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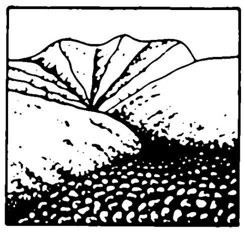

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При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).
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Risk assessment of potential debris flows in the watershed of the Chen-Yu-Lan River

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Оценка риска потенциальных селевых потоков в бассейне реки Чен-Ю-Лан

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Селевые потоки, вызванные тайфуном Торайи, привели к большим жертвам и тяжелому экономическому ущербу для собственности в бассейне реки Чен-Ю-Лан в области Нанту, Тайвань. В данной работе рассматриваются потенциальные очаги селевых потоков в бассейне р. Чен-Ю-Лан, избранном Советом сельского хозяйства в качестве ключевого участка исследований. Для построения базы данных по факторам, вносящим вклад в возникновение селевого потока, использовались программное обеспечение ArcView и WinGrid для геоинформационной системы (ГИС). Кроме того, с помощью Статистического пакета программного обеспечения социальных наук (SPSS) проведен многомерный факторный анализ баз данных по факторам, вносящим вклад в формирование селя. С помощью канонического дискриминантного анализа были отобраны 10 факторов, вносящих вклад в потенциал селевого водотока: площадь бассейна, средний уклон водосбора, форма, густота речной сети, повторяемость селей, извилистость, длина селевого русла, вегетационный индекс и уклон русла. Проведено сравнение этих аналитических результатов со случаями селевых потоков при тайфунах Херб и Торайи. Проверена процедура определения селевого потенциала водотоков с использованием ГИС для уменьшения селевой опасности и принятия административных решений. Это также обеспечит количественный метод анализа селей для соответствующего управления в будущем.

Debris flows caused by the Toraji typhoon have brought about heavy casualties and property losses within the Chen-Yu-Lan River watershed in Nan-Tou County, Taiwan. In the study, the potential debris flow creeks in the watershed of the Chen-Yu-Lan River, as announced by the Council of Agriculture, are chosen as the study sites. The ArcView and WinGrid geographic information system (GIS) software was used to build the databases of the contributing factors for debris-flow occurrences. Statistical Package for the Social Science (SPSS) software was used for factor analysis (FA) in multivariate statistics analysed from the databases of contributing factors. Through canonical discriminant analysis (CDA), ten contributing factors including watershed area, watershed mean slope of the major stream, form factor, river density, stream frequency, sinuosity, fault length in watershed, bare area, vegetation index and stream bed gradient were selected for estimating the hazard potential of debris-flow creeks. Through comparing these analytical results with the debris-flow cases in the typhoons Herb and Toraji, the procedures of defining potential debris-flow creeks and potential estimations using GIS in this study are verified to be suitable for hazards mitigation of debris flows and as policy references for the hillside developments. It can also provide a debris flow quantification method for the management in the future.

1 Introduction

After the 921 Chi-Chi earthquake, steep topography, weak geology, and slope land overuse caused frequent debris flow in mountain areas, in which people also suffered from debris flow during plum rains and typhoon seasons. In recent years, natural disasters such as landslides and mudflows usually occur in mountain areas during and after typhoon and rainstorm in Taiwan. Recently, a lot of debris flow disasters have occurred on the Chen-Yu-Lan stream. In this research, thirty creeks in the Chen-Yu-Lan watershed with potential debris flow announced by the Council of Agriculture (2001)were studied to verify the canonical discriminant function. It was found that the total correct percentage of the test samples is 83.3%. Besides, the potential of debris-flow creeks is classified into two categories: high potential and low potential, based on the discriminant scores. As comparing these analytical results with the debris-flow cases in typhoon Herb and Toraji, the procedures of defining potential debris-flow creeks and potential estimations using GIS in this study are verified to be suitable for hazards mitigation of debris flows and as policy references to the hillside developments.

2 Methodology

Thirty potential debris-flow creeks in the Chen-Yu-Lan watershed were investigated. In this study, ten factors that govern debris flow were studied, including watershed area, watershed mean slope of the major stream, form factor, river density, stream frequency, sinuosity, fault length in watershed, bare area, vegetation index and stream bed gradient. Satellite images were used during different periods as combined with DTM data to establish the procedures suitable for landslide investigations in this watershed. SPSS was used for factor analysis (FA) in multivariate statistics analyzed from the databases of contributing common factors followed by canonical discriminant analysis, CDA by Fisher discriminant analysis.

Based on the canonical discriminant function using the module of canonical discriminant analysis in SPSS software on the samples, debris flows occurred in 12 creeks; whereas no debris flows were found in the other 12 creeks. Then, to verify the canonical discriminant function with the other 30 test samples of the creeks announced by the Council of Agriculture, the total correct percentages of the test samples is 83.3%.

3 Regional Overviews

The Chen-Yu-Lan watershed located within the areas of Hsin-Yi, Shuili and Luku towns of the Nantou county in Taiwan was investigated. It is near rectangular in shape, and Chen-Yu-Lan River is the main stream in the investigated area. The length of the river is 42.40 km, and watershed area is 45000 hectares (ha). The mean slope difference is 1/20, 3.7 times Chuoshuei River Basin. The area tilted from south-east to north-west is a straight rift valley with a typical sharp slope mountain as shown in Figure 1. Table 1 shows the slope form of Chen-Yu-Lan River. The downward erosion to waterbed is severe. In the study (Lee, Chyi-Tyi, 1996), the height (over 3000 m), sharp slope (6.75%) and wide waterbed (over 1 km) are the three features of Chen-Yu-Lan River.

Table 1. The slope form of Chen-Yu-Lan River valley.

Slope grade	Slope (%)	Area (ha)	Percentage %
first-grade slope	< 5	980	2.2
second-grade slope	5~15	1708	3.8
third-grade slope	15~30	2779	6.2
fourth-grade slope	30~40	3151	7
fifth-grade slope	40~55	7209	16.1
sixth-grade slope	> 55	28948	64.7
	total	44775	100
average slope 63.98%			

4 Results and discussions

In this study, the statistic analysis is based on the database generated by DTM, with threshold value of 120, together with the information provided by the Ministry of Interior Affair, in order to conclude the most accurate model.

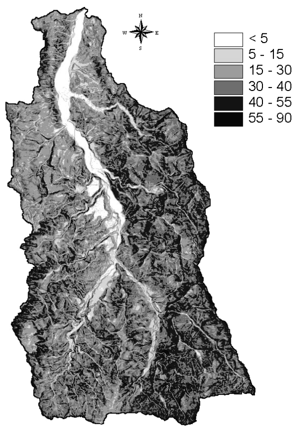

Fig. 1. The slope and area chart of Chen-Yu-Lan River valley.

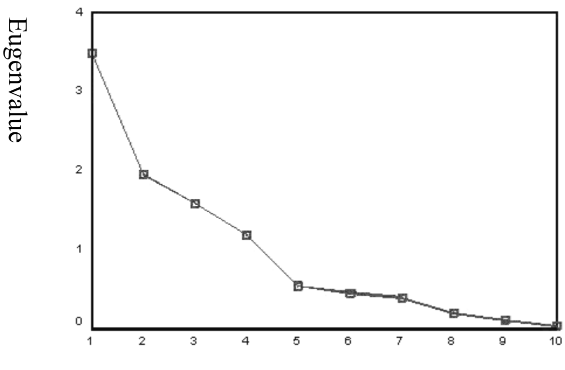

Fig. 2. Scree plot.

4.1 The simplification independence of influential factors

Table 2 lists all the selected factors, and further simplification were introduced to sort out those influential factors with the most significant effect. Factor analysis was used in this study to simplify vast number of factors into a few common factors.

Based on Kaiser's rule (Kaiser, 1960), using the matrix of varimax and keeping only those values greater than 1 for factor analysis, four factors were at last abstracted. From Figure 2, it shows the eigenvalue of the common factor 4 is 1.195 (>1) and the percentage of the 4 common factors in the total variation are 34.87%, 19.55%, 15.82% and 11.95%, respectively. Because the accumulated variation degree of these 4 common factors is summed up to 82.2% of the overall variation, these 4 factors could represent all influential factors.

The more the first common factor, the less the others. With this trend, the four factors: watershed area, sinuosity, bare area and fault length in watershed are categorized as the first common factor. The river density and stream bed gradient are the second common factor, while watershed mean slope of the major stream and vegetation index belong to the third. The fourth common factor includes the stream frequency and form factor.

4.2 The result of canonical discriminant

In this section, the common factors were applied to identify which creek exhibits the higher potential of debris flow. Creeks were categorized into: "1" the high potential debris flow creeks after the Toraji typhoon (H1-H12); and "0" the low potential debris flow creeks after the Toraji typhoon (N1-N12). After the factor analysis, the Canonical Discriminant Function could be obtained, which is shown in Table 3 and is defined as $D=0.579Y1+0.182Y2+0.830Y3-0.510Y4$

Using the Canonical Discriminant Function on the 30 high potential debris flow creeks announced by the Council of Agriculture, all but 5 are categorized as low potential debris flow creek, as listed in Table 5. The accuracy of this model is 83.3%. Those creeks causing property damages and casualties within Chen-Yu-Lan watershed have all been identified as high potential debris flow creeks (25 creeks). It shows that, with significant factors, great differentiation between high and low potential debris flow creeks can be obtained. The results are similar to the category made by the Council of Agriculture.

5 Conclusions

1. The Statistical Package for the Social Science software (SPSS) was used in multivariate statistics to analyze from the databases of contributing factors. It provides the procedures of defining potential debris-flow creeks and potential estimations using GIS, ArcView, WinGrid, to build the databases of the contributing factors for debris-flow occurrences. It is verified suitable for hazards mitigation of debris flows and serves as policy references to the hillside developments. It also can provide a quantitative method of debris flow for the related management in the future.

Table 2. Rotated factor matrix.

	Common factors			
	1	2	3	4
watershed area(km^2)	.98	2.72E-02	-1.22E-02	-.11
sinuosity	.96	3.33E-02	1.79E-02	4.7E-03
bare area (ha)	.90	-3.99E-02	3.45E-03	-5.76E-02
fault length in watershed (M)	.52	8.36E-02	.29	.14
river density	-8.7E-02	-.90	5.25E-02	6.7E-02
stream bed gradient (%)	2.9E-02	.70	8.23E-02	2.3E-02
watershed mean slope of the major stream (%)	-.16	.27	.69	-4.1E-02
vegetation conditions	.28	-.24	.68	-6.05E-02
stream frequency	4.3E-02	-8.3E-02	-2.60E-02	.93
form factor	-.36	.414	-.40	.48

Table 3. Coefficient of standardization discriminant function.

	D (Canonical Discriminant Function)
1st Common factor Y1	.579
2nd Common factor Y2	.182
3rd Common factor Y3	.830
4th Common factor Y4	-.510

Table 4. 30 high potential risk streams classification results.

			forecast		total
	Two kinds of groups		low potential risk stream [0]	high potential risk stream [1]	
original	Number	0	0	30	30
		1	30	0	30
	%	0	100	0	100
		1	0	100	100
Cross-validation (a)	Number	0	5	25	30
		1	25	5	30
	%	0	16.7	83.3	100.0
		1	83.3	16.7	100.0

2. According to the literature review, ten contributing factors were selected for estimating the potential of debris-flow creeks, including watershed area, watershed mean slope of the major stream, form factor, river density, stream frequency, sinuosity, fault length in watershed, bare area, vegetation index, stream bed gradient.

3. Factor analysis was used to condense multivariables into four common factors, which represents 82.2% of all variables.

4. The accuracy of the canonical discriminant function developed by multivariate analysis is 83.3% indicating that the results of this study can be used for risk analysis of debris flow.

5. The model of his study is believed to be of objective value due to its non-involvement of individual bias, which suggests that it be appropriate to estimate the potential of debris flow using this model.

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