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The Developing of The Evaluation Methods of Large-scale Landslide Effecting Area

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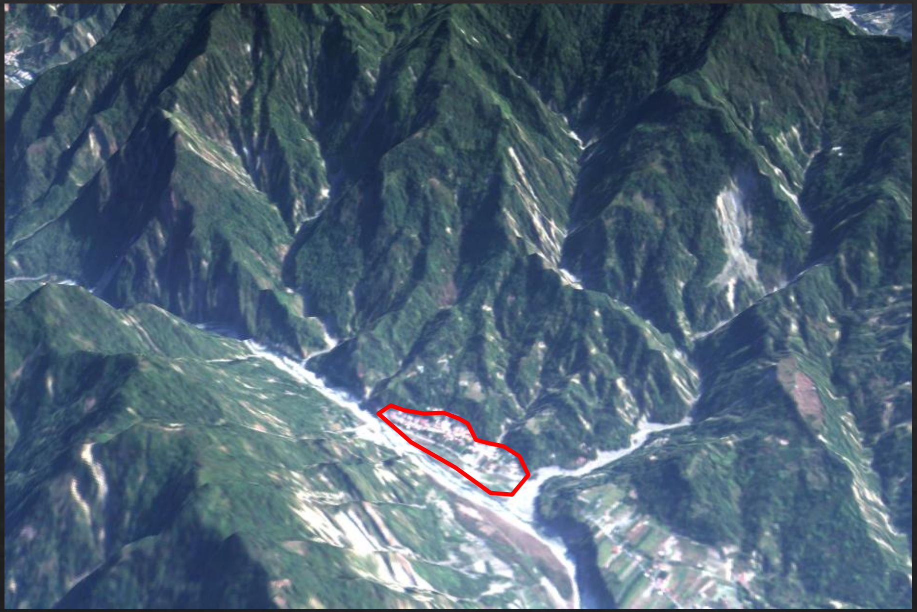
Outline

- Background
- The effect of large-scale landslide
- The evaluation methods of large-scale landslide effecting area
- Case Study
- Conclusion

Background



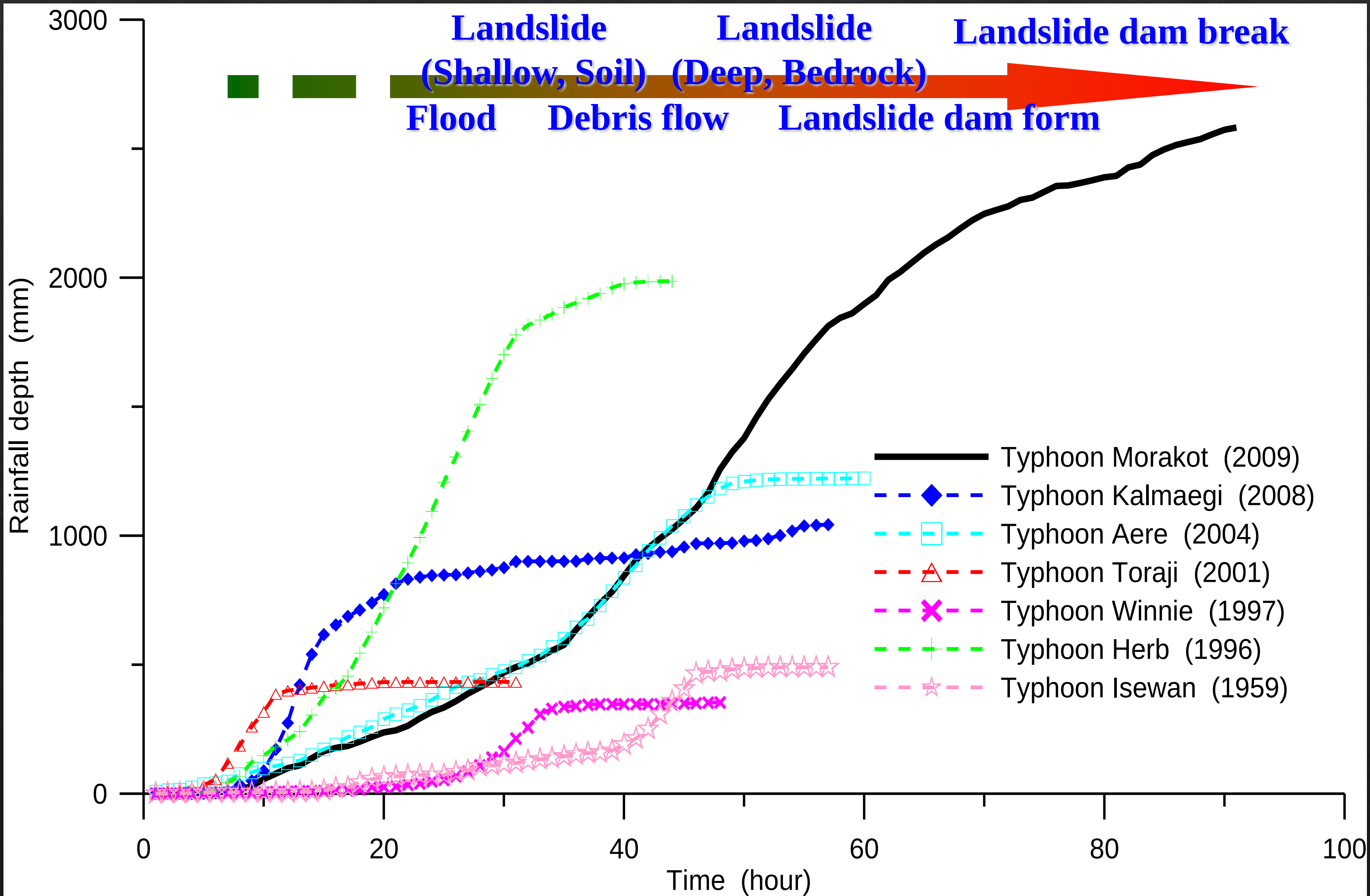
Before Typhoon Morakot in Hsiaolin Village

(FORMOSAT-2)

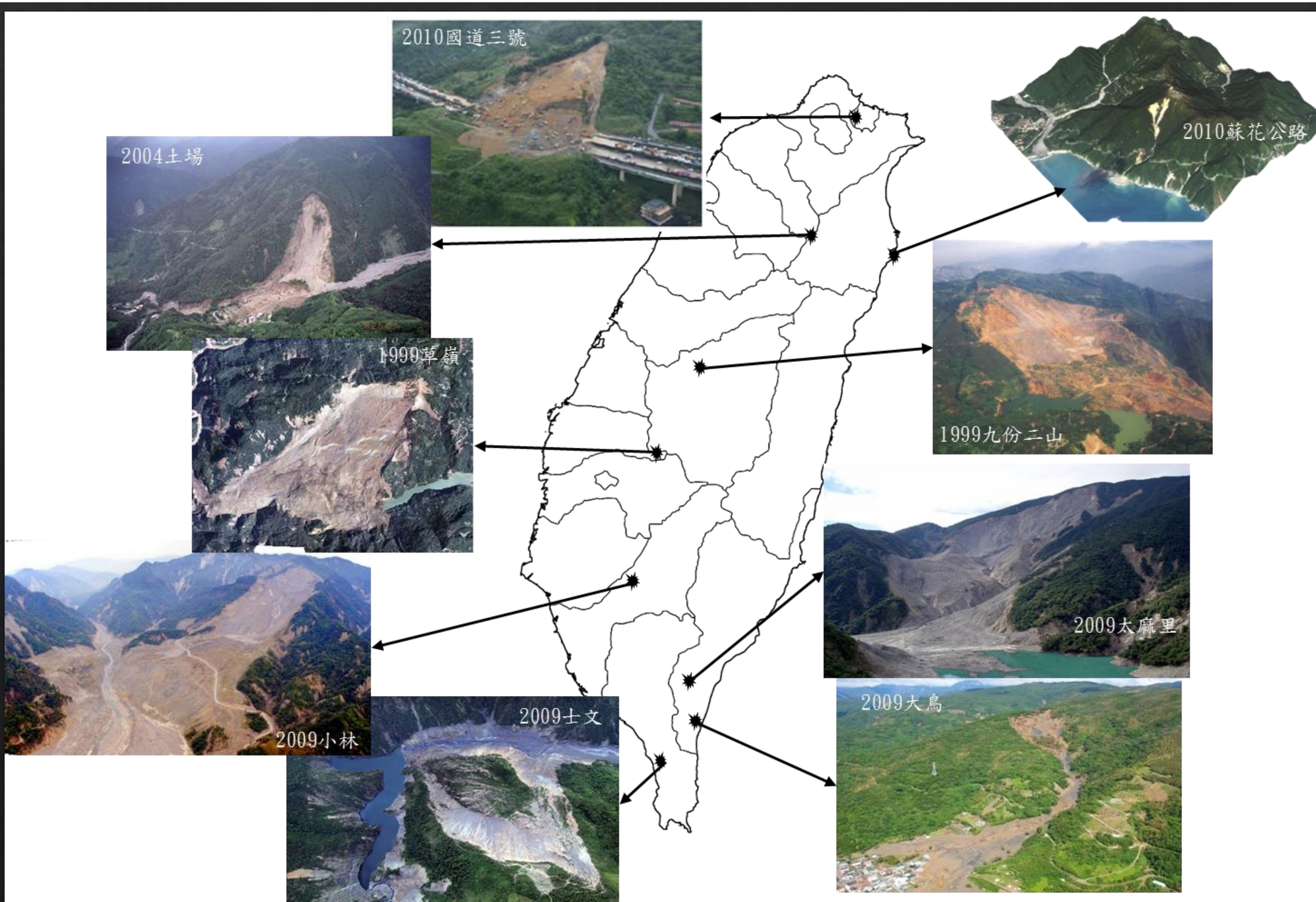
After Typhoon Morakot in Hsiaolin Village

(FORMOSAT-2)

The relationship between accumulative rainfall and duration of catastrophic typhoons

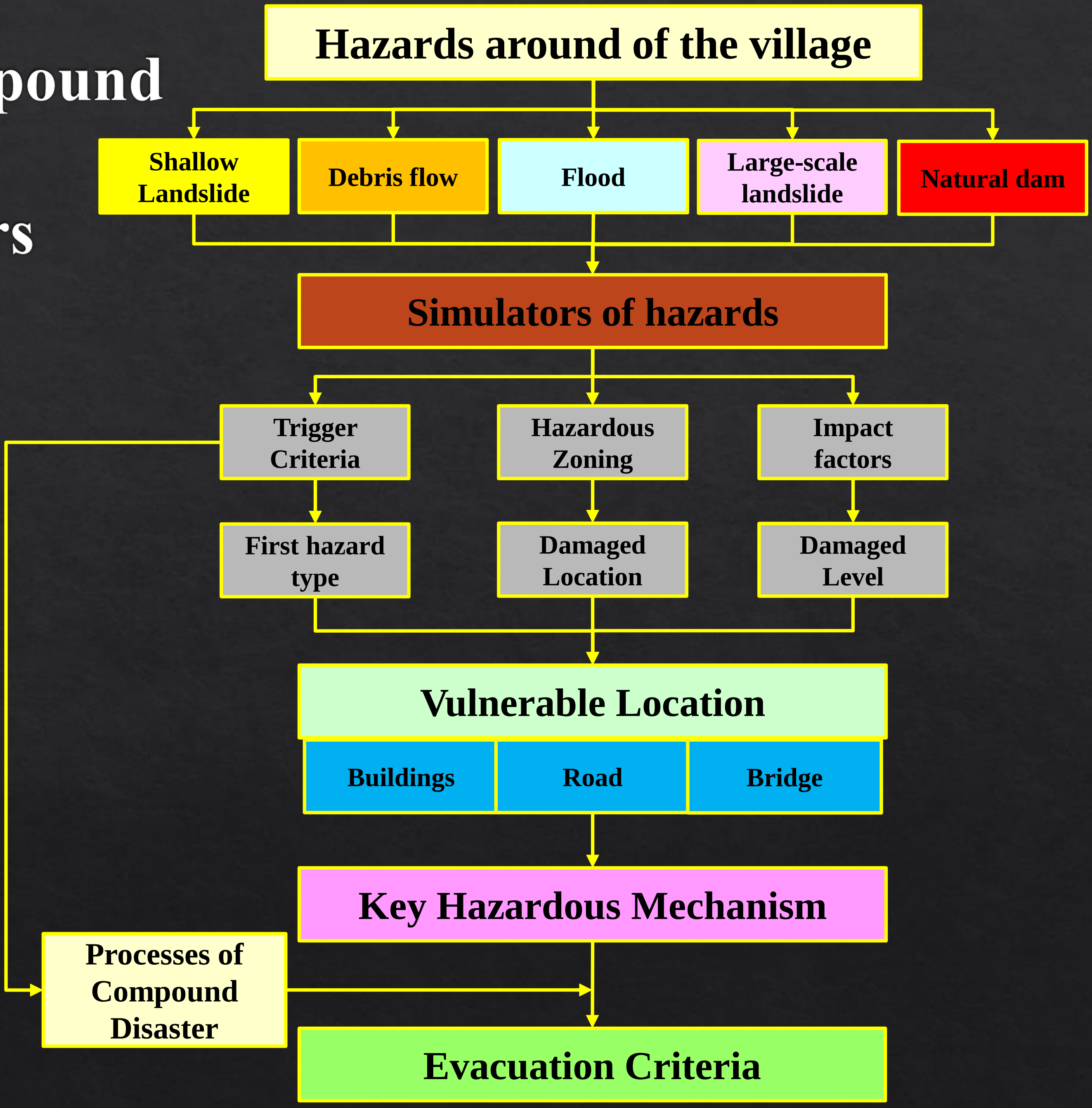


Background


2010國道三號
2004土場
1999草嶺
2009小林
2009士文
2010蘇花公路
1999九份二山
2009太麻里
2009大鳥

Strategy for Compound Sediment Disasters

- Before large-scale landslides were triggered, other kinds of disasters had already occurred.
- The purpose of the **neck point analysis** is to decide the optimal evacuation time



Strategy for Compound

- For the mitigation strategies, lots technology should be developed in near feature.

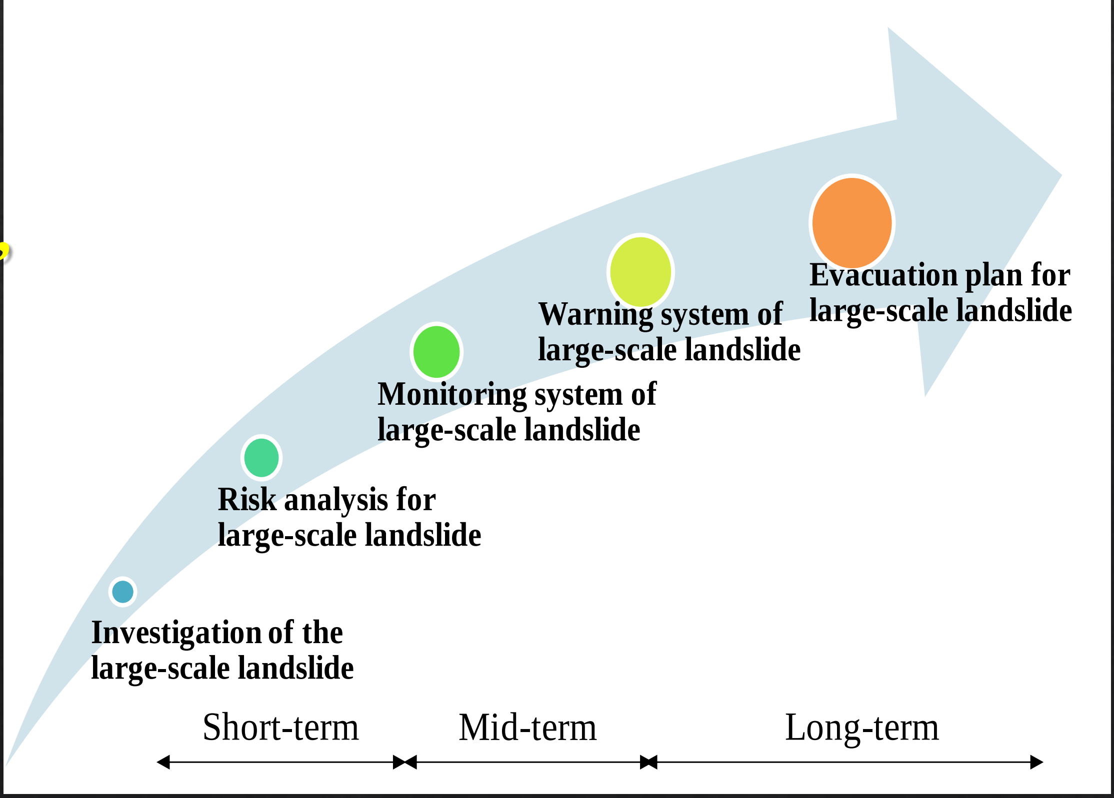
Risk = Hazard x Vulnerability

For Hazard, include

- Slope, lithologic, groundwater…etc.
- Activity
- Magnitude (volume, speed…etc.)
- Dip slope

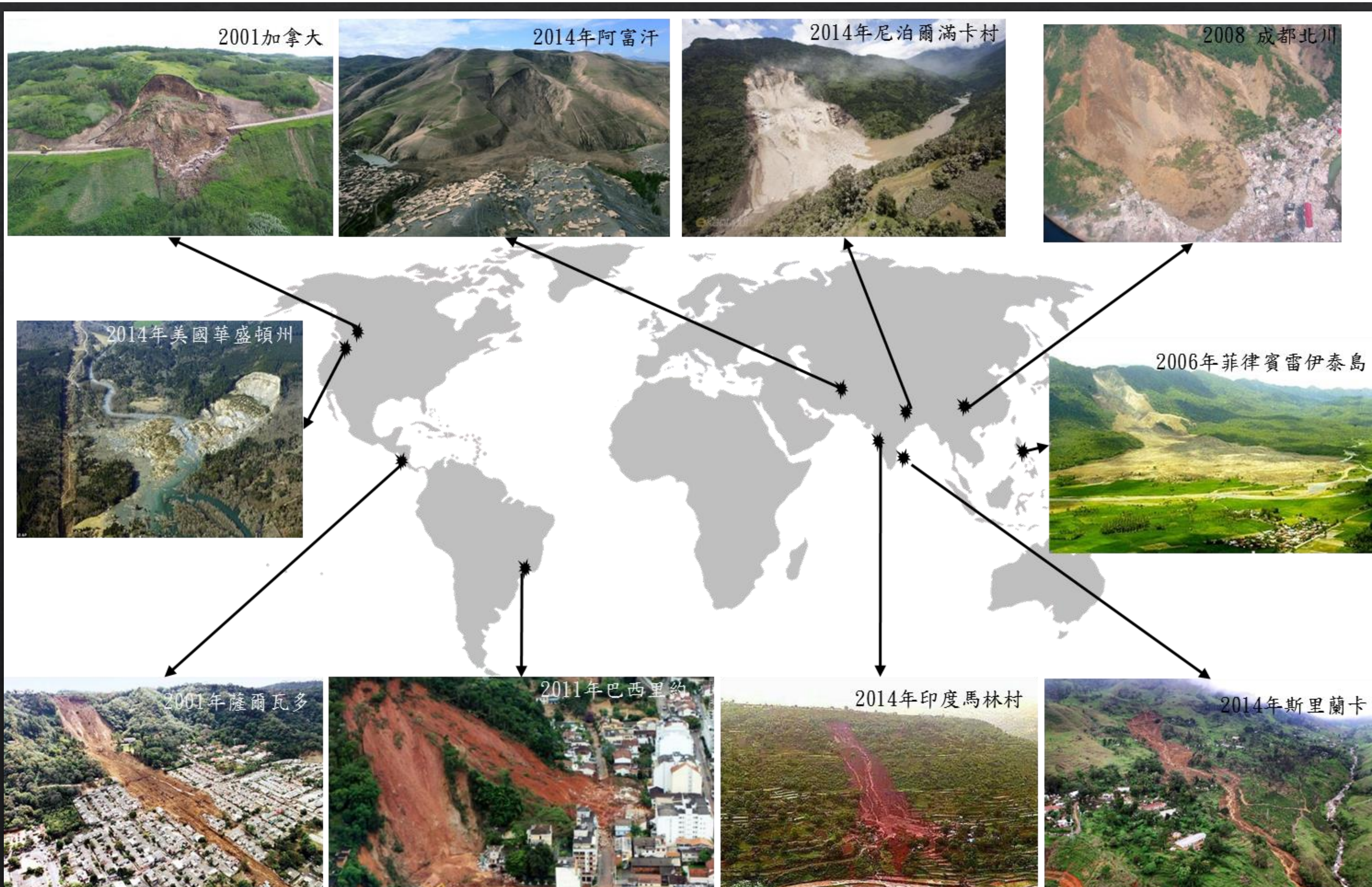
For Vulnerability,

- Location
- Protection target
- Reconstruction

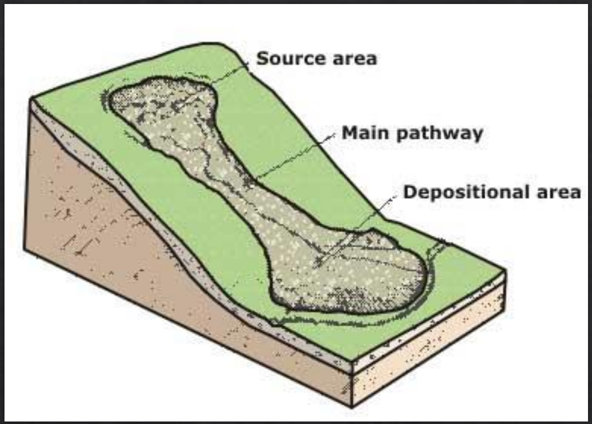


The effect of large-scale landslide

Large-scale landslide in the world



The definition of effecting area



- Source Area
  - Main Material of landslide
- Transportation Area
  - The pathway of the material movement
- Deposition area
  - where the material stop

in Source area

Santa Catarina in Brazil, 2008

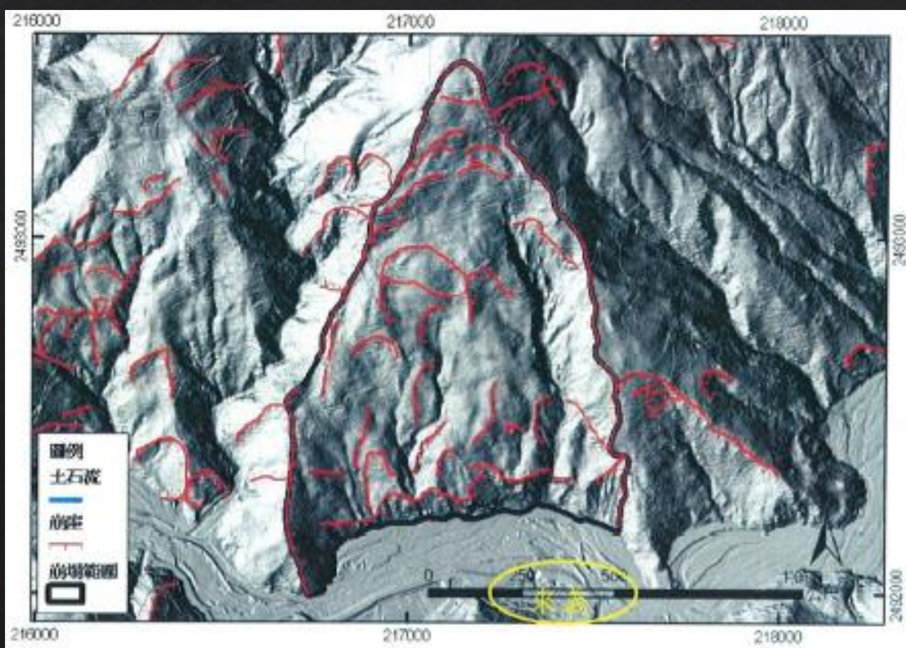
in Transportation area

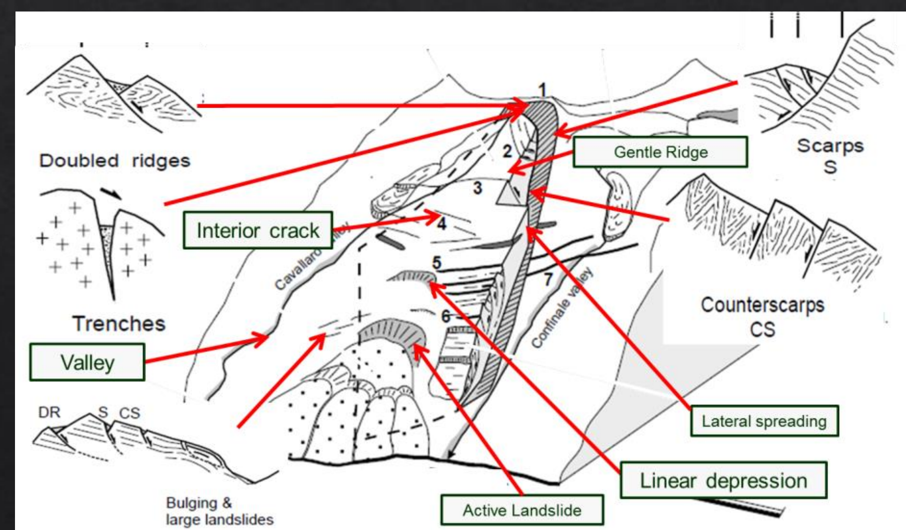
Santa Maria Tlahuitoltepec, Mexico,2010

in Deposition area

La Conchita Landslide – 2005

- **For source area, the potential area of the large-scale landslide could applied**

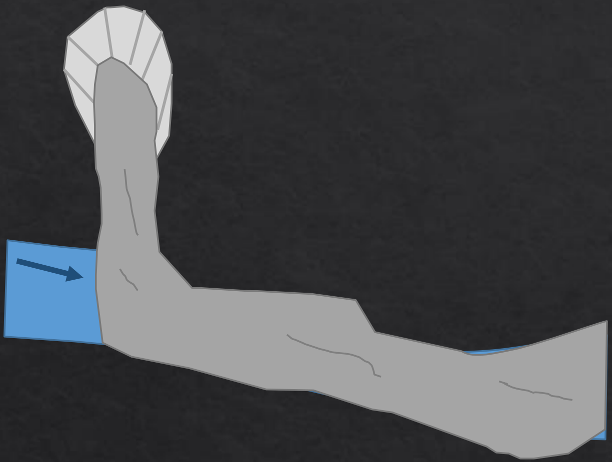




Type I – Landslide type

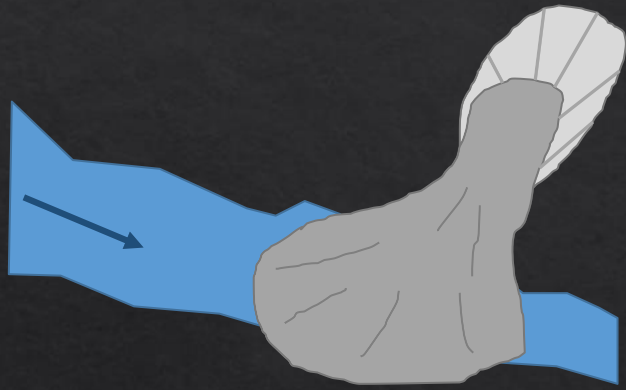
- The material runs into a plane or mild slope (without any restriction by the topography)

Type II – Debris flow type



- The material runs into a river
- The topography of the watershed reach the occurrence condition of debris flow

Type III – Landslide dam type



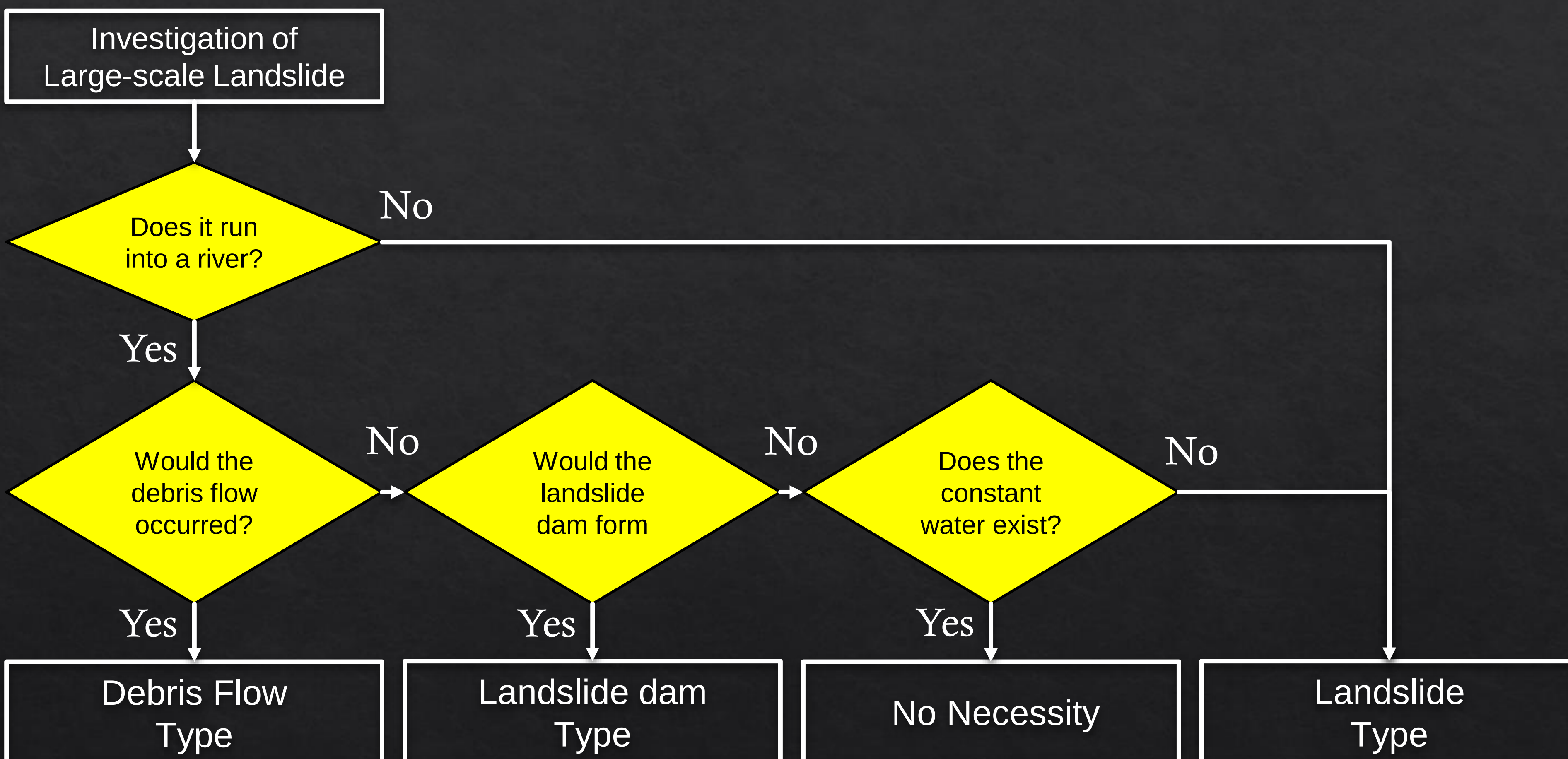
- The material runs into a river
- The river slope is small
- The volume of the material could block the river flow

Others

- During the landslide movement, the material sometime broke the watershed boundary and runs to different direction

- The material runs into the main channel, but could not form the landslide dam

Flowchart of the effecting area classified



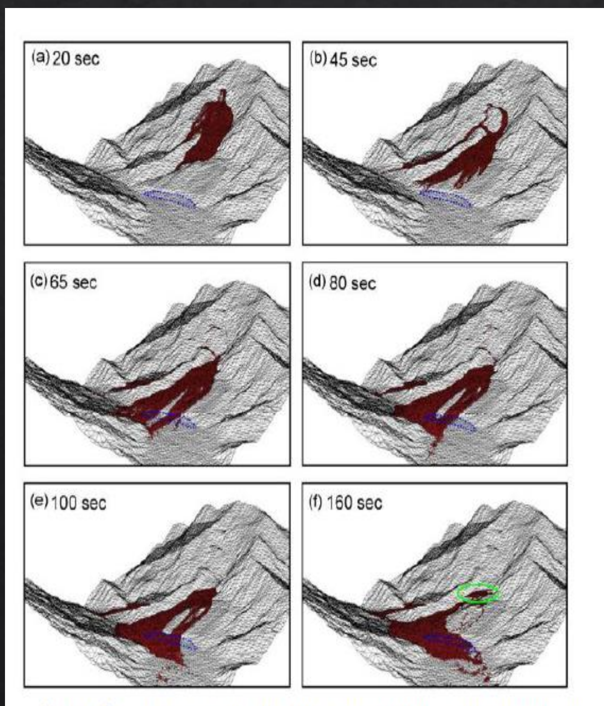
The evaluating methods of large-scale landslide effecting area

The evaluating methods

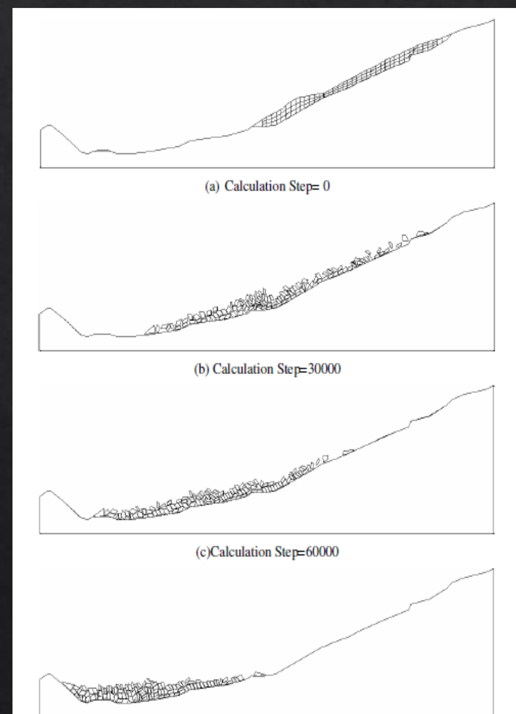
Method	Targets	Strengths	weaknesses
Field Survey	• Source Area • Transportation Area • Deposition area	High resolution Easy use	Takes Time High Cost Unpredictable
Physical Model	• Source Area • Transportation Area • Deposition area	High resolution Well Reappear Predictable	Takes Time High Cost Model Scale
Numerical Model	• Source Area • Transportation Area • Deposition area	High resolution Predictable	Complex Parameter Professional user
Empirical Equation	• Transportation Area • Deposition area	Easy use Predictable	Low resolution Without engineer effect

Numerical Method

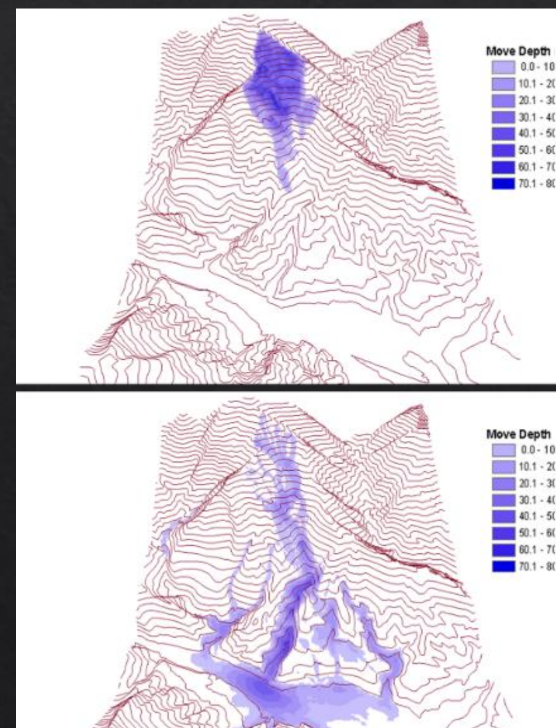
- Distinct Element Method, DEM
- Discontinuous Deformation Analysis, DDA
- Computational Fluid Dynamics, CFD



Case of DEM



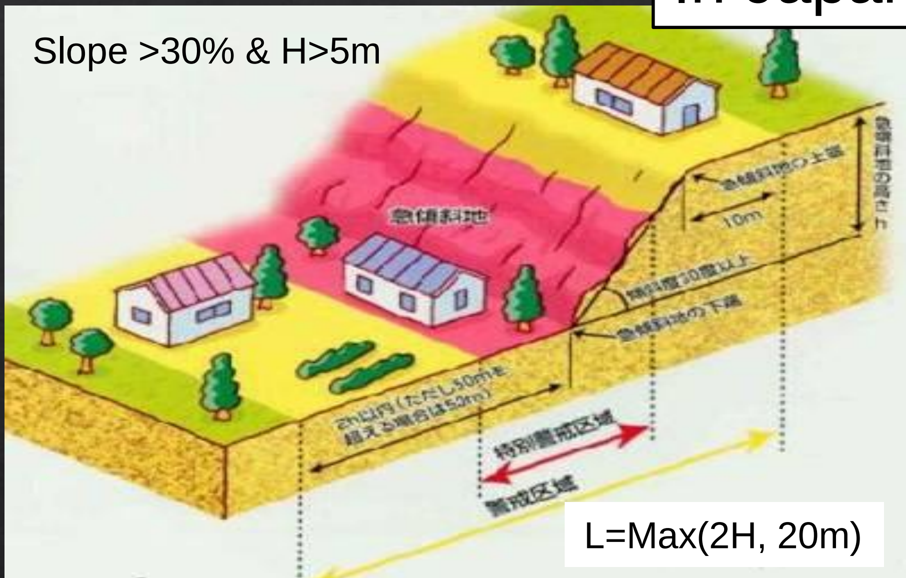
Case of DDA

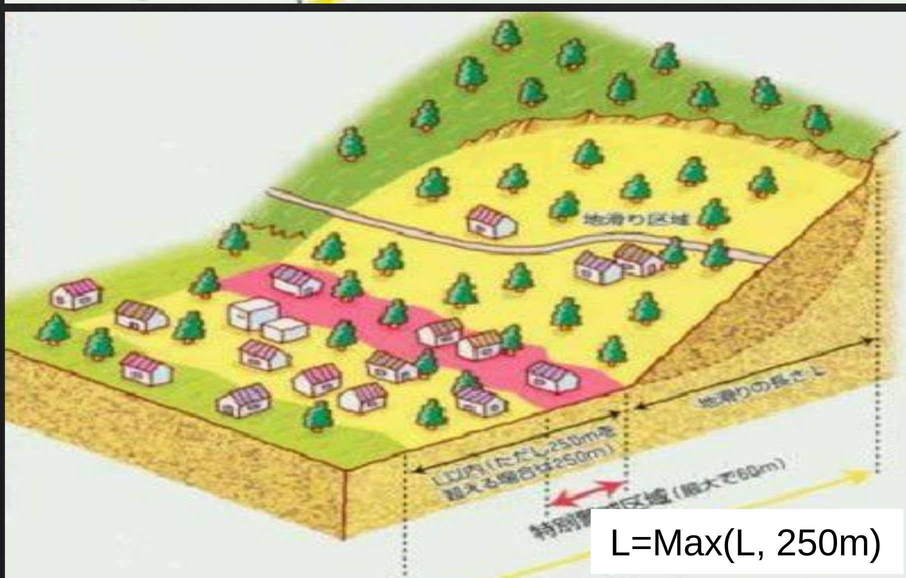


Case of CFD

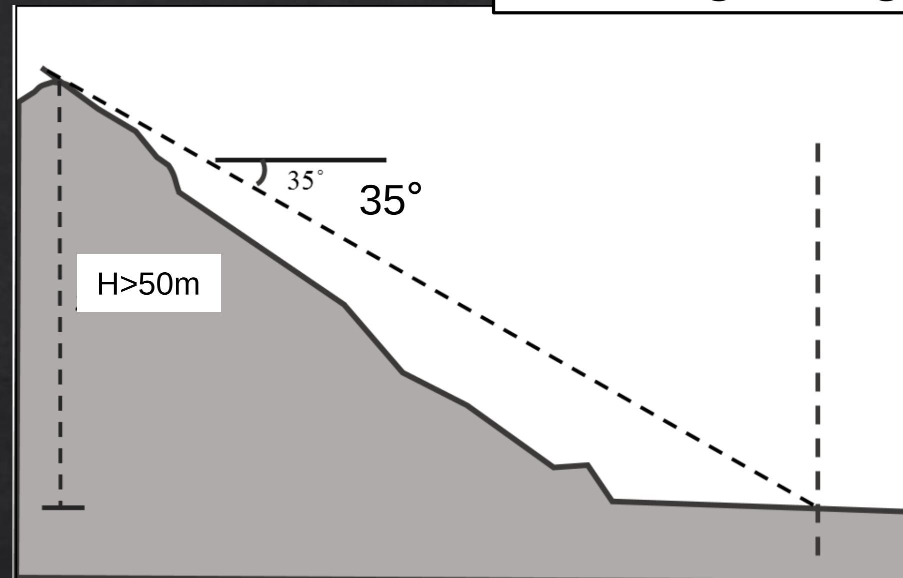
Empirical Method

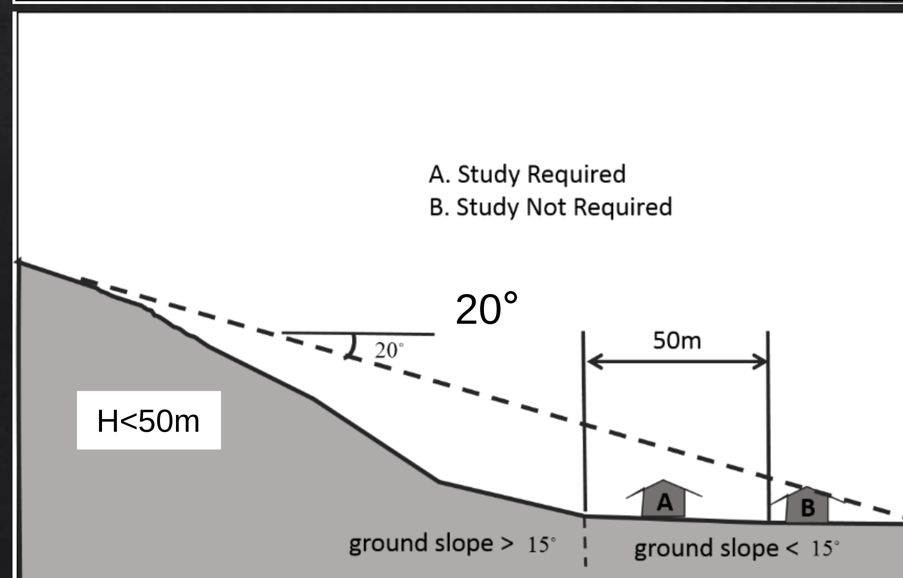
In Japan





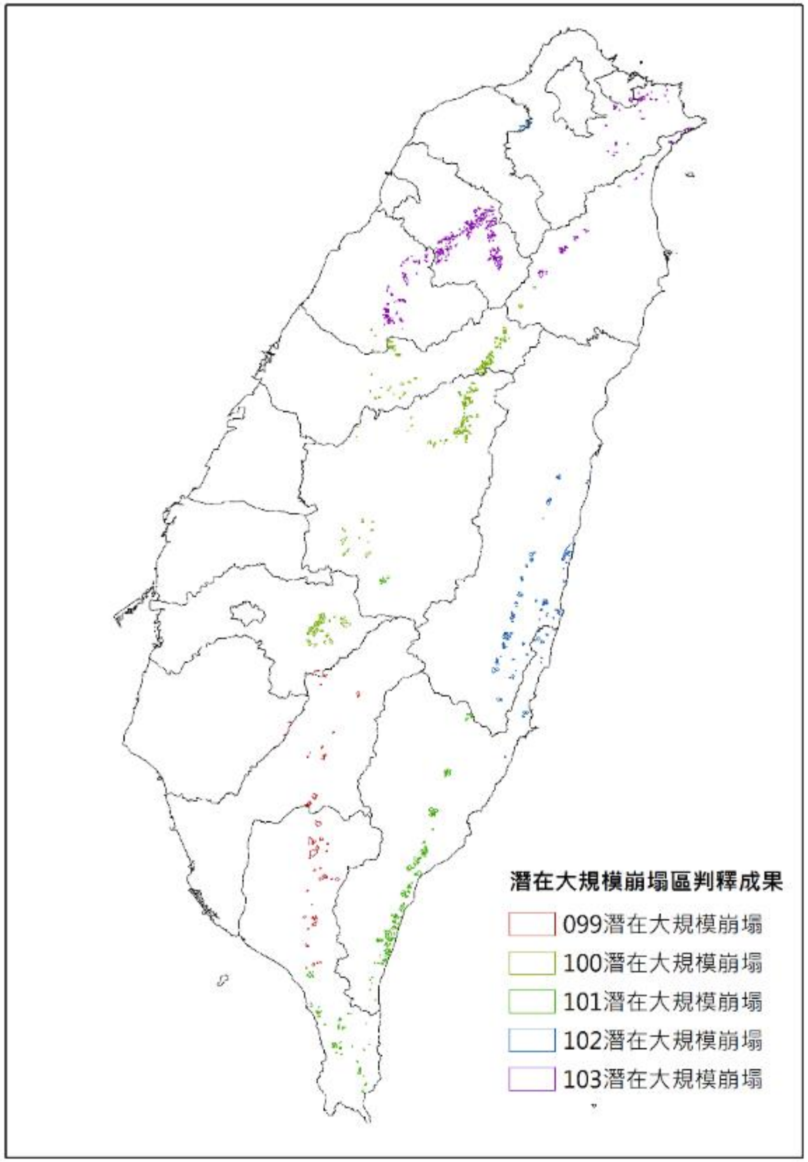
In Hong Kong



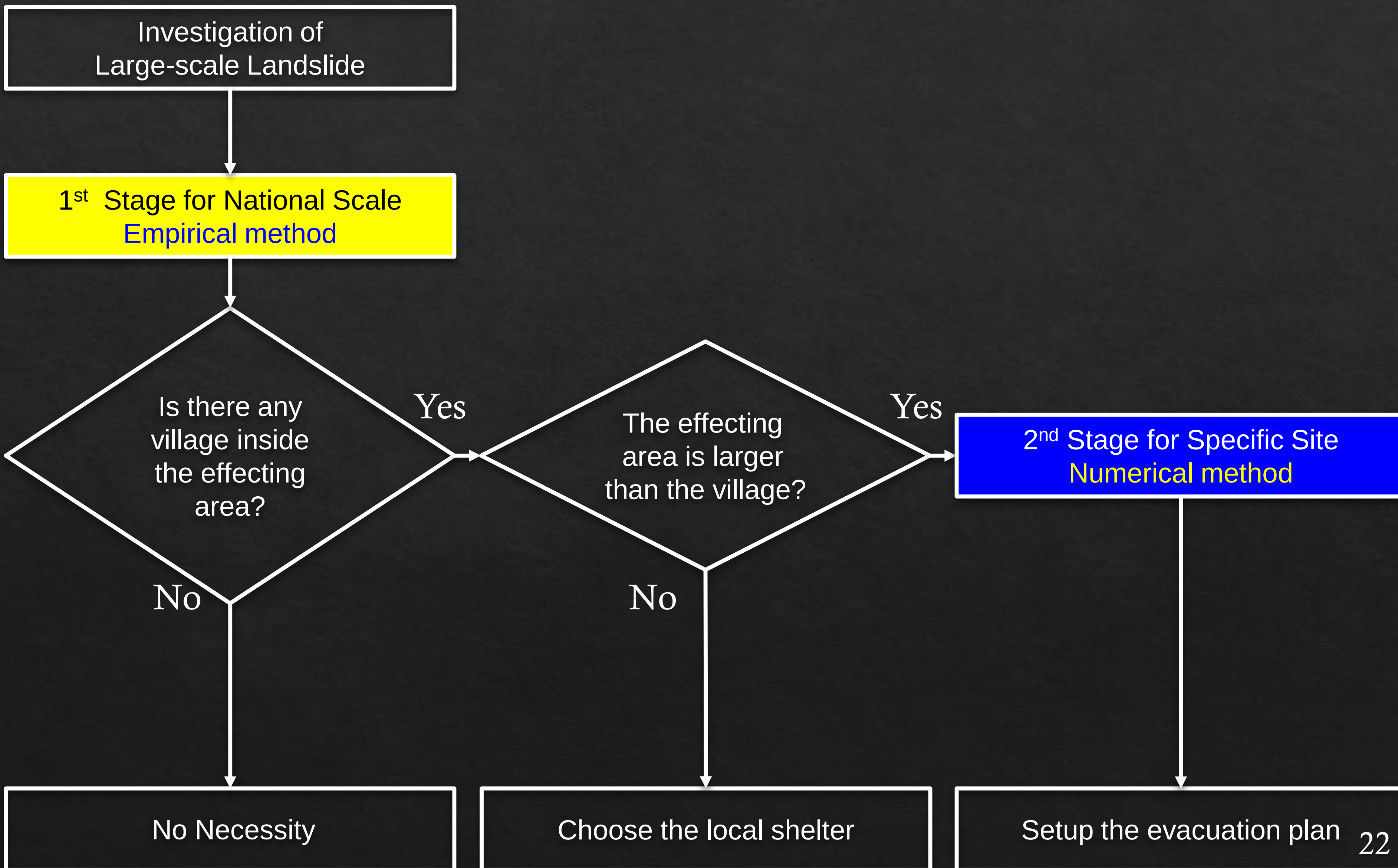


- Current Result (~2014)
  - 2,103 sites were identified
  - 96 sites located nearby 84 villages

For whole Taiwan
Sites ：8,800 sites
Nearby Villages : 308 sites

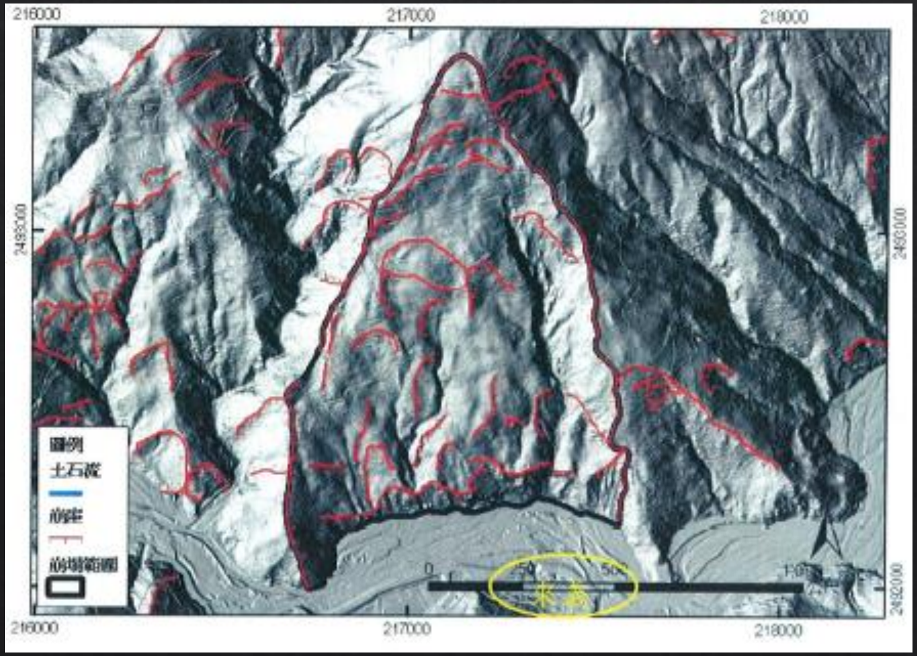


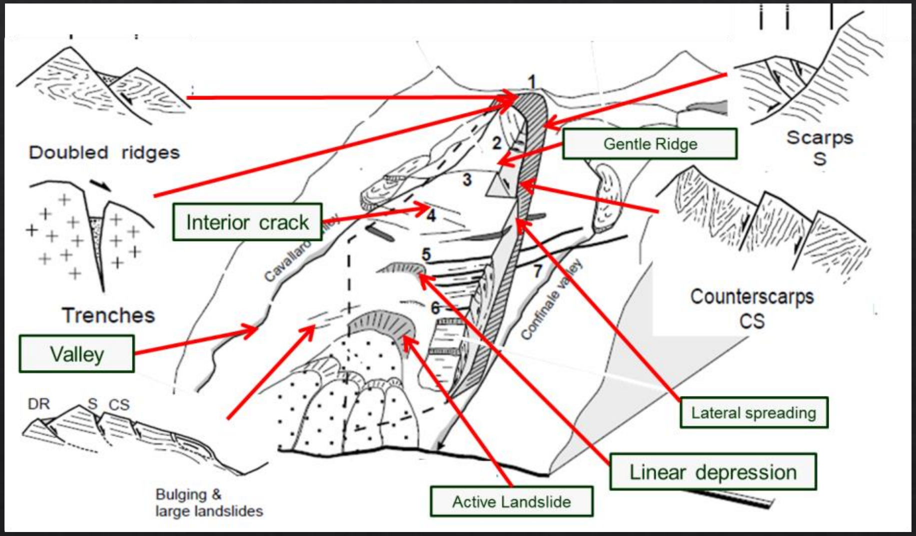
Flowchart of the effect area evaluation



Evaluation of Source Area

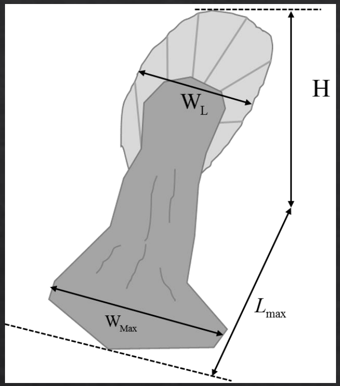
- For source area, the potential area of the large-scale landslide could applied

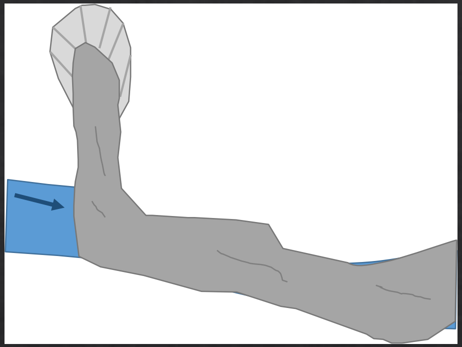


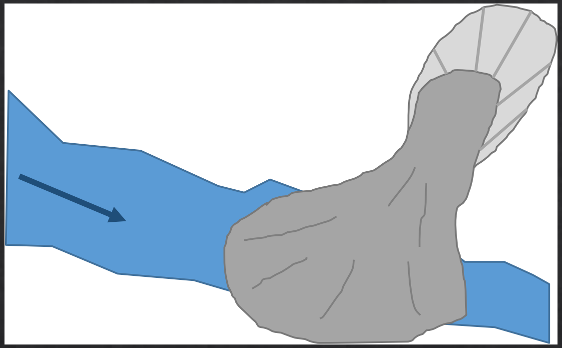


Potenz

Evaluation of transpiration and deposition Area







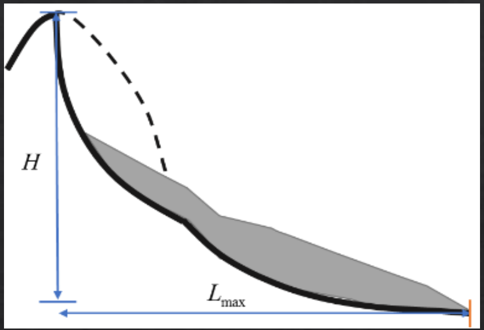
- Type I
  - Maximum Runout Distance
  - Maximum Deposition Width
- Type II
  - The occurrence condition of debris flow
  - The runout area of debris flow fan
- Type III
  - The formation condition of landslide dam
  - The length/height of the dam
  - The effecting area of the dam/dam break

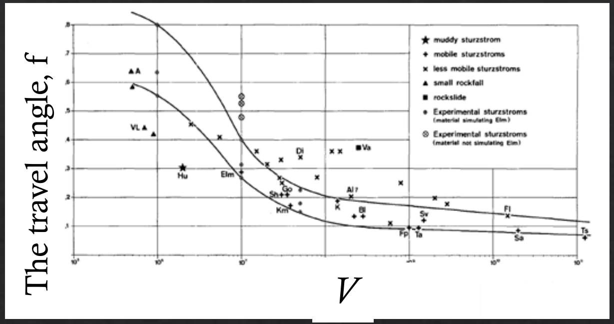
Evaluation of Type I

◈ **Maximum Runout Distance, L_{max}**

$$f = \log\left(\frac{H}{L_{Max}}\right) = 0.624 - 0.157\log V$$

(Scheidegger, 1973)

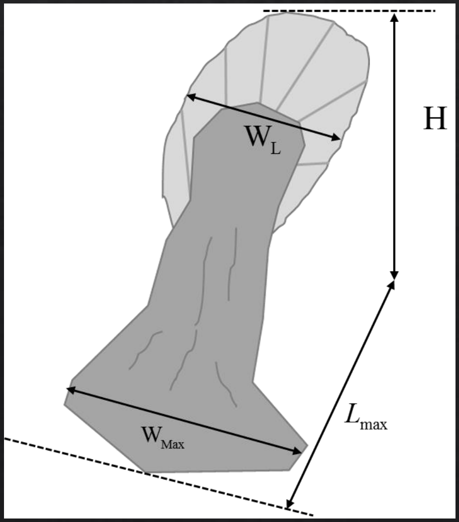


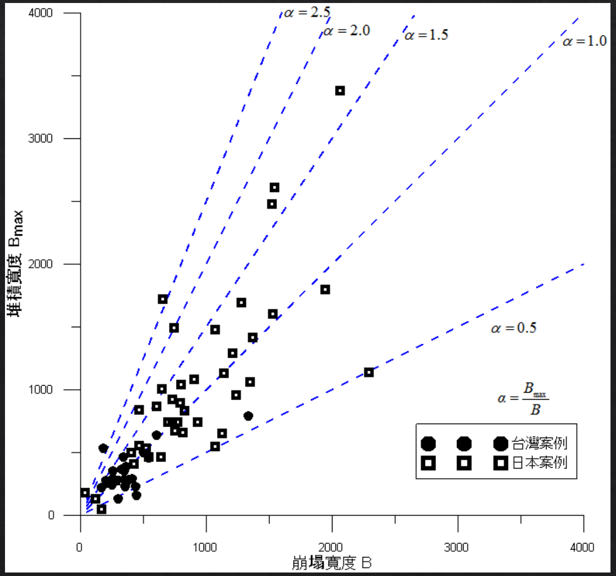


◈ **Maximum Deposition Width, W_{max}**

$$W_{Max} = 2W_L$$

(Shieh, Tsai, this research)



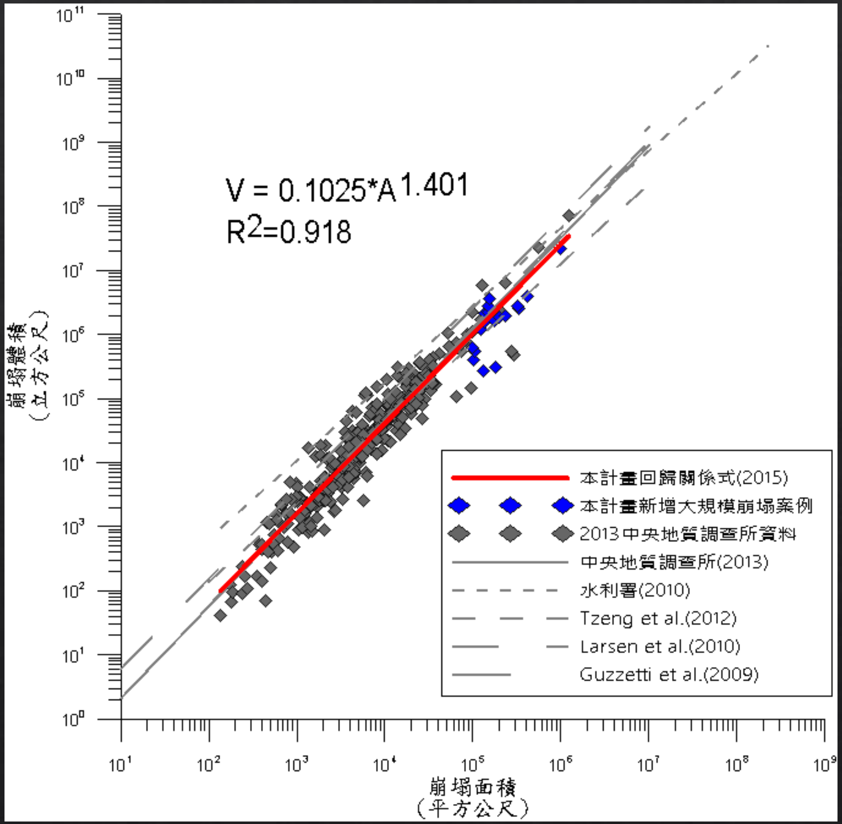


The landslide volume

- The relation between area (A) and volume (V) of landslide could be described as power law (Guzzetti, 2009)
- More than 300 site were used to built the equation in Taiwan

$$V = 0.1025 \times A^{1.401}$$

(Shieh, Tsai, this research)



Evaluation of Type II

- The occurrence condition of debris flow
  - Area of Effective Watershed is great than 3 ha.
  - Effective Watershed：the watershed of the river bed slope over 10 degree

- The runout area of debris flow fan (SWCB)
  - The runout distance, L

$$\log(L) = 0.42 \times \log(V \times \tan\theta_d) + 0.935$$

  - The angle of debris fan, θ

$$\theta = 105^\circ$$

  - The runout volume (V)
    - From source area

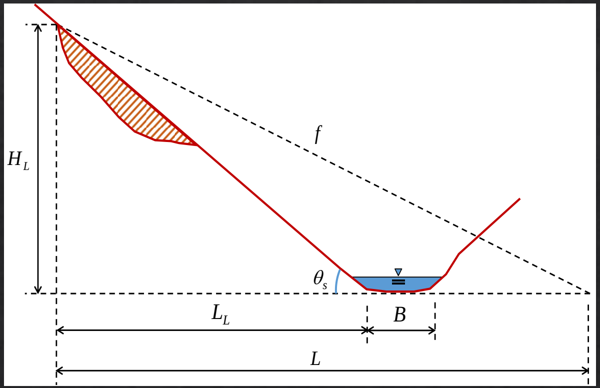
$$V = 0.1025 \times A^{1.401}$$ (Shieh, Tsai, this research)

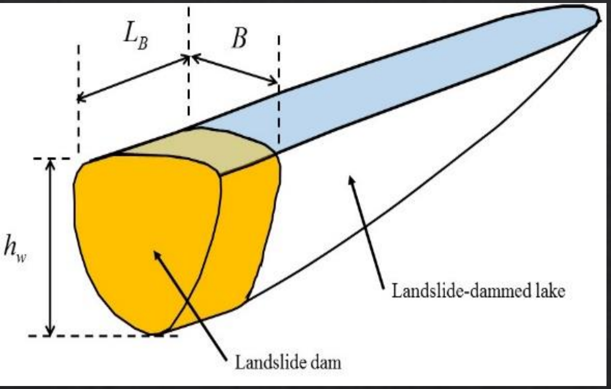
    - From watershed

$$V = 0.1025 \times A^{1.401}$$ (Shieh, 1998)

Evaluation of Type III

- The formation condition of landslide dam
  - The runout distance larger than the river width
  - The dam height larger than the water depth in river





- The runout distance

$$L_{\max} = \frac{\mathrm{H}}{10^{0.624-0.157\log V}} \geq L_L + B$$ (Shieh & Chen, 2015)

- The length/height of the dam

$$H_D = 18.933 V^{0.969} > h_w$$ (Tseng, Kuo & Shieh, 2014)

Evaluation of Type III

- The effect area of Type III could be divided into three part
  - The landslide dam zone
  - The flood zone
    - Upstream：Backwater
    - Downstream ：Dam break

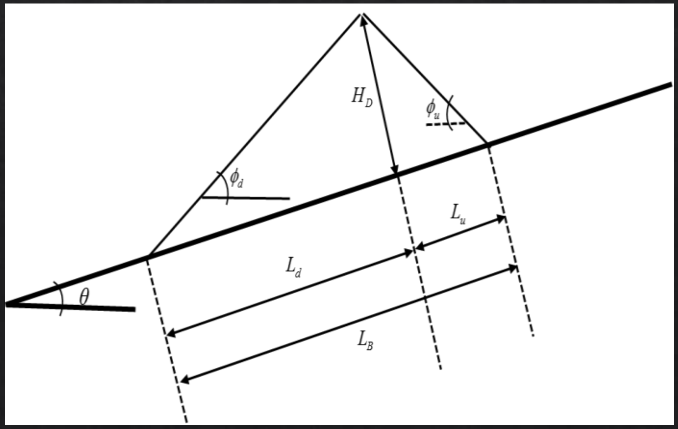
- The landslide dam zone (Tseng, Kuo & Shieh, 2014)

$$L_B = L_d + L_u$$

$$L_d = \frac{H_D}{tan(\phi_d - \theta_r)} \qquad L_u = \frac{H_D}{tan(\phi_u + \theta_r)}$$

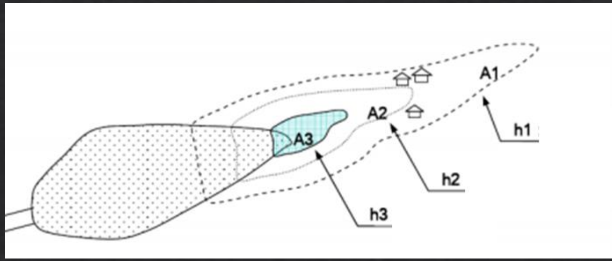
$$H_D = 18.933V^{0.969}$$

$$\phi_d = 2.677\theta_r^{\,0.486} \qquad \phi_u = 1.075\phi_d\theta_r^{\,(-1.613)}$$



Evaluation of Type III

- The flood zone
  - Upstream：Backwater
    - Backwater area could identify with the dam height



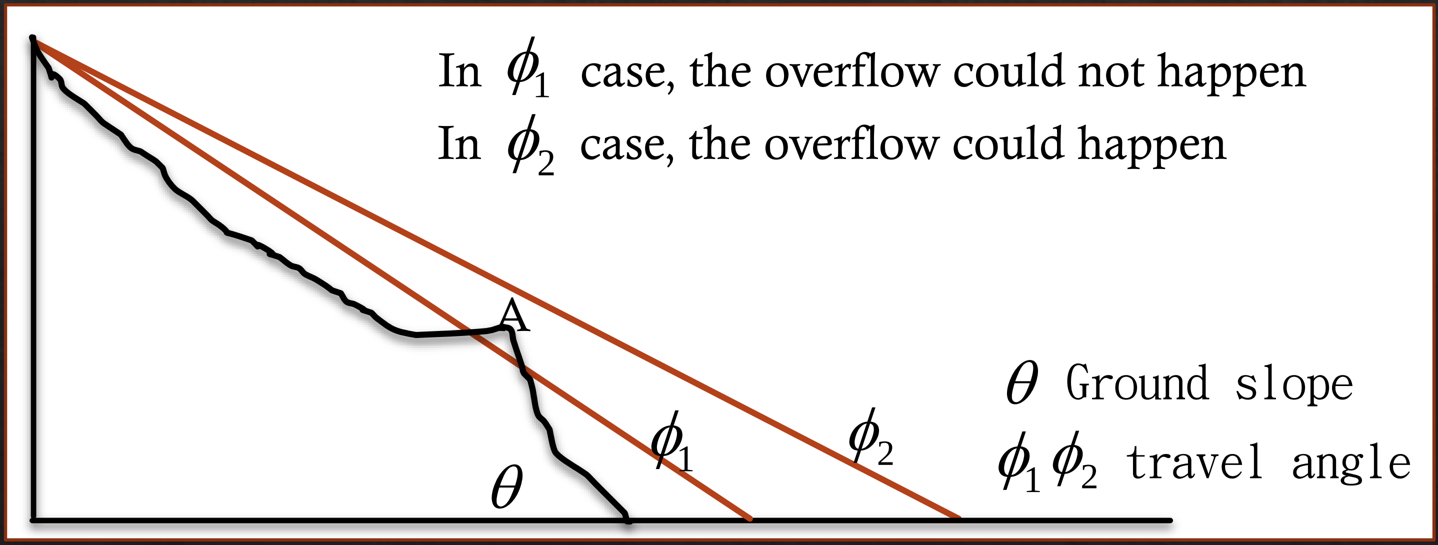
  - Downstream ：Dam break
    - The effecting area could be evaluating with the surge theory

$$\left(x - x_{dam}\right) = \left(V_0 + 3\sqrt{gy} - 2\sqrt{gy_0}\right) \cdot \left(t - t_0\right)$$ (Shieh and Wang, 2013)

    - The dam break simulation is also wide use
      - Peak Discharge, Qp
      - Water Level, H
      - Bed Variation, Z+ΔZ

Evaluation of Overflow

- The travel angle could used to judge the overflow condition.
- The idea of travel angle could set as “Energy Profile” (Okura,2000)
- By the compare between the Energy Profile and ground surface, the overflow condition could be easily decide.



Verification

Parameter Setting

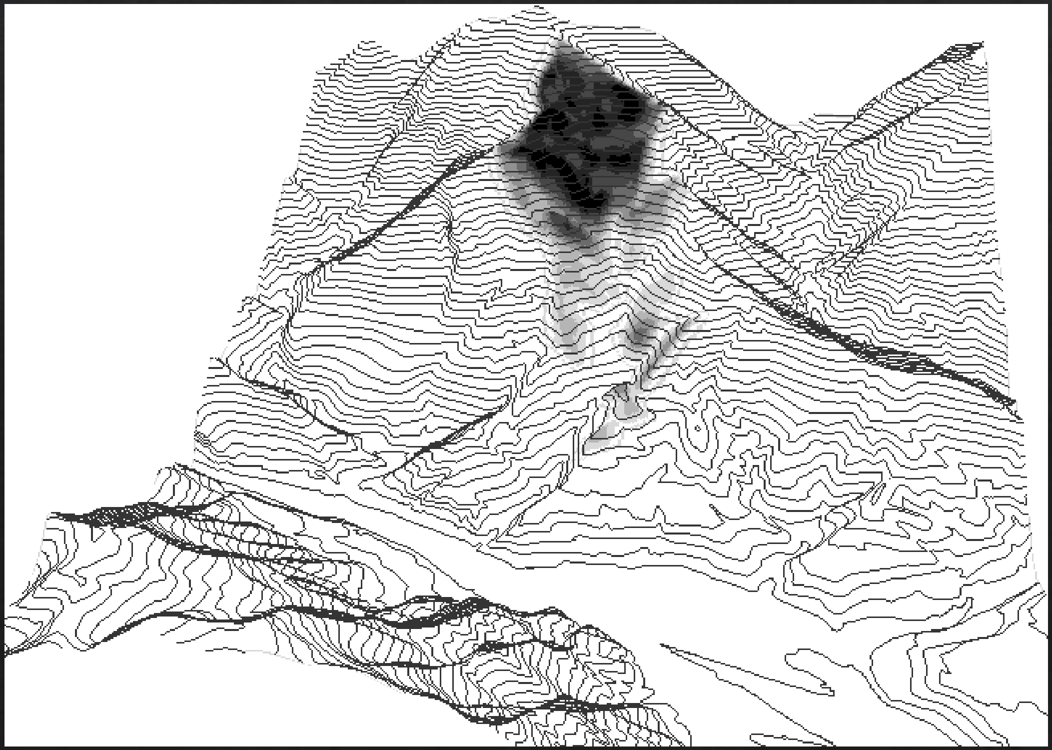
Inter-friction angle : 35 °

Diameter of sediment : 0.5 meter

Density of sediment: 2650 kg/m^3

Density of water : 1000 kg/m^3

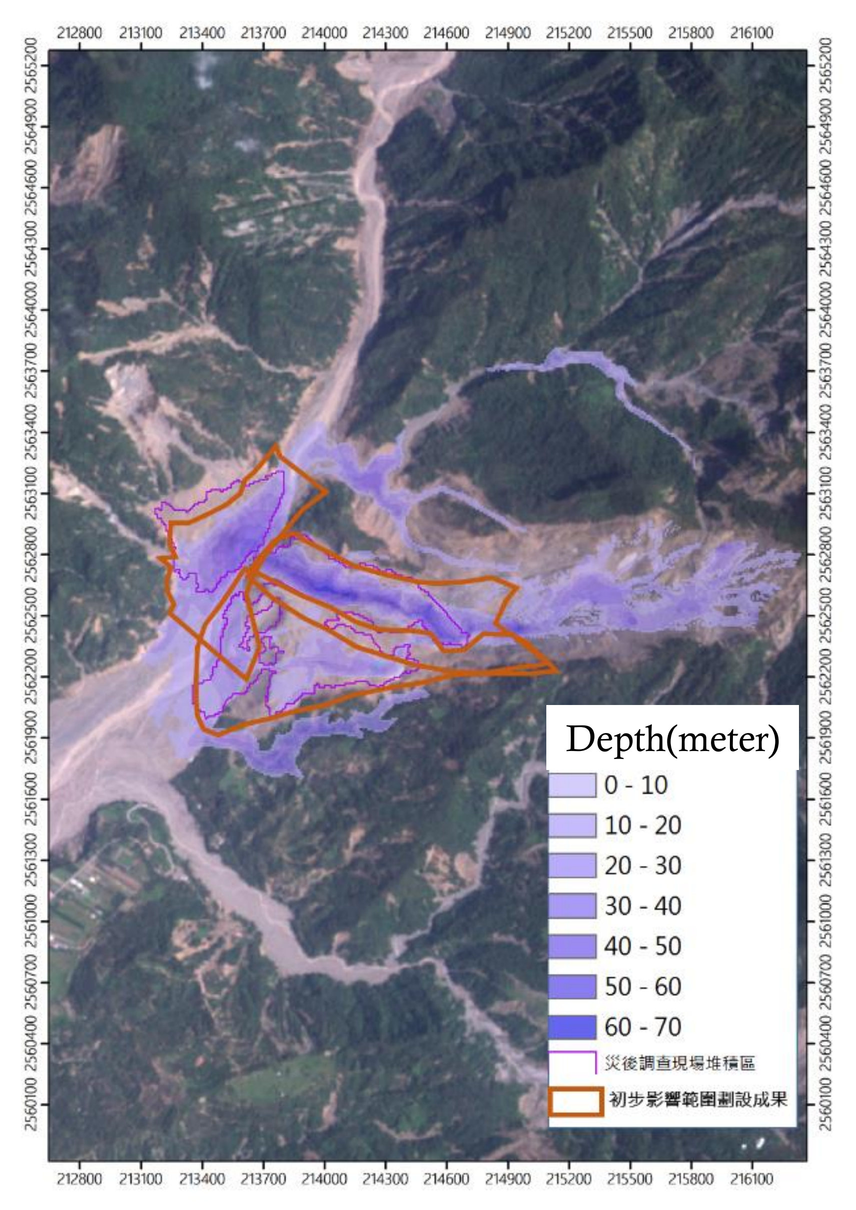
	Scenario
Terrain Setting	Major landslide Bank/Bed Erosion occurred (Block A+B+C)
Sliding Volume Setting	Block A (2483 X 10^4 Cube meter) Block B+C (168 X 10^4 Cube meter)




DEPTH
-0.0461 - 0.5
0.501 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80

Review between methods

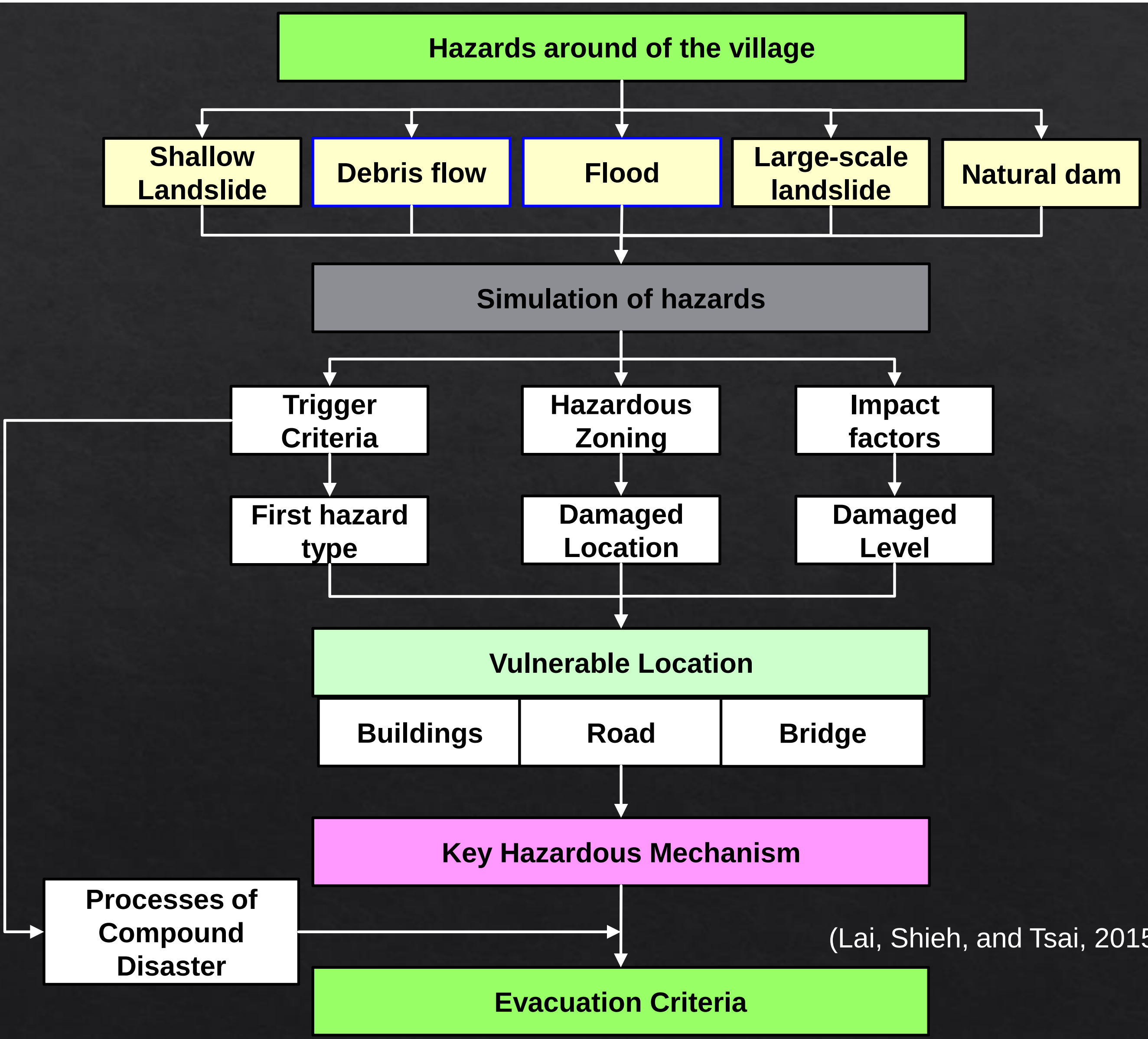
- The classify method could judge different kinds of deposition in Hsiaolin Village
- With Empirical Method
  - Effecting area was clearly identify.
- With Numerical Method
  - Not only effecting area, deposition depth, movement velocity could reappear well.



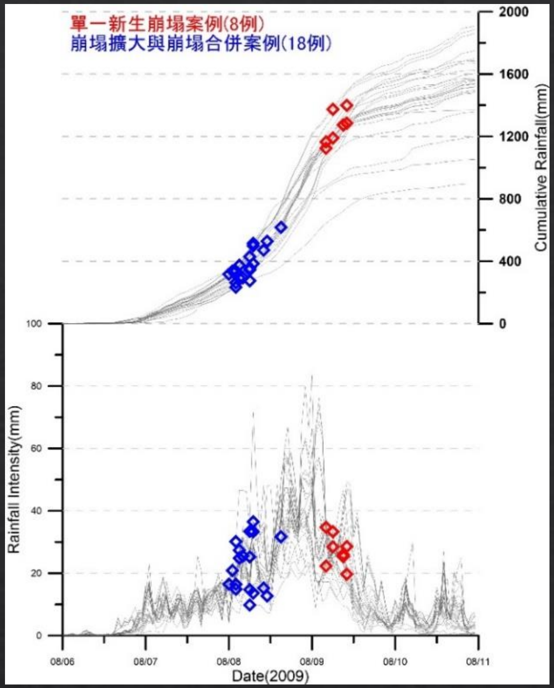
Evacuation plan

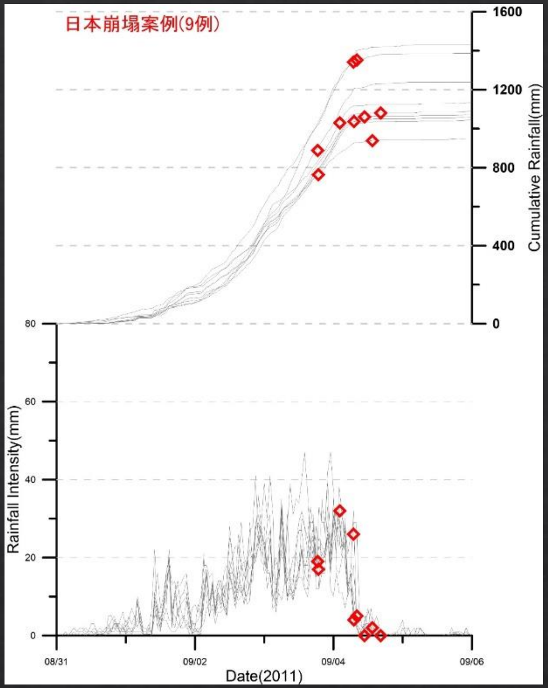
- Before large-scale landslides were triggered, other kinds of disasters had already occurred.

- The purpose of the **neck point analysis** is to decide the optimal evacuation time



(Lai, Shieh, and Tsai, 2015

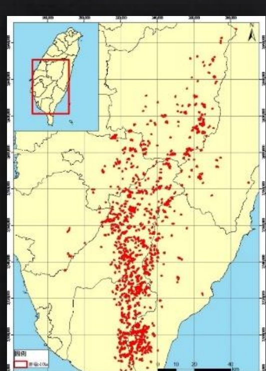




Idea of warning system for large-scale landslide

Landslide during Typhoon Morakot

事件	資料來源	發生時間	發生地點	R(m)	A(ha)	D(m)	f	Φ(度)	θ(度)	R/D	Φ/θ
台灣2009莫拉克颱風事件	國內文獻訪談紀錄	2009/08/09 10:00	布唐布納斯溪	1.40	351.08	66.14	0.21	11.63	32.57	0.02	0.36
		2009/08/09 06:00	寶來上游	1.37	51.85	27.97	0.32	17.64	32.76	0.05	0.54
		2009/08/09 04:00	妙崇寺	1.17	14.64	15.83	0.42	22.96	32.87	0.07	0.70
		2009/08/09 04:00	萬山	1.12	10.64	13.72	0.46	24.49	34.83	0.08	0.70
		2009/08/09 10:00	清水溪(荖濃溪)	1.39	81.39	34.26	0.29	16.01	30.96	0.04	0.52
		2009/08/09 09:00	南沙魯村	1.27	10.07	13.38	0.46	24.76	28.80	0.10	0.86
		2009/08/09 09:00	錫安山對岸	1.27	61.42	30.19	0.31	17.01	28.88	0.04	0.59
		2009/08/09 06:00	小林村	1.19	248.71	56.64	0.22	12.55	27.80	0.02	0.45
	地震資料推估研判	2009/08/09 02:00	樣本36	1.57	111.96	39.55	0.27	14.94	26.59	0.04	0.56
		2009/08/09 12:00	樣本63	1.49	67.94	31.59	0.30	16.64	28.87	0.05	0.58
		2009/08/08 08:00	樣本64	0.64	36.07	23.76	0.35	19.05	36.65	0.03	0.52
		2009/08/09 17:00	樣本65	1.18	158.18	46.20	0.25	13.86	36.73	0.03	0.38
		2009/08/09 04:00	樣本67	1.15	73.94	32.81	0.29	16.34	39.59	0.04	0.41
		2009/08/10 12:00	樣本70	1.62	146.15	44.59	0.25	14.10	31.81	0.04	0.44
		2009/08/09 07:00	樣本71	1.29	57.15	29.22	0.31	17.27	38.17	0.04	0.45
		2009/08/09 05:00	樣本74	1.46	14.97	15.99	0.42	22.86	26.73	0.09	0.86
		2009/08/09 07:00	樣本75	1.01	12.38	14.68	0.44	23.75	37.78	0.07	0.63
		2009/08/09 05:00	樣本77	1.40	11.70	14.31	0.45	24.03	40.53	0.10	0.59
		2009/08/09 02:00	樣本80	1.48	12.07	14.52	0.44	23.88	31.04	0.10	0.77
		2009/08/08 17:00	樣本87	0.69	16.11	16.53	0.41	22.52	41.31	0.04	0.55



- 科技部-莫拉克颱風之災情勘查與分析
- 水土保持局-重大土石災情報告
- 水土保持局-地震網應用於坡地土砂災害監測之評估
- 地質調查所-強化豪雨引致山崩之即時動態潛勢評估與警戒模式發展

Landslide during Typhoon 12 in Japan

事件	資料來源	發生時間	發生地點	R(m)	A(ha)	D(m)	f	Φ(度)	θ(度)	R/D	Φ/θ
日本2011 12號颱風事件	千木良論文資料	2011/09/04 16:22	Akatani	1.08	42.37	19.35	0.35	19.17	34.00	0.06	0.56
		2011/09/03 18:46	E-Akatani	0.76	22.14	9.49	0.32	17.73	31.00	0.05	0.57
		2011/09/04 07:06	Ooto-Shimizu	1.04	13.23	7.03	0.39	21.18	34.00	0.06	0.62
		2011/09/04 10:45	Nagatono	1.06	22.07	18.58	0.43	23.28	33.00	0.08	0.71
		2011/09/04 13:30	Tsubonouchi-C	0.94	11.29	10.63	0.37	20.47	27.00	0.09	0.76
		2011/09/04 02:13	Uguwara L	1.03	24.68	6.48	0.47	25.16	30.00	0.09	0.84
		2011/09/04 06:54	Iya	1.34	33.69	15.43	0.45	24.18	28.00	0.15	0.86
		2011/09/03 18:30	Nojiri	0.89	26.61	6.01	0.57	29.78	31.00	0.12	0.96
		2011/09/04 08:06	Kuridaira	1.35	54.85	25.52	0.60	31.15	32.00	0.12	0.97
		2011/09/04 00:40	Fudono	0.84	5.17	4.64	0.60	31.15	32.00	0.18	0.97

千木良雅弘等，2011年台風12号による深層崩壊

Other case

事件	資料來源	發生時間	發生地點	R(m)	A(ha)	D(m)	f	Φ(度)	θ(度)	R/D	Φ/θ
台灣其他事件	震測資料	2006/06/10 01:00	樣本16	0.92	11.80	14.37	0.44	23.99	32.24	0.06	0.74
		2008/07/19 05:00	樣本20	0.36	10.31	13.52	0.46	24.65	37.03	0.03	0.67
		2008/09/18 03:00	樣本21	1.22	89.29	35.72	0.28	15.69	32.58	0.03	0.48
		2008/09/18 02:00	樣本22	0.61	14.71	15.86	0.42	22.94	36.00	0.04	0.64

水土保持局-地震網應用於坡地土砂災害監測之評估

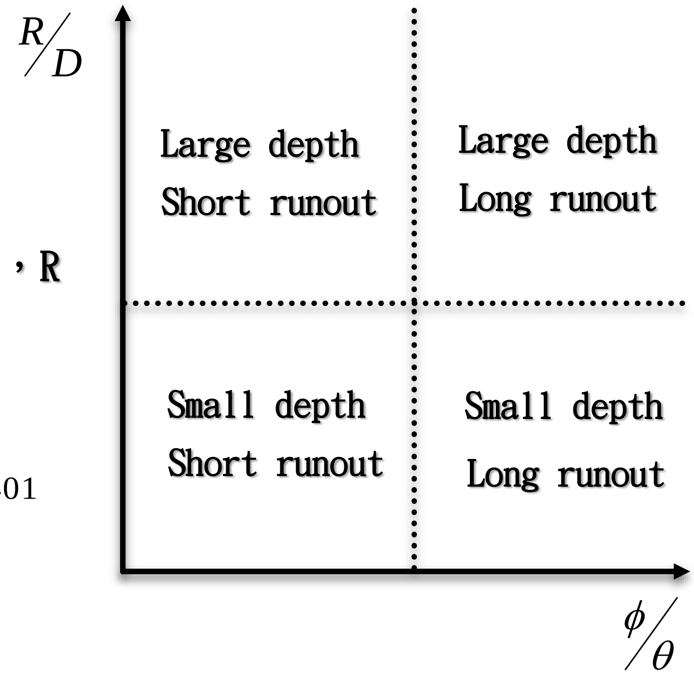
Dimensionless Rainfall Factor

Cumulative Rainfall，R

Landslide Depth, D

$$V = 0.1025 \times A^{1.401}$$

$$D = \frac{V}{A}$$



Surface Slope，θ

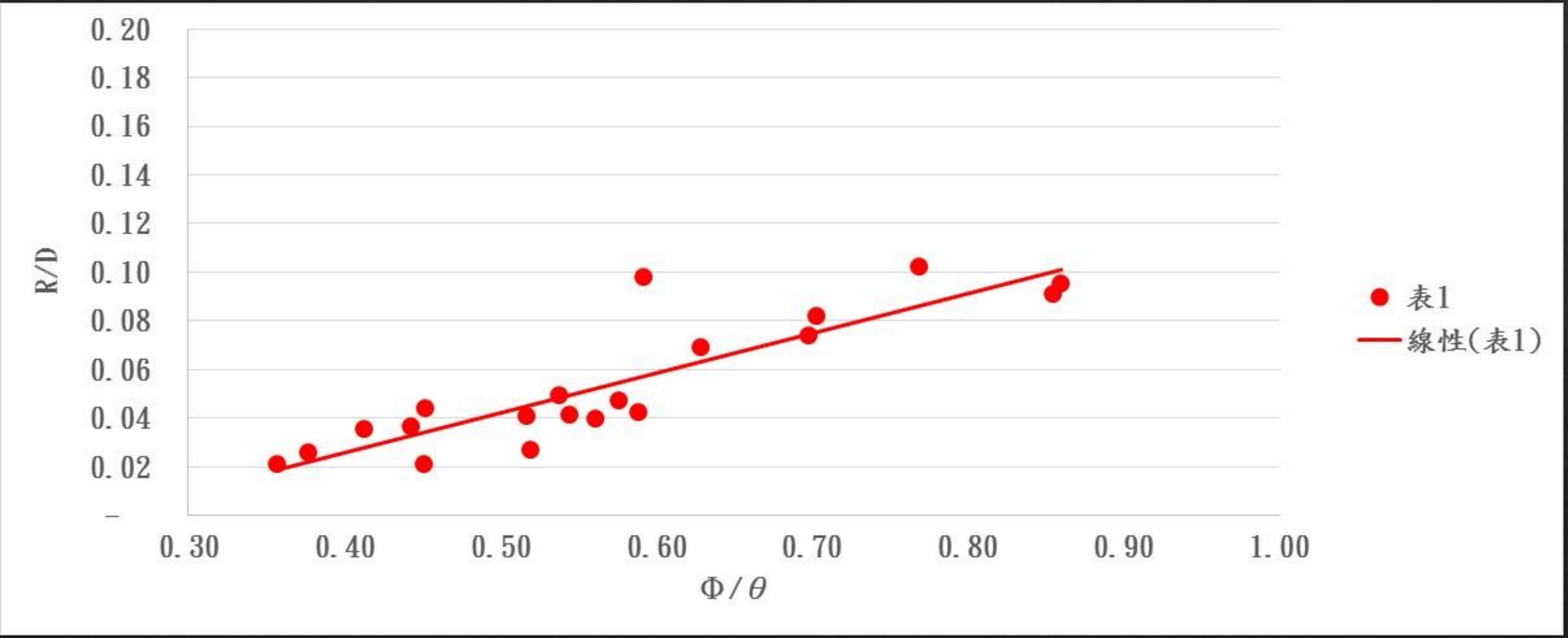
The travel angle, ϕ

$$\log_{10} f = -0.1466 \log_{10} V + 0.62419$$

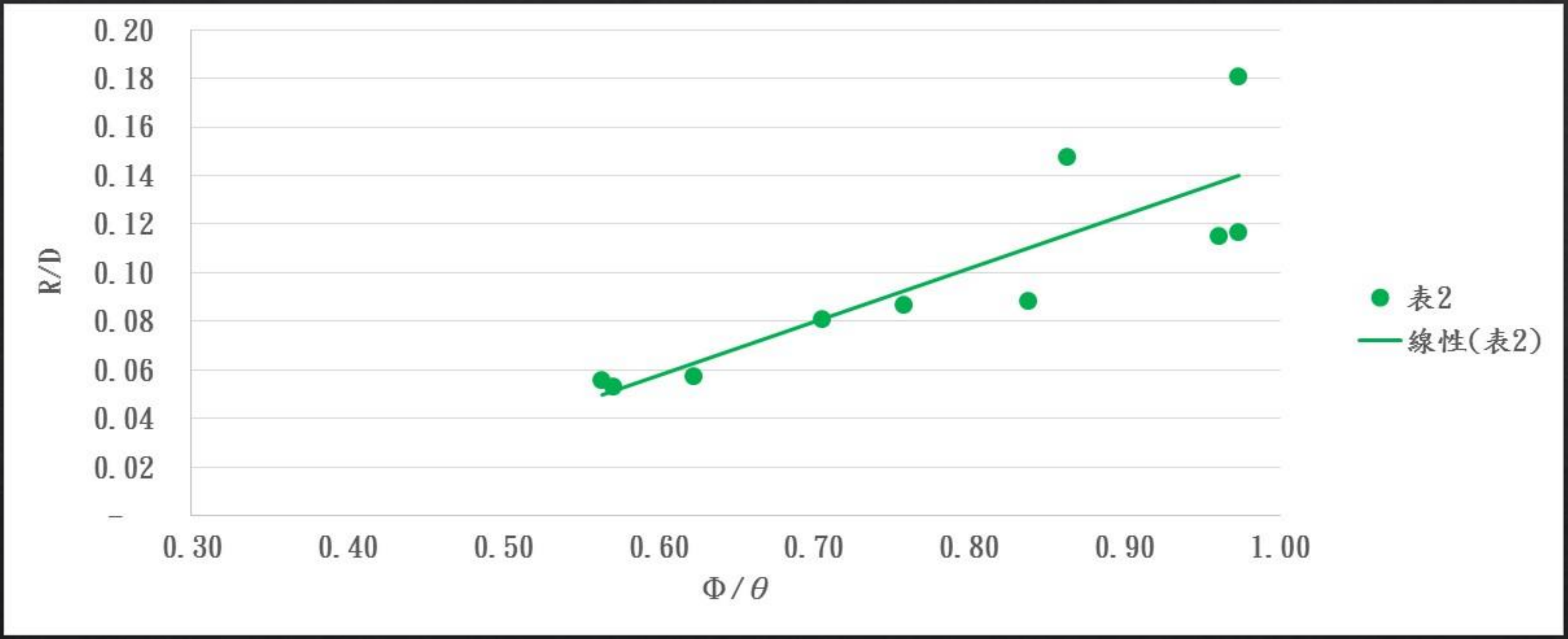
$$f = \tan\phi$$

Tsai etc., 2015

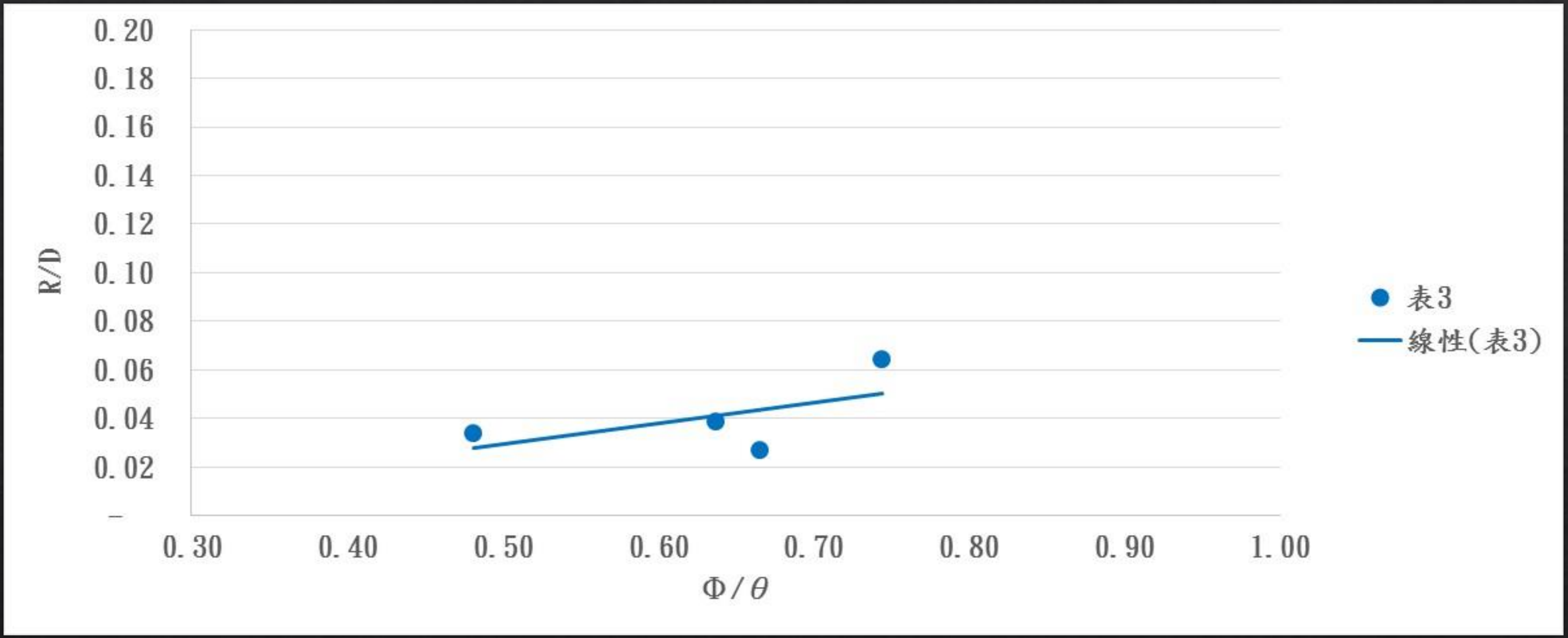
Result of Typhoon Morakot

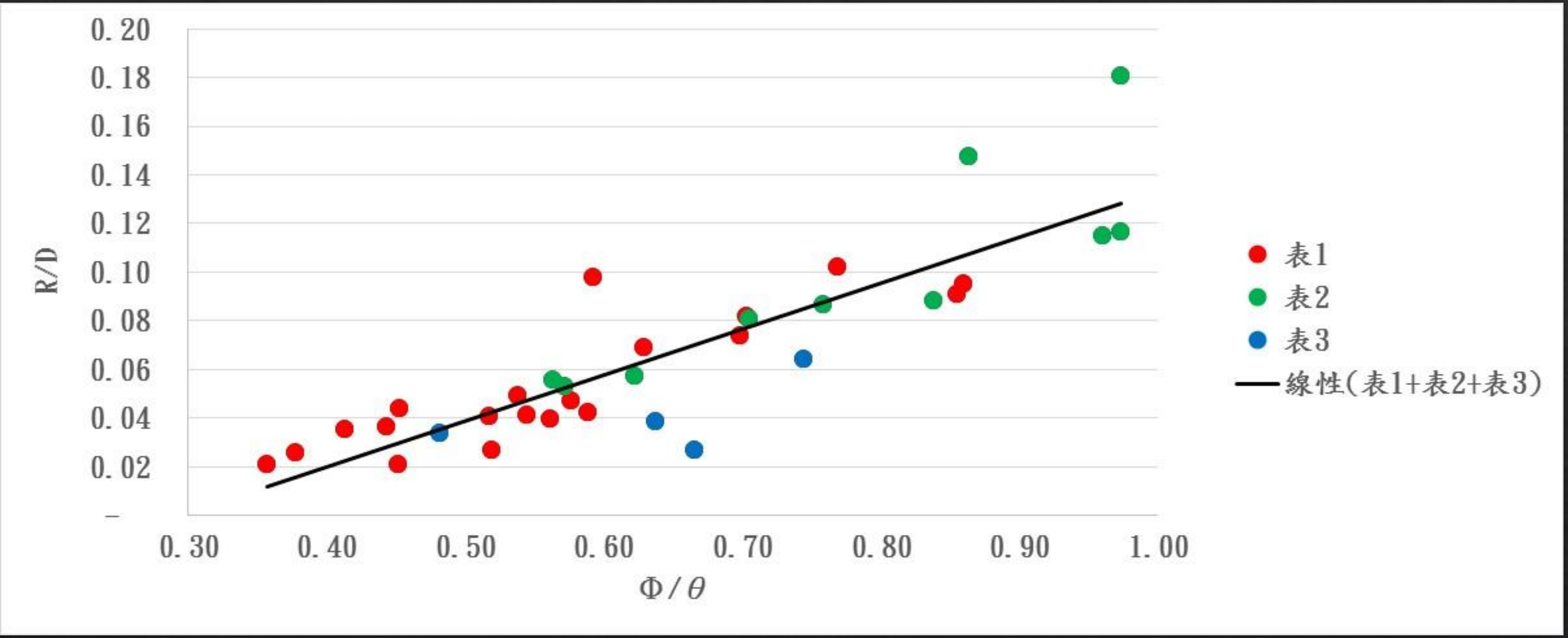


Result of Typhoon 12



Result of others landslide

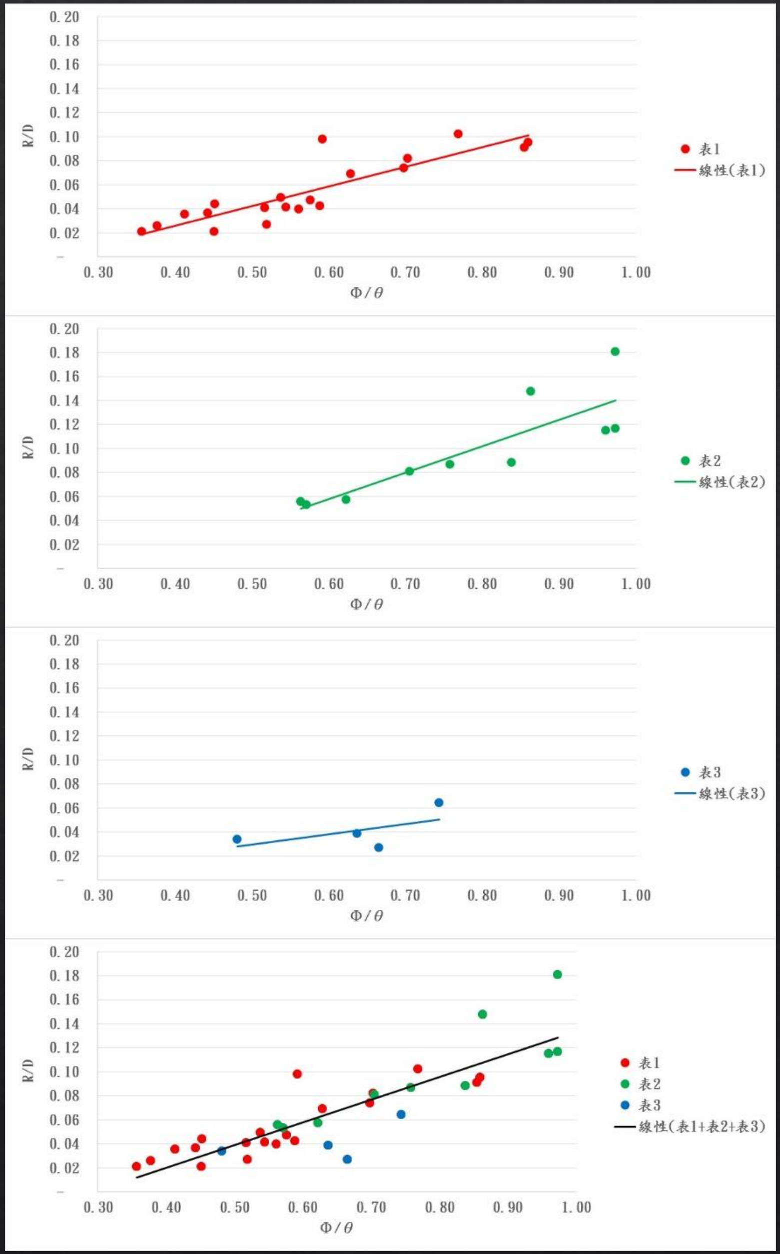



0. 20
0. 18
0. 16
0. 14
0. 12
0. 10
0. 08
0. 06
0. 04
0. 02
–
R/D
0. 30
0. 40
0. 50
0. 60
0. 70
0. 80
0. 90
1. 00
Φ/θ
表1
表2
表3
線性(表1+表2+表3)

Summary

- With the Dimensionless Rainfall Factor, landslide in different country, different event, different geology condition could have a Approaching trend.
- The occurrence of large-scale landslide should have some similar condition. It is important to understand the mechanism.

- Base on the preliminary result, we could predict the occurrence rainfall with the landslide area and surface slope。



Conclusion

Conclusion

- To decrease the large-scale landslide disaster, SWCB start the mitigation strategies of large-scale landslide disaster and try to develop new technology.
- To understand the possible disaster of large-scale landslide, the effecting area could be investigate with the scale and position of the potential area of large-scale landslide.
- The disaster of large-scale landslide could be divides into three type, in this stage, the evaluating of the effecting area was propose in this research, the on-site monitoring system, evacuation plan, and warning system could be set according to the result.
- The result of dimensionless rainfall factor point out the possibility of early warning with the rainfall data.

Thank you
for your time and attention