APPLICATION OF GIS AND REMOTE SENSING FOR MAPPING FLASH FLOOD RISE IN HOA BINH PROVINCE UNDER CLIMATE CHANGE CONTEXT

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Abstract: *Hoa Binh is one of the provinces strongly suffering from natural disasters, especially flash floods. High slope mountainous terrains, reduced vegetation cover and unfavorable weather conditions form favorable conditions for flash floods to occur. This article develops a map of flash flood risk zoning in Hoa Binh using remote sensing and GIS technology. First, the factors affecting the risk of flash floods are identified, and each factor is classified based on the level of influence, then proceed to overlay the component maps causing flash floods. Factors affecting flash flood risk include: Slope, soil type, land use type, forest cover density and rain. As a result, areas at risk of flash floods are identified with 3 level: High, medium and low. This information can be used as a basis for forecasting areas at high risk of flash floods in the province.*

Keywords: *Flash flood, hazard map potential, remote sensing, geographic information system, Hoa Binh.*

1. Introduction

Flash flood is one of the natural disasters that occur suddenly, rapidly and in a complex manner, with great devastation in small mountainous basins, inflocting serious damages to both human live and the econoney. According to the climate projections, climate change will cause abnormal weather phenomena that promote flash floods in the coming time. In particular, this phenomenon often occurs in mountainous provinces. Therefore, the damage caused by natural disasters in general and flash floods in particular will increase many times compared to the plains.

Recently, with the development of remote sensing technology, it is possible to predict rainfall in advance (analysing weather remote sensing data), determine the current cover status (analyzing ground observation remote sensing images) with data about Topography, geomorphology, land properties are synthesized and by GIS tools to be able to predict areas with high risk of natural disasters, which is a great application potential.

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Carlin, Nancy 2009 [1] use data layers: Land use, soil, slope, hydrological network. In which land use, soil was obtained from Natural Resource Conservation Service, the data was in shapefile format; slope and hydro network was interpolated from DEM. Each of the above factors will be ranked according to their different sensitivity to the cause of flash floods, in each factor which divided with different levels, and for the river network, a buffer zone is created with distances a, b, c corresponds to its hazard in rivers, all of the above data classes are convert to raster with a resolution of 90 m, then proceed to add the layer data together to identify areas at risk of flash floods. Finally using the collected rainfall to describe the flash flood in La Crosse County, Wisconsin. Gregory E. Smith, 2010 [3] in which the author uses 4 data classes: Slope map, calculated from a DEM map with a resolution of 90 m. Landuse map: Was established from interpreting Landsat TM satellite images with a resolution of 30 m. Land map: Get the composition of the grain structure. Density map forest: Formed from satellite images. Hierarchy for the 4 maps above then proceed to superimpose maps up to find potential flash flood areas.

Many authors developed different methods to evaluate and produce susceptibility flood hazard maps using qualitative and quantitative techniques [9], artificial neural networks (ANNs) [2, 6], frequency ratio [7], decision tree (DT) [14], logistic regression [11]. Using geographic information systems and re-mote sensing images can expedite the location of areas that are likely to flood and are powerful tools to attain accurate land use maps and therefore, detection of land use changes will be possible [15].

The water velocities have the tendency to be high in flash floods; as discharge increases, water velocity increases. With these higher velocities, streams tend to import and transport larger particles. These large particles restricted to rocks, which could be objects of infrastructures in its way. Within the study area, the industrial zone is located, counting much of heavy industry plants (cements, steel, fertilization, etc.) having thousands of individuals and equipments, in addition to infrastructures.

Studying the flash floods in such area becomes essential to raise the flag of the risk before occurrences. In order to determine the flash flood risk in the study area bivariate statistical methods have been used to define the area of risk. Techniques for the reconstructing of such flooding mapping and its belongings and breaking down different impacts using remote sensing information were created before with [7, 8, 12, 13] mentioned that the frequency ratio is able to perform bivariate statistical analysis and the impact of classes of each conditioning factor on flooding. The weak point of this method is the relationship between the variables, which are mostly neglected with determining the suitable flood impact factors.

In Viet Nam, Nguyen Tham and Ho Dinh Thanh 2009 [10] established flash flood risk map of Gia Lai province based on the analysis of topographic maps, geological maps, hydrographic network map, 3 forest type maps to create derived maps such as slope map, wind direction map, elevation stratification map from topographic map, 3 forest type maps and average rainfall maps.

Institute of Meteorology, Hydrology and Climate Change. Synthesis report. Ministry-level project "Investigation, survey, zoning and warning the possibility of flash floods in mountainous areas of Viet Nam - Phase 1", 2009, MONRE [4]. According to the analysis in the Project, the topographic factor that best reflects the flash flood formation is the slope, the maps are built on digital map data with the scale 1: 50000.

Hoa Binh is province a located mountainous region, which is prone to frequent natural disasters, especially flash floods, floods and inundation. These natural disasters have unpredictable developments, affect socioeconomic development and cause serious damage to people, so it is necessary to establish flash flood warning risk zoning maps, tube floods, inundation to support, as well as replanning resettlement areas for people.

2. Introduction to the study area

Hoa Binh is a mountainous province located in the Northwest Viet Nam. The province has borders with Hanoi Capital, for exchange between the Northern Delta, the North Central Coast and the Northwest; located within the range of 20°19' - 21°08' North latitude and 104°48' - 105°40' east longitude, It borders Phu Tho province to the North, Son La province to the West, Ninh Binh, Ha Nam and Thanh Hoa provinces to the South. On the map of Viet Nam, Hoa Binh province is located at the gateway to the Northwest region, with a natural area of 4,590.6 km². In terms of geographical position, Hoa Binh is an intermediate buffer zone between the Delta on one side and the high mountains and dense forests of the Northwest on the other, which is connected via National Highway 6 (road).

Hoa Binh province has 10 administrative units at district level, 151 main units at commune level (129 communes, 12 wards, 10 towns). With a unique geographical position with many hills and mountains, Hoa Binh is often affected of typical natural disasters such as: The occurrence of heavy rains with high frequency, causing landslides, flooding, flash floods, etc [15].

Figure 1. Geographical map of Hoa Binh province

3. Research Methods

3.1. Input data

Data classes used:

Table 1. Input data for the study

No.	Data files	Data content	Resolution	Year Built	Source
1	Digital elevation model by Dem in Hoa Binh province	Elivation	30 m	2019	https://earthexplorer.usgs.gov/
2	Current land use map	Classification of land use types	1/25,000	2015	Department of Natural Resources and Environment of Hoa Binh province
3	Soil Map	Classification of soil types	1/25,000		Department of Natural Resources and Environment of Hoa Binh province
4	Administrative boundaries of Hoa Binh province	Demarcation of the district and the communes within the district	1/100.000	2015	Natural resources
5	Landsat 8 images		30 m	2021	https://earthexplorer.usgs.gov/

3.2. Implementation software

The entire process of editing, processing data as well as creating a partition map is done on Arc Map 10.5 software. It is the leading GIS system today, providing a comprehensive solution from data collection/input, processing, analysis and distribution of information on the Internet to different levels such as personal geographic database or Enterprise databases. In terms of technology, GIS experts now consider ESRI technology to be an oen, comprehensive and complete solution, capable of exploiting all GIS functions on different applications such as: Desktop. (ArcGIS Desktop), servers (ArcGIS

Server), Web applications (ArcIMS, ArcGIS Online), or mobile device systems (ArcPAD)... and highly interoperable with a wide range of our products many different companies [8].

ArcGIS Desktop (with the latest version, ArcGIS 10.5) includes powerful tools to manage, update, analyze, and publish information, creating a complete geographic information system (GIS), enabling:

Create and edit integrated data (integrated spatial data with attribute data) - allows the use of many different types of data formats even those obtained from the Internet;

Query spatial and attribute data from multiple sources and in different ways;

Display, query, and analyze spatial data associated with attribute data;

Create thematic maps and prints with professional presentation quality. ArcGIS Desktop is a suite of application software including: ArcMap, ArcCatalog, ArcToolbox, ModelBuilder, ArcScene and ArcGlobe. Using these applications concurrently, users can perform many GIS applications from simple to complex, including mapping, geographic analysis, editing and data editing, data management, data display and processing. ArcGIS Desktop software is provided to users at 1 of 3 levels with different levels of expertise: ArcView, ArcEditor, ArcInfo.

3.3. Methods of implementation

The scientific basis for the formation of flash floods has a very close relationship with the characteristics of topography, climate (precipitation, temperature), geology, soil, weathered crust, vegetation cover (Figure 2).

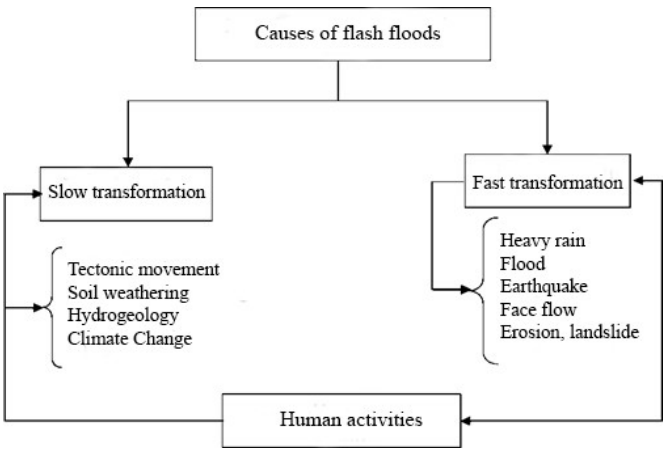

Figure 2. The relationship of factors forming flash floods

The method of building a map of potential zoning for flash floods in Hoa Binh province is based on overlaying of factors causing flash floods. Each factor affecting flash flood with a different index, the index of the factors is determined based on the FFPI (Flash Flood Potential Index) equation and in each factor, the FFPI classification is performed in each factor. [3]. The classification of FFPI in each factor depends on each element of the factor. The construction of the flash flood potential zoning map is carried out according to the process shown in Figure 3.

The FFPI is flash flood potential index released by the National Weather Service. The index of approaching flash flood potential is based on the geographical parameters of the basin.

The Flash (FFPI) indicates:

- It is possible that the physical properties of the watershed cause the area to suffer from flash floods or tube floods.

- When changing the properties of these objects, it is possible to increase or decrease the sensitivity of flash floods.

- It is possible to identify different basins with flash flood potential based on the similarity of flash flood triggers.

As noted by Smith (2010) [3] parameters affecting flash flood potential include.

• The slope characterizes the flow concentration rate.

• The soil type characterized by its ability to absorb water.

• The land use type characterized by infiltration capacity and flow rate.

• Forest density characterizes water resistance and permeability

• Rainfall is characteristic of the amount of water

In this research, forest cover density is obtained from satellite image classification based on 3 indexes: vegetation index (VI), bare land index (BI), shading index (SI). The process of building a forest cover density map is shown in Figure 4.

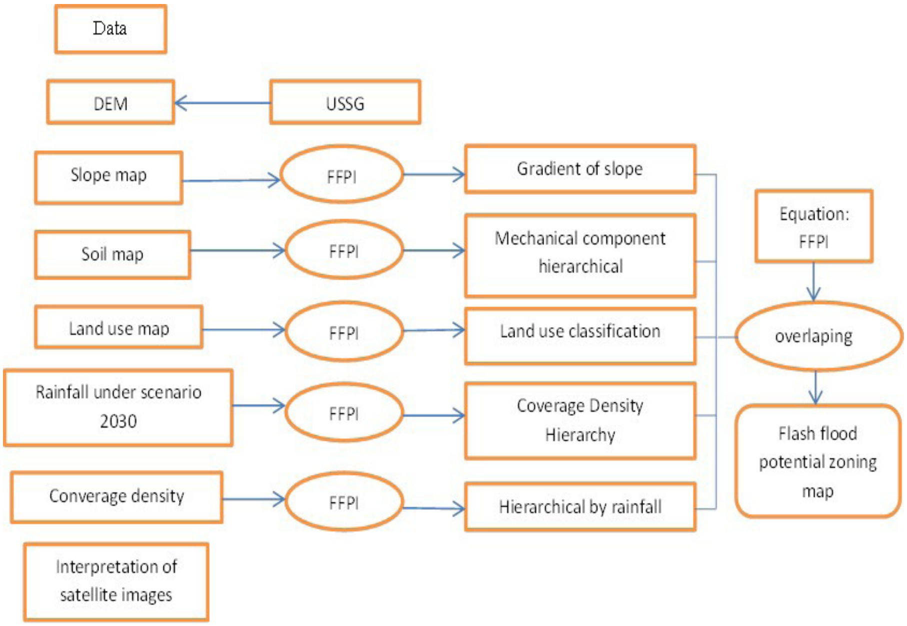

Figure 3. Diagram of the process of developing a map of the zoning of flash floods

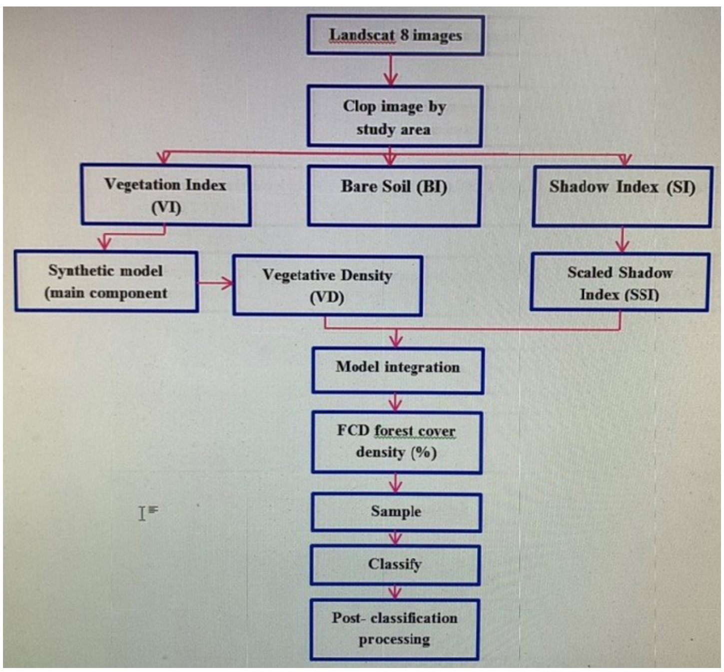

Figure 4. The process of making a forest cover density map

4. Results and discussion

4.1. FFPI hierarchy map for slope factor

From DEM data, the slope map of Hoa Binh province is built (Figure 5, 6).

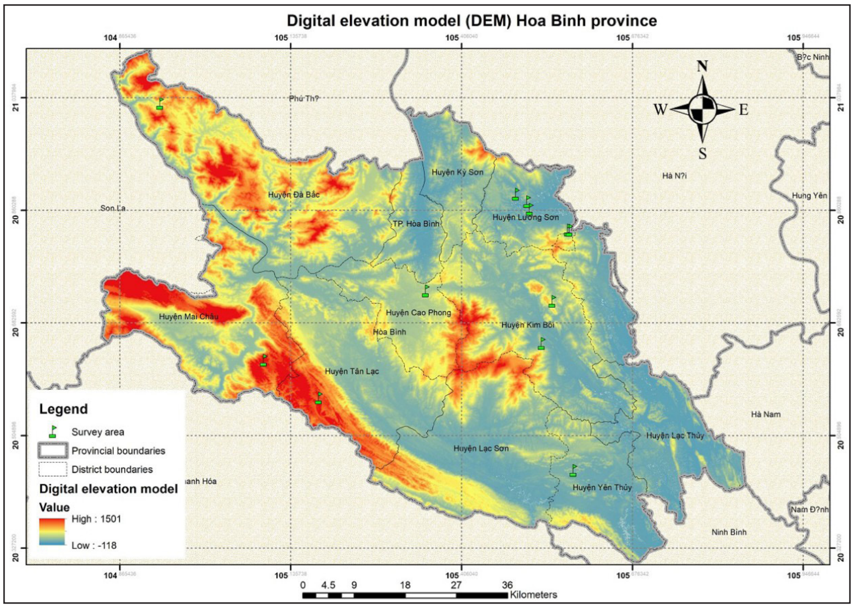

Figure 5. Digital elevation model (Dem) Hoa Binh province

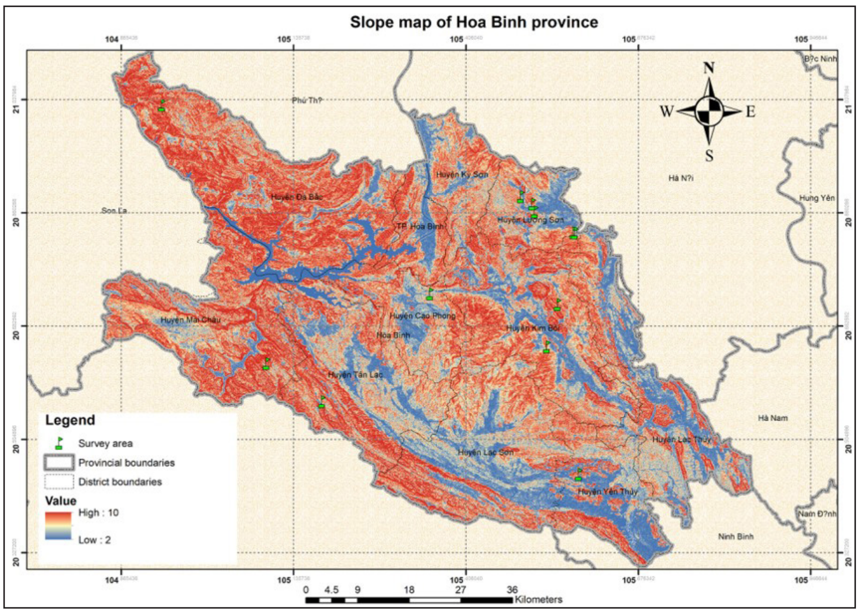

Figure 6. Hoa Binh province slope map

The influence of slope on flash flood is expressed through time and speed of flow concentration. Equation for calculating flow concentration time: [3]

$$T_c = 0{,}0078\left(\frac{L}{\sqrt{S}}\right)^{0.77}$$

In there:

Tc: Flow concentration interval,

L: Is the length of water flowing in the main river from the source to the basin outlet section

S: average slope of the basin.

d: Hierarchy of flash flood potential index for slope map.

Table 2. FFPI hierarchy for slope maps [3]

Slope (%)	FFPI
>30	*10*
27	*9*
24	*8*
21	*7*
18	*6*
15	*5*
12	*4*
9	*3*
6	*2*
<3	*1*

The result of slope map is shown in Figure 7.

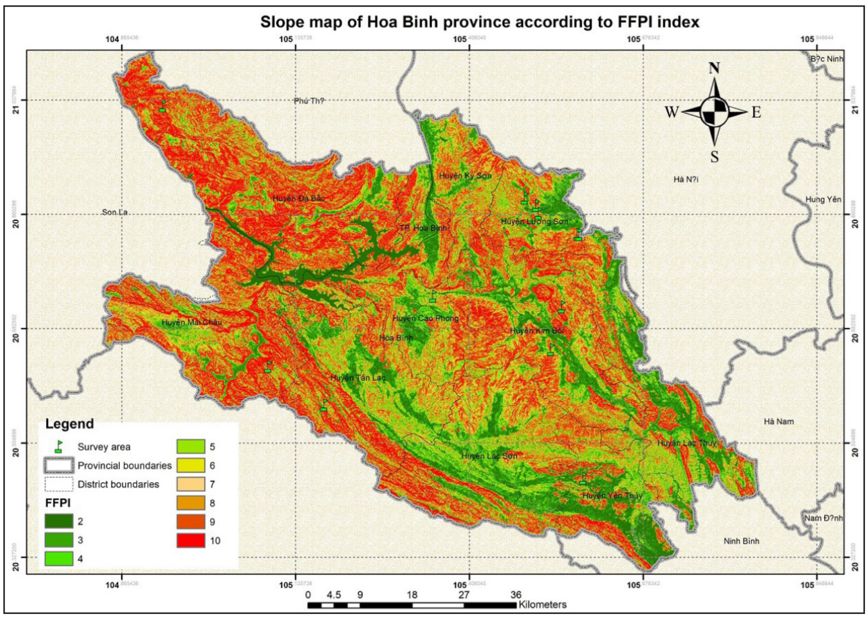

Figure 7. Slope map of Hoa Binh province partitioned by FFPI

4.2. FFPI hierarchy map for soil factor

Based on different soil groups, low permeability, moderate permeability, high permeability FFPI will gradually increase.

About 70% of Hoa Binh province's area belongs to the clay group and has very little permeability, so the FFPI index in most districts including Hoa Binh city is high, which is one of the important criteria influencing the risk of flash floods in Hoa Binh province when heavy rain occurs.

Table 3. FFPI classification of land (according to E. Smith, 2010) [3]

Mechanical components	Mechanical components	FFPI
Clay	Lighting	9
Silty Clay	Limestone	8
Clay Loam	Clay meat	8
Sandy Clay	Sand Clay	7
Silty Clay Loam	Clay meat and limon	7
Sandy Clay Loam	Meat mixed with sand and clay	7
Loam	Meat	6
Silt	Limon	5
Silty Loam	Limmon mixed meat	4
Loamy Sand	Sand mixed with meat	4
Sandy Loam	Sand mixed meat	3
Sand	Sand	2

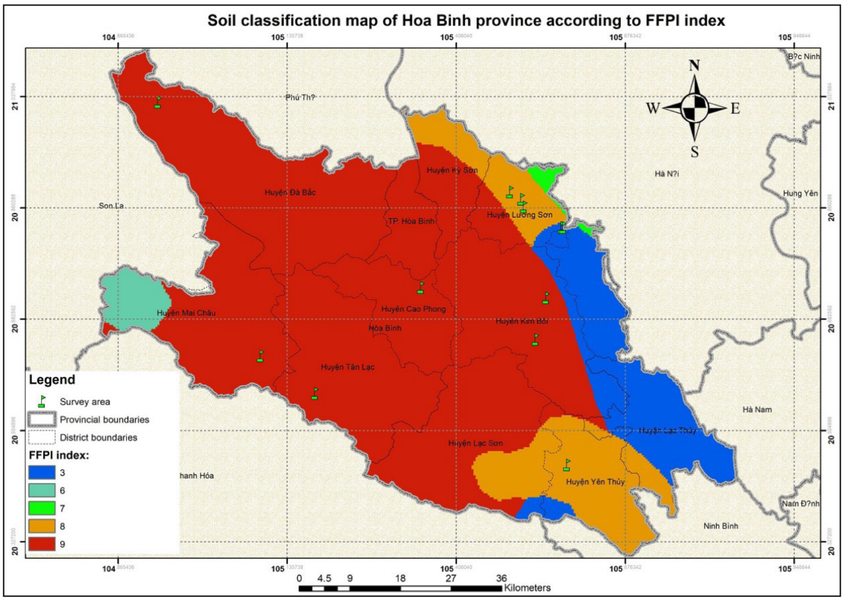

Figure 8. The map of soil water infiltration according to the FFPI

4.3. FFPI hierarchical map for forest cover density factor

Forest density significantly affects flash flood frequency and magnitude. Flash flood potential index is assigned a value from 1 to 10 based on forest cover density. A low potential flash flood index value corresponds to a place with large forest coverage, and vice versa.

From the results of calculation of forest coverage index (FCD), we can see that areas with forest cover of 60% or more are relatively high in Hoa Binh province. However, there are still many areas with low forest cover area (below 30%) such as Lac Son, Yen Thuy, Lac Thuy, Kim Boi, Luong Son and Ky Son districts. Areas with low forest cover are mainly those with densely populated areas or agricultural land. Therefore, these areas are assessed to have a high FFPI index.

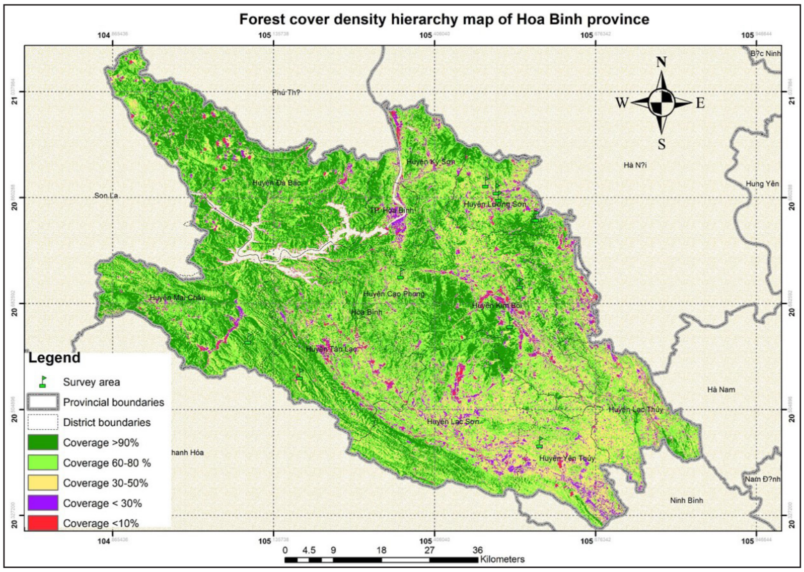

Figure 9. Forest cover density (FCD) map of Hoa Binh province

Table 4. FFPI hierarchy according to forest cover density [3]

Cover density (%)	FFPI
1 - 10 %	ten
10 - 20 %	9
20 - 23%	8
30 - 40%	7
40 - 50%	6
50 - 60 %	5
60 - 70 %	4
70 - 80%	3
80 - 90%	2
90 - 100%	first

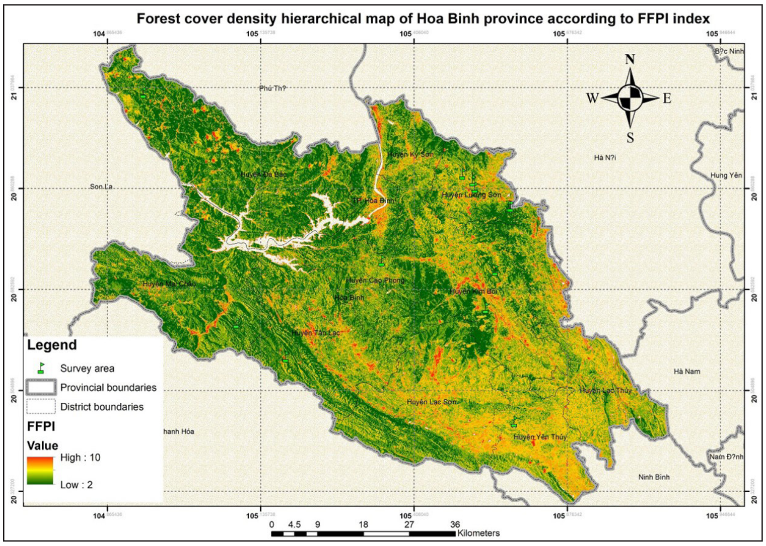

Figure 10. Forest cover density map according to the FFPI

4.4. FFPI hierarchy map for land use

Land use is a continuous, pervasive and highly diverse process. It not only changes the physical properties of the soil, but also the cover, even the topography. For example, after construction makes the surface smoother, which increases the flow concentration time and flow rate. Thus, land use even in some places, sometimes very large, will affect the formation of flash floods and inundation.

The current land use status of the study area is shown in Figure 11 below:

For the types of land use which are urban land, construction land, traffic land corresponding to large FFPI. In contrary, land use type is natural forest land, plantation forest with small FFPI.

From the current status of the land use map in 2015 of Hoa Binh province, it can be seen that the majority of Hoa Binh province is located in areas with low risk of flash floods and inundation in the case of assessment according to the target criteria. land use purposes. Areas with high FFPI are mainly residential areas, agricultural land and infrastructure with high economic value (Figure 12).

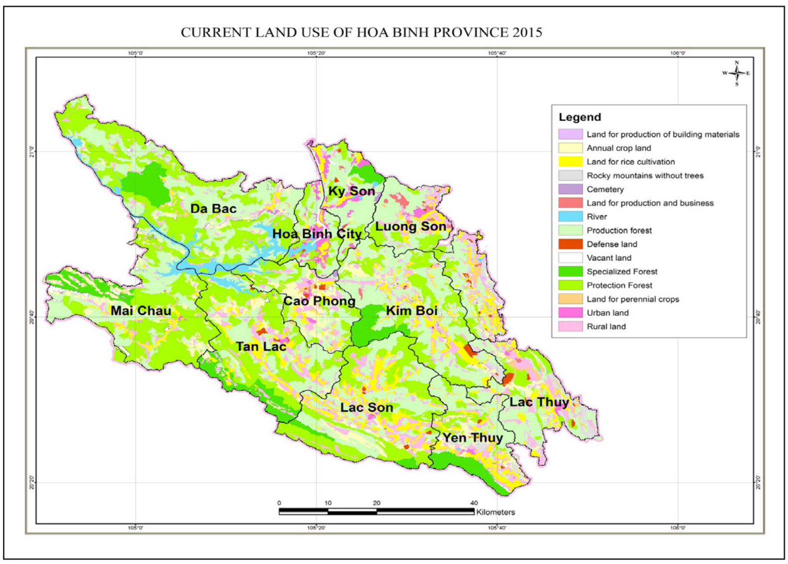

Figure 11. Map of land use in Hoa Binh province in 2015

Table 5. FFPI classification by land use type [3]

LHSDD	FFPI
River	1
Protection Forest	2
Producttion forest	3
Suf	4
Vacant land	4
Annual crop land	5
Old tree	5
Upland rice	5
Cemetery	7
Rural land	7
Land for production of construction meterials	8
Land for production and business	8
Defense land	8
Urban land	9

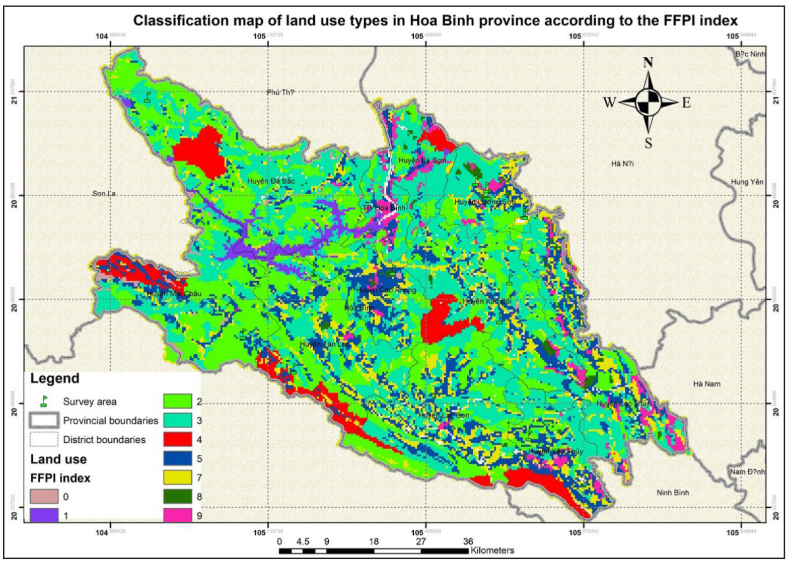

Figure 12. Hierarchical map of land use in Hoa Binh province according to the FFPI

4.5. FFPI hierarchical map for precipitation

Precipitation is one of the main factors causing flash floodsand inundations. Hoa Binh is located in the tropical monsoon climate area with the following characteristics: Hot, humid, cold winters. Rain usually concentrates in July, August, and the whole season's rainfall accounts for 85 - 90% of annual rainfall. Estimated average monthly rainfall is over 100 mm, the highest time is 680 mm. The precipitation class used by the research team is synthesized from rainfall data under the climate change scenario to 2030.

Tan Lac, Lac Son and Cao Phong districts are the districts with the highest rainfall under the climate change scenario 2020. This is also an area with a high potential area acod the risk of flash floods, landslides and floods, flooding the FFPI clasification.

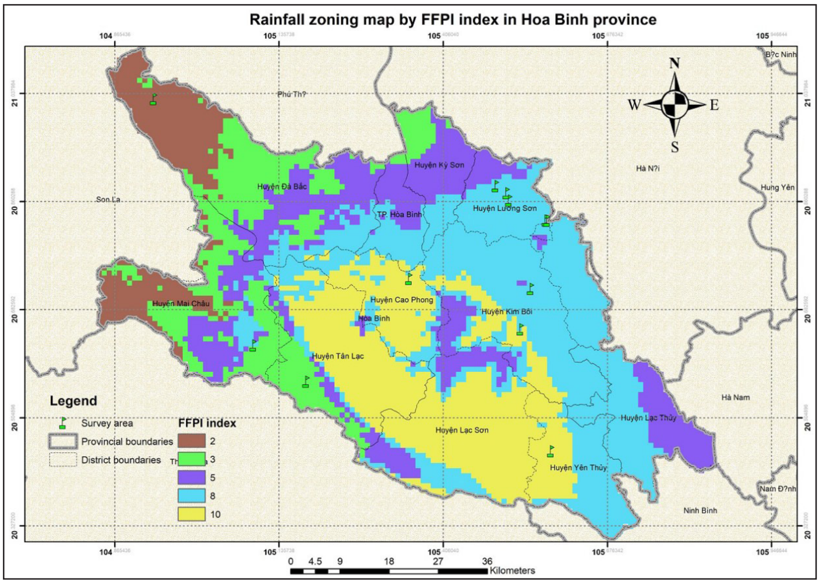

Figure 13. Rainfall zoning map by the FFPI in Hoa Binh province

4.6. Equation FFPI

This is the equation that has been synthesized from the analysis of flash floods that have occurred in the world

*FFPI = (1.5*Slope + LC/LU + Forest + Soil+Railfail)/N* [3]

In there:

FFPI: Flash flood potential index, pipe flood,

Slope: Slope factor,

LC: Factor of land use type,

Forest: Forest element

Soil: Earth Factor

Railfail: Rain Factor

N: Total index of impact on potential flash flood

The map of flash flood potential zoning in Hoa Binh province was established on the basis of a 5-layer overlay map of the component factors causing flash floods:

Gradient map of slope

Soil classification map

Land use classification map

Coverage density map

Rainfall hierarchy map

General equation for flash flood potential zoning in Hoa Binh province:

*FFPI = (1.5 * X1 + X2+ X3 +X4+X5) / 5*

In there:

FFPI: flash flood potential index

X1, X2, X3, X4: Slope index, land use type, soil type, cover density.

Overlapping the map layer, we have a warning map for flash floods and inundation in Hoa Binh prvince.

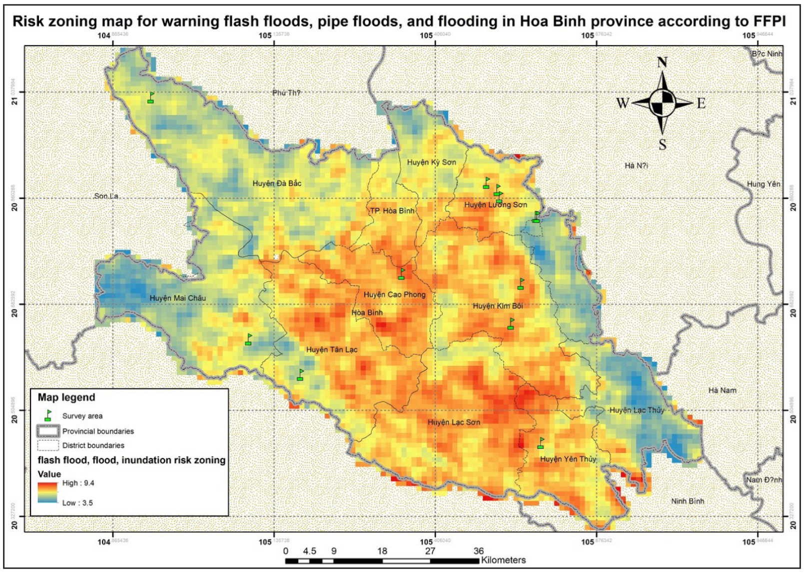

Figure 14. Risk zoning map for warning flash floods, pipe floods, and flooding in Hoa Binh province according to FFPI

5. Results and discussion

Convert all the maps above in vector to raster format (that conversion field is the factor of flash floods, pipe floods and inundations) where all images are converted to the same resolution (size pixels) and get the result as shown in Figure 14. Therefore, the map will be divided into 4 intervals:

1 - 2 areas with very low flash flood potential

2 - 4 Areas with low flash flood potential,

4 - 7 Areas with medium flash flood potential

7 - 8 Areas with high flash flood potential

8 - 10 Areas with very high potential for flash floods

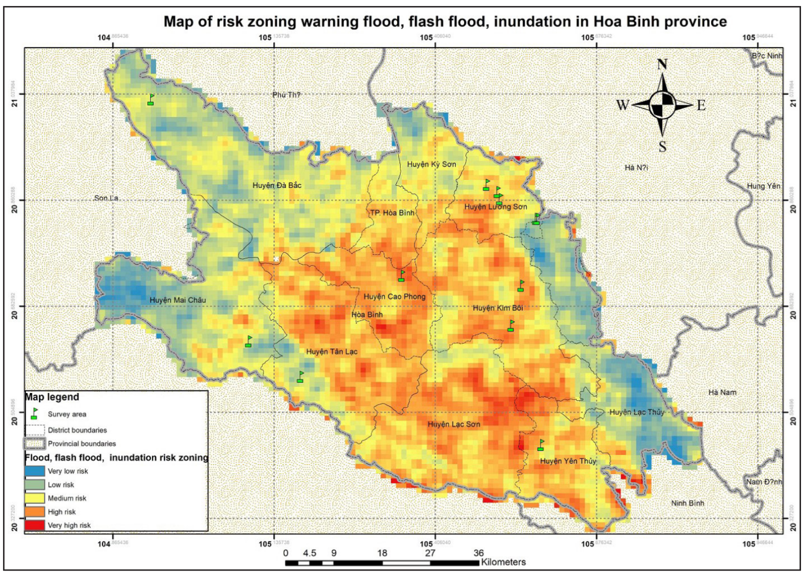

Figure 15. Risk zoning map warns of flash floods, pipe floods and inundation in Hoa Binh province

The final research results are shown in Figure 15. Overlapping more points that the group has surveyed with flash floods occurring in the past, we see that they are also located in high-risk and very high-risk areas, which is completely consistent with the research results.

Areas with high and very high flash flood potential: Covering about 60 - 70% of the total area of the province and distributed in districts such as Cao Phong, Yen Thuy, Luong Son, Kim Boi, Lac Son, Tan Lac and Cao Phong. Areas with medium and low flash flood potential: Accounting for 30% of the total area of the study area and mainly concentrated in districts such as Mai Chau, Lac Thuy and Da Bac.

In total the area of high risk of flash floods is 68,781 (ha) equivalent to 0.15 (%) of the area of Hoa Binh province. In which, Tan Lac district in the area of communes bordering Lac Son and Cao Phong districts is the area with the highest risk of flash floods with the area at risk of flash floods reaching 22719.4 (ha). Lac Son district is the district with the second highest risk of flash floods in Hoa Binh province with a total area of 14,069 (ha) high-risk areas. In addition, Cao Phong district is also located in areas with high risk of flash floods in Hoa Binh province with more than 12,000 (ha) located in high risk areas for flash floods and 5,351 (ha) in average muscle areas. Average muscle. The least high flash flood risk area that the research team found was the triangular area bordering the three districts of Cao Phong, Kim Boi and Lac Son with 10,000 (ha) in the high-risk area and 25,403 (ha) in an area of moderate risk. Hoa Binh province has 4 large areas with high risk of flash floods and tube floods, mostly concentrated in districts bordering Thanh Hoa province. However, most of Hoa Binh province is still located in the area with medium flash floods.

6. Conclusions and recommendations

6.1. Conclusions

By optical remote sensing technology, application of FFPI index method and a supporting software (ArcMap of ESRI), the authors have performed the process of analyzing component factors: Forest, altitude, slope, land use status... From the component maps that have been built, the map is superimposed in the process of overlaying the map using the FFPI index as a basis for calculating the potential for flash floods in areas of the province. Calculation results will use remote sensing images to re-evaluate and correct to get the most accurate map to warn of the risk of flash floods This is a suitable process for creating a warning map of flash flood and inundation of Hoa Binh province because the selection of input factors (causes of flash flood) are all taken into account. Calculated and those factors are again superimposed to select areas at risk by the FFPI index.

Also, from the warning map of flash flood and inundation, it can be seen that Hoa Binh is at risk of flash floods in the rainy season because most of the area is located in the area with a steep slope > 20%. Besides, the geological characteristics of the province are not very stable, this will create more favorable conditions for the process of flow generation, helping the flood flow to form faster.

The study applied Geographic Information System combined with remote sensing to identify flash floods, tube floods and potential flooding for Hoa Binh province. The selected natural factors for the assessment process include slope, land use type, soil type, forest density. The results have partitioned the potential level of flash floods in the district. Areas with high and very high flash flood potential in districts such as Cao Phong, Yen Thuy, Luong Son, Kim Boi, Lac Son, Tan Lac and Cao Phong. Areas with medium and low flash flood potential are in districts such as Mai Chau, Lac Thuy and Da Bac.

6.2. Recommendations

During the implementation, the authors encountered many difficulties in the data collection process. The received images have low resolution, so it is necessary to further improve the image quality and the time taken for the images to be quickly updated to facilitate better research.

Accurately assessing the potential for flash floods, we can further evaluate the importance of river density, flood peak modulus, geology... which has not been done in this study.

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