The Earth Disasters Of Slopelands In Taiwan

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Abstract

Due to the fragile geological structure and steep terrain of mountains, Taiwan was prone to the slopeland hazards caused by typhoons, severe rainfalls, earthquakes and human activities, which usually inflict lots of losses with people's lives and properties. This study is going to analyse the types and the influences of the earth disasters of slopelands, by means of statistical data and GIS management, in order to realize the characteristics of the temporal and spatial distribution of the earth disasters of slopelands.

The result is shown follow as：

1. The disasters in the early period (before 1996) are mostly landslide and slope failure, and occurrence locations are mostly located at the east region and north region of Taiwan. It may be related to bad geology and steeper topography of east region and precipitous landforms and early city development of north region. After Typhoon Herb caused large-scale earth disaster occurrence in Nantou County in1996, debris flow had changed from the original fragmentary distribution into regional distribution in the middle region of Taiwan. Since the earthquake on September 21st of 1999, the whole Taiwan Island will all have disaster whenever typhoon comes invading.
2. By comparing the interrelations between disaster cause and type, the debris flow caused by typhoon and torrential rain, slope failure caused by earthquake, and the landslides caused by continuous rainfall are the most apparent.

【Keywords】: Earth Disasters of Slopelands, landslide, debris flow, potential streams of debris flow hazard

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INTRODUCTION

The area of Taiwan is subjected to the impact of plate tectonics compression, due to the fragile geological structure and steep terrain of mountains, was prone to the slopeland hazards caused by typhoons, severe rainfalls, earthquakes and human activities, which results in source of sediment from mountains and lead to occur disaster, and causes average death of more than 300 person every year and the loss of ten billions NT dollars. The earthquake in 1999 even increased the impact on earth disaster. This paper discusses the earth disaster on the characteristics, evolvement process, topographic condition and future motion by disaster cases over the years.

The type of earth disasters of slopelands

Earth disaster can be divided into many classes according to the difference of moving patterns, velocity and material composition for the convenient in investigation and statistics, namely slope failure, landslide and debris flow.

1.Slope failure

It is a small-scale earth or rock movement, which mostly happens at the cliffy and precipitous slope face and happens in a twinkling of eye with higher rate of movement. Its occurrence are always caused by earth or rock collapsing. Once it happens, the structural object it carries on ground may be completely destroyed.

2.Landslide

Its scale is larger than earth or rock body. It slowly moves on the slope face, and its typical characteristic of movement lies in its slow movement speed, which shows intermittent movement or continuously slow movement form. Generally, the structural object on the moving earth can still be maintained in original shape.

3.Debris flow

It is the movement of earth, rock and sand, and since the solid sediment grain mixes adequately with water, it moves forward through flowing patterns. Its definition is the mix of earth, sand, and gravel with water to form the movement phenomenon of highly concentrated fluid.

The slopeland hazards in the past

According to the investigation of National Fire Agency, Ministry of Interior in examining earth disaster condition of Taiwan area slopelands, the occurrences frequency of earth disasters of slopelands are totaled to 227 times, which causes the death of 5790 persons, and 1600 persons missing (Figure 1). The average of typhoon disaster occurrence in each year is 3.6 times, torrential rain disaster is 0.8 times, and earthquake disaster is 0.4 times (Figure 2).

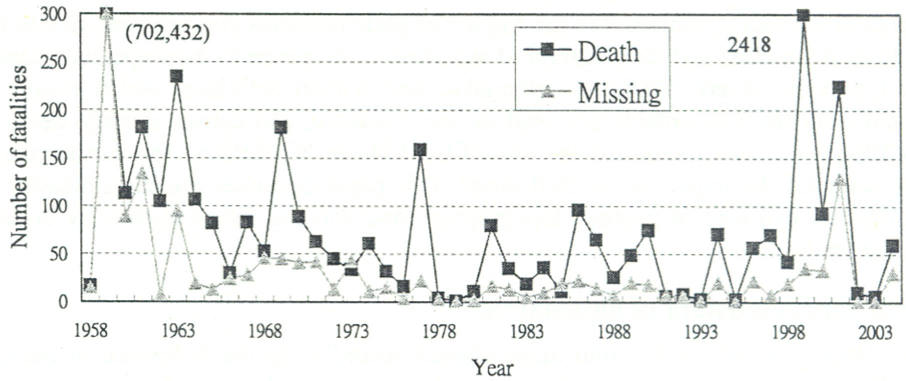


Fig. 1 The death and missing people number statistics caused by earth disasters of slopelands over the years (National Fire Agency, Ministry of Interior)

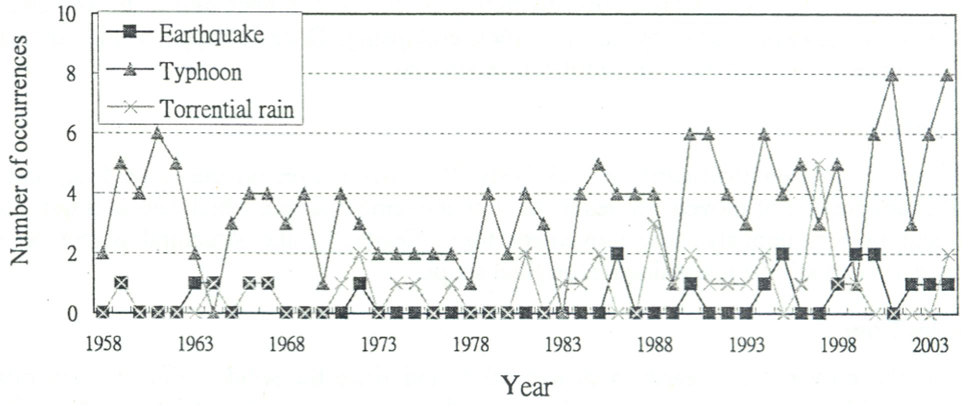
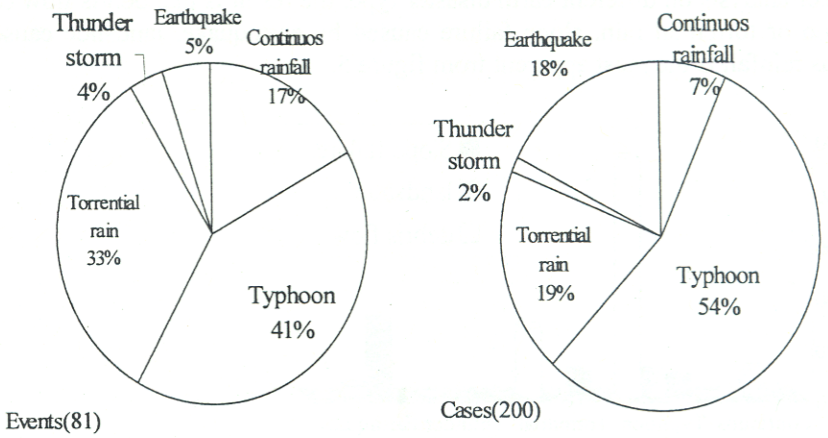
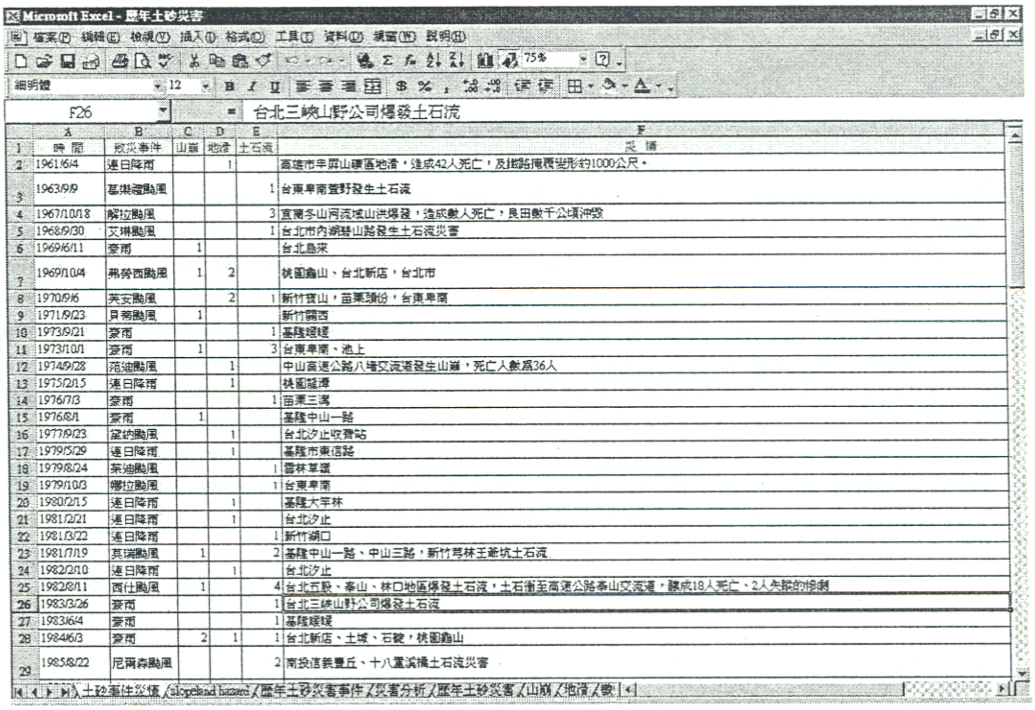


Fig. 2 The statistics of earth disasters of slopelands event over the years (National Fire Agency, Ministry of Interior)

To step forward understand the characteristic of slopeland disaster and the problem it brings, this paper tries to choose 81 kinds of events from earth disasters to establish database shown in Figure 3 from each unit in the past (the information of The Soil and Water Conservation Bureau (SWCB), National Science and Technology Center for Disaster Reduction, Central Geological Survey, National Chung Hsing University, Department of Geography of National Taiwan University, National Slopeland Disaster Prevention Team, Industrial Technology Research Institute and Prof. Jhang Shih-Jiao).





	時間	致災事件	山崩	地滑	土石流	災情
2	1961/6/4	連日降雨		1		高雄市半屏山礦區地滑，造成42人死亡，及鐵路掩覆變形約1000公尺。
3	1963/9/9	葛樂禮颱風			1	台東卑南萱野發生土石流
4	1967/10/18	解拉颱風			3	宜蘭冬山河流域山洪爆發，造成數人死亡，良田數千公頃沖毀
5	1968/9/30	艾琳颱風			1	台北市內湖碧山路發生土石流災害
6	1969/6/11	豪雨	1			台北烏來
7	1969/10/4	弗勞西颱風	1	2		桃園龜山、台北新店，台北市
8	1970/9/6	芙安颱風		2	1	新竹寶山，苗栗頭份，台東卑南
9	1971/9/23	貝蒂颱風	1			新竹關西
10	1973/9/21	豪雨			1	基隆暖暖
11	1973/10/1	豪雨	1		3	台東卑南、池上
12	1974/9/28	范迪颱風		1		中山高速公路八堵交流道發生山崩，死亡人數為36人
13	1975/2/15	連日降雨		1		桃園龍潭
14	1976/7/3	豪雨			1	苗栗三灣
15	1976/8/1	豪雨	1			基隆中山一路
16	1977/9/23	黛納颱風		1		台北汐止收費站
17	1979/5/29	連日降雨		1		基隆市東信路
18	1979/8/24	茱迪颱風			1	雲林草嶺
19	1979/10/3	娜拉颱風			1	台東卑南
20	1980/2/15	連日降雨		1		基隆大竿林
21	1981/2/21	連日降雨		1		台北汐止
22	1981/3/22	連日降雨			1	新竹湖口
23	1981/7/19	莫瑞颱風	1		2	基隆中山一路、中山三路，新竹芎林王爺坑土石流
24	1982/2/10	連日降雨		1		台北汐止
25	1982/8/11	西仕颱風	1		4	台北五股、泰山、林口地區爆發土石流，土石衝至高速公路泰山交流道，釀成18人死亡、2人失蹤的慘劇
26	1983/3/26	豪雨			1	台北三峽山野公司爆發土石流
27	1983/6/4	豪雨			1	基隆暖暖
28	1984/6/3	豪雨	2	1	1	台北新店、土城、石碇，桃園龜山
29	1985/8/22	尼爾森颱風			2	南投信義豐丘、十八重溪橋土石流災害

Fig. 3 Earth disasters of slopelands Database

According to the above mentioned 81 times of disaster events, and lead to 200 sites of disaster case, its disaster reason can be sorted such as shown in Figure 1. As for disaster event statistics, figure 4 (a) shows that the main cause are mainly rainwater (more than 95%) with the frequency brought by typhoon as the most, the next is torrential rain, continuous rainfall and earthquake; for the statistics of case number as figure 4 (b), typhoon is still the most, the next is torrential rain, earthquake and continuous rainfall; and the cases induced by one single event is typhoon and earthquake as the most.

Fig. 4 Landslope earth disaster event and the cause statistics of case number

The inducer analysis on different earth disaster type, the result is that debris flow caused by typhoon or torrential rain, slope failure caused by earthquake, landslide caused by continuous rainfall is the most apparent from figure 5.

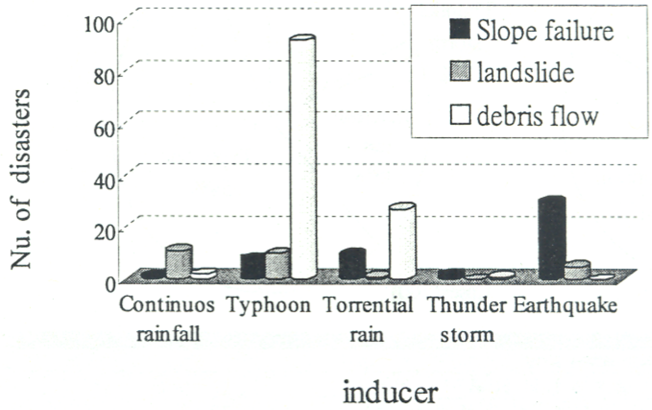
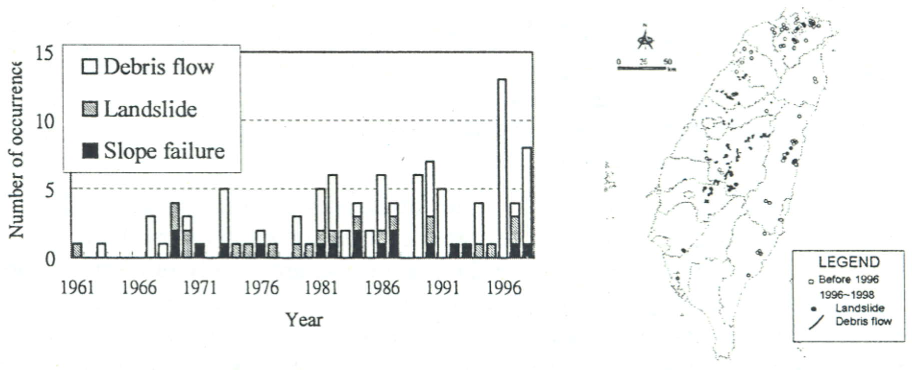


Fig. 5 The inducers analysis of different earth disaster type

The 200 sites of disaster cases over the years are sorted by variation of occurrence frequency in Figure 6(a), and the locations are shown in Figure 6(b), which displays whenever torrential rain or typhoon comes invading, each place in the whole Taiwan will be more or less reported to have earth disaster. In the early stages (before 1996), disasters are mostly landslides and slope failures, which mostly occurs at east region and north region of Taiwan. It may be related to bad geology and steeper topography of east region and precipitous landforms and early city development of north region. After Typhoon Herb caused large-scale earth disaster occurrence in Nantou County in 1996, debris flow had changed from original fragmentary distribution into regional distribution in the middle region of Taiwan. Since the earthquake on September 21st of 1999, the whole Taiwan Island will all have disaster whenever typhoon comes invading.



(a) (b)

Fig. 6 The amount and location of earth disasters of slopelands occurrences over the years

The Characteristics of Earth disasters of slopelands

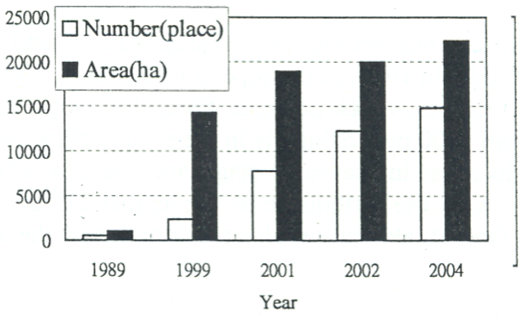
According to the earth disaster information investigated by The Soil and Water Conservation Bureau with the middle region area of Taiwan as the study range over the years, it covers seven cities and counties, namely Miaoli County, Taichung City and Taichung County, Nantou County, Changhua County, Yunlin County, Chiayi County and etc. The disaster cases are totaled to 32761 cases of slope failure and 385 cases of debris flow, which is used to carry out the discussion of information space distribution and the difference of time changing condition.

1.Slope failure and Landslide

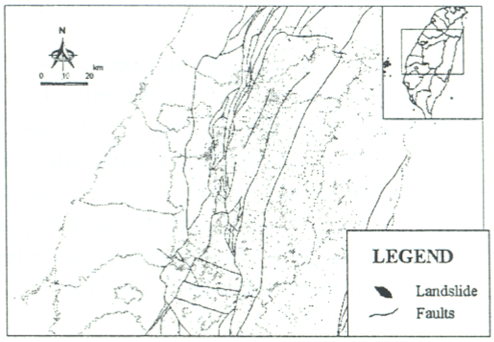
The slope failure statistics of middle region of Taiwan in each different stage is as shown in Table 1, and the occurrence site distribution is as shown in Figure 7. The data shows that in these recent two decades, slope failure number and area of middle region is increasing year by year, which increases rapidly especially after the earthquake event on September 21st. The slope failure number after earthquake is sixteen-folds before the earthquake, and the slope failured area displays the increment by small margin due to the influence of plants planting coverage.

Table 1 Table of different slope failure number and area statistics in middle region area of each stage

Time	Slope failure Number (Places)	Slope failure Area (Hectares)	Year Increasing Amount (Places)	Year Increasing Area (Hectares)
1989	567	1077	-	-
1999	2365	14347	180	1327
2001	7772	18936	2704	2295
2002	12274	20004	4502	1068
2004	14863	22362	1295	1179



(a)



(b)

Fig. 7 Changes in number and area of Slope failure over the years

By comparing and analyzing the slope failure information according to elevation of slope failure top, gradient and slope failure scale, this article further discusses the slope failure distribution and changing condition.

(1) Elevation

Since the altitude difference of Taiwan area is large, the natural environment will also differ accordingly and influence the occurrence of slope failure.

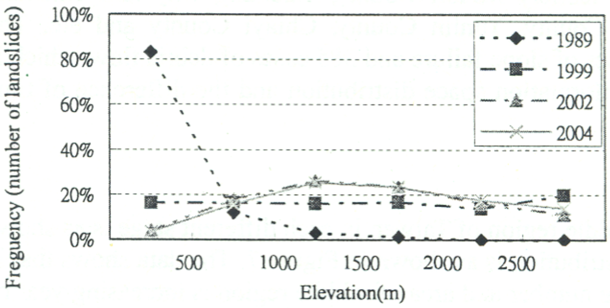


Fig. 8 Slope failure amount altitude distribution diagram in different period

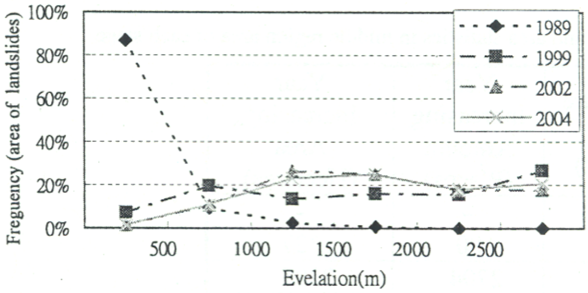


Fig. 9 Slope failure area altitude distribution diagram in different period

From the abovementioned information, the number and area of slope failure land does not increase with the increment of altitude. In 1989, most slope failure amount and area are distributed at the area below 500 meters, which occupies 86%. The slope failure with more than 500 meters but less than 1000 meters high is in the second place, which should be the slope failure record location in the early stage and the low altitude mountainous area that adjoined plain. After the earthquake on September 21st in 1999, many active faults with altitude less than 1000m causes slope failure, hence the slope failures number increases a lot.

(2) Slope

Generally speaking, steeper slope makes slope failure easier. At the indicated altitude of Taiwan area that is more than 100m, the area gradient that is larger than 30° occupies 43% （Wang-S, 1989）. The opportunity of these area to occur slope failure is larger.

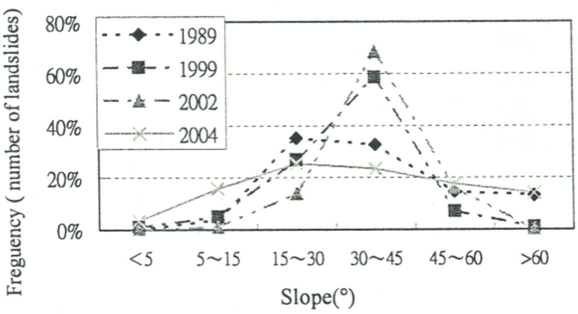


Fig. 10 Slope failure number gradient distribution diagram in different period

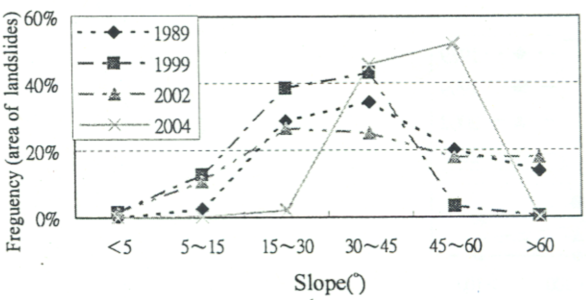


Fig. 11 Slope failure area gradient distribution diagram in different period

From the abovementioned information, the slope failure land number and area apparently increases at the gradient more than 30°, and the steeper slope is easier to induce slope failure. But as for large area of slope failure, the gradient distribution range of slope failure occurrence caused by earthquake on September 21st is large and the gradient is 15~45° gentler. While the gradient distribution range caused by the rainfall brought of typhoon is smaller and the gradient is 30~60° steeper.

(3) Scale

Slope failure scale influences the amount of earth source downstream. If the slope failure area is larger, the debris flow occurrence opportunity in downstream is also higher.

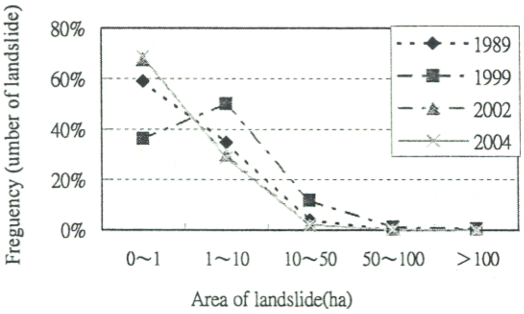


Fig. 12 Slope failure number scale distribution diagram in different period

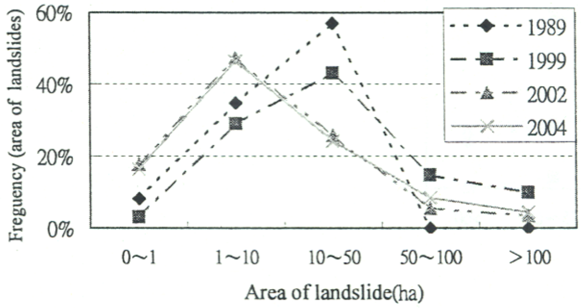


Fig. 13 Slope failure area scale distribution diagram in different period

The number of slope failure scale smaller than 1 hectare is the most, it occupies the most of the whole amount (about 80%), but most are the newly added slope failure caused by torrential rain, which enlarging opportunity is not high. On the contrary, the slope failure land larger than 1 hectare, which shares only 20% of slope failure number, occupies 70% of the slope failure area, and the slope failures will reoccur and cause disaster in the future. Therefore, related unit should pay more attention to the slope failure land, which area is larger than 1 hectare.

2.Debris flow

The stream statistics of middle region of Taiwan that occurs debris flow in different period is shown in Figure 2 with occurrence location as shown in Figure 14. From the information, debris flow increment number between 1999~ 2001 is the most and most are occurrence for the first time, which shows that the earthquake result on September 21st is continuously influencing. Due to the increment of management fund invested by related units, the newly added debris flow number reduces by a large margin since 2001.

Table 2 Debris flow changing condition and distribution diagram of middle region over the years

Time	Period Amount (places)	Accumulated Amount (places)	Increasing Amount (places)	Recurrence Amount (places)
<1996	73	73	73	-
1996~1999	102	175	88	14
1999~2001	133	308	125	8
>2001	27	335	15	12

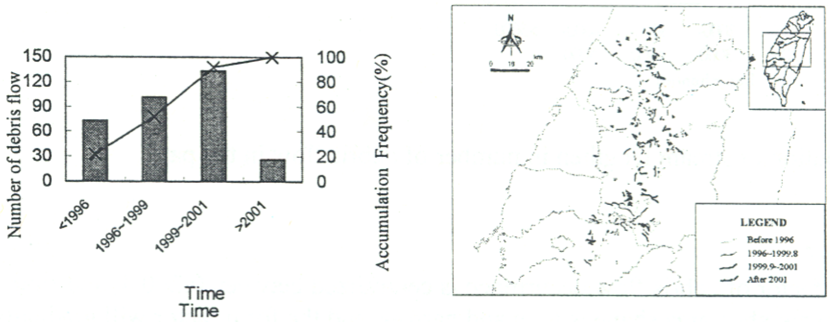


Fig. 14 Distribution time and location of debris flow in central Taiwan

The terrain characteristics of streams that occur debris flow are more obvious than slope failure. This article divides them into four items, namely watershed area, stream length, form factor and deposition gradient:

(1) Watershed area

The watershed area that occurs debris flow is centralized in the range between 0.1~0.5km^2 and 1~5km^2. The occurrence sites conjectured from the areas are located on the slope face and stream respectively. The watershed area of the newly added debris flow after the Typhoon Herb in 1996 are 0.1~0.5km^2 as the majority.

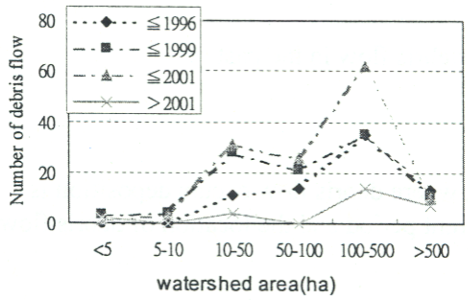


Fig. 15 Distribution of watershed area in number of debris flow in the past

(2) Stream Length

The stream length of 1000~2000m is the most. The stream length after Typhoon Herb in

1996 is 0~2000m as the most.

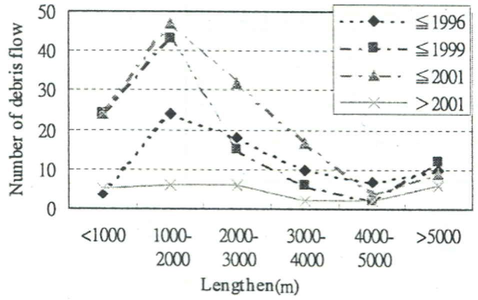


Fig. 16 Distribution of stream lengthen in number of debris flow in the past

(3) Form factor

The form factor of debris flow occurrence is centralized between 0.2~0.4, and from this inference, the watershed area shape is long and narrow, and the form factor will gradually increase every year.

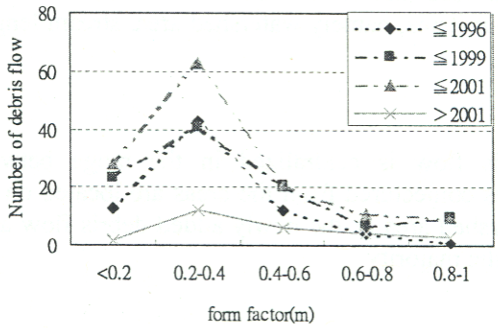


Fig. 17 Distribution of form factor in number of debris flow in the past

(4) stream gradient

According to statistics, the stream gradient, where debris flow occurs deposition is between 6~28° with 10~15° as the most. Different period and the location of debris flow do not have large influence on stream gradient.

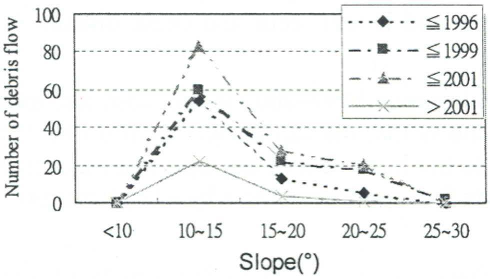


Fig. 18 Distribution of slope in number of debris flow in the past

Tab 3. The average value comparison of debris flow terrain characteristics over the years.

Year	Watershed area (ha)	Stream lengthen (m)	Form factor	Stream gradient (°)
<1996	375	3096	0.32	14.8
1996~1999	244	2361	0.41	16.1
1999~2001	206	2272	0.41	15.8
>2001	557	3267	0.45	14.6

CONCLUSIONS

1. Typhoon average disaster occurrence in Taiwan area is 3.6 times every year, torrential rain disaster is 0.8 times, earthquake disaster is 0.4 times, which cause the society problem with the average death of 126 persons and 35 persons missing every year.
2. The disasters in the early period (before 1996) are mostly landslide and slope failure, and occurrence locations are mostly located at the east region and north region of Taiwan. It may be related to bad geology and steeper topography of east region and precipitous landforms and early city development of north region. After Typhoon Herb caused large-scale earth disaster occurrence in Nantou County in1996, debris flow had changed from the original fragmentary distribution into regional distribution in the middle region of Taiwan. Since the earthquake on September 21st of 1999, the whole Taiwan Island will all have disaster whenever typhoon comes invading.
3. By comparing the interrelations between disaster cause and type, the debris flow caused by typhoon and torrential rain, slope failure caused by earthquake, and the landslides caused by continuous rainfall are the most apparent.
4. In these recent years, slope failure number and area of middle region of Taiwan is increasing year by year, which increases rapidly especially after the earthquake event on September 21st. The slope failure number after earthquake is sixteen-folds before the earthquake, and the area of slope failure displays the increment by small margin due to the influence of plants planting coverage.
5. Although the number of slope failure scope smaller than 1 hectare is the most, most of them have smaller opportunity to enlarge. On the contrary, the slope failure

number of the area larger than 1 hectare that shares only 20% of slope failure number, occupies 70% of the slope failure area and it will recur and cause disaster in the future.

6. The increasing number of debris flow between 1999~2001 is the most, and most of them occur for the first time, which shows that the earthquake result on September 21st is continuously influencing. Due to the increment of management fund invested by related units, the newly added debris flow number reduces by a large margin since 2001.
7. Debris flow has more significant characteristics, such as the watershed area is centralized in the range between 0.1~0.5km^2 and 1~5km^2, the stream length of 1000~2000m is the most, the form factor of watershed area centralizes between 0.2~0.4, and the stream gradient of 10~15° is the most.

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