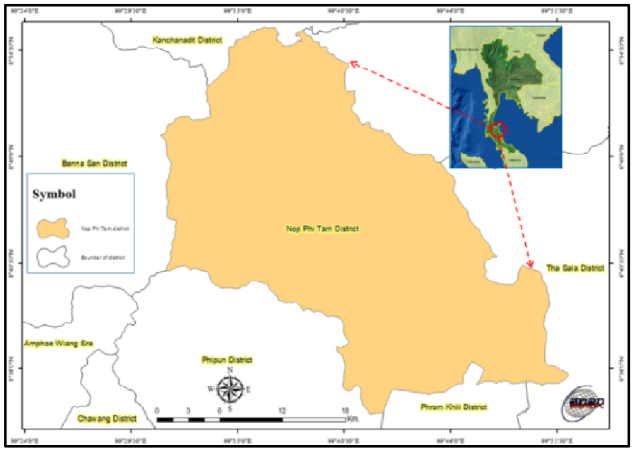

Fig.1 Study area at Nop Phi Tam district

3. OBJECTIVE

1. Analyses magnitude of landslide in Nop Phi Tam district and an area of magnitude compare with hazard map from DMR.
2. Re-weighing value of parameters for create susceptibility map in 2011

4. MATERIALS

Primary data are magnitude of landslide from interpreted GeoEye-1 data and natural color composite band after landslide occurred acquire date 5 April 2011 and 11 April 2011 and land use in 2011 from interpreted Landsat-5 TM. Secondary data are Slope, Geology, Elevation and Drainage data from DEQP (Department of Environmental Quality Promotion), soil data from LDD (Land Development Department), rainfall data from TMD (Thai Meteorological Department) and household data from CDD (Community Development Department)

5. METHODOLOGY

1. Image interpreted and analysis magnitude of landslide area from GeoEye-1 data which using a GIS technique. Land use Classification used feature class of land use data from LDD (2009).Overlay it on Landsat-5 TM (Date 12 April 2011 and 14 April 2011), then updated the feature class of land use in to the present.

2. Compared magnitude of landslide area with hazard map from DMR. Ranking level of hazard zonation in to the present by GIS technique and showed the result by the matrix table.

3. Analyzed correlation between magnitude and 5 parameters (i.e. elevation, slope, land use, drainage and geology) used regression analysis of Pearson's correlation coefficient for re-weighing value of parameters.

4. The susceptibility zone around intermountain plateau was classed base on Multiple Criteria Analysis technique (MCA).There were 9 considering factors used in MCA; i.e. elevation, household, slope, soil, land use, drainage, geology, magnitude of landslide and rainfall, then used GIS technique for classification susceptibility zone again.

6. RESULTS

1. The magnitude of landslide from GeoEye-1 data and land use classification in 2011 from Landsat-5 TM was using GIS technique. The results were obtained for interpretation of satellite image on Nop phi Tam district and accounting of landslide area for 0.421 Sq.km or 0.058 % of total area. When overlay map between magnitude and ground check by GPS the accuracy of interpreted landslide area for 94.15%.GeoEye-1 data was interpreted show in Figure 2

Fig. 2 Landslide area at Nop phi Tam district 2011

Land use classification was updated from 2009 (LDD) to 2011,with GIS technique there were 19 characteristic of land use namely (1)Evergreen forest (2)Para rubber (3)Plantation (4)Village (5)Scrub (6)River (7)Paddy field (8)Mine (9)Oil palm (10)Urban and built-up area (11)Road (12)Reservoir (13)Water(14)Mixed Aqua cultural land (15)Grass (16)Marsh and Swamp (17) Acacia (18)Irrigation canal and (19)Truck crop which descending respectively accounted area show in table 1.

Table 1: Land use type at Nop Phi Tam district 2011

Land use type 2011	Area(Sq.km.)	Land use type 2011	Area(Sq.km.)
1.Evergreen forest	413.27	11.Road	0.25
2.Para rubber	257.10	12.Reservoir	0.20
3.Plantation	23.36	13.Water	0.11
4.Village	12.98	14.Mixed Aqua cultural land	0.08
5.Scrub	3.97	15.Grass	0.06
6.River	3.55	16.Marsh and Swamp	0.05
7.Paddy field	2.43	17.Acasia	0.03
8.Mine	1.84	18.Irrigation canal	0.02
9.Oil palm	1.32	19.Truck crop	0.01
10.Urban and built-up area	1.05	Sum	721.69

2. Compared magnitude of landslide area with hazard map from DMR to ranking level of hazard zonation by GIS technique. The result found that mostly landslides occurred on very high risk with an area of 0.31 Sq.km or 83.05 % of all area, high risk an area of 0.03 Sq.km or 10.07 % of all area, moderate risk an area of 0.07 Sq.km or 6.88% of all area and not found landslide in low risk area. The result of comparing show in table 2

Table 2: Compared magnitude of landslide area with hazard map from DMR

Class Risk (DMR)	Magnitude of landslide area (Sq.km.)	%
Very High	0.31	83.05
High	0.03	10.07
Moderate	0.07	6.88
Low	-	-
Sum	0.42	100.00

3. Correlation between magnitude of landslide and 5 parameters (i.e. elevation, slope, land use, drainage and geology) by using regression analysis to re-weighing value of parameters. The results correlation of elevation and magnitude of landslide solve that increased and decreased in opposite direction because mostly high elevation (300-400m.) was high magnitude of landslide and declined at elevation more than 400 m. The relation slope and magnitude of landslide solve that mostly landslide occurred in range 6-30 degree and decrease when increases slope. The drainage has no relation with magnitude of landslide because increases magnitude of landslide when increase distance. Only land use and magnitudes of landslide had same direction and there were relations and correlation value was higher than elevation, slope and drainage. The mostly landslide occurred in evergreen forest area which in study area majority of the land use was evergreen forest and positive relation for the result of geology.

4. The susceptibility level around intermountain plateau was classed on Multiple Criteria Analysis technique (MCA).After re-weighing value of parameters (elevation, slope, land use, drainage and geology) found that geology washigh relation, so there was highest weighting value and then ranking parameters by correlation value, i.e. land use, drainage, elevation and slope. As for rainfall was mostly importance factors because landslide occurred when heavy rainfall on March 2011 which indicate by Figure 3, graph was highest level during March 2011and rainfall for 7 day (24^{th}-31^{st} March2011)was more than 100 mm. per day so the result was agree with hazard map of DMR: “rainfall per day are more than 100 mm”. Highest landslide occurred in figure 4. So the rainfall parameter weighting value was highest too.

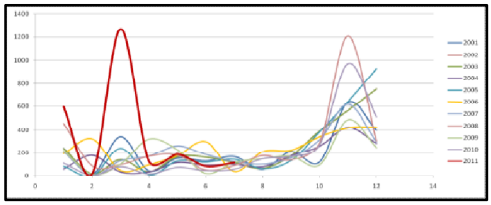

Fig.3 Graph of rainfall 10 year ago

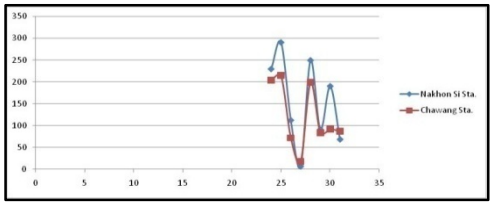

Fig.4 Graph of rainfall for 7 day (24-31) on March 2011

Soil weighting value was highest because when using overlay technique in GIS found that landslide of all occurred in Sandy soil or 100% of all area. Also the household weighting value was highest because if amount of household was high, amount of damage from landslide would high .Weighting and rating are show in table 3.

Table 3: Weighting and rating parameters used for landslide hazard zonation map in study area

Parameter	Correlation(r^2)	Weight value parameter	Description	Rating Value
1. Magnitude (Km^2)	-	5	>0.004 0.002-0.004 0.001-0.002 <0.001	5 4 3 2
2. Slope (Degree)	0.04452	1	>30 6-30 <6	4 5 3
3. Drainge (buffer m.)	0.60025	3	1300 1100 900 700 500	1 2 3 4 5
4.Soil	-	5	a. Sandy soil	5
5.Landuse	0.799236	4	a. Evergreen forest b. Para rubber c. Mixed orchard d. River, Canal	5 4 3 2
6. Geology (Rock Type)	1	5	a. Granite Rock (I) b.Sandstone/siltstone(S,M)	5 4
7. Elevation (m.)	0.159	2	> 400 301-400 201-300 101-200 0-100	5 4 3 2 1
8. Rainfall sum 7 day (mm.)	-	5	>987 741-987 495-740 248-494 1-247	5 4 3 2 1
9. Household (N. of house)	-	5	0-135 136-214 215-293 294-373 374-453	1 2 3 4 5

After re-weighting factor, the parameters was inputted into MCA technique by Principle of weighting factor technique was ranking to importance factors (Adul, 2007): Factor in vertical > Factor in horizontally=1, Factor in vertical = Factor in horizontally=2, Factor in vertical < Factor in horizontally =3, Factor in vertical same Factor in horizontally=0.Result of calculated weighting parameters are show in table 4.

Table4: Result of calculated weighting parameters

Parameters	Weight	*5*	*1*	*3*	*5*	*4*	*5*	*2*	*5*	*5*	Sum score	Weight
		X1	X2	X3	X4	X5	X6	X7	X8	X9		
Magnitude	*5*	0	3	3	2	3	2	3	2	2	20	0.1389
Slope	*1*	1	0	1	1	1	1	1	1	1	8	0.0556
Drainge	*3*	1	3	0	1	1	1	3	1	1	12	0.0833
Soil	*5*	2	3	3	0	3	2	3	2	2	20	0.1389
Land use	*4*	1	3	3	1	0	1	3	1	1	14	0.0972
Geology	*5*	2	3	3	2	3	0	3	2	2	20	0.1389
Elevation	*2*	1	3	1	1	1	1	0	1	1	10	0.0694
Rainfall	*5*	2	3	3	2	3	2	3	0	2	20	0.1389
Household	*5*	2	3	3	2	3	2	3	2	0	20	0.1389
	Sum	12	24	20	12	18	12	22	12	12	144	1

The result of susceptibility level was scored from calculate weighting factor and score of factor show in equation 1: F=0.1389X1+0.0556X2+0.0833X3…….. _____(1)

F= Sum of score

0.1389….0.1389 = weighting factor value 1-9

X1….X9 = Score of factor 1-9

The score in weight column was calculated and then classify by defined interval technique. The susceptibility landslide zone was divided for 4 zones (Very High susceptible area, High susceptible area, Moderate susceptible area and Low susceptible area). Susceptibility classification and landslide susceptibility area at Nop Phi Tam district show in table 5.

Table 5: Susceptibility Classification and landslide susceptibility area

Susceptibility Index	Susceptibility Class	Different categories	Area(km^2) for 2011	% of Area
>2.9	Very High Susceptible Area	Zone of Very High Susceptibility	15.37	2.13
2.2-2.9	High Susceptible Area	Zone of High Susceptibility	127.39	17.65
1.4-2.1	Moderate Susceptible Area	Zone of Moderate Susceptibility	462.84	64.14
<1.4	Low Susceptible Area	Zone of Low Susceptibility	116.04	16.08
Sum			721.64	100.00

7. CONCLUSION

Landslide hazard map was divided to 4 susceptibility zone around intermountain plateau at Nop Phi Tam district. The susceptibility level increase when susceptibility indexes (F) was increase. The northeast region of watershed is high and very high susceptibility area for landslide, which was evergreen forest area. The village in southeast that was moderate susceptibility zone and landslide occurred less than other village. The susceptible map of the study area was show in Figure 5.

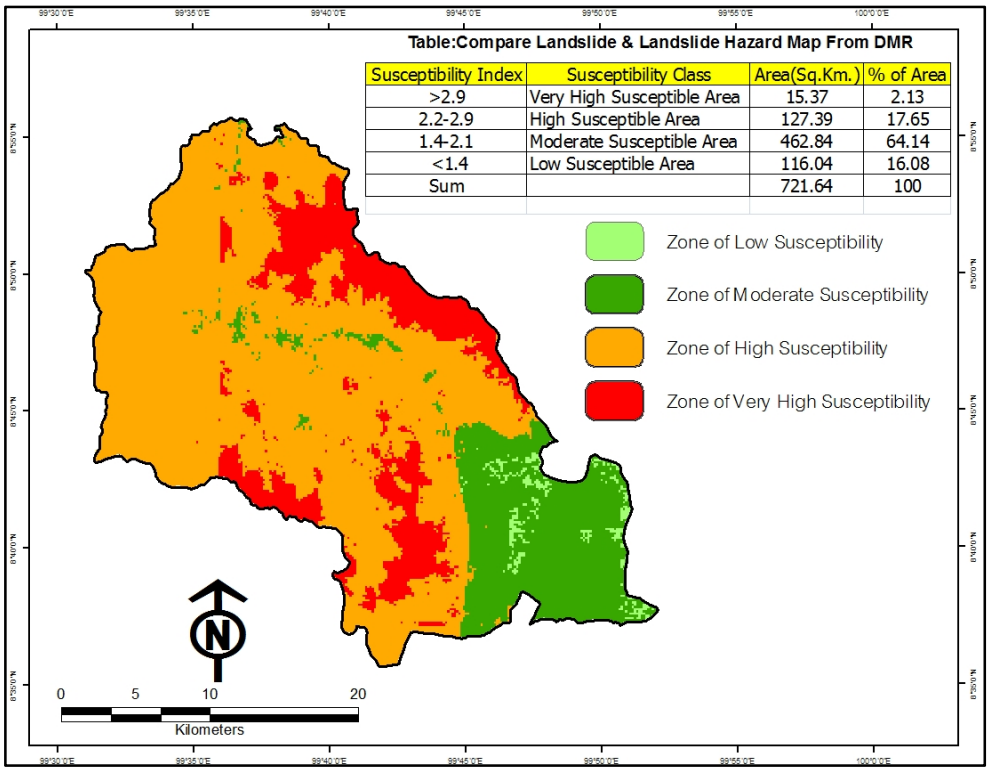

Fig. 5 Susceptibility Map

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