THE DISCUSS ON THE SEDIMENT DISASTERS CAUSED REASON IN HAOCHA TRIBE AREA

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ABSTRACT

From 2005 to 2008 series of typhoons and heavy rainfall makes Haocha tribe suffered serious landslide, debris flow and flood disasters. Investigate and to discuss the history of disasters, environment geology, reasons of disasters and changes of river in this research. Study found that disasters caused by the excessive rainfall, bad environmental geological conductions, adverse drainage system, narrow river cross section and different stream depth, which were made the stream deeper, serious vertical and horizontal expansion erosion. As well as this tribe located in the deposit layer by the stream side, houses close to stream bank and hillside as inadequate buffer distance of such factors. Due to near 4 years precipitation data analyzed result, the annual precipitation in rainy season more than other region of Taiwan. With the result Haocha tribe was surrounding geological conditions become more vulnerable and susceptible to erosion or landslide disaster. The sediments were transported from watershed upstream to downstream, not only to raise the stream bed, but also to change the topography, especially in narrow and curves area due to flood erosion.

Key Words: Typhoon, Sediment disaster, River depositing, Environment geology

INTRODUCTION

Since the Haocha tribe in Wutai Township, Pingtung County suffered Typhoon Haitang in July 2005, the ground and surface soils became soft and have disintegrated. Situated at steep mountainous area, the slope there became more susceptible to erosion and landslide, and bare. The typhoon and torrential rain in August 2007 severely hit Haocha tribe again, especially the 0809 flood disaster, 0813 torrential rain, Typhoon Sepat, and continuous torrential rains (Pingtung County Government, 2007a). After having experienced the natural disasters, Haocha tribe is likely to face disasters, such as flood, landslide, and debris in the future. In order to avoid occurrence of secondary disasters, government bureaus have focused on post-disaster restoration. Based on the investigation of relocation outline plan of Haocao tribe, the indigenous villages of Pingtung County with potential danger after preliminary evaluation in 2007 included Chilu Village, Haocha Village, Dashe Village and Jiaping Village. Pingtung County Government proposed the village relocation plan to the Council of Indigenous Peoples in the same year due to inadequate building land or disasters in the area (Pingtung County Government, 2007b). The Haocha tribe is one of the villages under the urgency of relocation. Regarding the village relocation plan, the authorities have order to conducted

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safety evaluation of surrounding environment before verification of urgency of relocation. Since occurrence of landslip of Typhoon Herb in 1996, 0813 torrential rain in 2007 and Typhoon Sepat, Haocha tribe has suffered many disasters over the past decade, which have led to great impact on the tribe safety. The 0513 storm and Typhoon Kalmaegi in July in 2008 destructed temporary access road, and residents had to take the risk of crossing a river or riding by transport cage. Based on expert review on the site, it is agreed that the transportation and tribe safety should be evaluated cautiously. This study focused on the threats posed by historical disasters and tribe restoration, and discusses the history of disasters, environment geology, characteristics of regional loamy sand, and slope stability analysis.

MATERIALS AND METHODS

Research area

1. Location

Haocha tribe is located at Wutai Township of Pingtung County. Wutai Township is the only township belonging to Ailiaonan River. It is adjacent to Dawu Mt. and Wutou Mt. in the east, northwest branch of Dawu Mt. and Taiwu Township in the southwest, faces Ailiao River in the west and faces Majia Township Paiwan Village, and adjacent to Jinbu Mt. and Wutai Mt. in the north. The topography of the village is the lowering slope of north towards south. The major access road can be accessed by Provincial Line 24 and Pingtung County Road 187 at Taiwan Indigenous Peoples Cultural Park in Majia Township. Haocha tribe can be accessed from 7 km via the road in Cultural Park (Fig. 1).

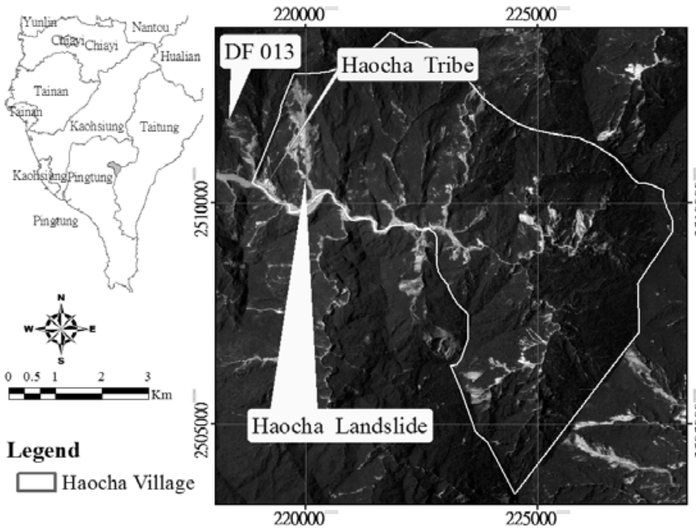

Fig. 1 Location of the research area

2. Topography and geological

The Haocha tribe is located at river terrace, covering an area of about 10 ha, with an average gradient of 11.78%, belonging to the Grade II slope. However, the mountain group back on to the tribe has the steep slope of Grade IV. The general stratigraphy consists of Lushan formation and Sulo formation. It’s the collective term of Miocene Tananao schist within the outcropped Central Mountains, and comprise of cinereous slate, hard-shale, phyllite and metamorphic sandstone. They have no strata sequence. Moreover developed water systems closed to ridge of Central Mountains are scattered, and lithology chiefly is consisted of metamorphic sandstone.

Research methods

This study collected the environment geology map of Majia Village and Haochao area, Pingtung County, plotted by Energy and Environment Research Institute of ITRI, as entrusted by the Construction and Planning Agency, from 2005 to 2008. It discussed the general environment geology of the research area, conducted statistic analysis of the actual precipitation data to understand the rainfall characteristics, and employed the 3S technique (Lei *et. al*, 2001; Tsai *et. al*, 2006;) to discuss the topography change and the effect of loamy sand siltation on the tribe safety, in order to understand the disaster situations and possible subsequent impacts. The analysis data were sourced from the field survey and analysis records or the data provided by relevant units. In order to know the stabilization of slope closed to the mountains, stabilization analysis was conducted for the slope suffered the landslide and debris flow, in order to find out the potential danger in the surrounding environment Haocha tribe. (Jan, 1994; Ou Yang, 2003)

RESULTS AND DISCUSSION

Environmental characteristics

1. Disaster history

Taiwan faces frequent torrential rains, flood disasters, earthquakes and sediment disasters. The north side of the Haocha tribe is adjacent to the mountains, and soil on the slope surface has been weathered and softened due to rain erosion. Under continuous rain, soil would suffer saturated softening or even landslide or debris flow. Understanding the disaster history can provide a useful reference to engineering planning and strategy formulation. Table 1 summarizes the disaster situations which occurred in the surrounding environment of Haocha tribe in recent years (Pingtung County Government, 2009a).

Table 1 Disaster history of the study area aggregate

Date	Disaster situation
1996.07.31	Typhoon Herb resulted in strong torrential rain. The access road was obstructed in Haocha village due to the disaster, bridge was broken for the first time, some houses in the tribe were buried due to debris flow, and four persons were dead.
2005.07.18	Typhoon Haitang caused torrential rain. The Haocha tribe suffered landslide, with large landslide area in the lower region, and the area was about 65 ha; sediment disaster in Ailiaonan river was aggravated.
2006.07.14	When Typhoon Bilis occurred, the Haocha bridge was broken again, and the access roads were obstructed in many sections, and the Pingtung County DF013 potential stream cause sediment disaster.
2007.08.09	The continuous torrential rain softened the soil layer, and debris on the slope was moved downwards. The sediment in river course increased, which is the reason for aggravation of disasters of 0813 and Typhoon Sepat.
2007.08.13	The Typhoon Wutip accompanied with southwest air current resulted in continuous torrential rain, Pingtung County DF013 potential stream occurred debris flow. The debris on the slope at north side of the tribe flowed to the tribe, and the Ailiaonan river at the south side rose and encroached to the houses nearby. The access road foundation was empty, and the road was obstructed, the river was blocked. The Babagu Bay area in the Cultural Park suffered landslide, and the height of the collapsed accumulated earth was about 8~10m.
2007.08.16	Typhoon Sepat expanded the disaster situations in Haocha tribe.
2008.05.31	Coincided with the rainy season, the Central Weather Bureau issued the report of torrential rain, the continuous torrential rain (05/28~06/05) destroyed the temporary access road at Ailiaonan river in the Haocha tribe.
2008.07.17	Typhoon Kalmaegi with torrential rain destroyed the temporary access road built in early July.

2. Rainfall characteristics

The historical disasters and rainfall changes can provide a basis for estimating the occurrence frequency of future disasters, and serve as one of the factors for evaluation of tribe safety. The rainfall station that is closest to the Haocha tribe is the New Majia station (01Q920). This station has gathered the historical precipitation data for 33 years (1976~2008). Fig. 2 shows the rainfall trends of New Majia rainfall station for 33 years. The average annual precipitation is around 4187.7mm. In five years, the annual precipitation exceeded 5000mm, over the 30-year period. However, since 2005, the annual precipitation exceeded 5000mm in four consecutive years, and the highest precipitation reached 8253mm, which is 2 times higher than the historical average. The abnormally high precipitation in 2005 was due to the precipitation of 2630 mm in July (Fig. 3), which is 3 times of the average precipitation in July in the previous 33 years, as Typhoon Haitang (2005/07/18~2005/07/22) resulted in the precipitation of 2605mm. The heavy rainfall resulted in slope landslide in surrounding tribes.

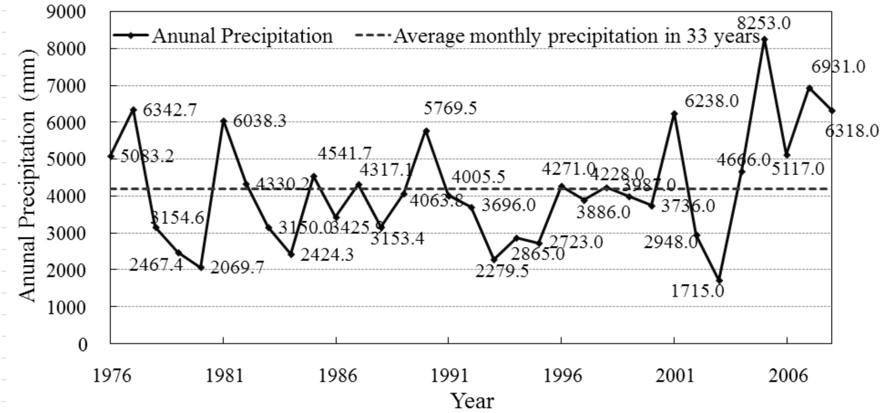

Fig. 2 Precipitation trends of New Majia rainfall station for 33 years

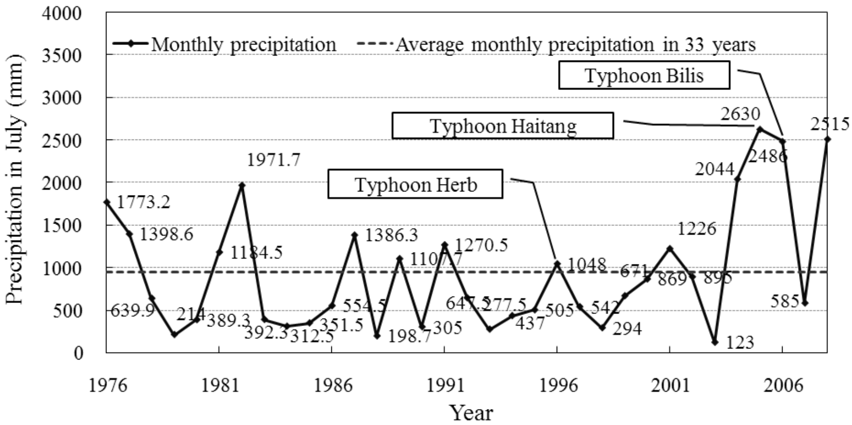

Fig. 3 Precipitation trends of New Majia rainfall station for 33 years in July

The precipitation was 2486mm in July 2006, and worsened the previous landslide around the tribe. Large amount of the collapsed debris accumulated in Ailiaonan River, and landslide occurred in the places around the river. The 2006 Hengchun Earthquake made the surface rock looser. The 0809 Flood in 2007, 0813 torrential rain and Typhoon Sepat resulted in a precipitation of 3706mm in August (Fig. 4), which was 4 times of the average precipitation in August over the past 33 years. Typhoon Sepat (2007/08/08~2007/08/16) caused precipitation of 1792mm. On August 13, the precipitation was up to over 1000mm. The Haocha tribe suffered very serious sediment disaster. (Hsu and Dai, 2008)

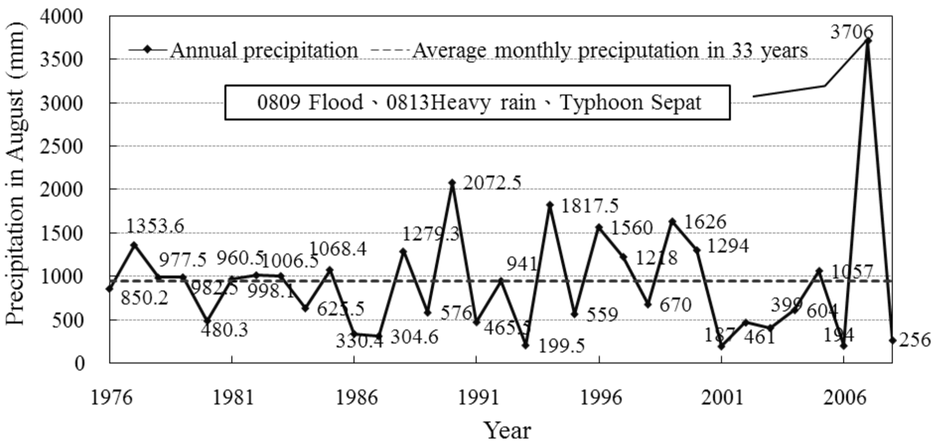

Fig. 4 Precipitation trends of New Majia rainfall station for 33 years in August

Generally, when accumulated rainfall ranges from 50 to 160mm and daily rainfall is over 200mm, minor landslide may occur. When accumulated rainfall is over 150mm and daily rainfall is 100mm, medium accumulated layer landslide and debris landslide are more likely to occur with increase of rainfall. Large landslide would take place when accumulated rainfall is 200~350mm and daily rainfall is more than 110mm (Wang *et al.*, 2006). Chen and Jan (2004) analyzed the flood on July 2 and slope landslide, and proposed the percentage relationship between the rainfall intensity or accumulated rainfall and the amount and percentage of slopes collapsed; namely 33% of slopes would collapse when the rainfall intensity is 80~100mm/hr, and 36.7% of slopes would collapse when accumulated rainfall reaches 600~800mm. Landslide is more likely to occur when the accumulated rainfall exceeds 800mm.

According to the rainfall data from the New Majia rainfall station, the accumulated rainfall from July 17 to 22 in 2005 reached over 2600mm, and daily rainfall was up to 1030mm on July 18, the highest hourly precipitation reached 68mm/hr. From August 7 to 15, and August 17 to 26 in 2007, the accumulated rainfall was more than 1800mm, and the day accumulated rainfall was up to 1119mm on the day of August 13, and highest hourly precipitation reached 113mm. The day accumulated rainfall was 995mm on August 19, and highest hourly precipitation reached 94mm. Hence, Typhoon Haitang, 0813 Torrential rain and Typhoon Sepat can result in slope landslide or sediment disaster.

3. Environmental and geological characteristics

According to the environment geology map F6655SH2210-DI-0061 Drawing No.9518-Ⅲ-028 and F626WR2210-DI-0061 Drawing No. 9518-Ⅲ-029 of Majia village and Haocha area, Pingtung County plotted by ITRI, the environment geology chiefly covered by the two maps is Miocene Lushan formation (MI), consisting of slate, hard-shale and metamorphic sandstone. The environment geology around the major access road in the Haocha area mainly comprises of slate, thin interbed of shale and sandstone, with thick sandstone. The environment geology of rear Haocha No.2 Bridge to the Haocha tribe is composed of thick layer of slate, occasionally with thin to middle layer of metamorphic sandstone. The tribe is just sited at the Pleistocene terrace accumulative formation (Qt), comprising of gravel, slate rocks, debris, sand and soil.

The potential stream of Pingtung County DF013 debris flow suffered bank erosion, with the slope erosion due to rainfall, which caused shallow landslide and other geological disasters. Colluvial soil accumulates in the catchment area of the potential stream. The large landslide also has the bank erosion problem, but the main reason is abundant rain. After field survey, the large landslide still continues retrogressive erosion. The disaster pattern of the connective road in Haocha tribe mainly include landslide and gully erosion, and the bank of the Ailiaonan River suffered stream erosion. The sediment in the upstream of the Haocha Bridge flows to the downstream with the flood, causing the bank erosion at concave bank at the left side of the river, the contracted cross-section passing through stream bend increase water flow and erosion. The sediment accumulated in the upstream and downstream is not easy to transport and move downwards.

The stream erosion is caused by water (including surface runoff) flowing from upper to lower. The flowing water can move some fine sand which is the tool of eroding river bed or slopes at the both banks, and can deepen, widen and lengthen the erosion of the land. The deepening is the vertical erosion, forming the eroded gully on the bare ground. The widening is the lateral erosion, the lengthening is the downcutting which result in sinking of erosion basis, and stream extends toward the upstream for balance. This expansion towards the upstream is regressive erosion. The regressive erosion is often accompanied with landslide. The continuous landslide means sediment is transported towards downstream, without subsidence over many years. At last the terrain of concave slope like spoon forms at upstream of the tributary. The gully erosion often occurs at the steep slope, and extension direction is the same with the slope direction, strip eroded gullies occur on the slope surface, and sediment can be found within the gullies. The upper slope of the eroded gullies is likely to suffer landslide. The eroded gullies often develop the slope of valley banks, and are tree-like or groove-shaped. Generally, stream erosion often changes the landform gently, and its harmfulness is not observed easily. However stream erosion is the main disaster cause of landslide if torrential rain or typhoon and precipitation occur. Thus stream erosion is the geological disaster which should not be neglected.

The slope surface at north side of the Haocha tribe and the large landslide geology of Haocha belong to colluvial soil. Its structure is rather irregular, largely composed of rocks, silt, clay and even organic substances, and characteristics of it varies greatly and is difficult to determine. The inner structure is loose, and water-permeable; but the surface soil layer is impermeable because of weathering and growth of plants (Hung, 2007). After landslide, the slope became more moderate, but colluvial soil can make the underground water pressure increase, which is adverse to slope stability. The safety coefficient of the slope stability of such geological structure tends to 1. Heavy rainfall can cause small landslide, more entire colluvium avalanche.

4. Topographic changes

After Haocha tribe experienced many disasters, the environment has been changed obviously by baptism of the nature. This study conducted analysis of changes of Ailiaonan river and its main stream by right of the Aerial photo in 2003 and the Formosat-II photo in 2006~2008 (Fig. 5 and Fig. 6), and selected 9 river cross sections for comparison of changes in different periods. Table 2 shows the river width changes in different periods, and it can be found that widths of the cross sections 3, 5 and 9 have greater difference before 2006. After 2006, the cross sections 4, 8 and 9 became wider, the most obvious one is the cross sections 8 where the site of old pavilion in Haocha tribe was located, and the rate of change is about 4 times. It is obvious that Ailiaonan river cross section closed to Haocha tribe was too narrow, but after flood erosion and scouring of levee or bank, the cross section becomes wider and threatens the river terrace area in the Haocha tribe.

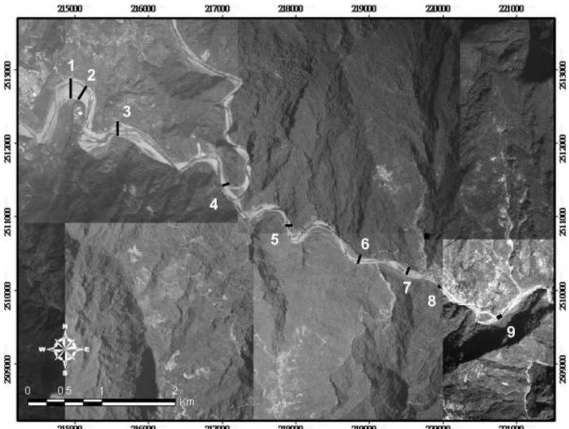

Fig. 5 Aerial photo in 2003

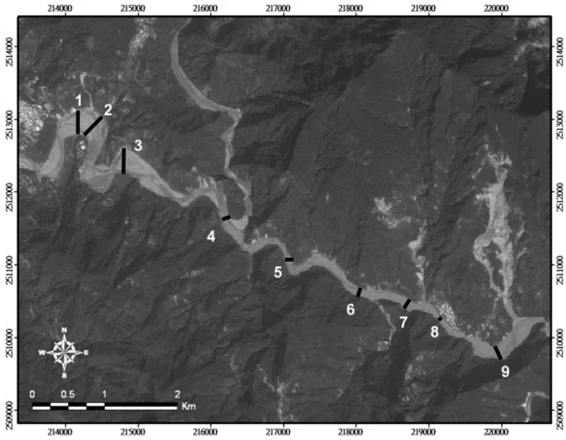

Fig. 6 Formosat-II photo in 2008

Table 2 Comparison of stream changes for Ailiaonan river (Unit: m)

Section	2003 Aerial Photo	2006 Formosat- II	2007 Formosat- II	2008 Formosat- II
Section 1- bending section 1 of Ailiao river	285	307	307	307
Section 2- bending section 2 of Ailiao river	230	360	360	360
Section 3- Ailiao river	208	375	390	390
Section 4- Ailiaobe river and Ailiaonan river	75	100	185	215
Section 5- Haocha bridge	60	120	126	140
Section 6- Ailiaonan river	77	120	127	131
Section 7- downstream of Pingtung Countu DF013 potential stream and Ailiaonan river	100	141	149	152
Section 8- the site of old pavilion in Haocha tribe	20	25	78	80
Section 9-the pocket of downstream at Haocha landslide	75	160	190	192

Investigation and analysis of sediment disasters

The abundant rainfall made Haocha tribe suffered landslide, debris flow, slope erosion, river depositing, and other sediment disasters. The sediment volume is estimated based on the field investigation data of landslide area, quantification adopts remote sensing (Figs.7 and 8), and sediment yield can be estimated by right of field investigation; the average landslide depth of the area is estimated on site, or referenced to past studies (Table 3).

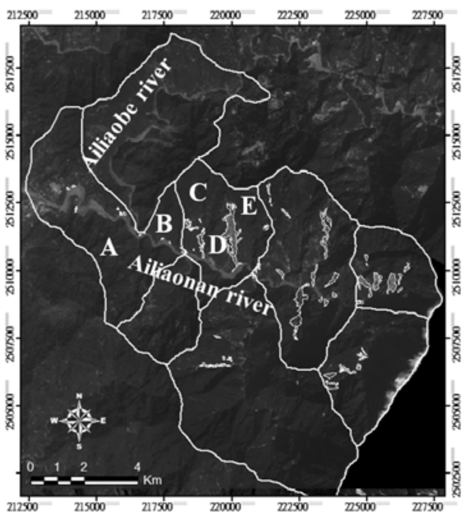

Fig. 7 Landslides area in 2006

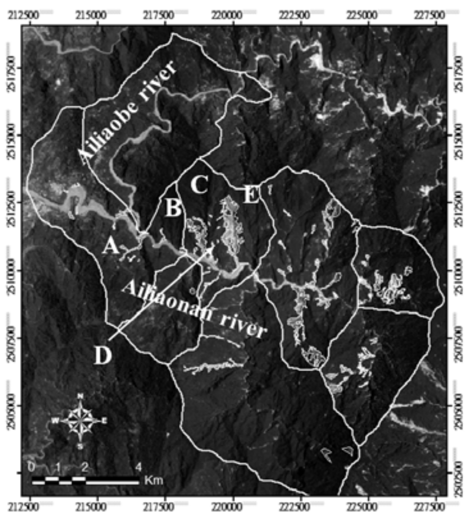

Fig. 8 Landslides area in 2008

Table 3 shows the estimated results of landslide area and volume of landslide. The sediment yield of the landslide area is calculated by the equation below, i.e. $V_\ell = D \times A_\ell$; where V_ℓ =sediment volume, A_ℓ =landslide area (projected area), D =average collapse depth.

Table 3 Comparison of landslide changes for Ailiaonan river

Point	Landslide Area(ha)		Volume of Landslide (10^4 m^3)	
	2006	2008	2006	2008
Point A- Shihzih bridge	0.00	10.78	0.00	22.48
Point B- the slope of main road	0.56	2.24	0.20	1.50
Point C- Pingtung County DF013 potential stream	15.46	32.60	27.10	60.00
Point D- two landslides of the rear Haocha tribe	0.00	3.67	0.00	5.74
Point E- the serious landslide in eastern side of Haocha tribe	58.41	91.40	160.63	274.00
Total volume of landslide in Ailiaonan river	232.97	394.17	330.92	589.93

Slope stability analysis

The slope stability is an important indicator when evaluating the potential danger of the slope in this area. In order to stability of the slope in the northern side of Haocha tribe, this study utilized STABL for analysis. No physical tests and drilling investigation were conducted for Haocha tribe, so the geological drilling report from the adjacent area was gathered. In combination with soil characteristics and field investigation, suitable mechanical parameters can be estimated for analysis of slope stability. The A-A' and B-B' profile in Fig. 9 shows the slope location analysis.

Fig. 9 Slope stability analysis to select the location profile diagram

In accordance with #2 drilling and test parameters (BCP, 2008; Pingtung County Government, 2009b), the characteristics of soil layer of Haocha tribe is similar with Wutan village, but the surface colluvial soil is similar with the slope soil of Cultural Park. Table 4 shows the parameters of Haocha tribe. The difference between peak cohesiveness (Cp) and residual cohesiveness (Cr) is significant, and the safety coefficient is related to cohesiveness. If rock cleavage is develop, weathering would increase, rocky releases joints, and cohesiveness of rock stratum would weaken gradually. In order to know the slope stability characteristics of the rear Haocha tribe, different cohesiveness values are used. Analysis was conducted for the slope stability after earthquake and torrential rain. The results indicate that the safety coefficient of slope in different states increases with increase of cohesiveness (Table 5). In terms of the analysis results, surface colluvial soil in Haocha tribe was weathered and the cohesiveness approaches the residual cohesiveness. In case of earthquake and torrential rain, landslide or erosion is likely to occur. However, the correlation between weathering, joint release, and cohesiveness has not been further discussed in this study.

Table 4 The stratum characteristics and mechanical parameters

Area	Depth/ Thichness(m)	Geological	Formation characteristics	γ_t (t/m^3)	Ø' (deg)	C' (kg/cm^2)
Taiwan Indigenous Peoples Cultural Park	11.0	Alluvium (Q_6)	Medium silt sand (Colluvium)	2.09	28.6	0.0
	1.8		Medium sand (Colluvium)	2.30	34.0	0.0
	13.2		shale with broken rocks	2.21	-	-
Wutan Village	8.7	Lushan Formation (MI)	Grizzly shale, broken joints, weak lithology	1.63	-	-
	11.3		Grizzly shale	2.71	Øp=30.8 Ør=28.7	Cp=12.38 Cr=1.40
Haocha tribe	2.0	Lushan Formation (MI)	Thick layer of shale, with occasionally with thin to middle layer of metasandstone (Colluvium)	2.20	28.6	0
	-			2.46	30.8	1.4~12.38

Table 5 The result of stability analysis

Cohesiveness C' (kg/cm^2)	A-A' profile (F.S)			B-B' profile (F.S)		
	Peacetime	Earthquake	Heavy rain	Peacetime	Earthquake	Heavy rain
1.40	1.11	1.03	0.72	1.27	1.04	0.86
1.80	1.32	1.25	0.92	1.39	1.15	0.98
2.00	1.43	1.36	1.03	1.46	1.21	1.03
3.00	1.99	1.96	1.56	1.75	1.49	1.32
4.00	2.57	2.55	2.12	2.06	1.78	1.60
5.00	3.15	3.15	2.68	2.36	2.06	1.89
6.00	3.74	3.77	3.25	2.67	2.35	2.19

Haocha tribe is located at the river terrace area where rainfall is abundant. The rain water that penetrates the ground becomes underground water, which weakens soil cohesiveness or friction, and penetrates rock joints or bedding surface. The water pressure increases joint or makes rock stratum lose balance, and reduce the stratum stability. As a result, the slope slides and structures are damaged. The analysis results indicate that slope stability of Haocha tribe is related to rainfall characteristics.

CONCLUSIONS

1. The disasters were caused by the excessive rainfall, poor environmental geological conductions, adverse drainage system, narrow river cross section and different stream depth, inadequate buffer distance of houses from stream bank and hillside. Furtherre, after torrential rain, the topography of Ailiaonan river changed obviously and bending section became more susceptible to erosion.
2. Haocha No.2 Bridge connects the downstream of Ailiaonan river. Due to debris flow, the sediment accumulated at the downstream of bridge resulted in river depositing. It's inferred that sediments transported. In addition, the pocket of downstream at Haocha landslide formed, it provided the deposition area for sediments transported; in case of heavy rainfall, the sediments moved towards, which threatened safety of Haocha tribe.
3. According to historical rainfall and causes of disasters, when daily rainfall reached 800mm, hillside of Haocha area was prone to landslide. Pingtung County Emergency Response Center can set the rainfall warning value as 600mm, and evacuation value as 800mm in hillside emergency response mechanism.

4. The sediment volume increased due to landslide and erosion, affecting river pipelines, engineering construction and catchment area. In order to accurately estimate sediment volume, aerial photography and measurement can be conducted for Ailiaonan river to acquire new DTM data and compare with old data.
5. Restoration and relocation plan for a tribe has not been decided clearly. The landslide, flood and sediments are the main potential disasters. Therefore the consciousness of organization of disaster prevention in the area should be strengthened to raise disaster prevention capability.

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