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Studying the Current Situation and Establishing a Map of Flash Flood Risk Zoning in Lai Chau Province, Vietnam

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Abstract

Lai Chau is a mountainous province in the North of Vietnam that frequently experiences flash floods. Flash floods in Lai Chau province were formed by the combined effects of many factors such as topographical characteristics, current land use, soil type, vegetation cover combined with river density and rainfall. In this study, the author analyzed the current state of flash floods, assessed the factors that caused flash floods and established a map of flash flood zoning in Lai Chau province. The flash flood risk area map is built on the basis of GIS spatial analysis, combining hierarchical analysis (AHP) and multi-criteria analysis method (MCA). Data collected for the study is mainly from Sentinel 2 images, statistical data and actual investigation. Research results show that the area with high and very high potential for flash floods accounts for 22.03% of the natural area, and the area with medium risk accounts for 44.42%. Areas with low and very low levels account for 33.55% of the area in Lai Chau province of Vietnam.

Keywords: GIS; zoning; risk; flash floods; Lai Chau.

1. Introduction

Flash flood is a natural disaster occurring in most countries around the world, including Vietnam. Flash flood is a type of flood with high flow rate, often containing a lot of solid matter, occurring suddenly in a short time on small basins with steep terrain, so they have great destructive power. Flash floods induce severe impacts in both the built and the natural environment.

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The effects of flash floods can be catastrophic and show extensive diversity, ranging from damages in buildings and infrastructure to impacts on vegetation, human lives and livestock. The effects are particularly difficult to characterize in urban areas [1]. According to statistics in 20 years (2000-2020) in the northern mountainous provinces of Vietnam, there have been 318 flash floods, killing 406 people, injuring 1012 people, destroying 7129 houses and causing damage to property, estimated at more than $800 million [2]. Flash floods not only cause damage to people and property but also cause panic and worry for people.

Lai Chau is a mountainous province in the North of Vietnam that is heavily affected by natural disasters, especially flash floods. Lai Chau province focuses mainly on ethnic minorities, with very limited skills in dealing with flash flood risks. In recent years, due to the impact of climate change and socio-economic development activities such as exploitation of natural resources, opening of roads, construction of infrastructure, deforestation, construction of hydroelectricity,... has affected the buffer surface, obstructing the flow, leading to more frequent flash floods in Lai Chau province. Therefore, it is necessary to study the current situation and establish zoning and flash flood warning maps in Lai Chau province.

The development of Remote Sensing Technology (RS) and Geographic Information Systems (GIS) has contributed significantly in modeling and forecasting flash floods. Current trending flash flood susceptibility assessment focuses on the use of machine learning, spatial statistics, and multi-criteria decision-making algorithms. The directions for studying the susceptibility to flash floods are provided by machine learning models such as logistic regression laws [3-4], decision trees [5-6], artificial neural networks [7-10] support vectors [11], neural fuzzy inference systems [12]. Bilateral statistical models, including studies involving: frequency ratio [13], weight of evidence [14], statistical index, the coefficient of certainty [15] and the entropy index [16]. For multi-criteria decision making (MCDM), commonly used analytical hierarchical techniques [17], multi-criteria optimization (VIKOR) [18] and sorting techniques are commonly used. order of preference according to the similarity to the ideal solution [19]. Method of applying K-Star model to determine and calculate flash flood potential index (FFPI). The studies of flash floods based on GIS and remote sensing technology according to the FFPI model have been studied by many authors [20-24]. Research on the combination of hierarchical analysis system with multi-criteria analysis (MCA) builds a flash flood warning warning model [25].

In Vietnam, studies on flash flood warning mainly focus on building zoning maps for early flash flood warning. In which, the study of developing a map of flash flood risk zoning to serve the prevention of flash floods for Yen Bai province [26]. Research and develop early flash flood warning map in Thuan Chau district, Son La province [27]; Study on flash flood warning in Lao Cai province [28]. These studies mainly focus on establishing flash flood maps from independent factors, lacking systematic character. In Lai Chau province, there is no comprehensive study on flash floods, no detailed zoning maps and flash flood warnings for each basin. Therefore, within the scope of this study, the author conducts an analysis of the current flash flood situation and establishes a flash flood zoning map for Lai Chau province. This is a study of scientific and practical significance. For the first time, the current status of flash floods in a mountainous province of Vietnam has been investigated and statistically detailed to the commune level. The flash flood zoning map is built based on GIS technology and remote sensing, accessing zoning for each river basin.

2. Materials and Methods

2.1. Materials

Materials on the current state of flash floods in Lai Chau province are collected from the disaster statistics material source of the Center for Disaster Control of Lai Chau province in the period 2001-2021. In addition, this study has inherited data from studies related to flash floods in the northern mountainous region of Vietnam, including Lai Chau province [25-28]. During the research process, at statistical points where flash floods often occur, the author conducts surveys and interviews with local people and authorities to collect documents related to the current state of flash floods, assess preliminary level of impact caused by flash floods. To create a map of flash flood risk zoning in Lai Chau province, the study uses many different data sources, including survey data, statistical data, monitoring data, satellite image data.

2.2. Methods

Data collection and field survey

During the research, the authors conducted many field trips to assess the overview of the research area, collect relevant documents and data, review and verify the results of the study. In particular, data on flash flood history and flash flood locations within 20 years (2001-2021) were surveyed and interviewed people about related contents.

Remote sensing image processing

Selecting two processing methods are NDVI differencing method and post classification method [29], in which the vegetation cover emissivity applied to the study area is calculated according to formula $\varepsilon = 1.0094 + 0.047 \ln(NDVI)$.

Multi-criteria integration (MCA)

The method of integrating hydrological and geomorphological models of the basin with the help of GIS technology. Applying this method, the research focuses on determining the factors that cause flash floods in the basin, combined with comparison with statistics to classify the ability of each information layer to cause flash floods.

GIS spatial analysis

Two algorithms used in GIS spatial analysis include spatial superposition algorithm and attribute classification algorithm. Processing spatial data analysis on QGIS software. In addition, the author uses the DEM model in analyzing topographic and geomorphological factors [30]; using GIS spatial interpolation algorithm to analyze and forecast rainfall data [31].

Hierarchical analysis (AHP)

The AHP method is used to determine the reliability of the matrix determined through the common consistency index (CR) for the factors that form flash floods. In which, CR is determined through the Random Consistency Index (CI) and the Random consistency Index by n (RI). CR is calculated by the formula: CR=CI/RI. Where, CI = λmax-n/n-1; λmax is the mean of the consistency vector; n is the number of criteria; RI is a random index and it depends on the number of criteria compared; case study n = 6, look up the table with RI = 1.25. If the value of the CR index is less than or equal to 0.1, then the consistency between the factors in the comparison matrix is ensured [32].

3. Results and discussion

3.1. Current status of flash floods in Lai Chau province

According to statistics in the 20-year period (2001 - 2021), Lai Chau province has had 41 flash floods, killing 92 people, damaging 1479 houses or being swept away, 7,327 households affected, total losses property damage was estimated at over $3.2 million. Flash floods occurred in almost all localities, mountainous communes and districts of Lai Chau province. The localities with great damage and high frequency of flash floods are Sin Ho district, Muong Te district, Than Uyen district and Phong Tho district. On average, there are about 2 flash floods every year, the repetition cycle is usually 2-3 years, in 2008 there were 6 floods.

Flash floods in Lai Chau province are often mixed flash floods, distributed in small basins, with high flow velocities and very large flood intensity. Flash floods in Lai Chau province occurred on small and medium-sized mountain basins or accumulation shelves on rivers with steep slopes. Floods often arise from upstream of small streams, most of which are tributaries of level I and II, where the soil and rock are strongly eroded and flow into the estuaries of rivers and streams. The time of flash floods in Lai Chau province coincides with the rainy season from May to October. However, the peak of flash floods usually occurs in June to August due to the circulation of storms.

Summarizing statistics in the last 5 years, Lai Chau province has had a number of large flash floods with the time, location, developments and damages shown in Table 1.

In general, flash floods occurring in Lai Chau province all have one common feature: they appear after heavy rains. In steep hilly areas, the soil has been weathered for many years, so in the rainy season it is always in a state of water saturation; meanwhile, the forest is reduced, the buffer surface is eroded, unable to hold water... In addition, people in flash flood areas in Lai Chau province often have the habit of living on rivers and streams, cutting down forests for farming, houses are also built close to rivers and streams or right on hillsides, at the foot of hills and cliffs. Therefore, when flash floods occur, the consequences are often great.

Table 1: Summary of flash floods in Lai Chau province in the period 2016-2021.

No	Time	Location	Developments	Damages
1	July 13, 2020	Phong Tho district, Sin Ho district	Heavy rain continuously for 20 hours, maximum rainfall reaches 190 mm	- 2 people died - 35 houses destroyed - 189 hectares of crops affected - Damage is 318,000 USD
2	June 24, 2019	Muong Te district	Heavy rain continuously for 24 hours, maximum rainfall reaches 210 mm	- 4 people died - 21 houses destroyed - 107 hectares of crops affected - Damage is 250,000 US
3	June 23-26, 2018	Than Uyen district, Sin Ho district	Heavy rain continuously for 24 hours, maximum rainfall reaches 280 mm	- 17 people died - 268 houses destroyed - More than 800 hectares of crops affected - Damage is 980,000 USD
4	August 3, 2018	Phong Tho district	Heavy rain continuously for 20 hours, maximum rainfall reaches 190 mm	- 12 people died - 43 houses destroyed - 180 hectares of crops affected - Damage is 340,000 USD
5	August 6, 2017	Muong Te district	Heavy rain continuously for 16 hours, maximum rainfall reaches 170 mm	- 1 person died; - 12 houses destroyed - 86 hectares of crops are affected - Damage is 157,000 USD

(Source: Statistical data, survey)

3.2. Factors causing flash floods in Lai Chau province

Research in Lai Chau province shows that flash floods mainly form in river basins. Statistics at the points where flash floods often occur have large catchment slopes, vegetation cover of less than 10%, maximum rainfall of over 200 mm/day, medium and poor permeability soil, slope geomorphology. V-shaped area or condensate valley. The factors that cause flash floods in Lai Chau province are mainly natural conditions. However, the content of the factors shows that there is the impact of human factors. Typically, factors such as farming methods and land use characteristics. People cutting down forests, burning fields to make ridges will reduce the vegetation cover, creating the risk of flash floods. The process of land use changes the characteristics, properties and composition of the land, affecting the risk of flash floods.

Based on survey data and studies on flash floods in mountainous areas of Vietnam [26-28], the study has identified 6 basic factors that form flash floods specific to the province. Lai Chau includes: Topographic

features (T), soil characteristics (So), vegetation cover (V), catchment slope (Sl), maximum daily rainfall (R) and density of rivers and streams (D). Using the AHP hierarchical analysis method to calculate the weights for the factors generating flash floods in Lai Chau province, the results are shown in Table 2.

Table 2: Weight matrix for factors generating flash floods in Lai Chau province.

Factors	T	So	V	Sl	R	D	Total	Weight
T	0,14	0,12	0,16	0,17	0,18	0,11	0,88	0,15
So	0,02	0,03	0,02	0,04	0,04	0,02	0,17	0,03
V	0,08	0,13	0,08	0,18	0,08	0,13	0,68	0,11
Sl	0,06	0,15	0,09	0,12	0,08	0,12	0,62	0,10
R	0,36	0,18	0,19	0,26	0,28	0,25	1,52	0,25
D	0,06	0,13	0,04	0,05	0,07	0,04	0,39	0,07

3.3. Establishing a map of flash flood risk zoning in Lai Chau province

On the basis of flash flood studies [25-28], the risk of flash floods in mountainous areas of Vietnam is divided into 5 levels: Level 1- very low risk of flash flood, Level 2 - low risk of flash flood, Level 3 - medium risk of flash flood, Level 4 - high risk of flash flood, Level 5 - very high risk of flash flood.

Applying GIS spatial analysis model, overlaying information layers of flash flood generating factors to create a map of flash flood risk zoning in Lai Chau province (Figure 1).

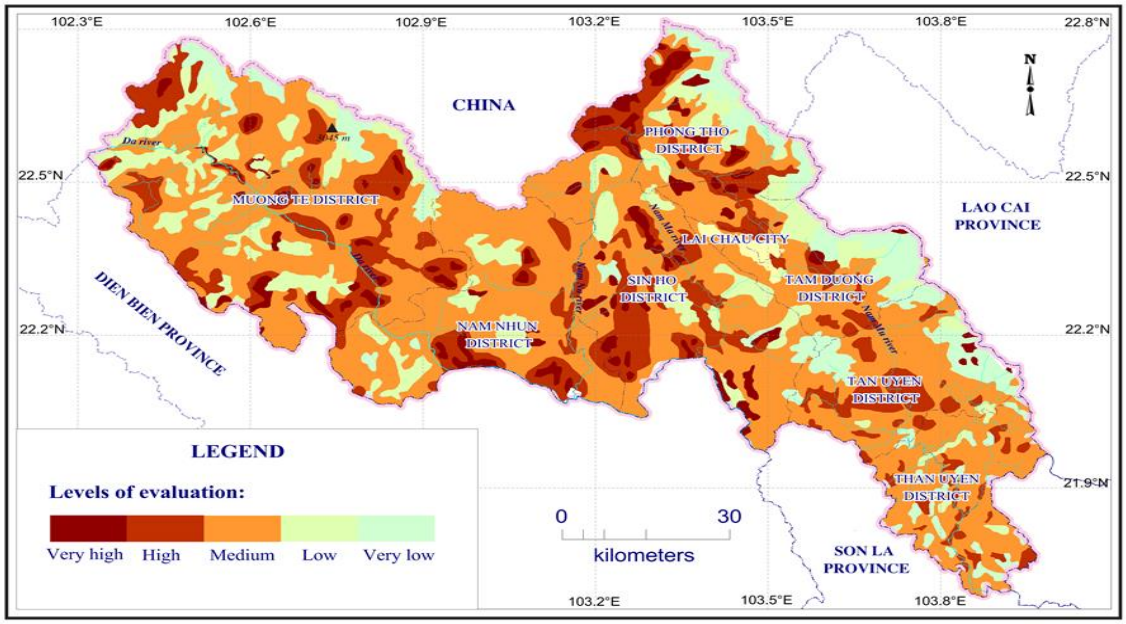

Figure 1: Mapping of flash flood hazard in Lai Chau province**.**

The analysis results show that the area with high and very high potential for flash floods accounts for 22.03% of

the province's natural area, concentrated in areas with steep slopes, and the terrain tends to accumulate water, vegetation is mainly shrub or bare ground, typical sloping soil. The medium risk area occupies over 44.42% of the area, with 4028.66 km^2, these are mainly planted forest areas, forests on rocky mountains belonging to slopes eroded on different rocks. The area is assessed to have low risk of flash floods, accounting for 21.38% of the area, about 1938,9 km^2, this is an area with a rather scattered distribution, belonging to areas with low flash flood generating factors, usually planted forests, terraces, glacial terrain, or areas with maximum rainfall. by day is quite low.

Based on the flash flood warning zoning map, it can be seen that the risk of flash floods in Lai Chau province varies between districts. Areas assessed as high and very high risk are concentrated in Phong Tho, Sin Ho, Nam Nhun and Muong Te districts. Phong Tho district is forecasted to have the highest and very high risk of flash floods. This is the upstream area of Nam Na and Nam Mu rivers with favorable geomorphological factors to form flash floods. Muong Te is the district with the largest natural area in Lai Chau province, and is also a district with an area that is assessed to have a very high and relatively high risk of flash floods, about 716 km^2. Areas with medium risk account for 38.43% of the area, areas with low and very low risk account for 43.17% of the district's area. Sin Ho and Nam Nhun districts have about 50-60% of the area assessed as being at moderate risk of flash floods. The area of the area is assessed at a very high level of 127.7 km^2 in Sin Ho district, where flash floods often occur due to flow factors, the possibility of water accumulation and blockage. Through the survey, this area is close to residential areas, so when flash floods occur, the damage is very large. The area of Than Uyen and Tan Uyen districts is mainly assessed to have a moderate level of flash flood, accounting for 60-70% of the area. The area with very high flash flood generation accounts for only 9.39% of Tan Uyen district and 2.52% of Than Uyen district. However, in fact, this is an area where flash floods often occur due to topographical and geomorphological factors The area of high-level flash flood in Tam Duong district is mainly concentrated along the 4D highway, the average flash flood area of the whole district accounts for 45.72% of the area. In fact, this is the area where many flash floods occurred, causing great loss of life and destruction of irrigation and traffic works. Areas with low and very low risk of flash floods also account for a high proportion, mainly in the core and buffer zones of Hoang Lien National Park, where natural forests have high coverage. The area of Lai Chau city is assessed as not having a very high level of flash floods. The high level occupies about 17.4% of the area, the medium level occupies about 23.78% of the area, the low level is 54.12% and the very low level is 4.7% of the natural area of the city.

4. Conclusion

Lai Chau is a province with frequent flash floods, with an average frequency of 2.5 floods per year, causing great damage to people and properties. Flash floods in Lai Chau province were formed by the combined effects of many natural and human factors. This study analyzed the current state of flash floods, assessed the factors that caused flash floods and established a map of flash flood zoning in Lai Chau province. The analysis results show that the risk of flash floods is high and very high, accounting for over 22% of the province's natural area. The map of flash flood risk zoning in Lai Chau province is a source of documents for the development of projects on territorial planning, environmental planning, disaster prevention and reduction in the locality.

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