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Risk assessment of flash – muddy flood and inundation of western Tam Dao mountainous region, Vinh Phuc province, Vietnam by using intergrated concept of hydrology and geomorphology

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Abstract. Flash flood, muddy flood and inundation are three phenomena of hydrological hazard. Normally, they are logically appeared in a catchment. In some other cases at mountainous region, they are separately appeared. Studies on these phenomena are still incompleted. Case study from area of Vinh Phuc Province, an intermediate watershed of Ca Lo River, located in Western Tam Dao Mountain which cover nearly all region of the Vinh Phuc Province. The performance of the concept was evaluated using statistical hydrological and geomorphological methods to assess the capability of the model in simulating the phenomena of flash flood, muddy flood in sloping regions and inundation in low land of the study area. By using ArcGIS 9.3 software, vertical eroded, watershed and stream accumulation, land cover, wetness index, geomorphology, and rainfall data layers have been created from DEM, SPOT images, topographic maps, and statistical data. By overlaying these layers and then reclassifying the integrated layer, difference types of flood can be separated as muddy flood, flash flood along accumulation network and inundation in low land. These results are useful date for regional planning of the Vinh Phuc Province.

Keywords: flash and muddy flood, inundation, sub-basin, hydrology, geomorphology, average slope value, integration.

1. Study area

With an area of 1373.2 sq km ,Vinh Phuc Province is located in Northern Vietnam (Fig.1) with geographic latitude 21° 01' N, longitude: 105° 52' E. The province has population of 1180.4 thousand habitants (2006).

Located in the plains and midland of Northern Vietnam, Vinh Phuc Province is surrounded by Tuyen Quang and Thai Nguyen provinces in the North, Hanoi City in the East and the South, and Phu Tho Province in the West. Local topography includes midland, low hill and plain. There are four large rivers: Hong (Red), Lo, Pho Day, and Ca Lo. In the north, Tam Dao Range with maximum elevation of 1500 m, running in north west – south east direction, is a natural border between Thai Nguyen and Vinh Phuc. In the south, Hong River separates Vinh Phuc from Ha Noi City.

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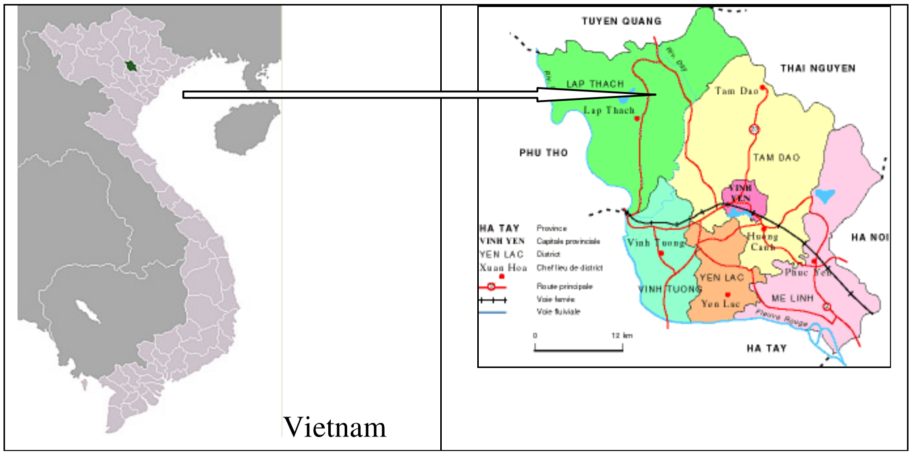

Fig. 1. The study area (before Me Linh District is merged into Hanoi City).

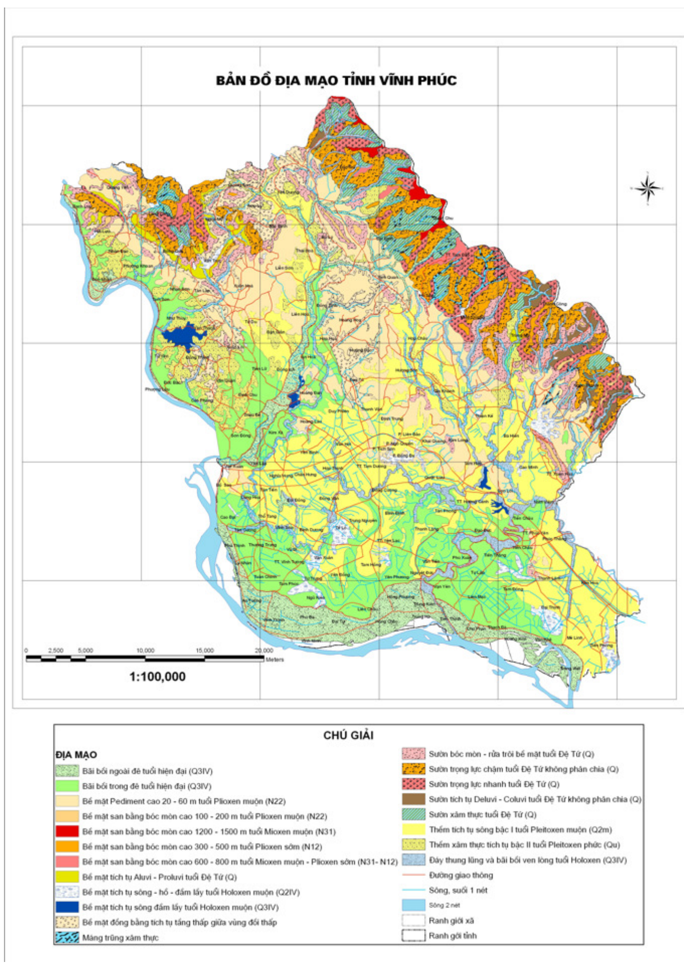

Fig. 2. Geomorphological map of the study area .

High precipitation (up to 3000 mm per year) and high slope of Tam Dao mountain are the main causes for flash floods and muddy floods, that were happened along old valley fill system and deposited cones plains, located at the foot of Tam Dao mountainous region. For environmental planning purpose, mapping for hazard of flash and muddy flash is a necessary work. [10]

Fig. 3. Some pictures of flash floods in the study area.

2. Theoretical concept about flash flood

A flash flood is a rapid flooding of geomorphic low - lying areas - washes, rivers, dry lakes and basins. It may be caused by heavy rains associated with a storm, hurricane, or tropical storm or melt-water from ice or snow flowing over ice sheets or snowfields in the temperature zone. In the tropical zone, flash floods may occur after the collapse of nature debris dam, or a human structure such as a man - made dam. Flash floods are distinguished from a regular flood by a timescale less than six hours. The temporary availability of water is often utilized by foliage with rapid germination and short growth cycle. Water rapidly out of its banks. Often this occurs in a short amount of time, only several hours or even less.[1,2]

Flash flood can be divided into 3 major types as follow [3,4]:

- Flash flood caused by heavy rain in natural water basins where have no human activities;

- Flash flood caused by heavy rain in water basins where have interfered of human activities with changing of natural balance (land cover, runoff, basin topography,…);

- Flash flood caused by damage of artificial or natural derby dams.

Characteristic of flash flood [5,6]

Difference to inundation flood in lowland areas which is slowly happening, flash flooding occurs when precipitation falls too quickly on saturated soil or dry soil that has poor absorption ability. The runoff collects in low - lying areas and rapidly flows downhill. Flash floods most often occur in normally dry areas that have recently received precipitation, but may be seen anywhere downstream from the source of the precipitation, even many miles from the source. In mountainous areas, flash floods are known to occur in the high mountain ranges. What makes flash floods most dangerous is their sudden nature and fast moving water? These regions tend not to have the infrastructure that wetter regions have to divert water from structures and roads, either because of sparse population, poverty, or because residents believe the risk by flash floods is not high enough to justify the expense. In fact, in some areas, desert roads frequently cross dry river and creek beds without bridges or living areas with houses are still take place at the high flash food sensitivity positions. With these characteristics, flash flooding occur in small areas but it’s destroy force is great, so that the risk is heavy too. Risks include dead of people, damages of infrastructure, housing, cultivation and changing the environment to negative direction.

Factors related to flash flood:

From the system viewpoint, we can comment: Flash flood and muddy flood are the open system has many factor, in this system, line flash flood and muddy flood is considered as the performance of the entire system. This system has many component factors. Severity of flood (strength, dangerous) is characterized by its kinetic energy P = mv2/2 (P: kinetic energy of the flood; m: ratio of the flow [tan/m3]; v: velocity [m/s]).

From here, we see the dominant factor is the strength of the flood: rainfall, river slope, side slope, abandoned materials and weak links (accumulate due old landslide, flash flood and muddy flood, shell thickness and type of weathering, vegetation cover,...)

Based on the specific conditions of the study area, can identify five key factors to decide the risk of flash flood and muddy flood as follow:

a. Maximum daily rainfall: is the direct cause and necessary prerequisite conditions to create flash flood.

b. The risk of landslide and erosion: is the ability to form the essential and structural material of flood flow. This information will be the integration of multiple related parameters but the process may create classes of independent information in flash flood study.

c. The average slope of the sub-basins: are representative parameter for a basin, are in direct ratio to the speed of the flash flood.

d. The buffers of first, second and third orders of drainage network, where flash – muddy flood often occur after raining. In the Geographical aspect, these buffers are same locations of valley fills types V-shape and U-shape.

e. Vegetation land cover or land use: is the related information to the ability to store water, limiting the energy of flash flood.

The theoretical model for stydying flash flood is presented in Fig. 4.

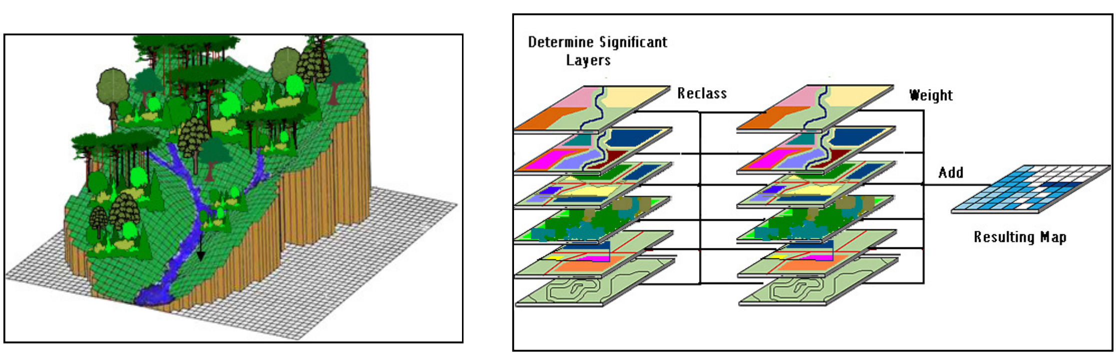

Fig. 4. Simulation in the 3D space and integrating information for mapping flash flood.

3. Mapping the risk of flash flood for study area

3.1. Defining information layers for integrated model to map the risk of flash flood – muddy flood

As we know, there are many factors that impact on the environment and cause the phenomenon of flash flood - muddy flood [9]. In the basin, to built flash flood - muddy flood risk maps, the above five factors are considered as inputs in the model analysis.

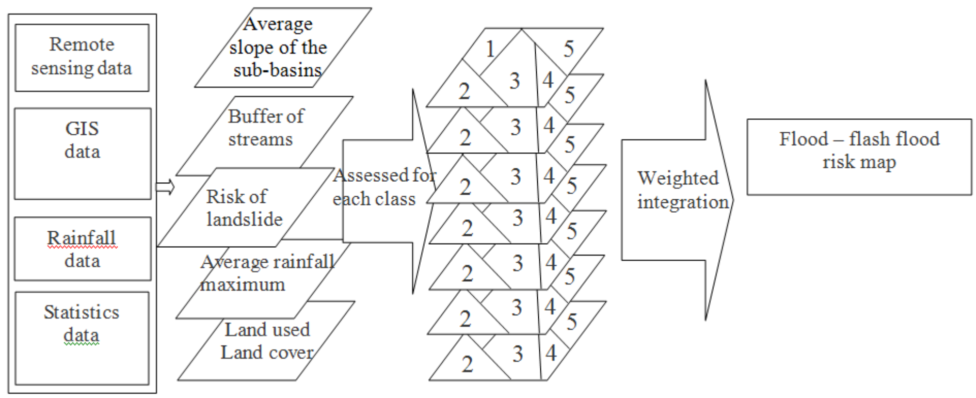

Fig. 5. Weighted model diagram for mapping the risk of muddy - flash flood in Vinh Phuc Province.

In the above weighted model diagram, deriving from the basic input data to build component factor maps. Then building hierarchy of each factor map the extent of influence on tube flood flash risk in the study area. The final work is integrating to build flash flood.

a. Landslide risk factor [9]: represent the sum of many factors affecting the flash flood – muddy flood as side slope, average annual rainfall, geology - petrography, breaking density, density deep cleavage, density horizontal cleavage, land cover; landslide risk map of the study area will be established by means of model weights (Fig. 6).

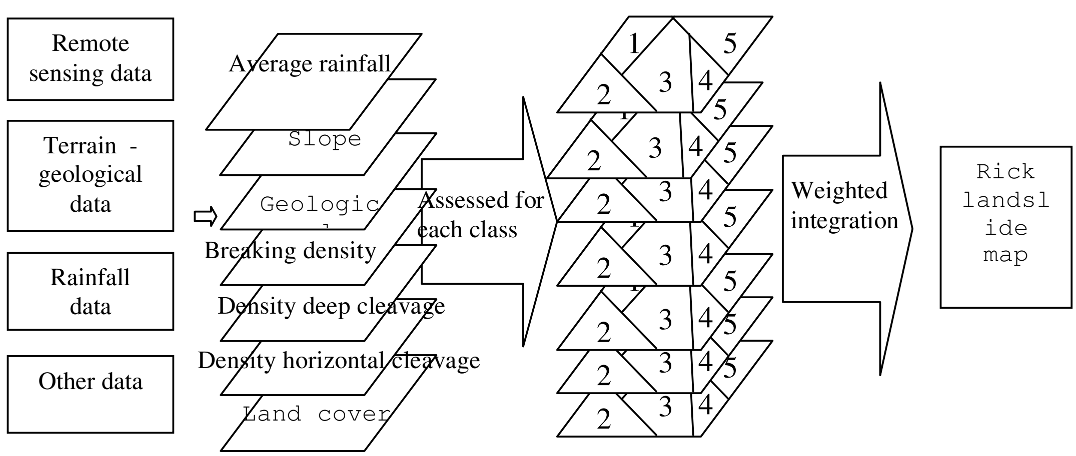

Fig. 6. Creation of layers for landslide risk map muddy flood risk map.

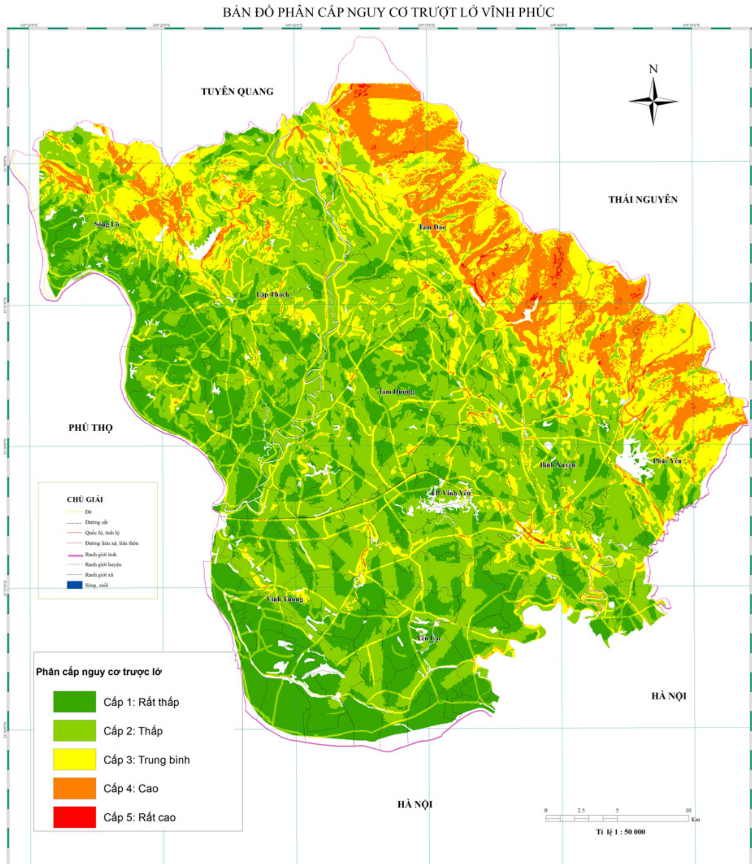

Fig. 7. Landslide risk map.

b. Maximum daily rainfall factor

Table 1. Scores for maximum daily rainfall

Factor	Value	Scores
	<250 mm	1
	250 – 290 mm	2
Daily rainfall maximum	290 – 330 mm	3
	330 – 370 mm	4
	>370 mm	5

Rainfall is the direct factor causing for flood. But for flash – muddy flood, it need to have very high volume of water occusing in a short time. Result of this situation is water running with very high speed. This data can be get from the maximum daily rainfall data during a long duration of many years. Normally, it need to have statistical rainfall data for more than 30 years.

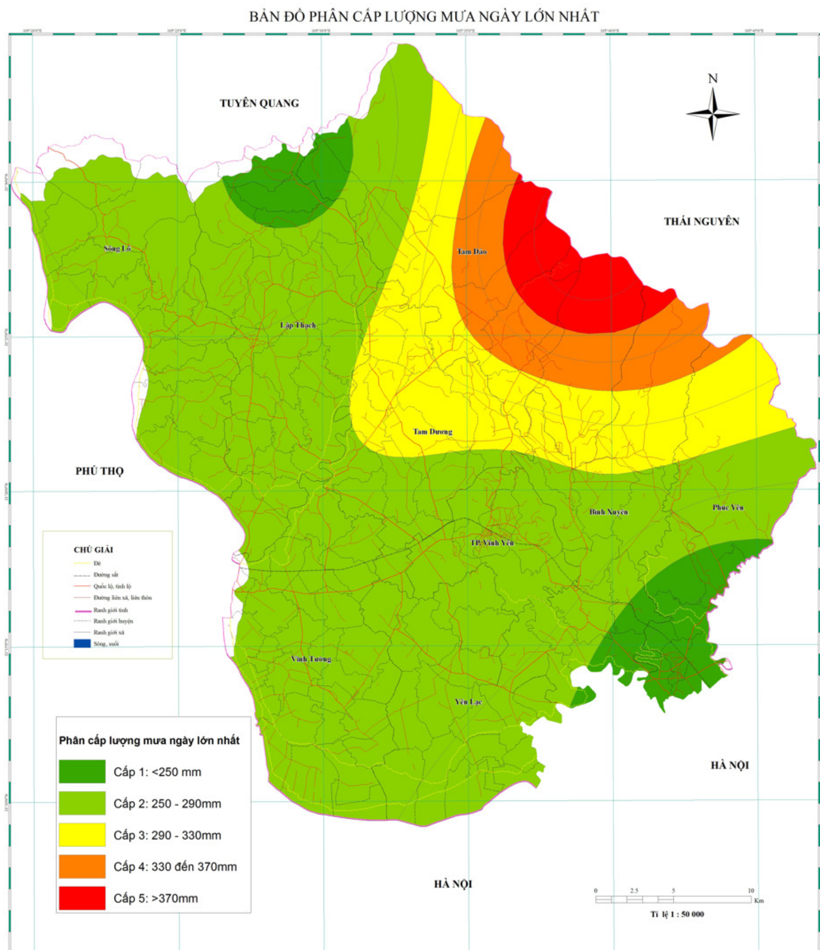

Fig. 8. Maximum daily rainfall map.

c. Average slope of the sub-basins factor: these basins are divided based on the division of the rivers and streams and an average slope of the basins plays an important role in the formation of flash flood - muddy flood disaster on the branch of river, streams of each basin.

Table 2. Scores for average slope of subbasins

Factor	Value	Score
Average slope of subbasins	$< 5^o$	1
	$5^o - 10^o$	2
	$10^o - 15^o$	3
	$15^o - 20^o$	4
	$>20^o$	5

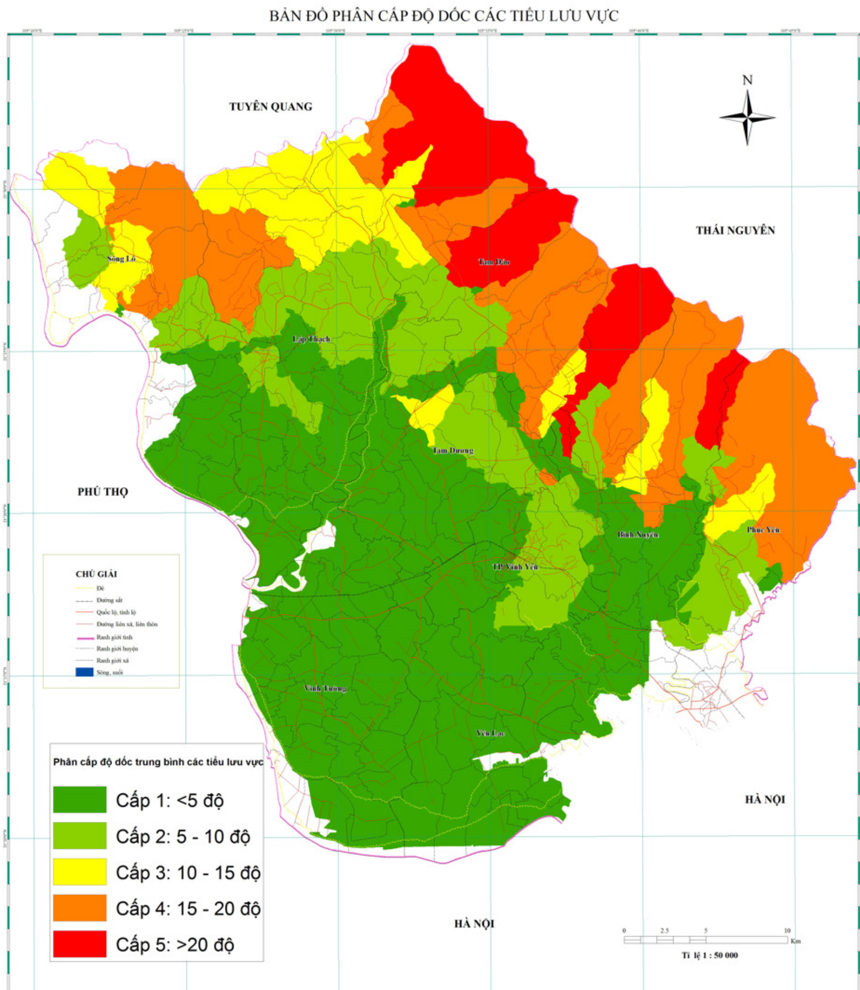

Fig. 9. Average slope of sub-basins.

d. Buffer zones of stream orders

Table 3. Scores for buffer of stream orders

Factor	**Value**	Scores
Buffer of stream orders	Branch 1	4
	Branch 2	5
	Branch 3	3
	Branch 4	2
	Branch 5	1

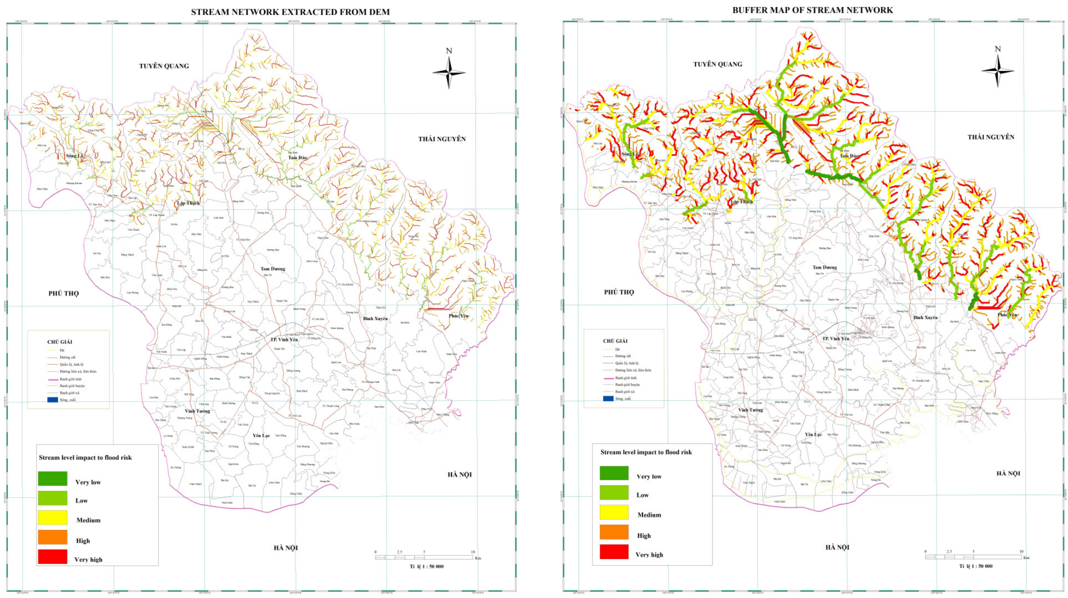

Figure 10. Stream network extracted from DEM (left) and buffers of stream network (right).

e. Forest cover / land cover

Table 4. Scores for land cover / forest cover

Factor	Value	Scores
	Rich forest	1
	Medium forest	1
	Poor forest	2
	Forest regrowth no reserves	3
	Forest regrowth with reserves low level	2
	Bamboo forest	2
	Bamboo mix wood forest	2
	Plantation	3
Forest	Specialties forest	3
	Grass land	4
	Grass land with brush	3
	Grass land with wood tree	3
	Forest garden	4
	Industrial forest , orchard (tree, orchard …)	4
	Agriculture land	5
	Resident areas	5
	Sand bar	5
	Water	5
	Other land	5

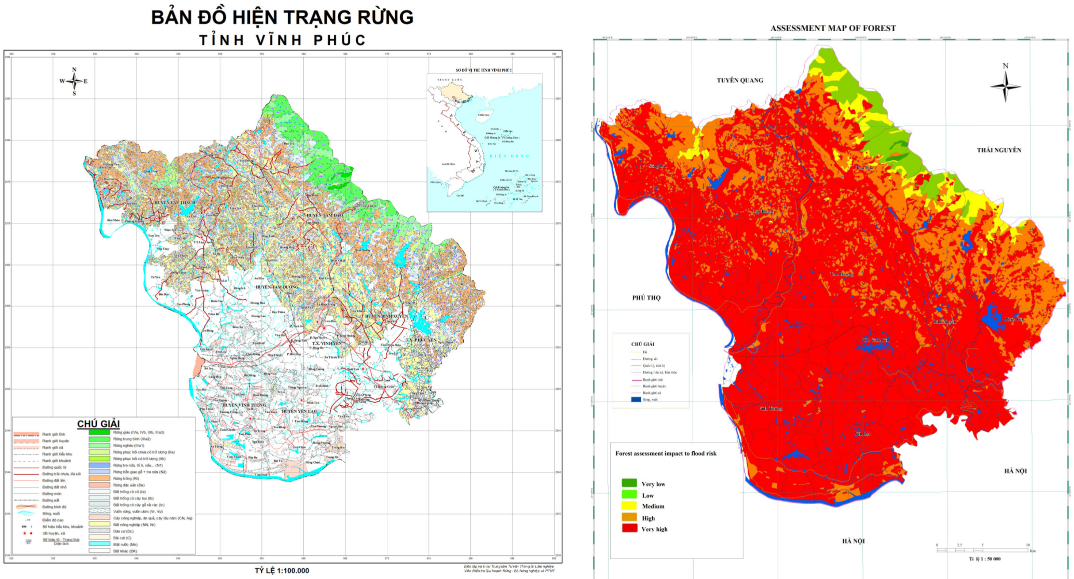

Fig 11. Forest map and forest assessment of flash - muddy flood risk.

4.2. Integrating data

Flash-muddy flood risk map is built on the basis of spatial analysis in ArcGIS software environment. In this model, five decisive factors to the possibility of flash flood-muddy flood are evaluated having different roles in the formula calculation [9]:

$$F = \frac{1}{m}\sum_{1}^{n}(\alpha A + \delta B + \gamma C...)$$

Where:

F: Flash risk level, ranking from 1-5

m: Ranking of index value (from 1-m)

1....... n: Data layers

α, δ, γ... : Weighted values for separated layer

A, B, C...: Weighted layers of separated factor.

The weighted values are attached to the information layers as follows: maximum rainfall: 3, average slope of the sub-basins: 2, the flow-accumulation value: 2, other layer: 1.

In ARC/GIS software, an equation is as follows:

F = 1/5(Landslide risk + 2*assessment for max daily rainfall + Assessment for average slope of the sub-basins + assessment for land use + assessment for buffer of stream orders)

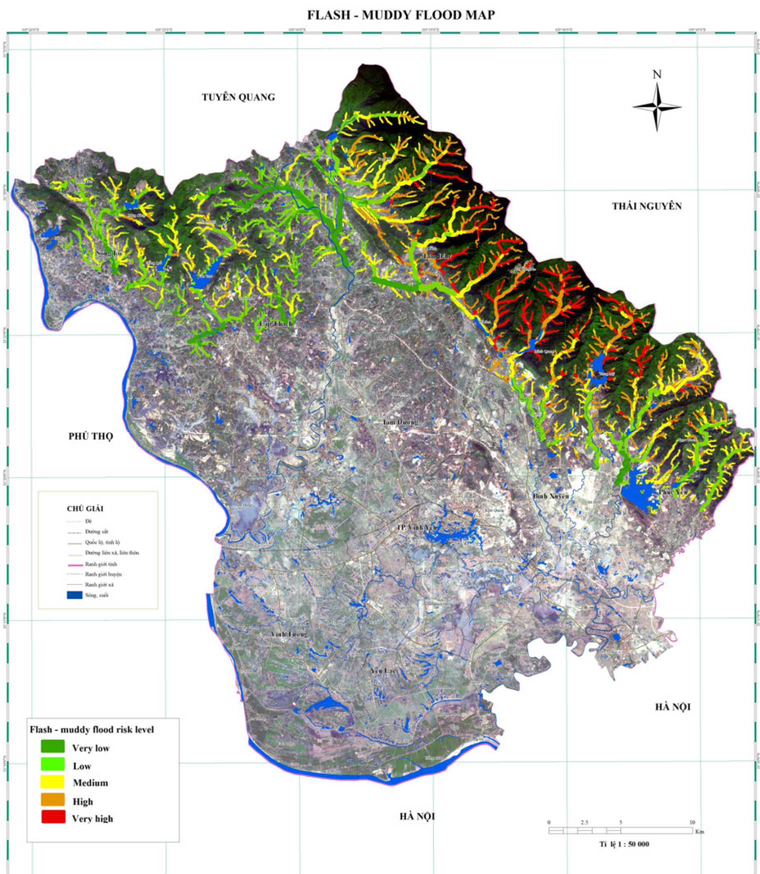

Fig. 12. Final map for flash-muddy flood risk map.

Flash - muddy flood risk map is the final map with 5 levels of risk as follows: very low, low, medium, high, and very high.

4. Results and discussion

4.1. Accuracy assessment

Comparing with historical data, flash – muddy flood has been occurred in many places of the study area. Locations of it are inside the piedmont alluvial plain which runing along the West – South side of the Tam Dao Mountain. Historicaly, flash floods has been taken in several villages such as: Tam Tien, Tan Phu, Xa Huong (Dao Tru Commune), Dong Quan, Ngoc Ly (Yen Duong Commune), Son Dinh (Dai Dinh Commune), Dong Que, Ngoc My, Bac Binh, Quang Son commune…[10]. Traces of these muddy flash flood flows existed along stream bed and stream terraces. These traces are located in the buffer zones of stream network, especially of the first and second orders (Fig. 13). Base the this result, we define that the layer of stream buffer can be used as a importance layer for study at medium and small scale. Geomorphology map with various features is needed for detail study.

Fig. 13. Signature of a flash flood in the study area in 2008. In the stream bed: sand pebbles, boulders are old signatures of old muddy - flash flood.

Depending on detail of elevation contours, stream network can be differenced so the results will be established with difference accuracy.

4.2. Application

Resulting map shows areas at risk of flooding, but it can not happen immediately but occurs after long periods of time. So the result will be a reference to the long-term planning study area. Especially the planned distribution of residential areas, avoid places with high possibility of flooding.

When decentralization is possible in areas with flooding, the planting and watershed protection forest can be focused in a more effective.

But the short-term forecasts can still be done if there is data to date on climate, particularly rainfall data measured at stations in the study area. Through this will be decided in time for the flood prevention.

4.3. Methodology

- The river network can be used for the model after editing with difference ID but in topographical map, a lot of locations of the first and second order are not showed because there are no water. If heavy rain happens in the region, these positions will occur flash –muddy flood. This limiting of topographical map can be sold by using the GIS tool of automatic river network extraction

- The model for flash - muddy flood used 5 parameters for calculation. In these numbers of parameters, only rainfall factor is flexible changed during season and yearly. For more accuracy, the long duration statistic data will give the high accuracy.

4.4. Conclusion

The study have solved a question for mapping of muddy – flash flood in mountainous areas, a topic is not new but still have a lot of discussion. With the GIS and

Geomorphological concept, muddy-flash flood can be established following the procedure.

With the climate change aspect, rainfall can not followed the normal rule of annual statistic so it is necessary to have hydrological station and rainy forecasting network. These work is useful for a creating of a early flash – muddy flood warning system. Local government can apply the result of the study for regional planning purpose, such as the planting of protection forests, assorted agricultural and hydraulic techniques based on general management of river basins, first of all, the proper planning on land use for sustainable development, which shall serve as the most economical and effective measures to be applied in the study area personally and also for all of Vietnam.

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