Landslide susceptibility assessment along the China-Thailand railway project in Saraburi and Nakhon Ratchasima Provinces, Northeastern Thailand

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Introduction

- The China-Thailand railway project marks the construction of Thailand's first dual-track standard gauge midspeed railways, expected to be 873km-long.
- The new railway line will span across Thailand and connect Vientiane in Laos and Kunming in China. It is also planned to reach Malaysia and Singapore in future.
- It will be divided into four sections, in Bangkok-Kaeng Khoi (Saraburi), Kaeng Khoi-Map Ta Phut, Kaeng Khoi-Nakhon Ratchasima, and Nakhon Ratchasima-Nong Khai.

https://thaienews.blogspot.com/2015/03/southeast-asia-regular-and-high-speed.html

Study Area

Study area covers mountainous area which is part of Saraburi and Nakhon-Ratchasrima provinces.

http://www.consmag.com/th/news/

http://daily.bangkokbiznews.com/detail/29940

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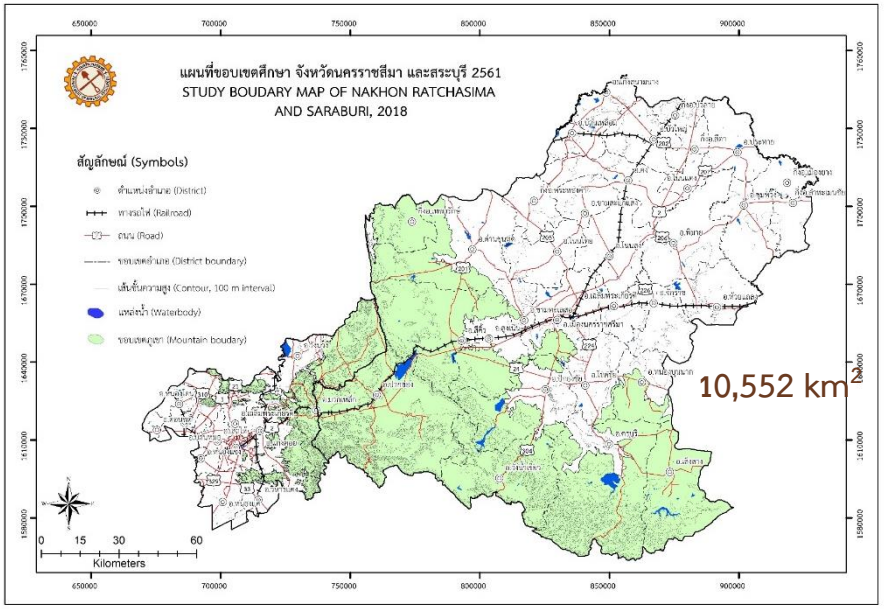
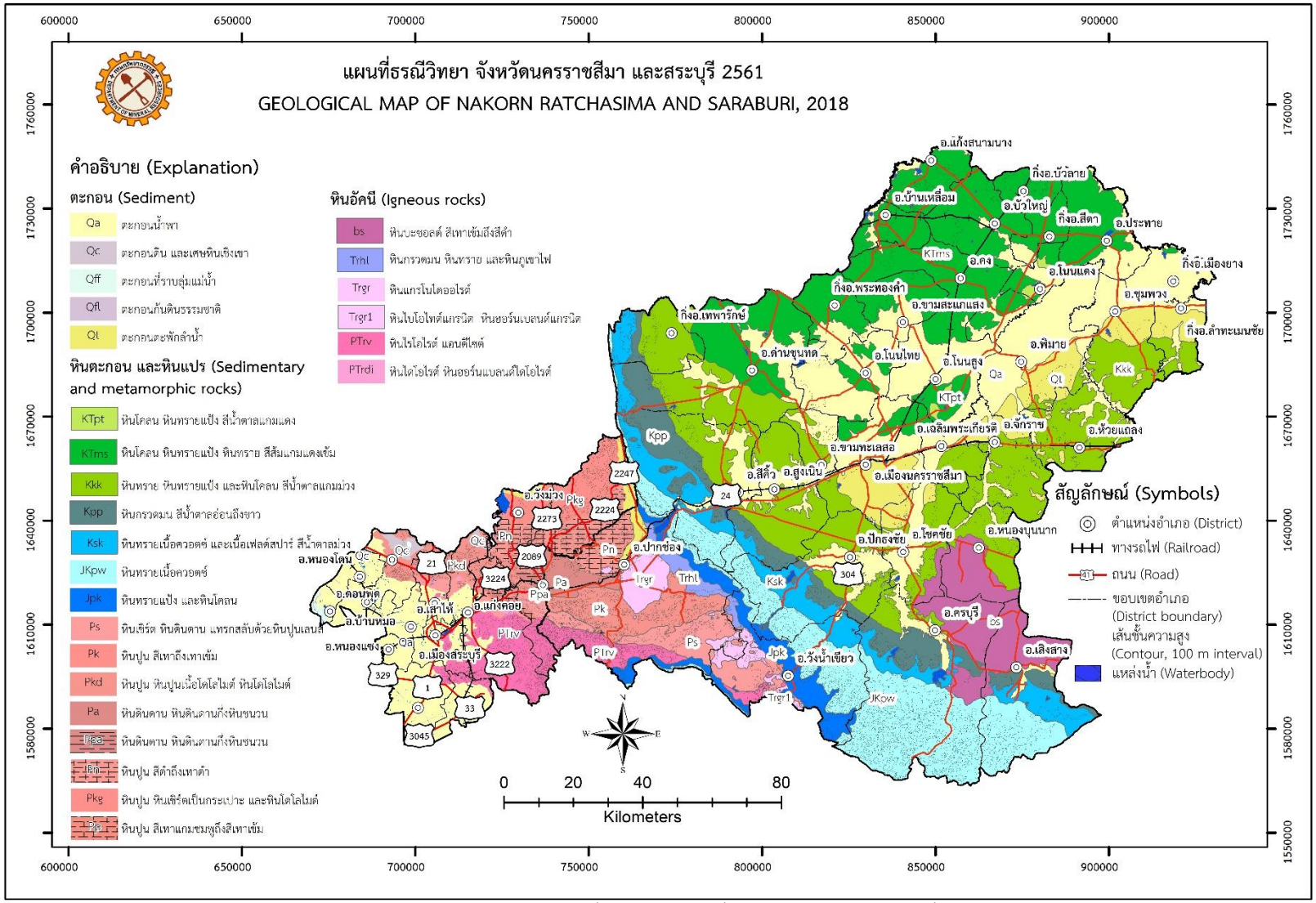


Geology



รายงานจำแนกเขตจังหวัดสระบุรีและนครราชสีมา (กรมทรัพยากรธรณี, 2550)

Landslide Susceptibility

- Landslide susceptibility is defined as a possibility of occurrence of landslide in a particular area once upon a time in the future
- Landslide susceptibility mapping delineates the hazardous zones due to occurrence of landslides
- The present study is focused on preparation of landslide susceptibility map with an application of Remote Sensing (RS) and Geographic Information System (GIS)

Method

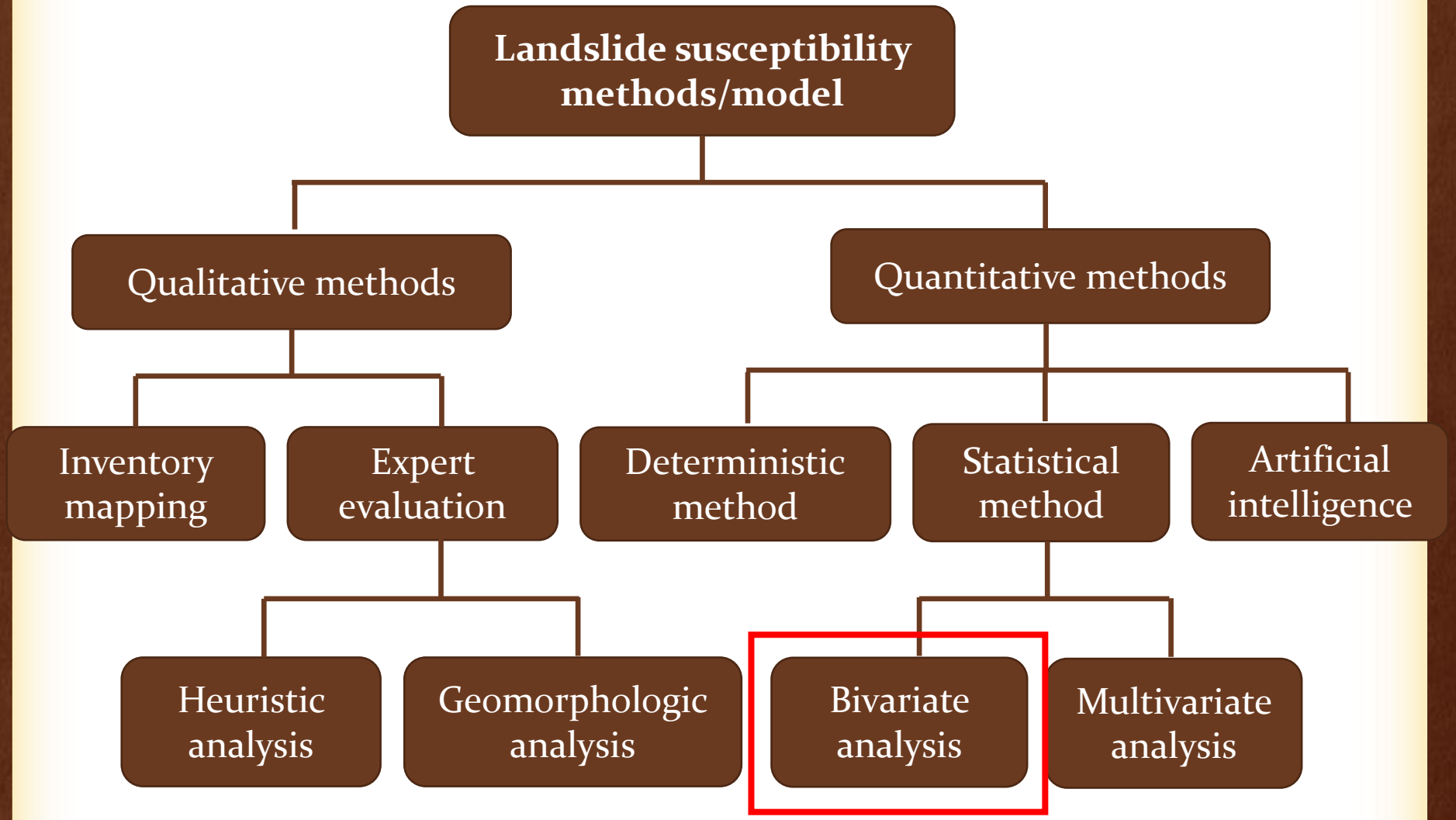


Diagram shows landslide susceptibility methods (Modified from He and Beighley, 2008)

Landslide inventory map

A landslide inventory map is the simplest output of direct landslide mapping. It shows the location of discernible landslides;

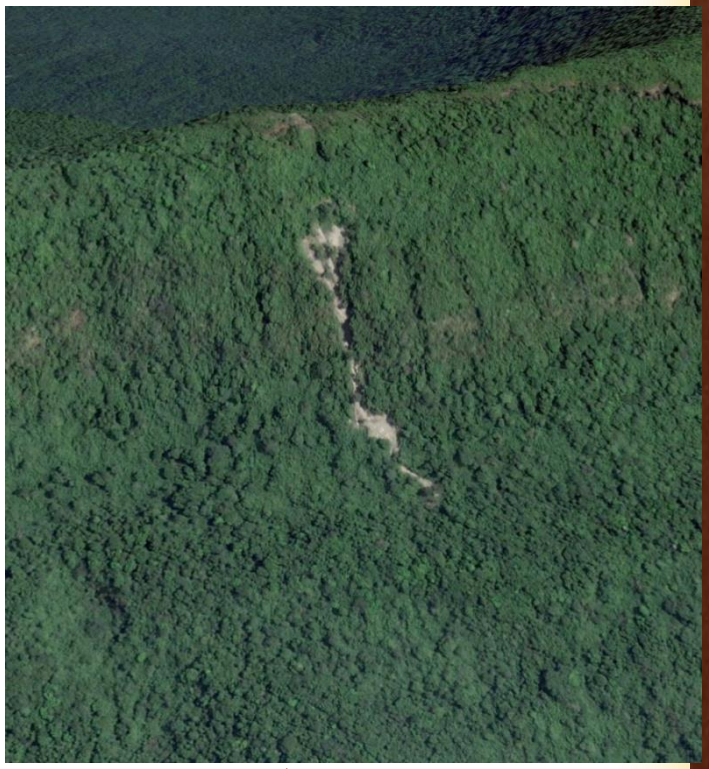
- Historical inventory
- Event inventory

Landslide maps can be prepared by collecting historical information, or from the analysis of aerial photographs together with field investigation.

Landslide inventory map

Visual interpretation using Google Earth imagery

With today's technology features on the land surface in locations all over the world are able to be seen on the Google Earth



Landslide scars in Saraburi Province (Images from 2013)

Landslide inventory map

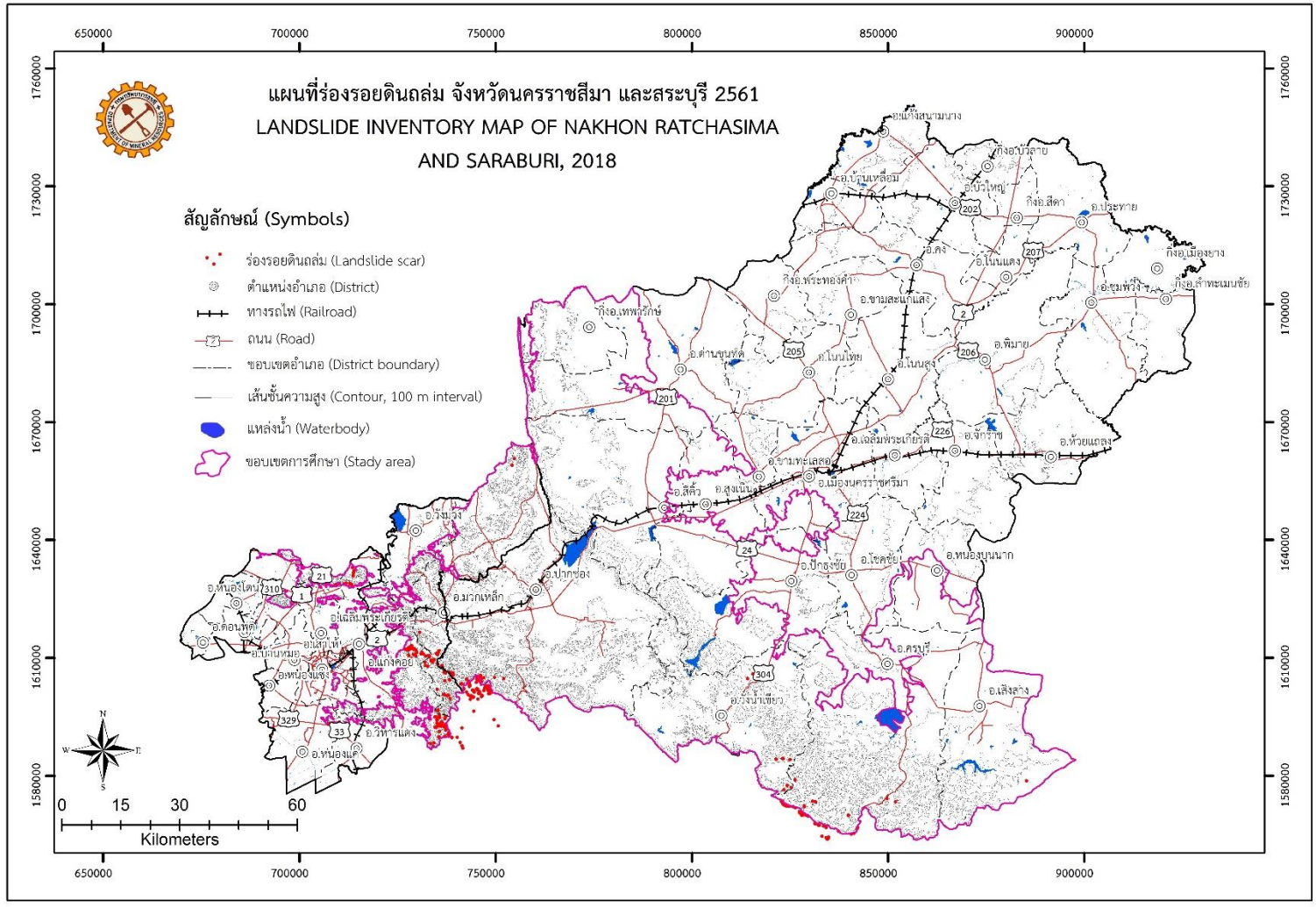
Field verification and survey

Landslide scars in Muak-Lek District, Saraburi (0748943E 1716774N)

Rock fall next to railway in Muak-Lek District, Saraburi (0728572E 1620547N)

Landslide inventory map

325 landslide scars were mapped from 1990 - 2017

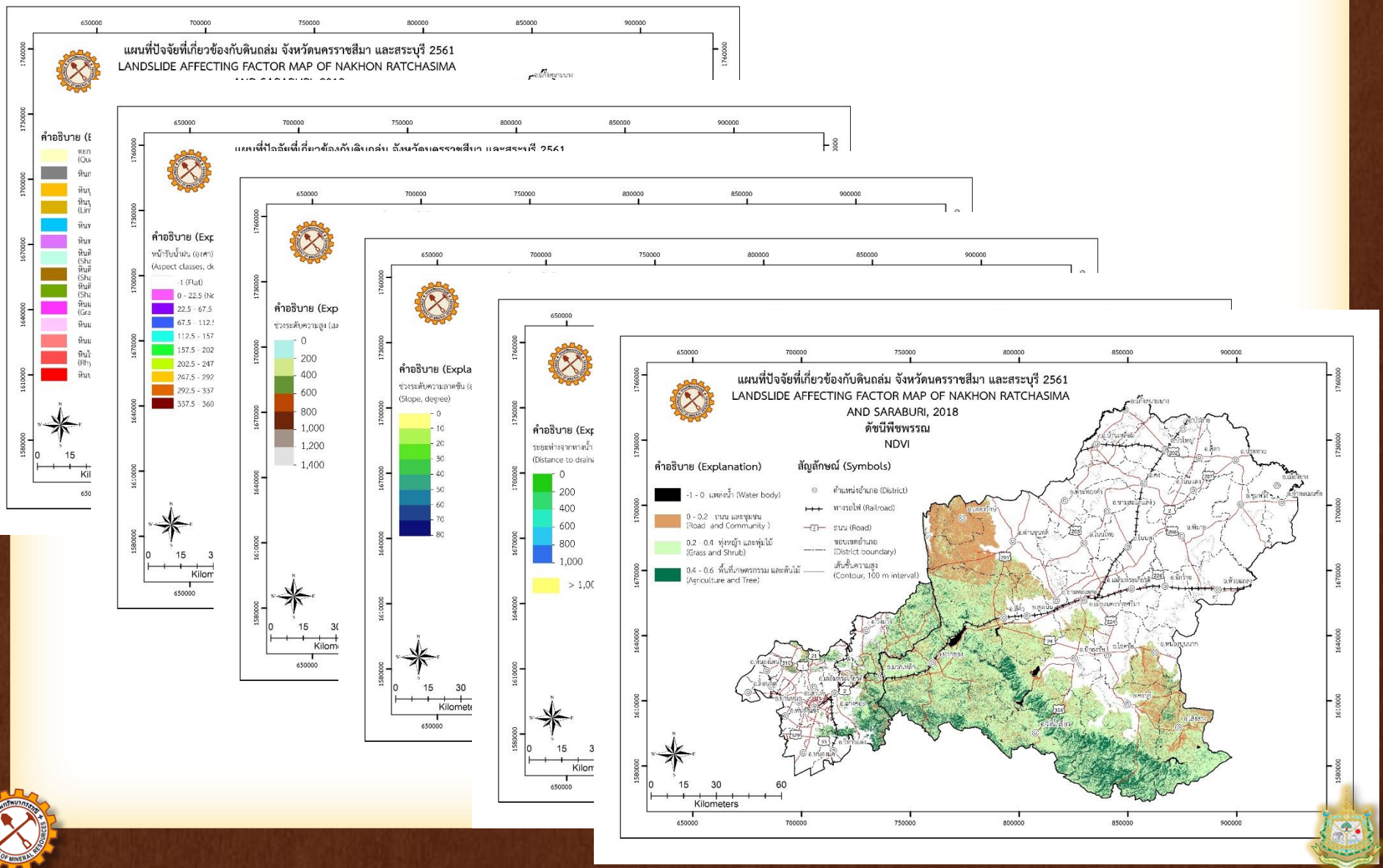


Landslide affecting factors

In this study, six independent factors were chosen as potentially contributing to landslide susceptibility ;

- Slope
- Elevation
- Aspect
- Lithology
- Drainage
- Normalized Difference Vegetation Index: NDVI

Landslide affecting factors



Method

Landslide susceptibility analysis using statistical method

1. Frequency Ratio

Frequency ratio methods are based on the observed associations between **distribution of landslides** and **landslide - related factor**, to expose the correlation between landslide locations and the factors in the study area

$$LS = Fr1 + Fr2 + ... + Frn$$

LS is Susceptibility values
Fr is rating of each factor's type or range
n is number of factors

(ArcGis 10.x and Microsoft Excel)

Landslide affecting factors

Factors	Class No.	Class Name	% of total area (a)	% of Landslide scar (b)	Frequency ratio = (b/a)
1. Lithology	1	Basalt	8.64	0.00	0.00
	2	Shale	6.11	0.38	0.06
	3	Siltstone & Mudstone	18.88	2.68	0.14
	4	Chert	0.52	0.38	0.74
	5	Conglomerate	9.48	0.00	0.00
	6	Granite	0.35	0.00	0.00
	7	Granodiorite	2.89	0.00	0.00
	8	Limestone	13.31	2.30	0.17
	9	Sediments	4.16	0.00	0.00
	10	Quartz arenite	29.53	8.81	0.30
	11	Rhyorite	5.82	85.44	14.68
2. Aspect	1	Flat(-1)	6.56	0.00	0.00
	2	North(0-22.5)	8.28	9.96	1.20
	3	Northeast(22.5-67.5)	13.69	11.11	0.81
	4	East(67.5-112.5)	11.50	9.20	0.80
	5	Southeast(112.5-157.5)	11.88	18.01	1.52
	6	South(157.5-202.5)	9.84	21.84	2.22
	7	Southwest(202.5-247.5)	10.78	13.03	1.21
	8	West(247.5-292.5)	10.45	8.81	0.84
	9	Northwest(292.5-337.5)	12.89	4.21	0.33
	10	North(337.5-360)	4.12	3.83	0.93
3. Distance to drainage	1	0-200	23.36	14.94	0.64
	2	200-400	20.40	26.44	1.30
	3	400-600	15.44	17.24	1.12
	4	600-800	10.73	12.26	1.14
	5	800-1,000	7.23	12.64	1.75
	6	>1,000	22.84	16.48	0.72

Landslide affecting factors

Factors	Class No.	Class Name	% of total area (a)	% of Landslide scar (b)	Frequency ratio = (b/a)
4. Elevation	1	0-200	6.38	2.68	0.42
	2	200-400	65.68	27.97	0.43
	3	400-600	20.75	31.42	1.51
	4	600-800	6.29	19.54	3.11
	5	800-1000	0.82	14.94	18.29
	6	1000-1200	0.08	3.45	44.53
	7	1200-1400	0.01	0.00	0.00
5. Slope	1	0-10	79.42	7.66	0.10
	2	10-20	13.81	18.39	1.33
	3	20-30	5.18	32.95	6.36
	4	30-40	1.39	31.03	22.26
	5	40-50	0.17	7.28	43.34
	6	50-60	0.02	1.92	95.45
	7	60-70	0.00	0.77	172.34
	8	70-80	0.00	0.00	0.00
6. NDVI	1	-1-0	0.70	0.00	0.00
	2	0-0.2	21.39	6.92	0.32
	3	0.2-0.4	65.56	54.23	0.83
	4	0.4-0.6	12.35	38.85	3.15

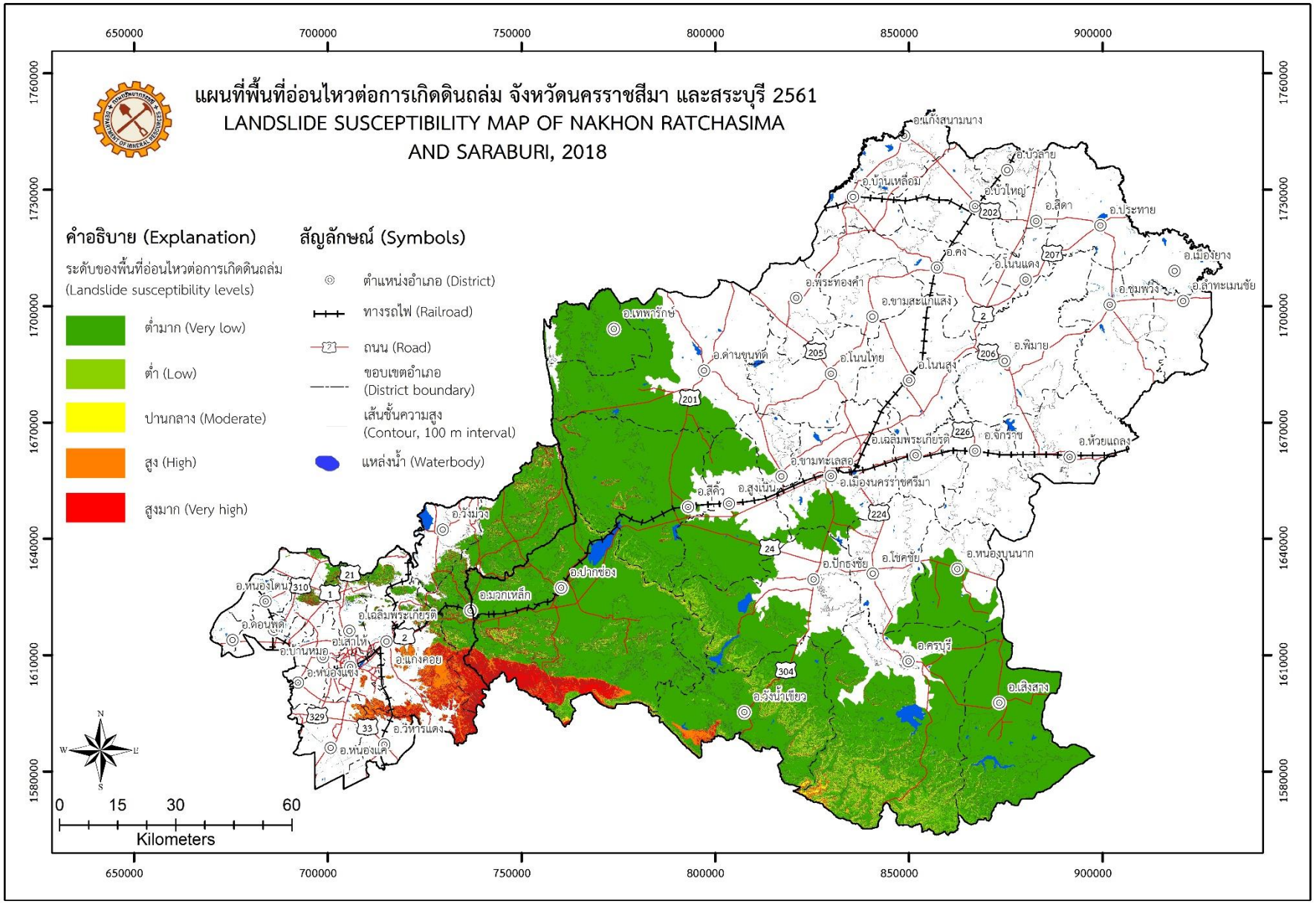
Landslide susceptibility classification

Once a landslide susceptibility map is created, it is necessary to divide this map into different susceptibility classes. For the susceptibility classification for this study, Relative landslide density (R) which is derived from the ratio of percentages of total landslide area in each susceptibility class to total area in the class and gives an indication of the goodness of fit, was used to classify susceptibility index. The susceptibility classes were meant to be 5 classes (very low, low, moderate, high, very high). The final landslide susceptibility map determined by frequency ratio method is shown in figure 6.

$$R = \left(\frac{\left(\frac{ni}{Ni}\right)}{\Sigma\left(\frac{ni}{Ni}\right)} \right) \times 100$$

Where ni is number of landslides in susceptibility class i,

Ni is total area occupied by the susceptibility class i.


แผนที่พื้นที่อ่อนไหวต่อการเกิดดินถล่ม จังหวัดนครราชสีมา และสระบุรี 2561
LANDSLIDE SUSCEPTIBILITY MAP OF NAKHON RATCHASIMA AND SARABURI, 2018
คำอธิบาย (Explanation)
ระดับของพื้นที่อ่อนไหวต่อการเกิดดินถล่ม (Landslide susceptibility levels)
ต่ำมาก (Very low)
ต่ำ (Low)
ปานกลาง (Moderate)
สูง (High)
สูงมาก (Very high)
สัญลักษณ์ (Symbols)
ตำแหน่งอำเภอ (District)
ทางรถไฟ (Railroad)
ถนน (Road)
ขอบเขตอำเภอ (District boundary)
เส้นชั้นความสูง (Contour, 100 m interval)
แหล่งน้ำ (Waterbody)
650000
700000
750000
800000
850000
900000
1760000
1730000
1700000
1670000
1640000
1610000
1580000
N
W
E
S
0 15 30 60
Kilometers
อ.แก้งสนามนาง
อ.บัวลาย
อ.บ้านเหลื่อม
อ.บัวใหญ่
อ.สีดา
อ.ประทาย
อ.คง
อ.โนนแดง
อ.เมืองยาง
อ.ชุมพวง
อ.ล้าทะเมนชัย
อ.พระทองคำ
อ.ขามสะแกแสง
อ.เทพารักษ์
อ.ด่านขุนทด
อ.โนนไทย
อ.โนนสูง
อ.พิมาย
อ.เฉลิมพระเกียรติ
อ.จักราช
อ.ห้วยแถลง
อ.ขามทะเลสอ
อ.เมืองนครราชสีมา
อ.สีคิ้ว
อ.สูงเนิน
อ.วังน้ำเขียว
อ.ปักธงชัย
อ.โชคชัย
อ.หนองบุนนาก
อ.ครบุรี
อ.เสิงสาง
อ.ปากช่อง
อ.มวกเหล็ก
อ.วังม่วง
อ.หนองโดน
อ.ด่านขุนทด
อ.บ้านหมอ
อ.เสาไห้
อ.หนองแซง
อ.แก่งคอย
อ.วิหารแดง
อ.หนองแค
201
205
206
207
202
226
224
24
304
329
33
310
21
1
2
3

Landslide susceptibility map

Very low
This zone defines areas with a very low landslide susceptibility level. These areas are assumed to be stable due to less evidence of landslide susceptibility and overall stable slope conditions.

Low
This zone defines areas with a low landslide susceptibility level. Areas in this zone appear conditionally stable showing fewer indications of landslide susceptibility. Landslide events are rarely possible but may occur at slopes, which are undercut, e.g. by road construction.

Moderate
This zone defines areas with a moderate landslide susceptibility level. Landslide events may occasionally happen in these areas, either triggered by strong rainfall, earthquakes or caused by inadequate land-use in steep slopes and by slope undercutting associated with road construction.

High
This zone defines areas with a high landslide susceptibility level. New landslide events may occur or older ones may be reactivated. The distribution is mainly linked to the flanks of the second order streams and road cuts.

Very high
This zone defines areas with a very high landslide susceptibility level. New landslide event may occur frequently or older ones may be reactivated. The distribution of the very high landslide susceptibility zones is predominantly in the steep areas adjoining the shear zone.

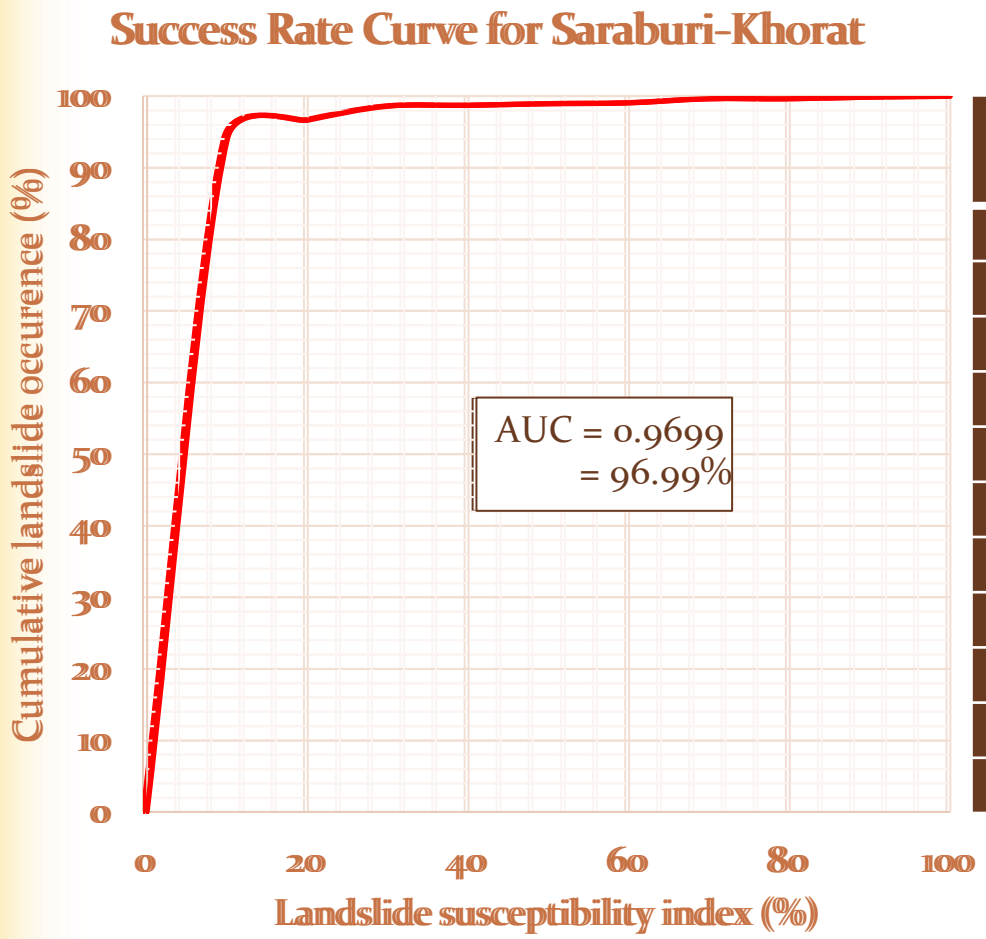
Model validation

The success rate based on the comparison between landslides used in the model and the landslide susceptibility map (Chung & Fabbri, 2003) and it measures a goodness of fit assuming the model is correct, or how well the predictive model fits the landslides from which it was derived (Chung & Fabbri, 2003)

The range of AUC and the corresponding performance index indicating the quality of the prediction algorithm (Hasanat, et al., 2010)

AUC	Performance
0.99 - 1.00	Excellent (A)
0.80 – 0.90	Good (B)
0.70 – 0.80	Fair (C)
0.60 – 0.70	Poor (D)
0.50 – 0.60	Fail (F)

Model validation



Susceptibility Range	Landslide %	Cumulative Landslide %
100-100	0.00	0.00
90-100	94.01	94.01
80-100	2.65	96.66
70-100	1.96	98.62
60-100	0.12	98.73
50-100	0.23	98.96
40-100	0.12	99.08
30-100	0.58	99.65
20-100	0.00	99.65
10-100	0.23	99.88
0-100	0.12	100

Conclusion

- The frequency ratio (FR) was chosen because it is simple, logical and has the ability to be executed without the need for sophisticated software packages.
- In this study, the analysis performed has revealed that different factors have different influence on landslides occurrence. The most important parameters have been pointed out above the others were lithology, slope and elevation. Other factors showed a high importance as well. However, for each factor, only some classes were found to play a very important role in the occurrence of landslides.
  - ✓ There is a strong indication that landslides are more likely to occur in Igneous rock (Rhyolite and Andesite).
  - ✓ There is a higher frequency of slope failure at relatively high elevation than at lower elevation as the expected result. The highest of the slope failures occur at elevations between 1,000-1,200 m.
  - ✓ In the case of the relationship between landslide occurrence and slope, as the slope increases, the landslide frequency generally increases.

Thank you for your attention

ขอบคุณค่ะ