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APPLICATION GIS AND REMOTE SENSINGTO ESTABLISH FLASH FLOOD HAZARD MAP IN TUYEN QUANG PROVINCE

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Abstract

Tuyen Quang is one of the provinces at high risk of flash floods in the Northern Midlands and Mountains of Vietnam. In the rainy season, like other localities in the region, Tuyen Quang has a long, concentrated rainfall combined with steep hills and mountains, large divisions, many rivers, and streams; In addition, the thinning of the vegetation cover due to excessive exploitation of the forest by the local people causes flash floods to appear more and more. Applying GIS and remote sensing to establish a map of flash flood risk is a quantitative approach and high reliability. This article has established a flash flood hazard map at a scale of 1/100,000 in Tuyen Quang province. In the map database, districts with a high risk of flash flood were identified, including Na Hang, Chiem Hoa, Ham Yen, and Lam Binh, the average flash flood hazard level included districts: Yen Son, Son Duong; Tuyen Quang city has a low risk of flash floods.

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ỨNG DỤNG HỆ THỐNG THÔNG TIN ĐỊA LÍ VÀ VIỄN THÁM ĐỂ THÀNH LẬP BẢN ĐỒ NGUY CƠ LŨ QUÉT TẠI TỈNH TUYÊN QUANG

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Tuyen Quang, nguy cơ lũ quét, thành lập bản đồ,ứng dụng GIS

Tóm tắt

Tuyên Quang là một trong những tỉnh có nguy cơ cao xảy ra lũ quét ở Trung du và miền núi phía Bắc Việt Nam. Về mùa mưa, cũng như các địa phương trong vùng, Tuyên Quang có lượng mưa tập trung lớn, kéo dài, kết hợp với địa hình đồi núi dốc, chia cắt lớn, nhiều sông suối; Ngoài ra, lớp phủ thực vật ngày càng mỏng do người dân khai thác rừng quá mức khiến lũ quét xuất hiện ngày càng nhiều. Ứng dụng GIS và viễn thám để thành lập bản đồ nguy cơ lũ quét là phương pháp tiếp cận định lượng và độ tin cậy cao. Bài báo này đã thành lập bản đồ nguy cơ lũ quét tỷ lệ 1/100.000 tỉnh Tuyên Quang. Trong cơ sở dữ liệu bản đồ đã xác định các huyện có nguy cơ lũ quét cấp cao gồm Na Hang, Chiêm Hóa, Hàm Yên, Lâm Bình, cấp độ nguy hiểm lũ quét trung bình gồm các huyện: Yên Sơn, Sơn Dương; Thành phố Tuyên Quang có nguy cơ lũ quét cấp thấp.

1. Introduction

Flash flood is a form of geological and hydrographic catastrophe with great devastation, causing serious consequences for the people. Tuyen Quang province is located in the northern mountainous region, the topography is quite steep and strongly divided. In addition, heavy rainfall, highly concentrated in the rainy season months, makes many areas at high risk of flash floods and landslides, especially in areas with devastated vegetation. Over the years, people here have always faced many risks of flash floods, along with property damage, changing the face of the landscape in the area. Nowadays, the application of GIS technology in flash flood research is becoming more popular and also brings many clear advantages.

Recently, there have been a number of research works related to the construction of flash flood warning models such as: Application of GIS and Remote Sensing in mapping the potential of flash flood in Son La Province, Vietnam by a team of authors from Faculty of Geography, Hanoi National University of Education; or Building an early warning system for flash flood in the mountainous area, a case study in Thuan Chau district, Son La province by a group of authors from Thuy loi University, University of Science, Vietnam National University, Hanoi Institute of Mechanism, Vietnam Academy of Science. These works have used methods such as the FFPI model, which is a quantitative model to determine the risk of flash flood generation based on the inherent characteristics of the study area such as

slope, soil texture, type land use, vegetation cover; or MCA multi-criteria integration model. This is a model that integrates hydrological and geomorphological models basin with the help of GIS technology.

In this paper, we use spatial data that can be modeled such as DEM, mean catchment slope map, landslide hazard map and mean annual precipitation map, combined with weights for each factor. The factors affecting flash flood by analytical hierarchical method (AHP) to map flash flood risk used in this paper show reliable results. The combination of using DEM model, hierarchical analysis method combined with satellite image analysis to create flash flood hazard map is the novelty of this study.

2. Data and research methods

2.1. Data

Data sources used for the study include:

- Map database: Geological map of Tuyen Quang province, topographic map of Tuyen Quang province at scale of 1: 100,000; slope maps, depth division maps, cross section maps, annual average rainfall maps, land use status quo maps of Tuyen Quang province; Remote sensing image Satellite-4_2.05

- Supporting software: Mapinfo 15.0, ArcGIS 10.5, Mapsource and Google Earth.

- Data collected from field survey.

2.2. Research Methods

The research methods of the topic include: remote sensing image analysis method, field survey method, AHP analysis method, GIS spatial data analysis method.

- Remote sensing image analysis is used to interpret flash flood locations in the study area.

- Field survey includes monitoring, conducting detailed measurements, determining the scale and characteristics of flash floods and the impact factors that generate flash floods. Since then, to conduct an assessment of the current state and changes of flash floods in the Tuyen Quang province.

- The method of hierarchical analysis (AHP) is to determine the role of each factor in the factors that generate flash floods on the basis of weighting and scoring.

Geographic Information System (GIS) is used to build spatial analysis, management, integration and overlapping layers of map information.

The AHP model combined with GIS will help to select elements, synthesize information suitable for research subjects.

To determine the level of risk of flash flooding, the thesis integrates the criteria according to the formula (1) (according to Patrono, et al., 1995):

$$\text{FSI} = \sum_{j=1}^{n} WjXij \quad (1)$$

In which: FSI (Flash flood Susceptibility Index): is the index of risk of flash flood occurrence

Wj: is the weight of factor j

Xij: is the number of grades i in the factor causing slip j

The integration of AHP into GIS via linked formula (1) and calculated by Raster Caculator tool of ArcGis 10.5 software

3. Research results

3.1. The main factors causing flash floods in Tuyen Quang province

The main factors that generate flash floods include: the risk of landslides, slope and precipitation. In which rainfall is the main factor; slope plays an important role in influencing flow rate; a landslide risk factor provides reinforcement for flash flood generation.[3]Each of the factors mentioned above has a different role and influence on the generation of flash floods. Therefore, it is necessary to analyze, evaluate the weight and score each factor accordingly.

Using the AHP assessment method, we assigned scores to each factor based on the importance of flash flood formation (in Table 1).

Table 1.Assessment scores of flash flood factors

Factors	***Average annual rainfall***	***Average slope of the sub-basins***	***The risk of landslides***
scores	5	3	1

Each factor will be weighted by AHP method, comparing the correlation between factors by making a matrix, calculating the corresponding weight score of each factor (in Table 2 and Table 3).

Table 2.Matrix of correlation between flash flood generation factors

Factors	***Average annual rainfall***	***Average slope of the sub-basins***	***The risk of landslides***
Average annual rainfall	1	1.7	5
Average slope of the sub-basins	0.6	1	3
The risk of landslides	0.2	0.6	1
Total	*1.8*	*3.3*	*9*

Table 3. Matrix determines weight of factors

Factors	***Average annual rainfall***	***Average slope of the sub-basins***	***The risk of landslides***	***Weight***
Average annual rainfall	0.6	0.51	0.6	0.568
Average slope of the sub-basins	0.33	0.31	0.33	0.323
The risk of landslides	0.11	0.18	0.11	0.130

3.1.1. The Average annual rainfall

Rainfall factor plays a key role in generating flash floods. Rainfall includes the intensity of rain and the time of rain being observed, measured and assessed the impact on the generation of flash floods.[2] Flash floods usually form in a short, sudden, high speed period, and often occur in areas with heavy, intense and prolonged rain. According to monitoring results over the past 20 years, the annual average rainfall of Tuyen Quang province is 1,600 - 2,100 mm / year. Rainfall is unevenly distributed throughout the year, concentrating mainly in the rainy season months (July, August and September), accounting for 72% of the total annual rainfall.

On the basis of the observed data, a map of the annual average rainfall of Tuyen Quang province was made. Analysis and statistics results from the map are shown in Table 4

Table 4. Hierarchy effect and area of annual average rainfall factor

Level affects the occurrence of flash floods	***Average annual rainfall (mm)***	***Area (km^2)***	***Area (%)***
Level 1: Very low	≤ 1,400	906.0	15.44
Level 2: Low	1,401 - 1,600	1,110.2	18.92
Level 3: Moderate	1,601 - 1,800	1,913.0	32.60
Level 4: High	1,801 - 2,000	1,482.3	25.26
Level 5: Very high	> 2,000	456.5	7.78
The whole province		*5,868.0*	*100*

3.1.2. The Average slope of the sub-basins

The average slope of the river sub-basins plays an important role in the generation of flash floods. The average slope map of the sub-basins was developed using ArcGIS 10.5 software in combination with Mapinfo 15.0 software.

The thesis has divided the average slope of the sub-basins into 5 levels affecting the possibility of flash flooding in Tuyen Quang province. The analysis results from the slope map are shown in the data sheet (Table 5).

Table 5. Hierarchy effect and area of sub-basin average slope factor

Level affects the occurrence of flash floods	***Average slope of the sub-basins***	***Area (km^2)***	***Area (%)***
Level 1: Very low	$\leq 10^o$	826.2	14.08
Level 2: Low	11^o - 20^o	1,932.9	32.94
Level 3: Moderate	21^o - 30^o	1,859.0	31.68
Level 4: High	31^o - 40^o	987.0	16.82
Level 5: Very high	$> 40^o$	262.9	4.48
The whole province		*5,868.0*	*100*

3.1.3. The risk of landslides

The risk factor for landslides is an important generation factor, creating raw materials for the formation of flash floods. The landslide hazard map is built on the integrated, weighted basis of component maps such as slope map, annual average rainfall map, rock component feature map, division map depth, transect maps, fault density maps and land use status quo maps.[2,4] After the landslide map was created and based on the score value, the author divided into 5 levels corresponding to its impact on the hazard of flash floods from low to high (table 6)

Table 6. Classification of influence and area of landslide factor on flash flood hazard

Level affects the occurrence of flash floods	***Area (km^2)***	***Area (%)***
Level 1: Very low	867.9	14.79
Level 2: Low	1,653.6	28.18
Level 3: Moderate	1,915.9	32.65
Level 4: High	1,186.5	20.22
Level 5: Very high	244.1	4.16
The whole province	*5,868.0*	*100*

3.2. Application GIS to establish flash flood hazard map in Tuyen Quang province

Assessment of flash flood risk in Tuyen Quang province, the project has developed flash flood hazard map at scale of 1: 100,000 by integrating AHP weighting model into GIS.

The flash flood hazard map was built on the basis of spatial analysis in ArcGIS 10.5 software. In particular, the calculation function on the map (Raster Caculator) has allowed the integration of many layers of information according to the mathematical functions on the ArcGIS 10.5 software. The classification function allows to simplify and classify flash flood risks according to 05 different levels.

The factors evaluated often differ in units of measure. Therefore, to assess the importance of these factors to the flash flood risk generation process, we evaluate them on a standard unit scale. All component classes were rated on a Saaty scale. With the decentralization of factor maps into 5 levels corresponding to Saaty's scale, the weighted points will be as follows:

Level 1: 1 point, level 2: 3 points, level 3: 5 points, level 4: 7 points and level 5: 9 points.

The factor maps, after decentralized affecting flash floods, determine corresponding weights and integrated the formula for calculating flash flood risk index (1) into the GIS environment through the Raster Calculator tool on the software. ArcGIS 10.5: Calculation results show that the value of flash flood risk (FSI) of the research territory varied from 1,692 to 9,213. To calculate the distance between the selected levels, the paper uses the formula for calculating the point distance:

$$\Delta FSI = \frac{FSI_{\max} - FSI_{min}}{n}, (2)$$

In which: ΔFSI: Flash flood hazard index

FSI_{max} *: Maximum value of flash flood risk score*

FSI_{min}*: Minimum score for flash flood risk score*

n: Number of levels to divide (n = 5)

Substituting values into formula (2), we have the distance between levels as follows:

$$\Delta FSI = \frac{9{,}213 - 1{,}692}{5} = 1.504$$

Flash flood phenomenon only occurs in the areas with the flow, so the flash flood risk map after re-classification according to 05 risk levels, separated by the flow units and area statistics of levels flash flood risks follow the flow in table 07.

Table 7. Area of flash flood hazard levels in Tuyen Quang province

Level of flash flood hazard	***Area (km²)***	***Area (%)***	***Valuable range of points***
Level 1: Very low	375.0	6.39	1.692 - 3.196
Level 2: Low	665.4	11.34	3.197 - 4.700
Level 3: Moderate	602.6	10.27	4.701 - 6.204
Level 4: High	155.5	2.65	6.205 - 7.708
Level 5: Very high	75.7	1.29	7.709 - 9.213
Total	1,874.2	*31.94*	
Provincial total	*5,868.0*	*100*	

Table 7 shows that the total area at risk of flash floods is 1,874.2 km2, accounting for 31.94% of the total area of the province. In which the ratio of very high risk area was 1.29%, high risk was 2.65%, mean 10.27%, low risk and very low risk 17.73%.

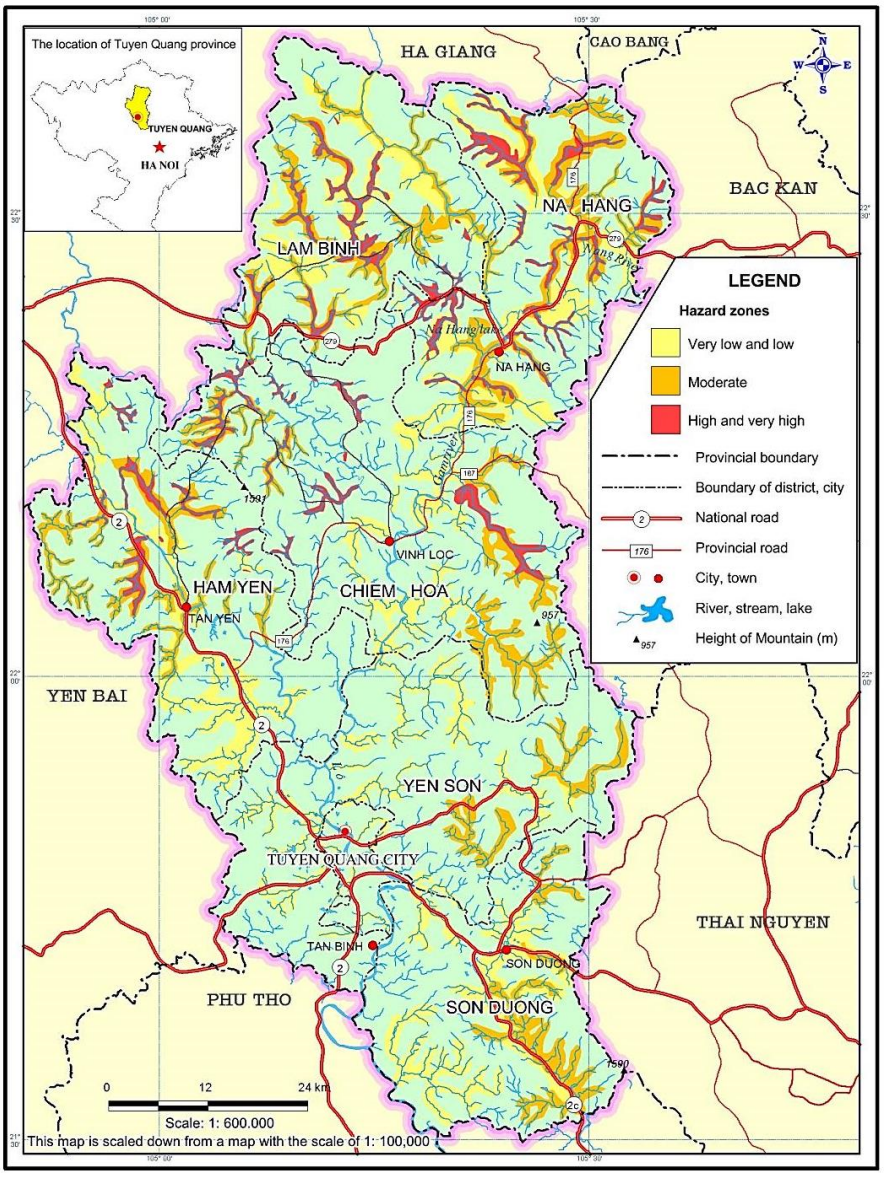
In terms of administrative units, we conduct statistics on flash flood risks in each district and city (Table 8).

Table 8. Statistics of areas of flash flood hazard levels by district-level administrativeunit in Tuyen Quang province

District-level administ-rative unit	Area (km^2)	Area (%)	**Level of flash flood hazard**					
			Level 1 and level 2 Very low and low		***Level 3 Moderate***		***Level 4 and level 5 High and very high***	
			Area (km^2)	Area compared to the whole province (%)	Area (km^2)	Area compared to the whole province (%)	Area (km^2)	Area compared to the whole province (%)
Tuyen Quang city	184.4	3.14	18.78	0.32	0	0	0	0
Chiem Hoa	1,146.2	19.53	156.68	2.67	118.53	2.02	53.99	0.92
Ham Yen	907.0	15.46	113.84	1.94	89.19	1.52	51.05	0.87
Lam Binh	917.6	15.64	126.75	2.16	113.84	1.94	42.84	0.73
Na Hang	865.5	14.75	135.55	2.31	173.69	2.96	71.00	1.21
Son Duong	790.6	13.47	267.58	4.56	56.92	0.97	7.04	0.12

District-level administ-rative unit	Area (km^2)	Area (%)	**Level of flash flood hazard**					
			Level 1 and level 2 Very low and low		***Level 3 Moderate***		***Level 4 and level 5 High and very high***	
			Area (km^2)	Area compared to the whole province (%)	Area (km^2)	Area compared to the whole province (%)	Area (km^2)	Area compared to the whole province (%)
Yen Son	1,056.7	18.01	221.22	3.77	50.46	0.86	5.28	0.09
The whole province	*5,868.0*	*100.00*	*1,040.4*	*17.73*	*602.6*	*10.27*	*231.2*	*3.94*

Table 8 shows: The districts with high and very high risk of flash flood are concentrated in the districts of Na Hang, Chiem Hoa, Lam Binh and Ham Yen. Districts at moderate flash flood risk include Son Duong and Yen Son. Tuyen Quang city has a low and very low risk of flash floods.



Flash flood hazard map of Tuyen Quang province

4. Conclusion

Through research and survey of flash flood situation as well as results of mapping flash flood risk in Tuyen Quang province, we would like to give some general conclusions as follows:

- In the whole province, there have been 19 points where flash floods occur with different types: flash floods on steep slopes, floods with congestion and mixed flash floods. The locations of flash flood-prone spots quite coincide with the high and very high risk of flash floods on the constructed map.

- The main factors causing flash floods are identified as annual average rainfall, average slope and the risk of landslides.

- The high risk of flash floods and catastrophes usually concentrates in areas with steep slopes and dense rivers and streams. In the area of Tuyen Quang province, special attention should be paid to and the possibility of flash floods occurring in communes Sinh Long, Thuong Nong, Con Lon, Khau Tinh (Na Hang district), Phuc Yen, Khuon Ha, Xuan Lap and Lang Can (Lam Binh district), Trung Ha, Hong Quang, Minh Quang, Kien Dai (Chiem Hoa district) communes, and Minh Khuong, Minh Dan and Yen Phuc communes (Ham Yen district).

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