



# ***The 2013 International Training Workshop on Earth Sciences***

## ***Debris Flow Disaster Management in Taiwan***

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Council of Agriculture**

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***1 November, 2013***



# ***Outline***

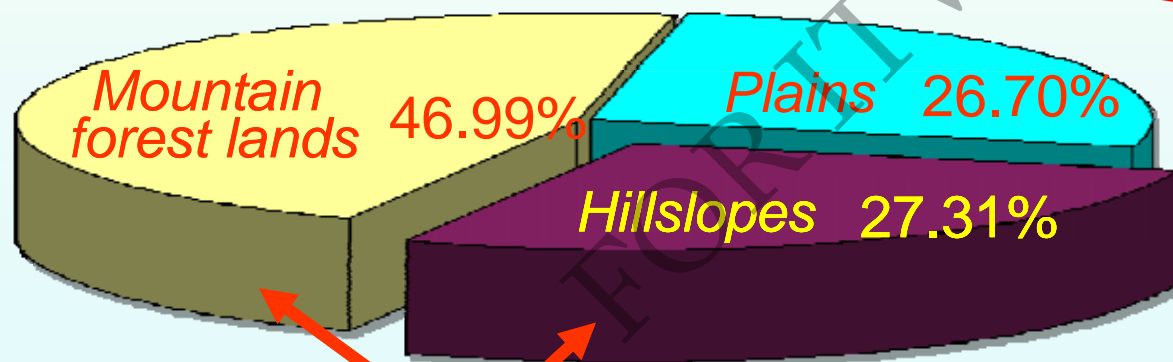
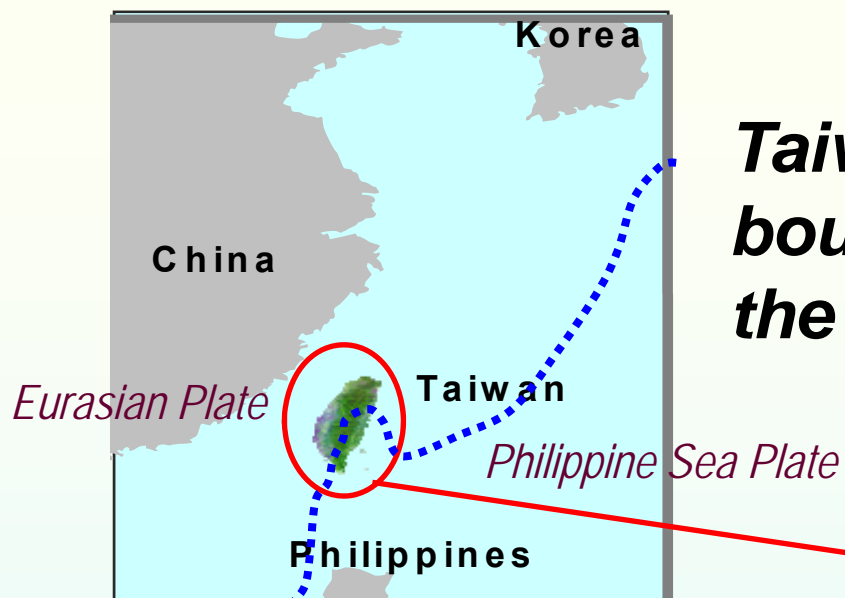
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1. ***Background Introduction***
2. ***Debris Flow Disaster Management — Preparedness, Emergency response and Recovery***
3. ***Challenges of Typhoon Morakot (2009) and Future Perspective***



# Introduction

**Taiwan is located at the convergent boundary of the Eurasian Plate and the Philippine Sea Plate.**



**Slopelands 73.30%**

**Land Resources Distribution**





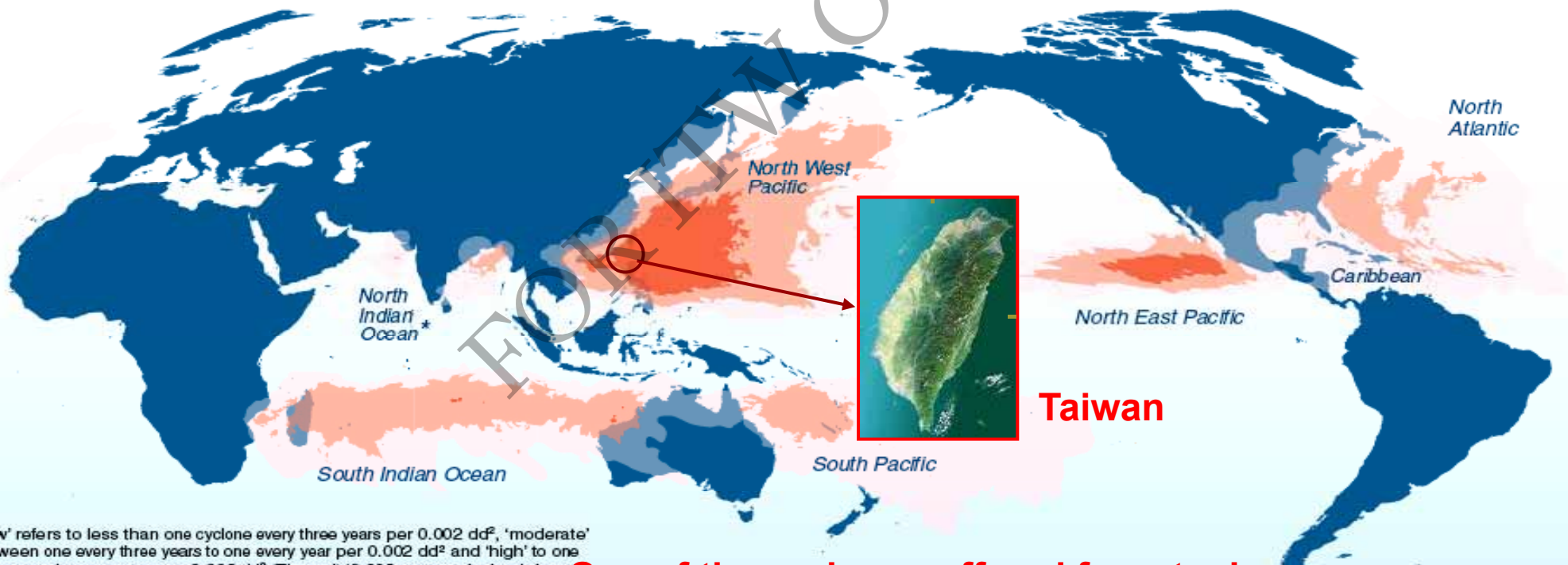
# Climate Change Impact

- ◆ Temperature increases about **1.4** in the last 100 years (1901-2006).
- ◆ Number of typhoons per year increased dramatically after 2000.  
From **N=3.2**(1951-2000) to **N=6.8** (2001-2009)

## Tropical cyclone frequency

Average number of cyclones:  
(1980-2000)

low moderate high



'Low' refers to less than one cyclone every three years per 0.002 dd<sup>2</sup>, 'moderate' between one every three years to one every year per 0.002 dd<sup>2</sup> and 'high' to one to three cyclones per year per 0.002 dd<sup>2</sup>. The unit '0.002 square decimal degree (dd<sup>2</sup>)' is equivalent to 25 km<sup>2</sup> on the equator, diminishing as latitude gets higher.

\* average based on eight years only.

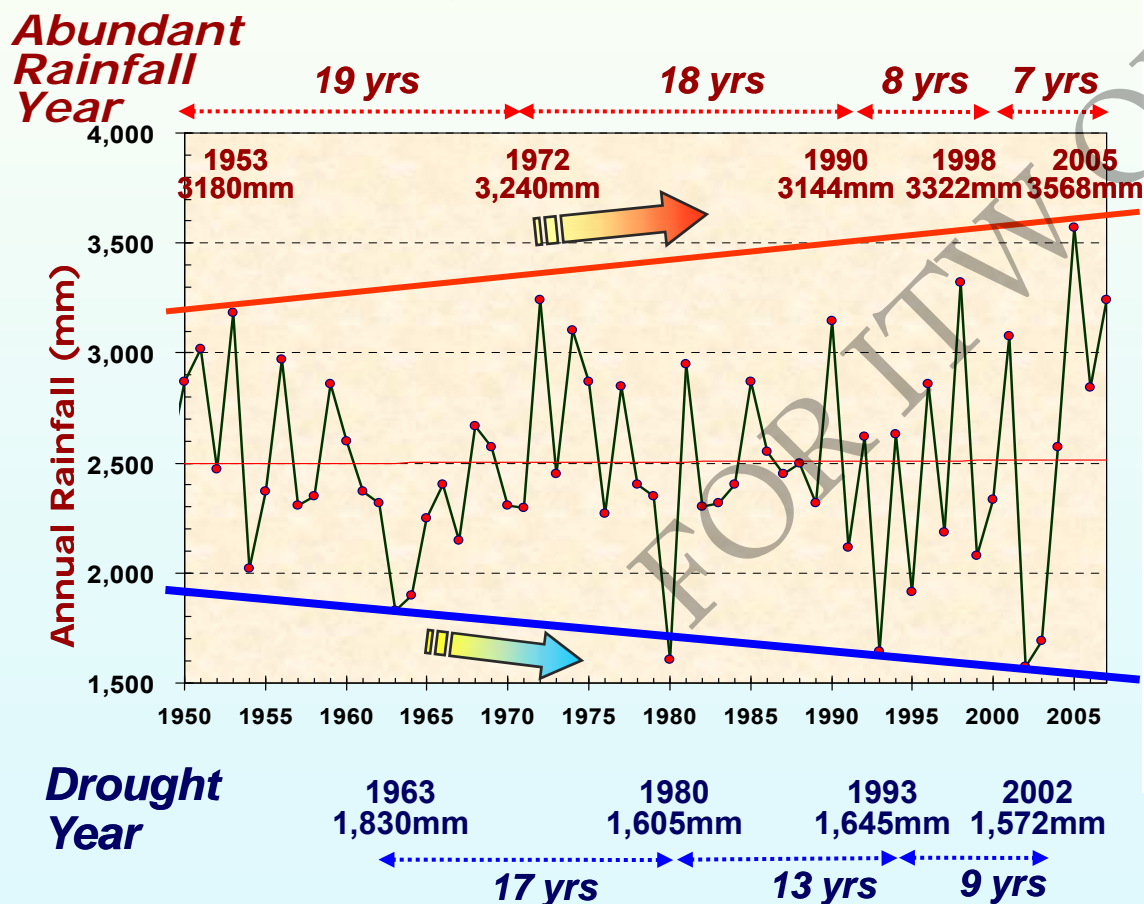
**One of the regions suffered from typhoons**

Sources: PREVIEW Global Cyclone Asymmetric Windspeed Profile, UNEP/GRID-Europe.

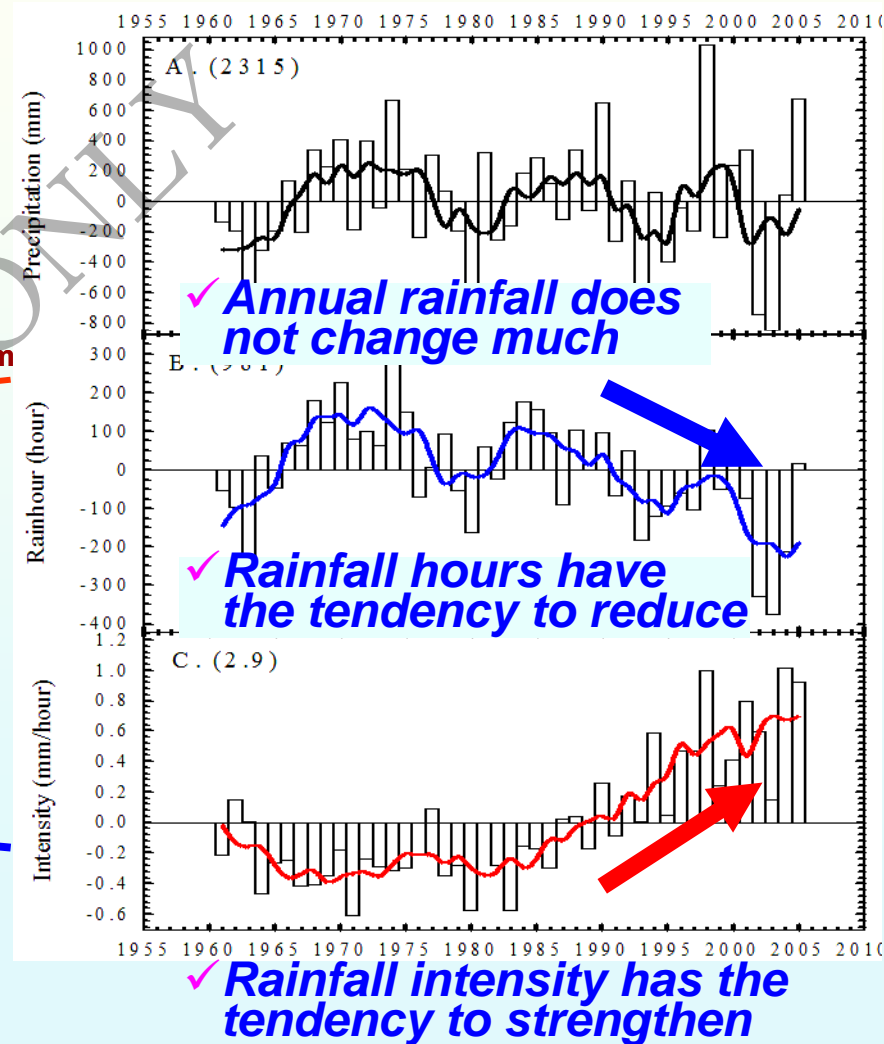


## Variation of rainfall pattern of Taiwan in last 50 years

**Significant change of rainfall and dry-rainy seasons increases the risk of watershed hazards.**

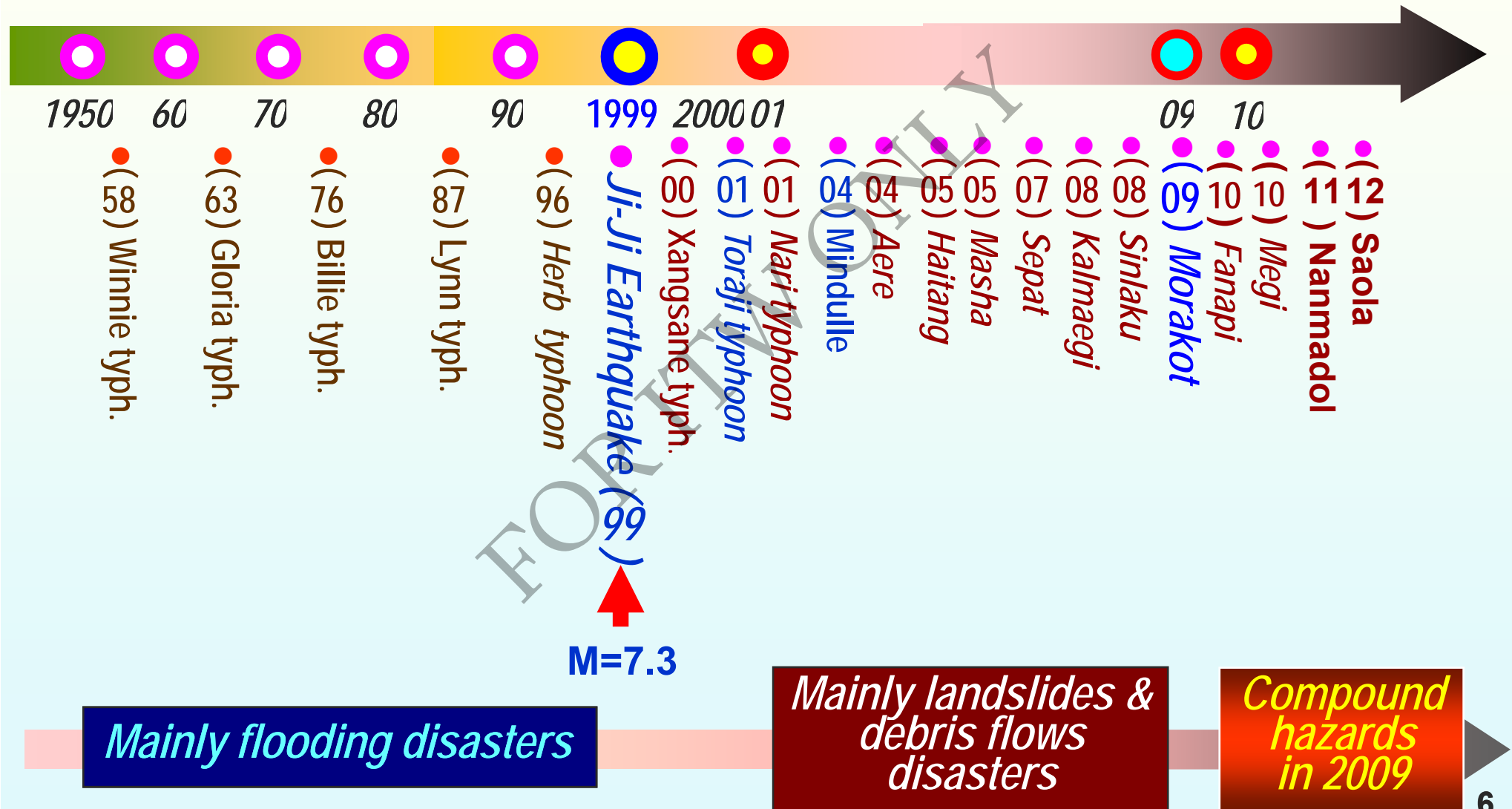


## Annual rainfall of Taiwan in the past 50 years





# Historic Typhoon Disasters in Taiwan







Soil and Water Conservation Bureau (SWCB)

1996-Herb

# Debris Flow Disasters in Taiwan



2004-Mindulle




2009-Morakot





## ***2. Debris Flow Disaster Management — Preparedness, Emergency Response and Recovery***





Source area  
Landslides

Transportation part  
Erosion effect

Deposition(fan) zone  
Affected area

2011南瑪都颱風屏東  
縣滿州鄉土石流災害



# **Hazard Assessment Procedures (NOAA-USGS)**

**Where?**

**(hazard mapping)**

**When?**

**(rainfall intensity-duration thresholds)**

**How big?**

**(volume or peak discharge)**

**How far?**

**(runout and inundation-area mapping)**

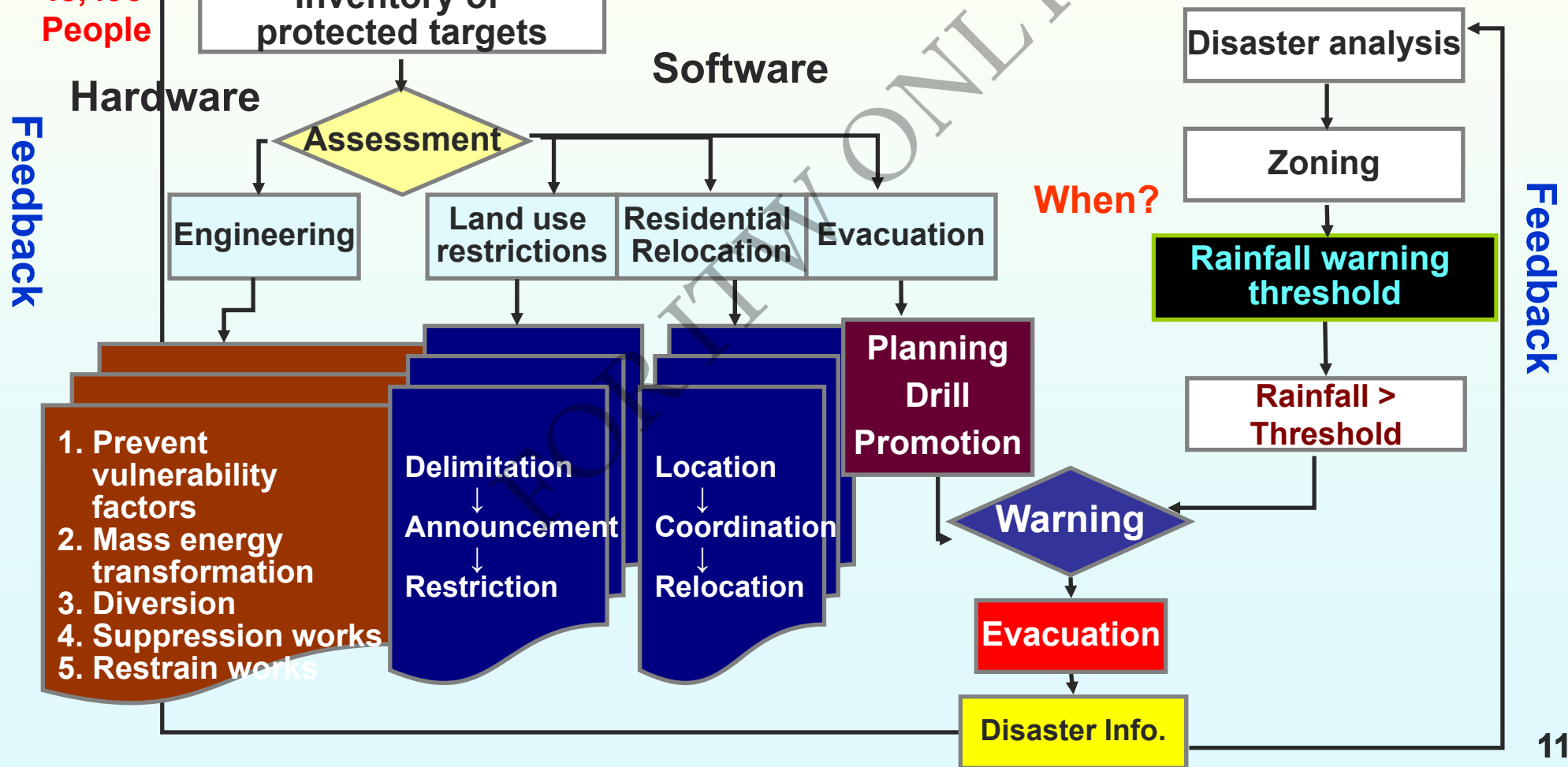
**1,664  
Torrents**

## Where?

# *Debris Flow Disaster Prevention Framework*

## How big (far) ?

**48,496  
People**





Soil and Water Conservation Bureau (SWCB)

# *Investigation of Potential Debris Flow Torrents & Landslides*

## ■ Potential Debris Flow Torrents

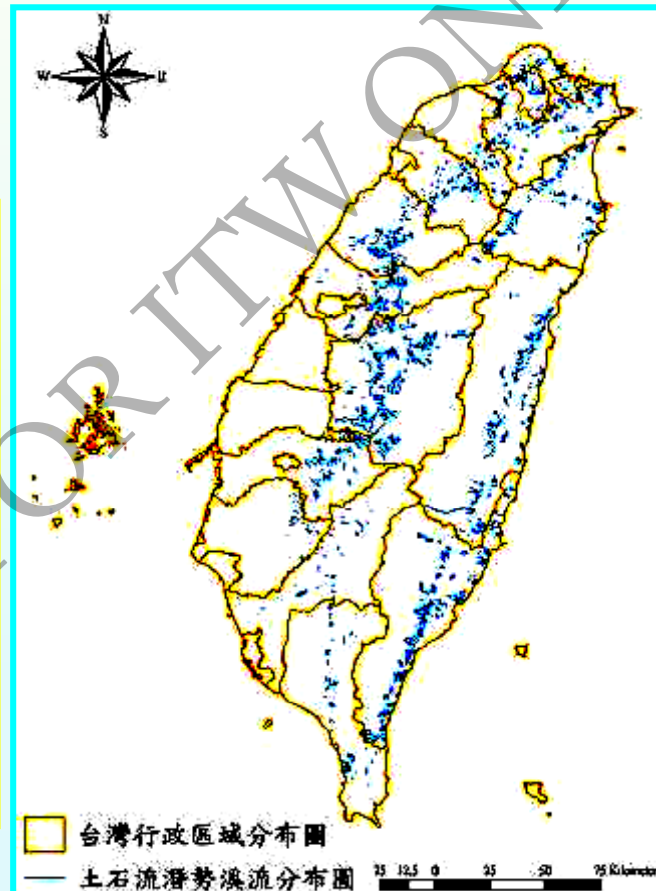
**1,664 Torrents**

## ■ Landslide Areas

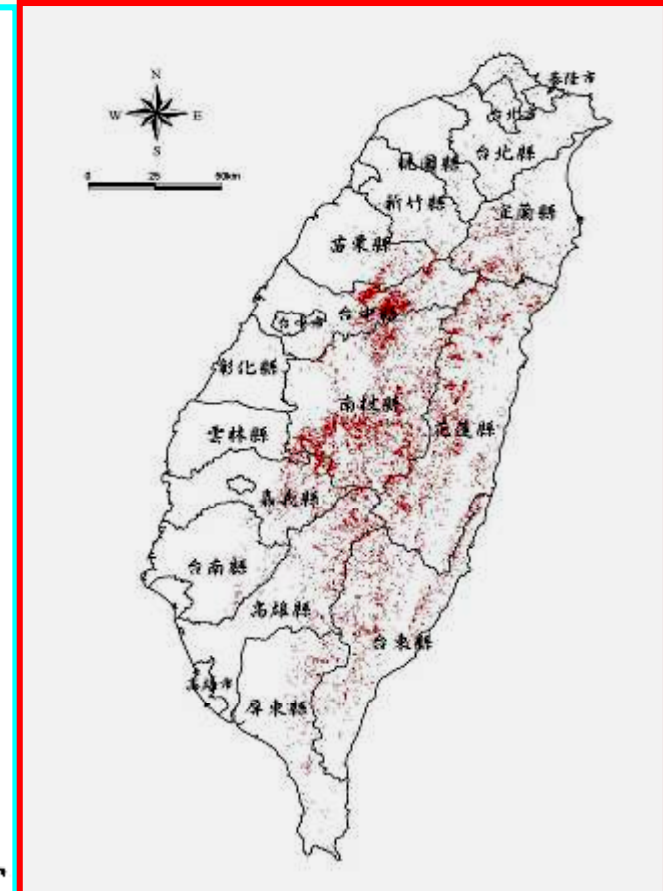
**46,950 ha**



*Potential Debris Flow Torrents*



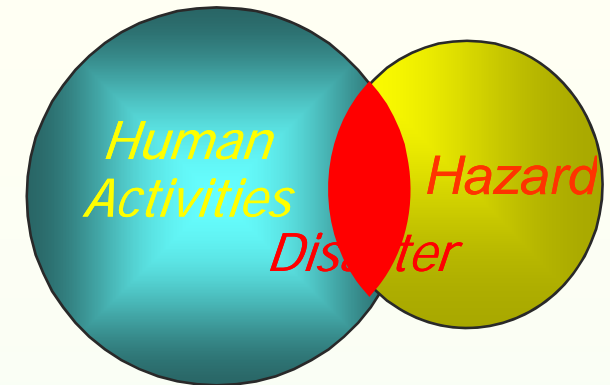
*Historic Landslides Distribution*







# Investigation of Potential Debris Flow Torrents



**Risk Degree=Probability X Assured Safety**

## Factors of Probability

- Valid watershed area : 3 ha before 921 earthquake(1999) adopted 10 ha
- Rock broken extent
- Length of fault, slope...
- Upstream collapse area

## Assured Safety

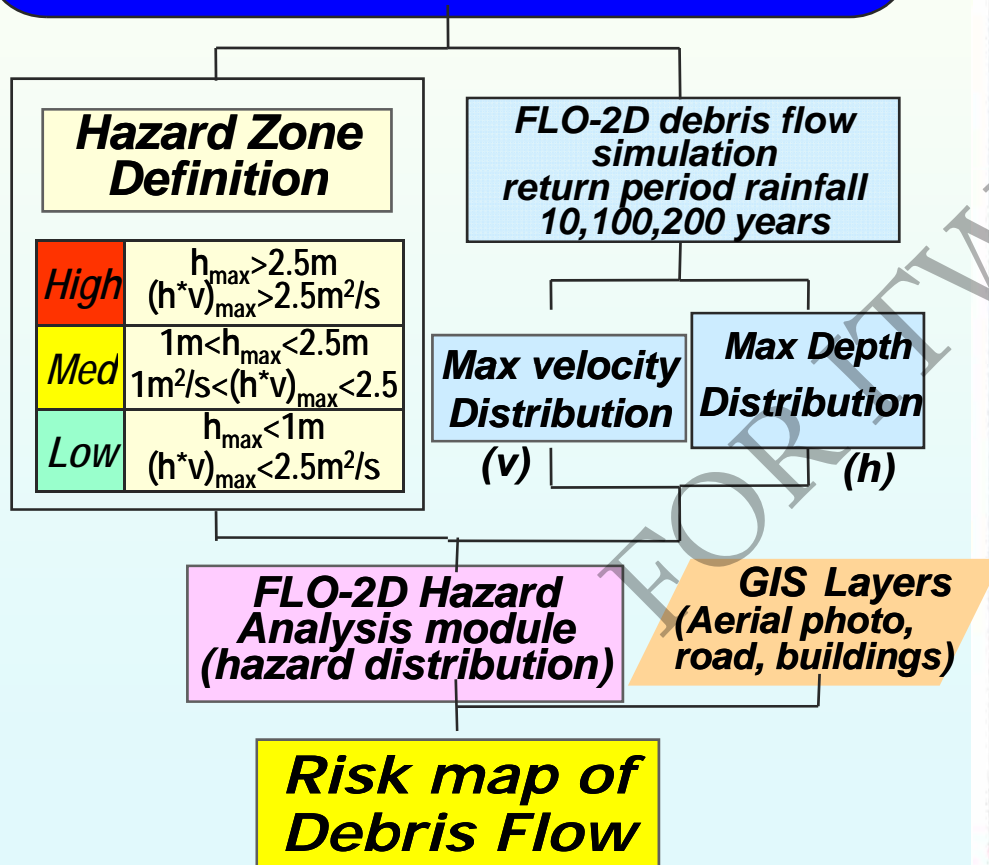
- Protected Targets: houses, school, roads, publics, farms.....etc.
- Including 10° slope deposit range

Risk		Probability		
		Low	Mid	High
Assured Safety	Low	Low	Low	High
	Mid	Low	Mid	High
	High	Mid	High	High

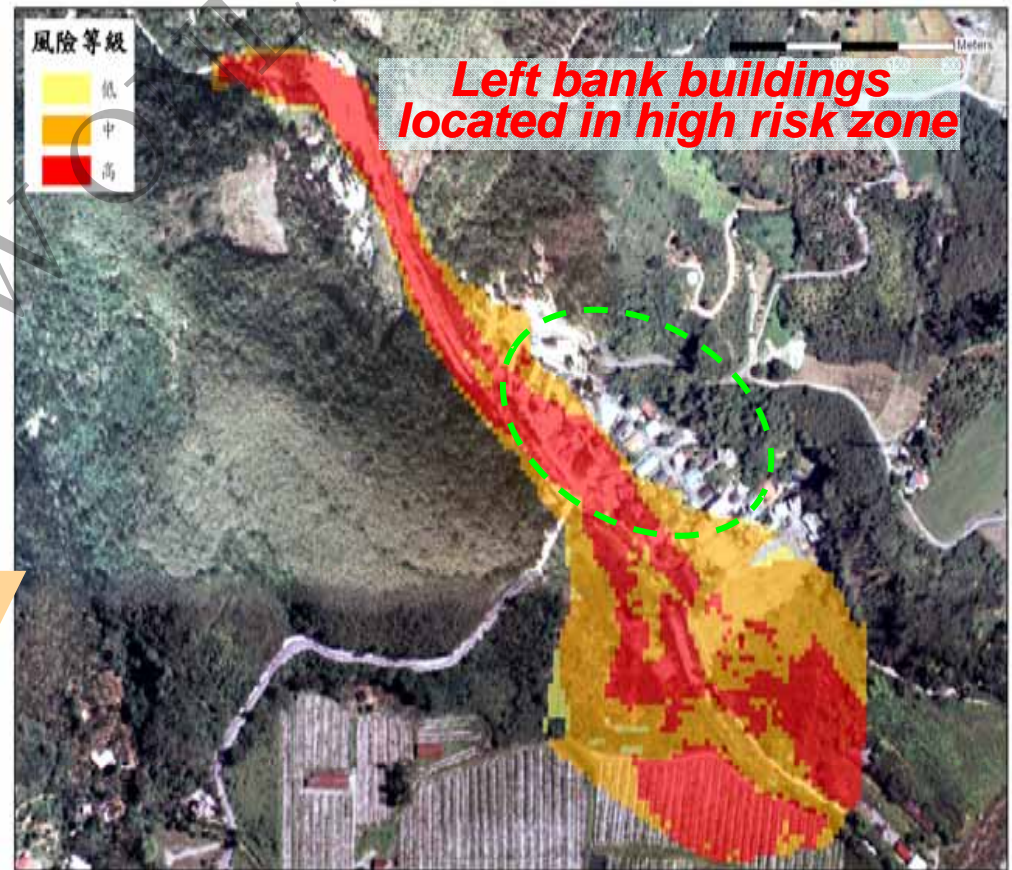


# Risk Mapping

## Debris Flow Risk Mapping



## Warning Simulation of Debris Flow Disaster Condition





# Localized Rainfall-based Debris-flow Warning Model

- **Rainfall Triggering Index (RTI)**  
= Rainfall intensity  $\times$  Effective accumulative rainfall

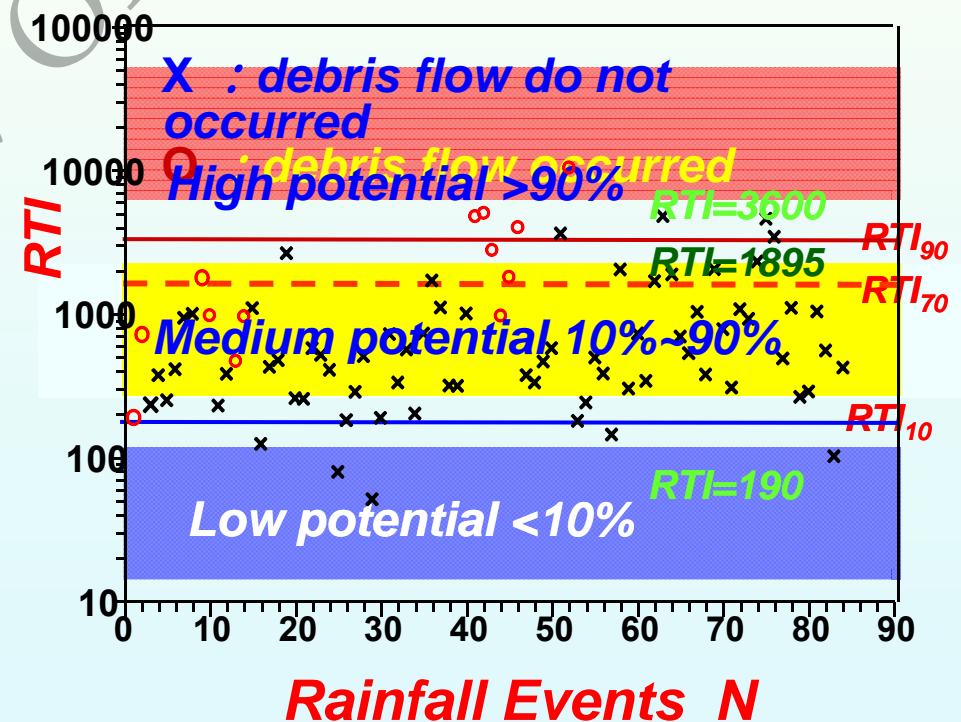
$$RTI = I \times R_t$$

$R_t$  : Effective accumulative rainfall  
= Accumulative rainfall  
+ Preceding rainfall for 7 days

$I$  : Rainfall intensity (mm/hr)

$RTI_{70}$  : RTI at 70% of probability that debris flow occurred

- The critical accumulative rainfall for evacuation ( $R_c$ ) is set for easier public understanding and local application





## *Does the public understand the warning model?*

- ❖ *The answer is **NO**.*
- ❖ *People can understand the accumulated rainfall, but **do not (do not want to) understand the rainfall intensity.***
- ❖ *Weather Bureau reports only the accumulated rainfall also.*
- ❖ ***More simplified model for the public is needed.***



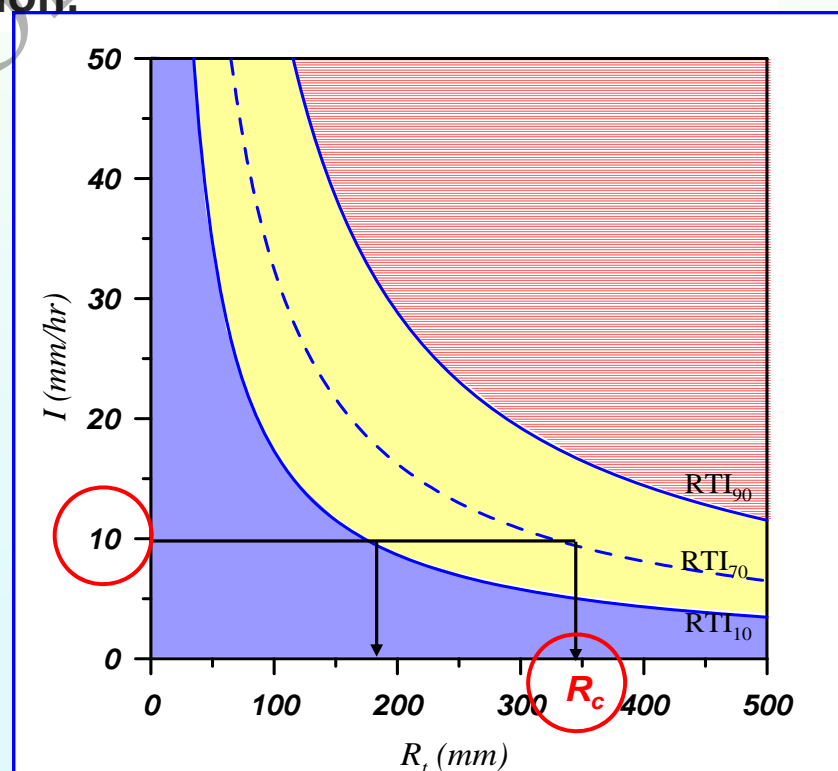


# *Simplified RTI model*

The critical RTI-value involves two parameters ( $I$  and  $R$ ) is too academic and not easy to understand for people living in mountainous areas.

The **critical accumulated rainfall ( $R_c$ )** is set for easier public understanding and application for evacuation.

$R_c$  is estimated from the critical RTI-value with a consideration of **rainfall intensity of 10 mm/hr**, and rounded with 50mm as an interval of the critical accumulated rainfall. That is to say for different counties,  $R_c$  could be 200, 250, 300, 350, 400, 450, 500, 550, or 600 mm.





# Warning criteria Table

Village and (N) : the numbers of debris flow torrents in the village

Rainfall station 2

Rainfall station 1

101年土石流警戒基準值明細表 101.02修訂

縣市	鄉鎮	警戒區範圍		土石流警戒基準值 (mm)	參考雨量站	
		警戒區座落村里 (土石流潛勢溪流總數)	土石流潛勢溪流數(條)		代表站1	代表站2
	蘇澳鎮	新陽里(4)	4	500	南澳	東澳
		南建里(1)、永春里(2)、長安里(1)、永樂里(7)、蘇北里(1)、聖湖里(4)	16		蘇澳	冬山
	三星鄉	集慶村(1)、拱照村(3)、天山村(1)	5	600	三星	寒溪

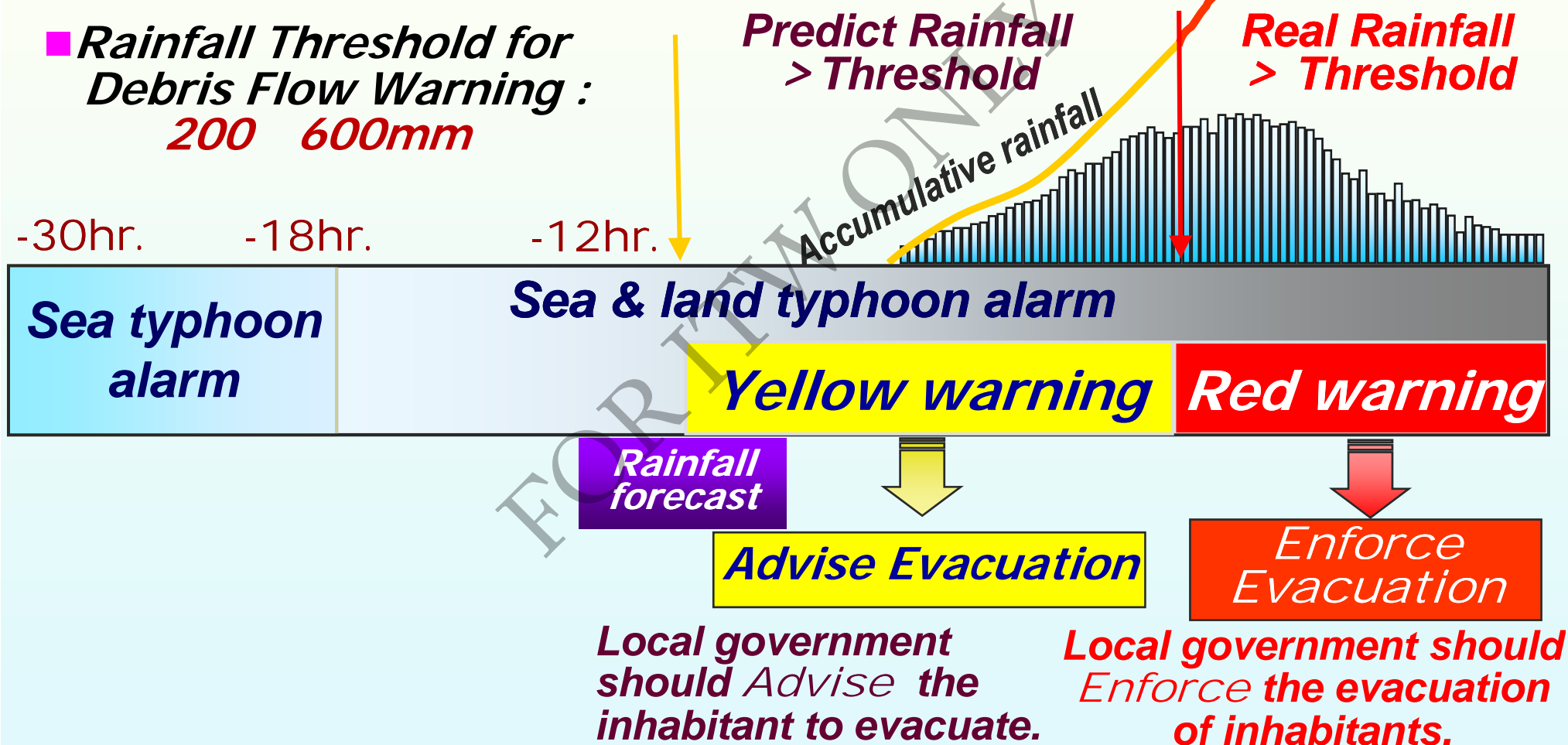
Township

Warning Criteria

Numbers of debris flow torrents in township



# Announcement of Debris Flow Warning in Taiwan





Soil and Water Conservation Bureau (SWCB)

## Debris Flow Emergency Operation Task Force of SWCB

Toll-free Hotline



0800-246-246

# Emergency Response during Typhoon

- Typhoon: Real-time weather condition
  - Rainfall monitoring: Every 10 min
  - Announce: Debris flow warning
- Debris flow information system

<http://246.swcb.gov.tw/>

[\*http://246eng.swcb.gov.tw/\(English version\)\*](http://246eng.swcb.gov.tw/(English version))







# Evacuation Routes and Drills for Debris Flow Disaster Mitigation

- 947 **Evacuation routes** planned
- 649 debris flow **evacuation drills** held
- 1387 **Debris Flow Volunteer Specialists**

## Evacuation Route Map



## Debris Flow Volunteer Specialist



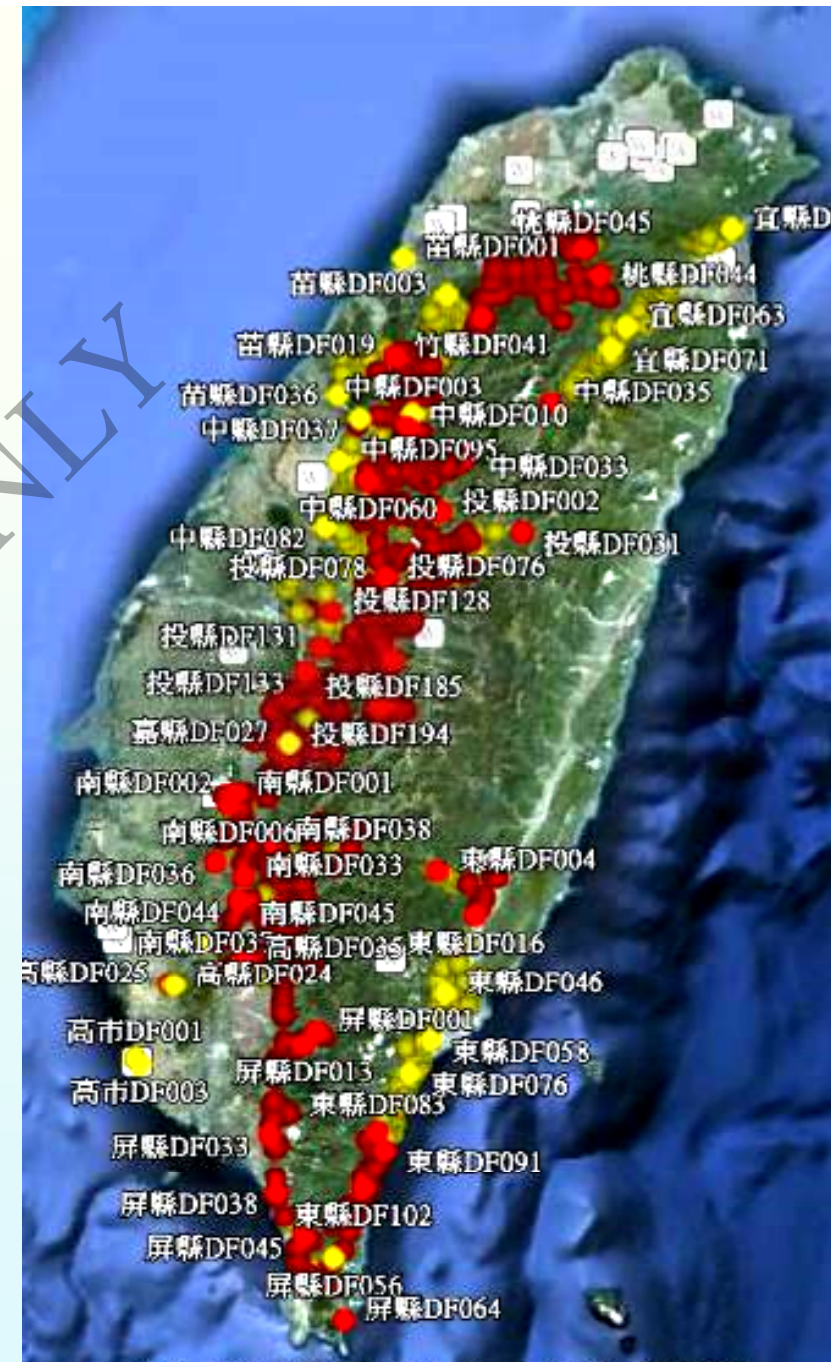


## Debris Flow Warning and Evacuation

- ◆ During the typhoon Morakot period, the SWCB had issued **21 debris flow warnings** to the public and local governments based on the real-time weather information from CWB.

Debris flow warning	Warning ravines	County (City)	Town	Village
Red alarm	519	12	61	230
Yellow alarm	338	14	58	163

**9,100 people** were evacuated by local governments according to the warning. Among them, **1,046 people** escaped from the possible casualties.







Soil and Water Conservation Bureau (SWCB)

## **17 On-site and 3 mobile debris flow monitoring station**

### **Monitoring Sensors**



### **Satellite Transmission**

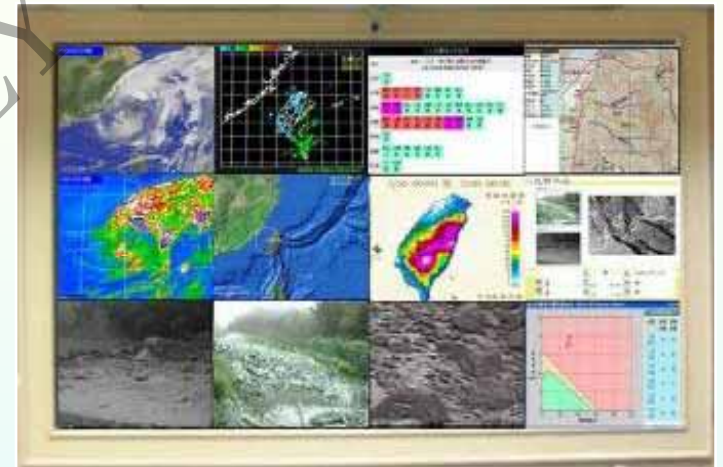


### **Instrumental cabin**



### **Information Display**

<http://246.swcb.gov.tw>





Soil and Water Conservation Bureau (SWCB)

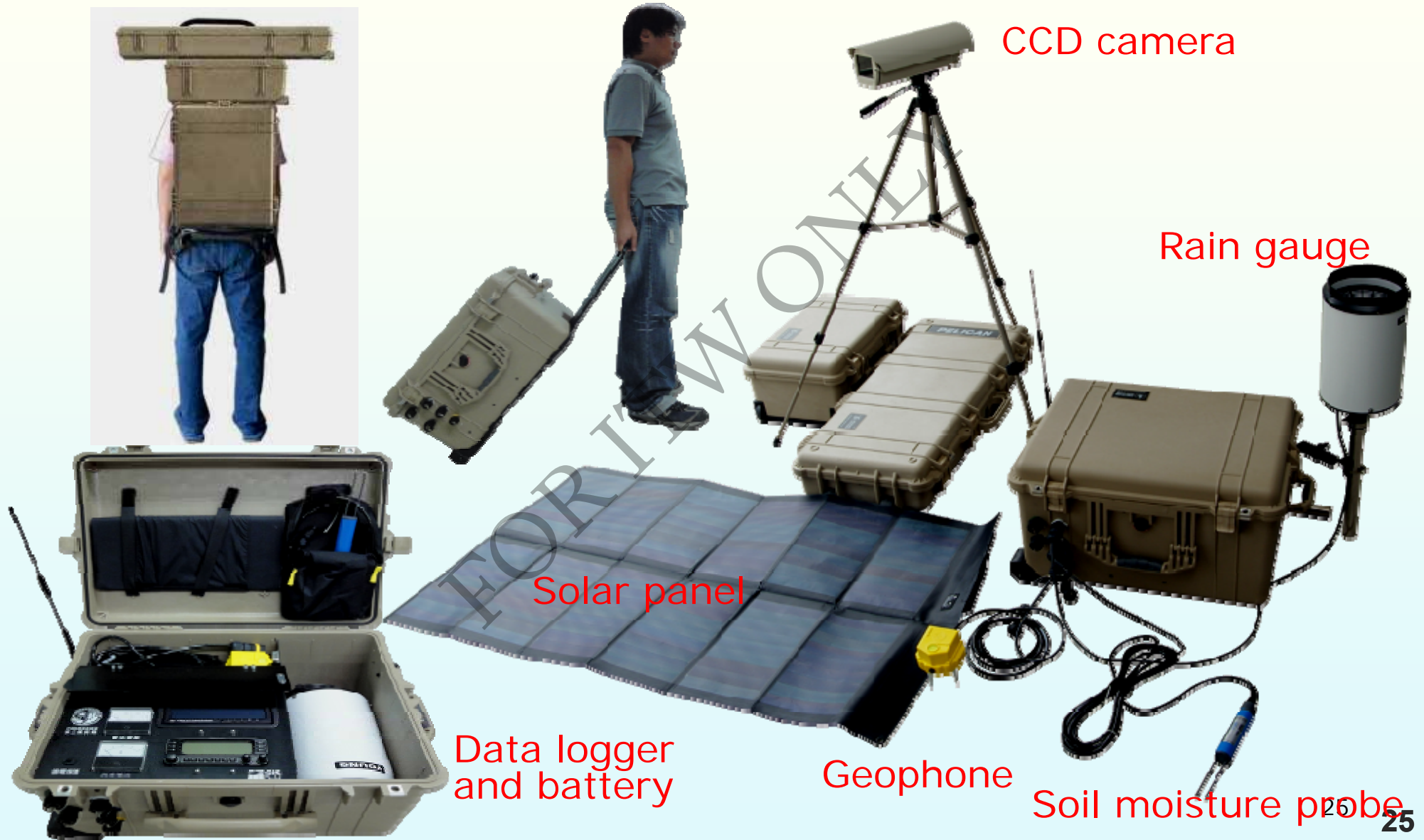
## *Evolution of mobile station*







## 14 Grid debris flow monitoring station (since 2010)





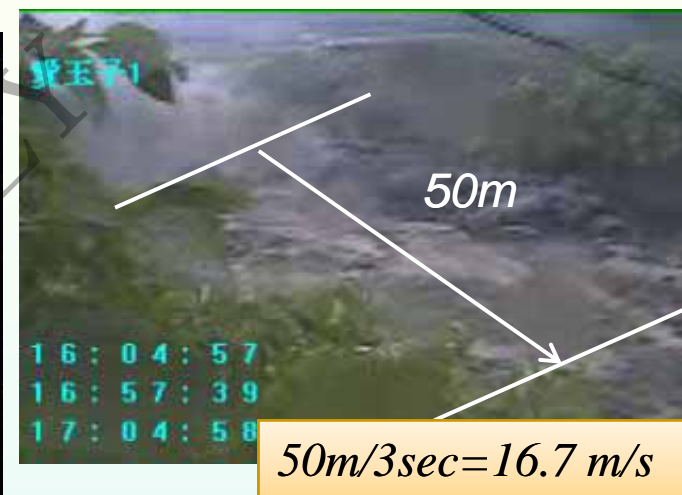
# Typhoon Morakot, Aug. 8, 2009

CCD image (front view)  
downstream

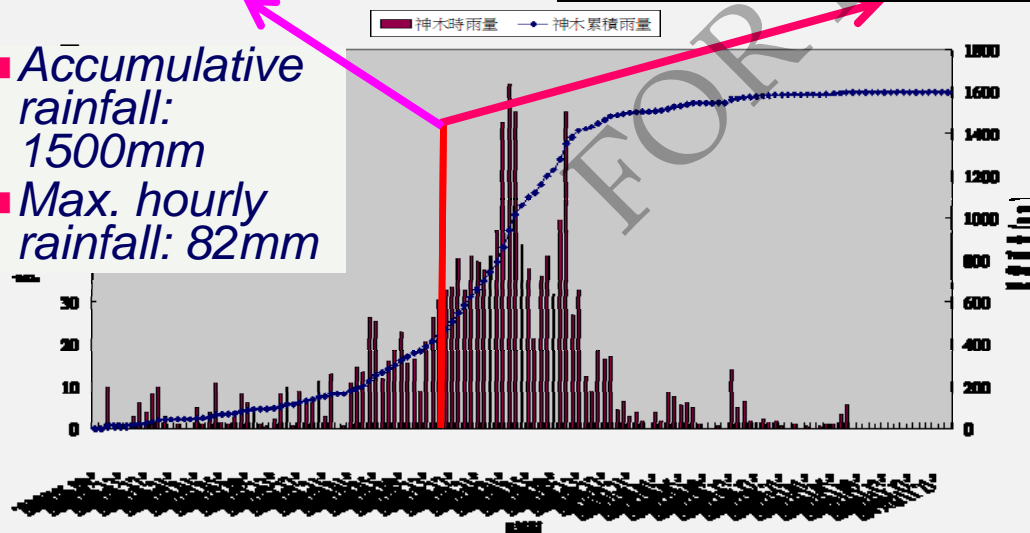
CCD image (side view)  
upper stream



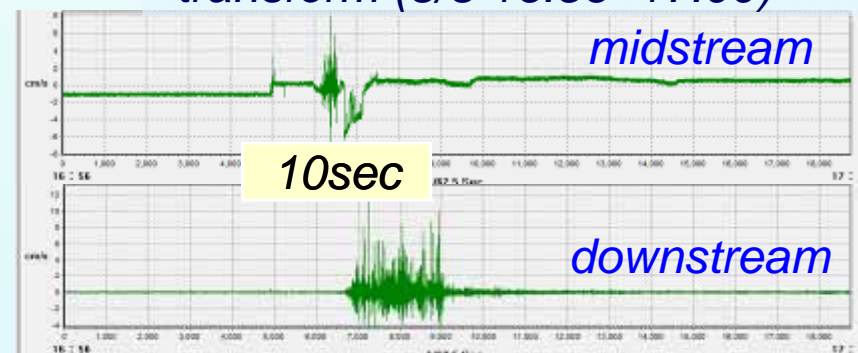
Velocity



- Accumulative rainfall: 1500mm
- Max. hourly rainfall: 82mm



- Geophone signal after wavelet transform (8/8 16:56~17:00)



$$173\text{m} / 10\text{sec} = 17\text{m/s}$$





Soil and Water Conservation Bureau (SWCB)

## ***Debris flows disasters after typhoon Morakot, 2009***

***Vertical incision***



***Lateral (bank) erosion***



***Aiyuzih creek***



***Deposition of debris***

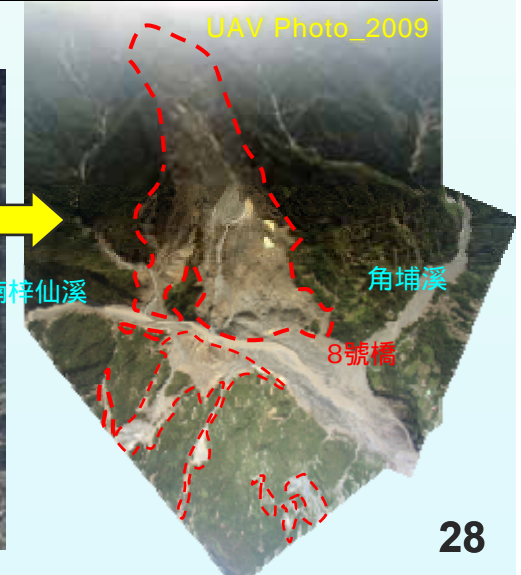




# *Unmanned Aerial Vehicle (UAV) to Collect and Analyze Disaster Information*



**UAV Video Data**







# ***Landslide Changing from UAV Images*** ***(Upstream area of Aiyuzih creek)***

**1996**



**2009**





# Debris Flow Disaster in Taitung County

Landslide area : 8 ha

Accumulative rainfall  
1,383 mm

Rainfall threshold of  
warning 350 mm

Maximum rainfall  
intensity 100 mm/hr

Sediments 300,000 m<sup>3</sup>

15 houses buried



# Engineering Construction Design

N  
4

Artificial Vegetation  
Recovery

Debris Flow  
Monitoring station

Slit dam

Check dam

Sedimentation  
pond

Retaining wall

Broaden the channel

Sediment dredging

Elementary school

Relay house





### ***3. Challenges of Typhoon Morakot (2009) and Future Perspective***

FOR ITW ONLY

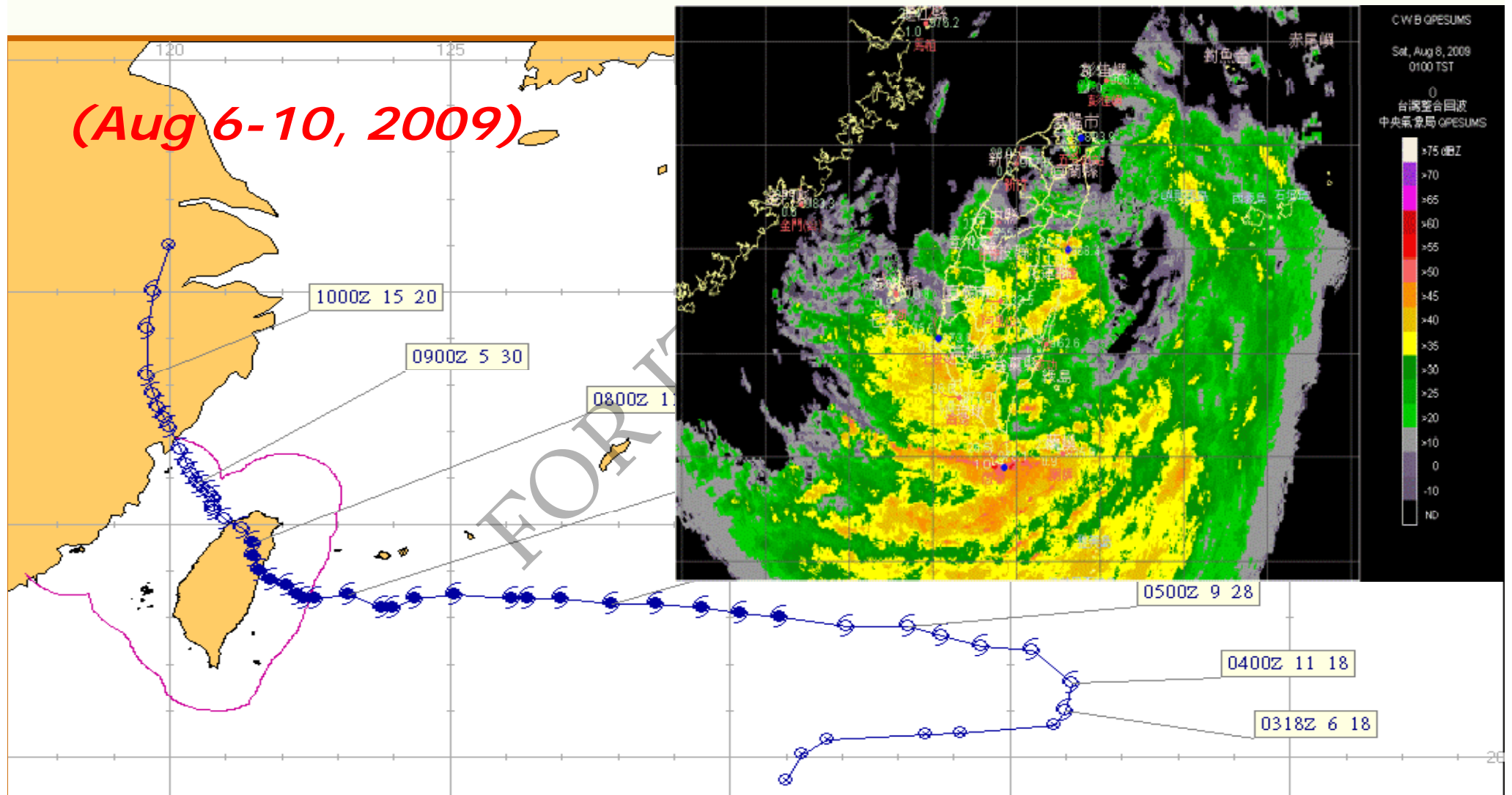




Soil and Water Conservation Bureau (SWCB)

# Typhoon Morakot, 2009

## Typhoon Route and Radar Echo Image

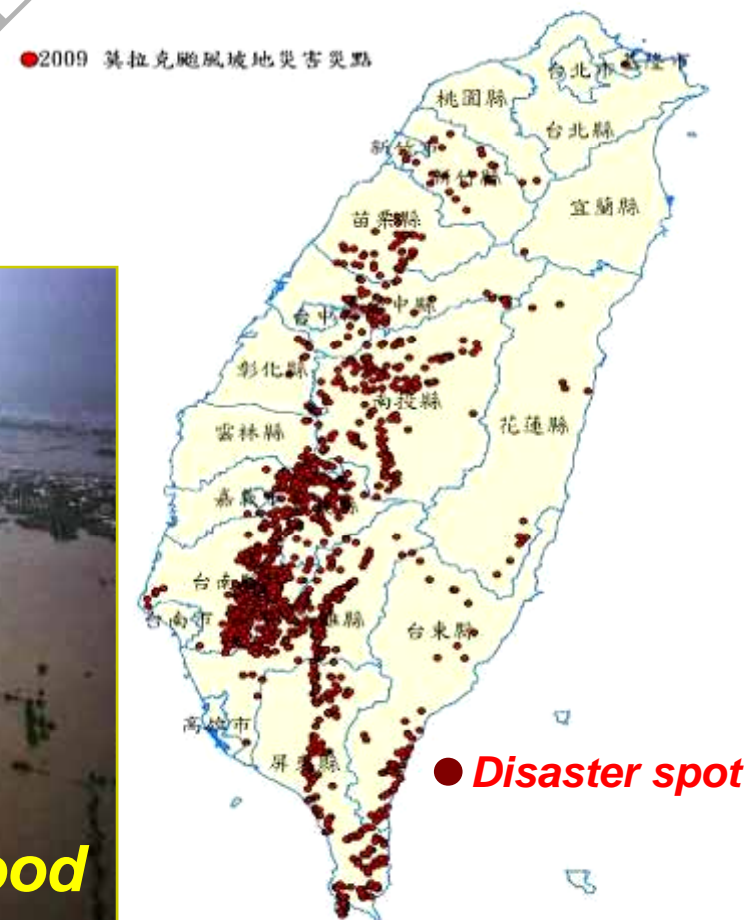




Soil and Water Conservation Bureau (SWCB)

# **Damage of Calamity Caused by Typhoon Morakot (Aug 6-10, 2009)**

- Max. accumulative rainfall (Aug 6-10, 2009): **3059.5mm**.
- Coverage area of total rainfall 2000mm: **320,000km<sup>2</sup>**.
- Total new landslides: **39,492 ha**.
- Evacuate and withdraw: **24,950 people**.
- Casualty and missing: **757 people**.
- Total damage: **6.7 billion USD(1.6% GDP)**

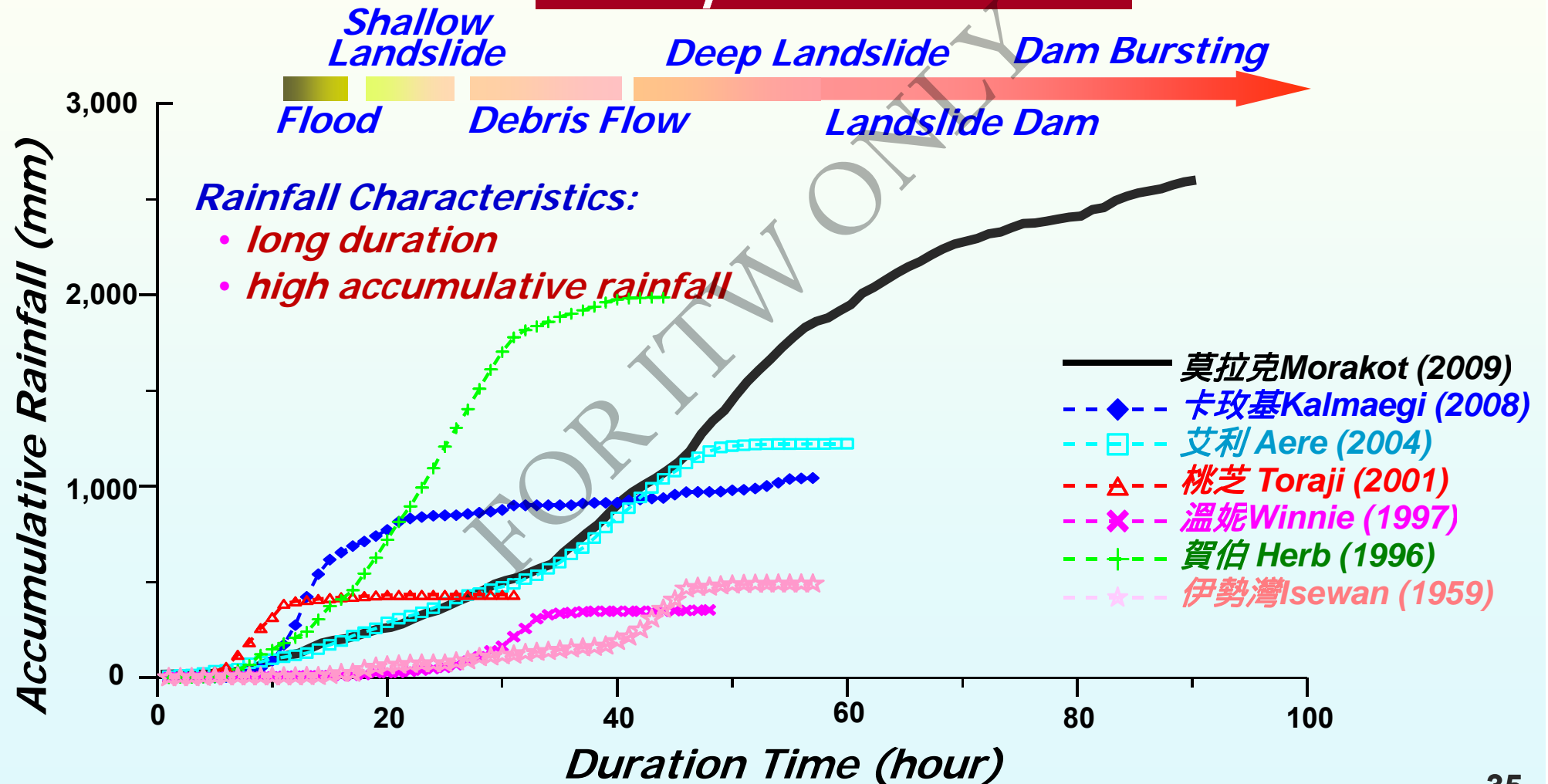






# Rainfall-Duration Curve between the Morakot & Historic Typhoons

## Compound Hazards





Soil and Water Conservation Bureau (SWCB)

## Compound Hazards Occurred Simultaneously

✓ **Compound hazards**  
at Hsiaolin Village, Chia-sien,  
Kaohsiung County:

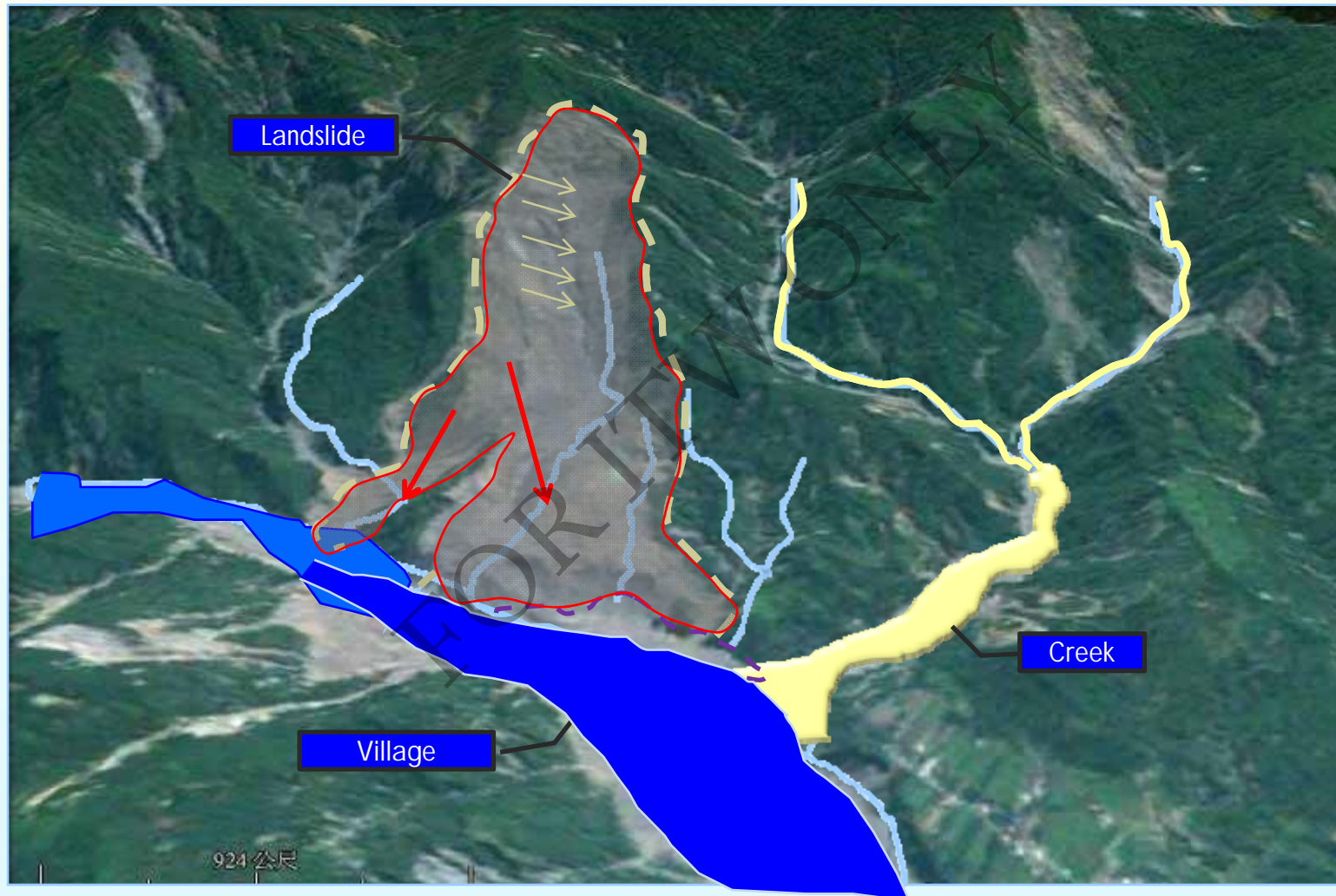
- ↪ **Flooding**
- ↪ **Shallow landslide**
- ↪ **Debris flow**
- ↪ **Deep-seated landslide**
- ↪ **Landslide barrier dam**
- ↪ **Dam breach**

- **Dead and missing: 457 people**
- **Accumulative rainfall: 2,076mm**
- **landslide coverage area: 350 ha**
- **Sediment yield of Landslide:  $25 \times 10^6 \text{ m}^3$**





## ***Sequence of compound disasters in Hsiaolin village***



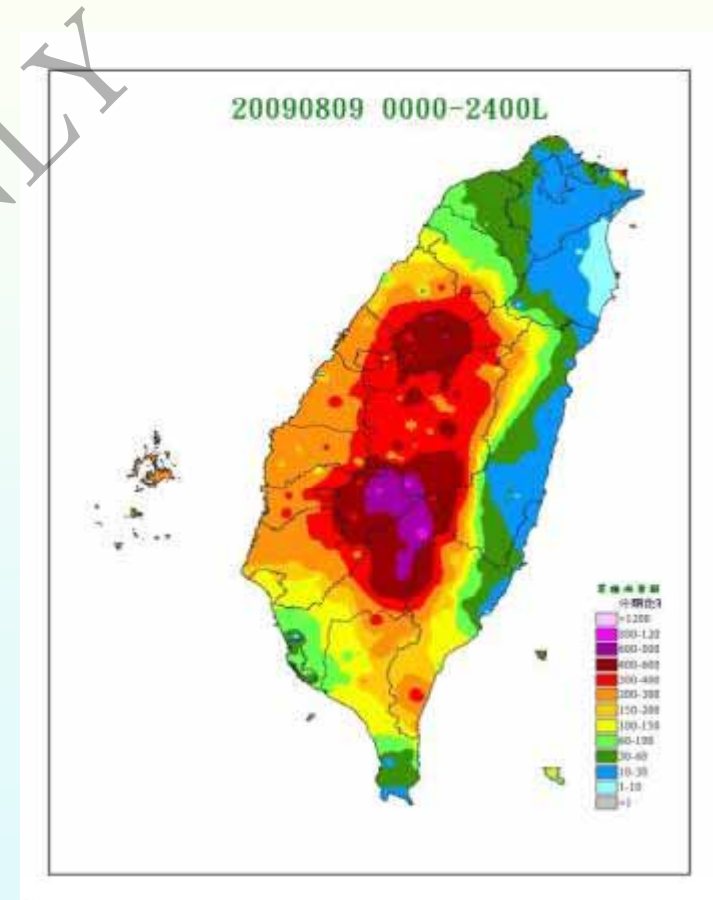




## ***Should extreme rainfall of Morakot be considered as a normal or a extreme weather event ?***

### ***✓ Extreme Rainfall Characteristics of Morakot***

- ◆ ***Basin-wide coverage***
- ◆ ***High intensity***
- ◆ ***Long duration***
- ***The max rainfall of Typhoon Morakot were Max 24-hr (1583mm) and 48-hr (2361mm). That rainfall approached to world records (48-hr 2467mm, 1958).***
- ***The 24-hr rainfall in Kaoping River Basin was over the expectation of 200-yr return period.***



***Total Rainfall Map of  
Typhoon Morakot, 8/6-8/9, 2009***

***Does the slit dam work?***

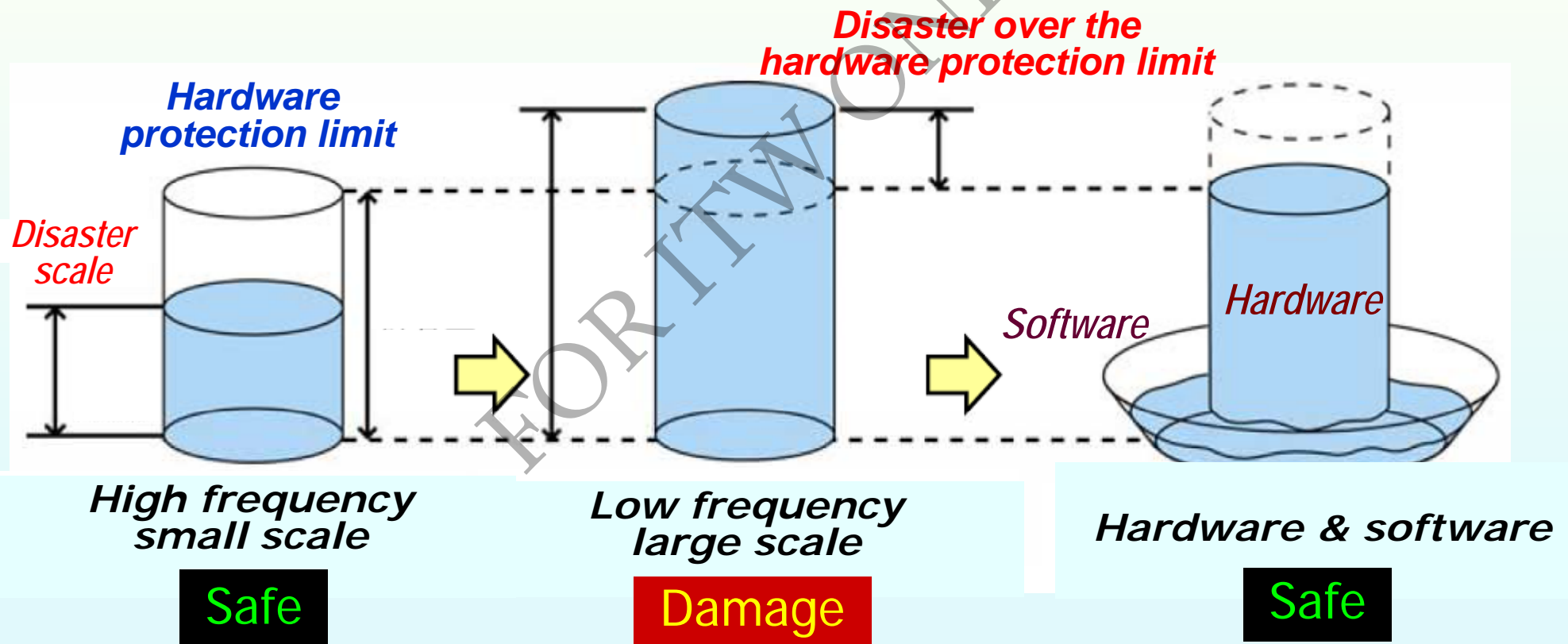






# *Integration of Software and Hardware*

- *Under climate change impact, strategy of disaster precaution should be considered from hardware to software.*
- *Non-engineering measures should combine with mitigation works.*





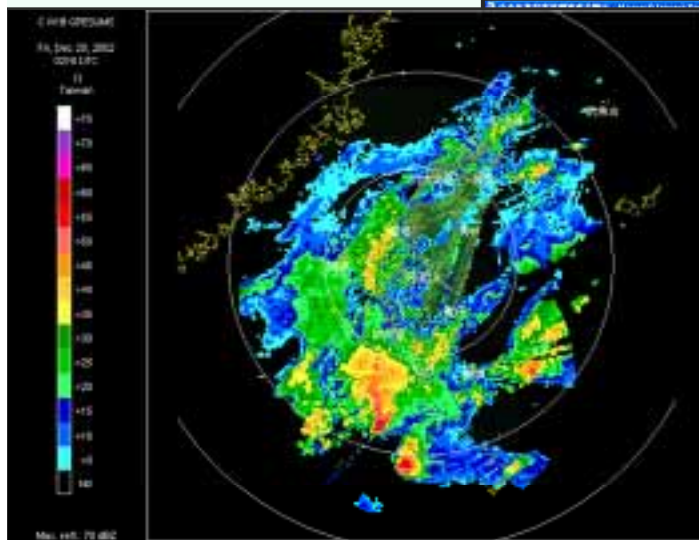
# Apply QPESUMS for Rainfall Estimate

- ◆ Forecast 1 and 3 hour rainfall
- ◆ Data analysis: compute the rainfall value in the villages and rainfall stations
- ◆ Assess the timing of warning declaration

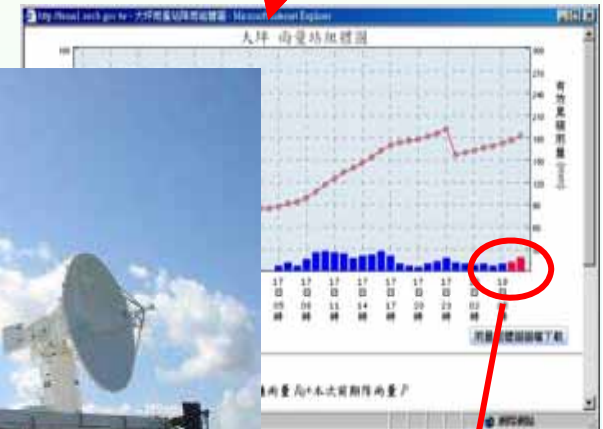
Enhance  
warning  
accuracy

Cooperation with NOAA, Water  
Resources Agency & Central  
Weather Bureau

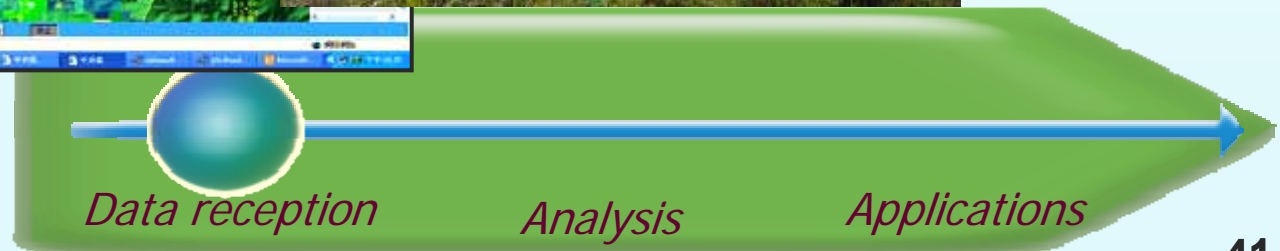
GIS display



Spatial resolution : 1.3km  
Time resolution : 10min



Forecast

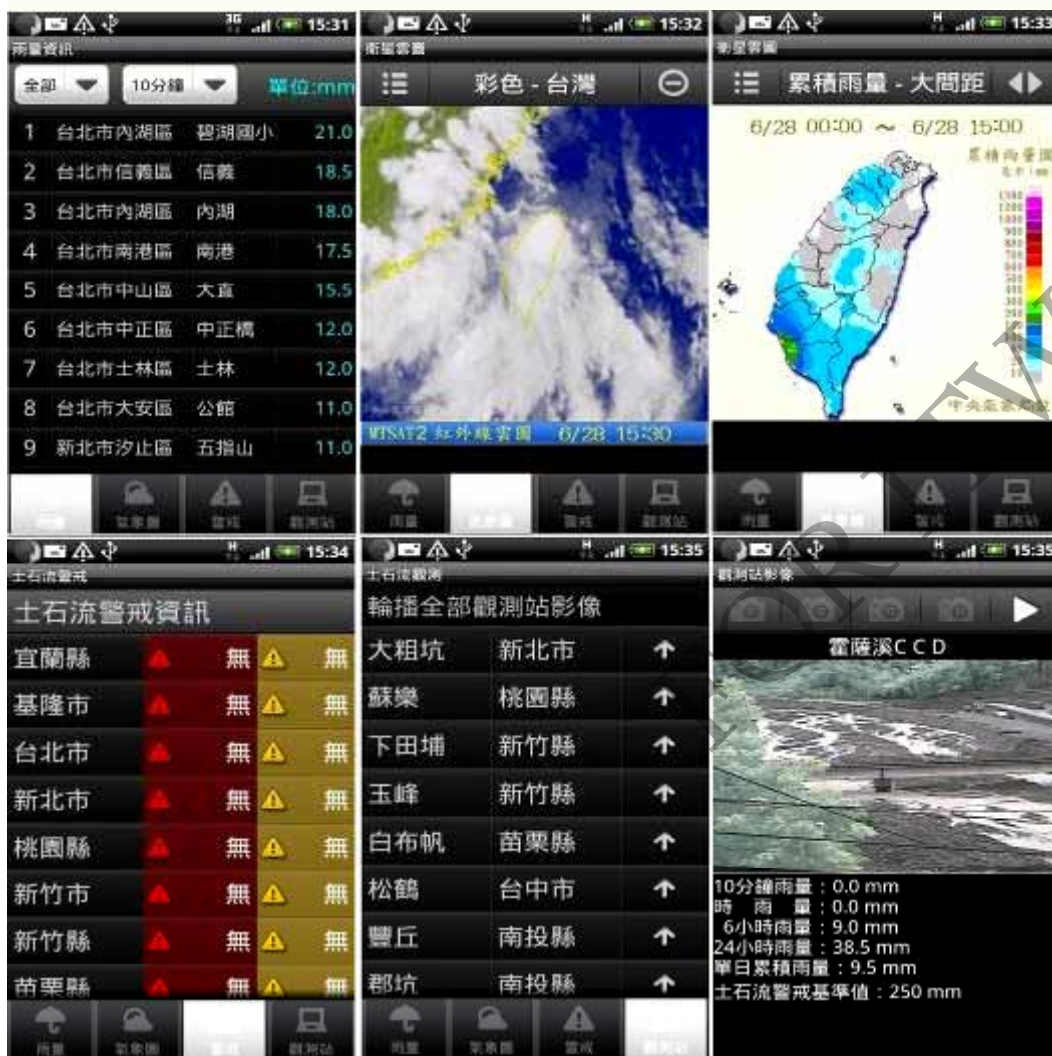






# ***App of Debris Flow Disaster Prevention Information***

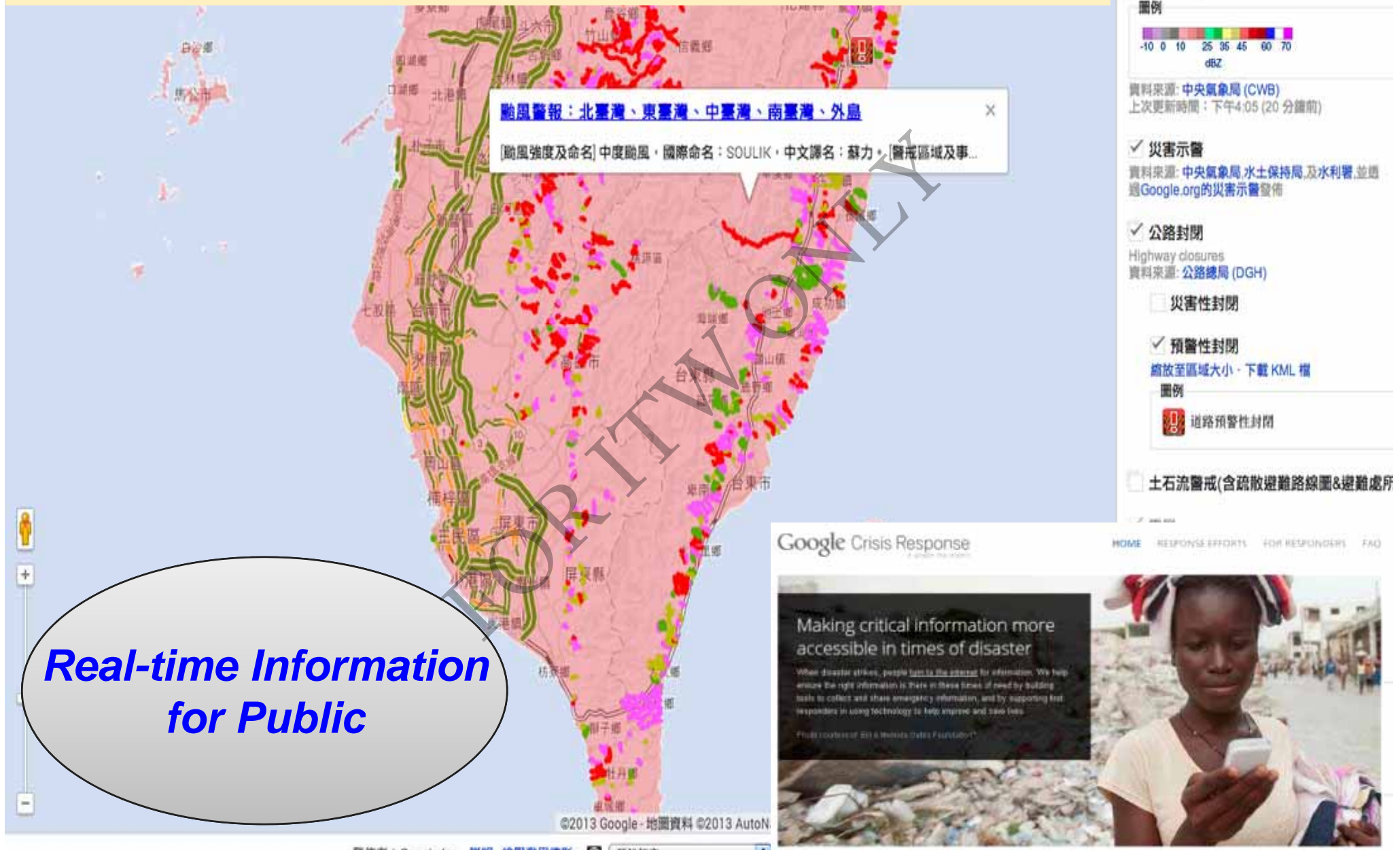
*iOS*  
*Android*



雨量站站名：大坑  
 地區：台中市北屯區  
 十分鐘雨量：0.0 mm  
 一小時雨量：0.0 mm  
 三小時雨量：0.0 mm  
 六小時雨量：0.0 mm  
 12小時雨量：0.0 mm  
 24小時雨量：0.0 mm  
 本日雨量：0.0 mm  
 預測一小時雨量：nm 1  
 預測二小時雨量：nm 0  
 預測三小時雨量：nm 0

# 座標：24.1936,120.813  
地址：新社鄉協成村興義街219號  
電話：04-25813437  
容納人數：200  
目前定位點：24.181664,120.648541  
直線距離：約 16762 公尺

# Application of Google Crisis Response







Soil and Water Conservation Bureau (SWCB)

華山

# *Integration of Debris Flow Disaster Mitigation & Rural Regeneration in Hua-shan, Ku-keng, Yunlin*

*The name of “Hometown of Taiwan Coffee” spreads all over the whole country.*

*Typhoon Nari, 2001*



*Debris flow monitoring*



*A news report about 2006 Coffee Festival in Hua-shan*

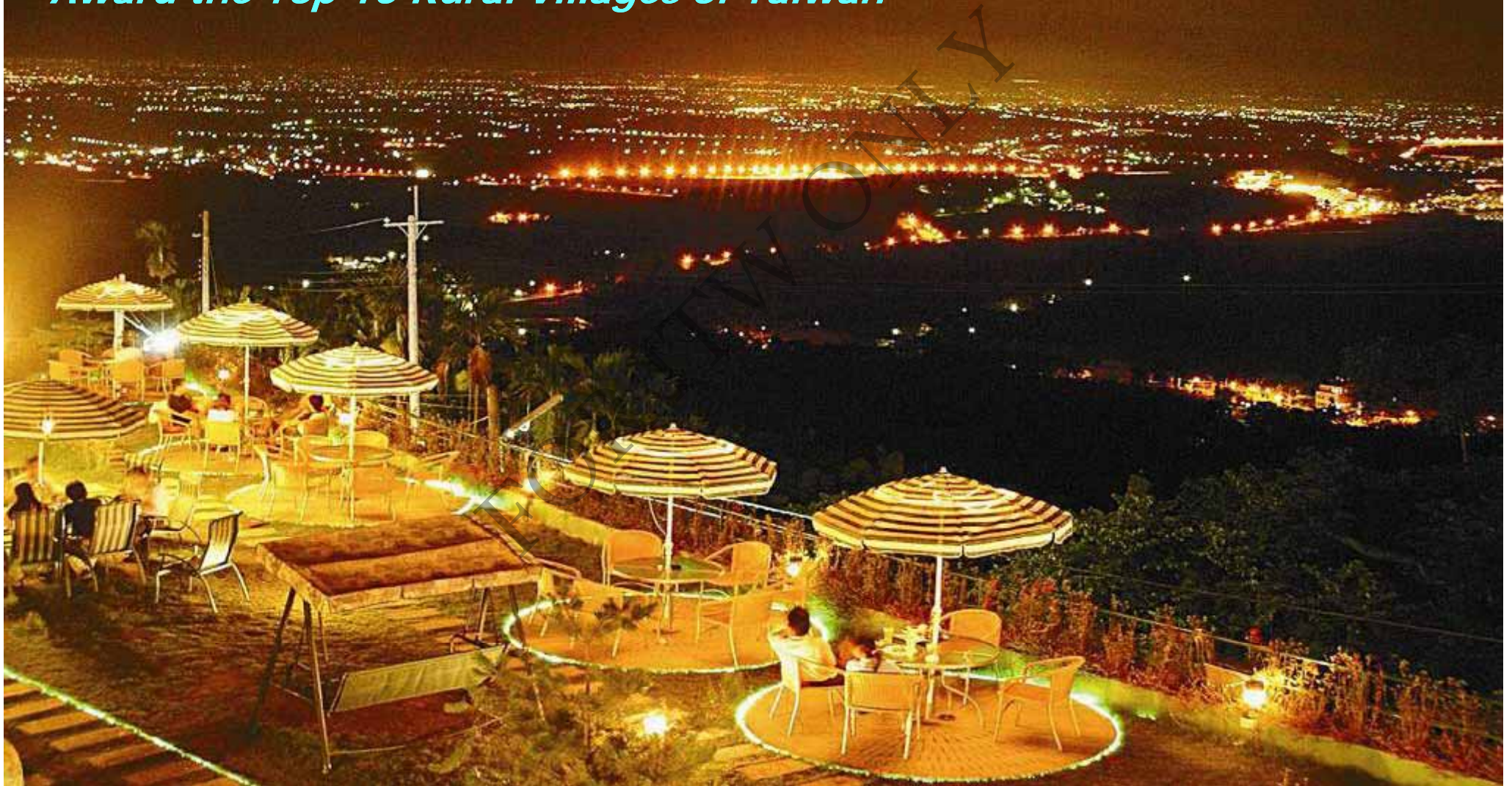


*After treatment*



# 華山經典農村

*Award the Top 10 Rural Villages of Taiwan*





# ***Future Perspective for Natural Disaster Management***

## ***- T.H.I.N.K -***

- ❖ ***Technology** : Research, development and practice.*
- ❖ ***Human management** : Improve people's awareness of precaution against disaster.*
- ❖ ***Investigation** : Investigate the potential locations to cope with disasters.*
- ❖ ***Notice** : Accurately control possible occurring time and give a declaration.*
- ❖ ***Knowledge** : Information and database as well as expert decision- making system.*



A scenic landscape photograph featuring a large, gnarled tree in the foreground. The tree has a thick trunk and branches with green foliage. In the background, there is a body of water, likely a lake or a wide river, and a range of blue mountains under a clear blue sky. The overall scene is peaceful and natural.

***Thank You for  
Your Attention***

***Soil and Water Conservation Bureau  
Always Working with You***