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RESEARCH AND ASSESSMENT THE RISK OF FLASH FLOODS IN MOUNTAINOUS DISTRICTS OF QUANG NAM PROVINCE

Speciality:

Physical Geography
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ABSTRACT OF GEOGRAPHY DOCTOR'S THESIS

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INTRODUCTION

1. RATIONALE OF THIS RESEARCH:

Quang Nam is located in the South Central Coast region of Vietnam with area of 10.438,3 sq.km, 70% of which is the mountainous areas and it is still a poor province (accounted for 3/62 poor districts in the whole country), there are 9 districts regarding mountainous districts amongst 18 districts and the city. Quang Nam's topography has complex structure. The mountainous area has the upper hand with deep separative level and high slope, rivers and streams system, narrow river-bed, several waterfalls and rapids, short and sloping rivers, and complex geological features. The interaction between monsoon circulations and features of mountainous system has brought Quang Nam a large amount of rain, average on 2000-2500mm per year, rain gathers according to seasons (accounts for 80% in rainy season).

The risk of flash floods mainly appears in the West mountainous area of Quang Nam such as Bac Tra My, Nam Tra My, Tay Giang, Nam Giang, Dong Giang, Phuoc Son, Hiep Duc, and Tien Phuoc, where gather the ethnic minority communities with slow economic development, difficult traffic, and lower social life in comparison with flat area.

In recent years, human factor in socio-economics activities using nature and unreasonable hydro construction also lead to the increase of flash floods hazards in Quang Nam. In the fact that it is necessary to find solutions as soon as possible not only to eliminate the risk and negative hazards consequences caused by flash floods but also create a better and safer environment for communities and provide them specific information to have initiative protection. Recently, assignment of protection and remedy is primarily traditional. Even though fast, tools and solutions of slow simulation and forecast have been concerned, studied for such a long time and achieved considerable progresses, the complex properties of flash floods in comparison with normal climate phenomenon and lack of sufficient and reliable information. The reliable level in flash floods forecast and warning still remains as a challenge. The areas having flash floods tend to lack technological – informative system, educational background is not good; therefore, using flash floods hazard maps to reduce the risk of damage and prevention is one of the most practical solutions today. The research and identification of causes of flash floods, the assessment risk of flash floods, on which to propose solutions to reduce and mitigate disasters is to a matter of practical and scientific significance and to make a great contribution to each specific locality, especially in Quang Nam province. Therefore, ***"Research and evaluation the risk of flash floods in mountainous districts of Quang Nam"*** was implemented.

2. OBJECTIVES AND TASKS OF RESEARCH

2.1. Objectives: To establish a scientific basis for the research and risk assessment of flash floods in mountainous districts of Quang Nam in order to propose solutions to prevent and address the negative impacts caused by flash floods hazards. .

2.2. Research Tasks:

1) To establish the theoretical basis and research methodology; 2) To analyze conditions and agents causing flash floods hazards in mountainous districts of Quang Nam; 3) To conduct the comprehensive assessment in terms of factors causing flood risk in the

mountainous districts of Quang Nam; 4) To propose solutions to prevent and eliminate damages caused by flash floods hazards in mountainous districts of Quang Nam.

3. RESEARCH SCOPE

- Spatial Scope: Mountainous districts of Quang Nam province including Bac Tra My, Nam Tra My, Phuoc Son, Tien Phuoc, Nong Son, Dong Giang, Nam Giang, Tay Giang, and Hiep Duc.

- Time Scope: Statistics data on climate from 1981 to 2015, including flash floods occurring from 2005 to 2015 were selected.

- Content Scope: 1) To identify conditions and factors causing flash floods in Quang Nam; 2) To apply the model combining landscape analysis and assessment in geography to generate a map of flood risk classification in mountainous districts of Quang Nam; 3) To propose restoration of forest cover and population redistribution is an important solution to prevent and address flood hazards in Quang Nam.

4. DEFENSES POINTS:

Point 1: Flash floods occurring in river basin which is the distribution process of flowing energy in small basin, therefore basic units used in flash flood risk assessment are sub-valley. Valley analysis is the combination of slope factors, topographic elevation, and precipitation participation in the dynamics of flows generation. Therefore, valley analysis should be connected with landscape analysis to assess the overall impact of landscape factors on the regulation of flows leading to flash flood.

Point 2: The mountainous districts of Quang Nam has complex structure, mountainous area has the upper hand with deep separative level and high slope, the rainfall mainly gather in each season, so the risk of flash flood is high. According to the approach mentioned in the point 1, the map of flash flood risk assessment in 9 mountainous districts of Quang Nam was established based on flash flood classification for 77 sub-basins. This map provides the scientific basis for planning the restoration of forest cover and population redistribution according to the administrative commune units which is an important solution in order to prevent and eliminate environmental hazards caused by flash floods.

5. **NEW CONTRIBUTIONS OF THE THESIS**

- The tendency of research and assessment the risks of flash floods based on connection between valley analysis of flood dynamics factors and analysis and assessment of landscape factors affecting the risk of flash floods in sub-basin was first applied in flash flood studies in Vietnam

- Establishing a map of assessment the potential of flash floods and a map of assessment flash floods risk in 9 mountainous districts of Quang Nam based on the potential distribution and flood risk in 77 sub-basins; Proposing the priority in order to restore the rate of forest cover and population redistribution according to administrative communes units in the study area.

6. THE SCIENTIFIC AND PRACTICAL SIGNIFICANCE OF THESIS

- Scientific significance: Contributing to clarify the theoretical basis, research direction and methods of assessment of risk of flash flood in mountainous areas in Vietnam.

- Practical significance: Providing materials, reference materials for studies on land use planning and population distribution to prevent and eliminate damages caused by flash floods in local areas, especially in mountainous districts of Quang Nam.

7. DOCUMENT BASIC OF THE THESIS

To conduct the thesis, several materials are used:
- Base maps (such as topographic and thematic maps).
- Data reports, statistics.

8. STRUCTURE OF THESIS

INTRODUCTION
CONTENTS
Chapter 1: Rationale and Research Methodology
Chapter 2: Features of Flood Formation Factors in Mountainous Areas of Quang Nam Province
Chapter 3: Assessment of the risk of flash floods in mountainous districts of Quang Nam. Proposing solutions to prevent and reduce environmental hazards caused by flash floods in mountainous districts of Quang Nam
CONCLUSION AND RECOMMENDATIONS

CHAPTER 1:
RATIONALE AND RESEARCH METHODOLOGY

1.1. The overview of studies on flash floods in all over the world, in Vietnam and Quang Nam province.

1.1.1 The overview of studies on flash floods in all over the world:

In the last few years of the end of the twentieth century, there were a variety of hazards exploding in every single continent, leading to great harm to people and property. That is reason why many Western European countries as well as North America had formed a new scientific research "natural hazards" in English, "Risques Naturels" in French, which focusing on the essence and damage. The United Nations publishing that the decade of 1990 - 2000 was known as the International Decade for the Reduction of Natural Disasters (IDNDR), especially the research on flash floods is regarding the most significant events.

a. Studies on distribution of flash flood risk:

(1) In the United States, hydrological/ hydraulic methods were applied. Typically, Greg Smith (2003) studied and applied this method to Colorado area, Brewster (2009) – Binghamton area, and Kruzdlo (2010) area - Mount Holly. The method of using GIS technology to build a GIS database that consists of 4 basic classes in raster form such as slope, vegetation cover/ land use, soil, and forest/ vegetation density; (2) The typical flood model of the ITC (Netherlands), based on ILWIS software source code, is represented by the GISIZ model, based on geographic-geomorphological approach. According to a geological perspective, the SINMAP image was constructed.

b. Flash flood warning projects:

In recent years, several studies on flood warnings with different methods have been conducted in the world. To obtain data of rainfall and water level, one of the strengths of hydrographic research is to use the flood occurring model. Flood models that are the most common can be classified into different types, depending on the input data requirements, the complexity of the model (such as DHM, HMS, TANK, SSARR, ANN, SCS, SWAT, VRSAP, MIKE 11-FF or RUNOFF) in each specific case to apply suitable model or combine them together. The research following the direction of hydrological and basin water balance in some methods such as Remote Sensing and GIS with specific

products including maps of flash flood distribution have been conducted in many countries all over the world such as USA, Brazil, Canada, India, Thailand, Taiwan, China, ... (1) Michel A built the Econova flood warning system in basins in Canada; (2) Steve P. and Sun developed the flood management system in basins of Tung Hoa, north of China (3) Joko W built the flood warning system in basins of Garang, Indonesia (4) Timothy LS and research group NOAA, USA introduced GIS flood hazard identification in 1993. (5) Mark Jackson et al., NOAA, NWS, USA published the Flash flood monitoring and prediction system (2005). Flash flood monitoring and prediction as an early warning tool for flash floods in the western United States. This is a continued product of Timothy L. S and Carpentera T.M. (6) In China's disaster warning system introduced by Zhou Jinxing, Wang Yan, 2004 (7) V. Estupina-Borrell et al., Institute of Fluid Mechanics, City of Toulouse, France, 2006, MARINE MODEL (Anticipation of Runoff and INTRANS for extreme events) to calculate flash flood.

1.1.2. The overview of research on flash floods in Vietnam

a. Researches on flash flood hazard distribution – Potential of flash floods:

Mainly in the tendency of the combination between hydrodynamics and collective geography: Some typical works such as: (1) Tran Viet An (2005), has studied on the flash flood distribution in Dien Bien and Son La provinces; (2) Nguyen Trong Yem et al., 2006, studied and built a map of flash flood risk distribution in Sa Pa, Bat Xat and Lao Cai city, Lao Cai province, where flash floods occur relatively frequently and severely; (3) Pham Thi Lan Huong and Vu Minh Cat (2008) have investigated and developed a potential flash flood warning map for the Northeast, piloted in three provinces of Cao Bang, Bac Kan and Thai Nguyen; (4) La Thanh Ha et al., 2009 have studied and built a flood risk map of Yen Bai, 2009 and mountainous areas in Vietnam; (5) Nguyen Ngoc Thach et al., 2011, in the framework of the cooperation project with India, studied and built a flood risk map of Vinh Phuc province, Bac Kan province and Pac Nam district, Bac Kan province; (6) Uong Dinh Khanh et al. Investigated and mapped the accident map of floods and mudflat in Ninh Thuan province, 2011 and the hazard map of landslide and flash flood in Quang Tri province.

b. Flood warning projects:

Mainly in the tendency of the combination between hydrodynamics and collective geography: Some typical works: (1) Do Dinh Sam et al., in 2006 study on conducting map (scale 1: 250.000) for warning flash flood in South Central Vietnam; (2) Ha Thanh Giang, in 2005 introduced the rain caculation and flash flood warning systems. The primary factor of flash floods is identified as rain and topography; (3) Ngo Thuan Thuan, in 2005 and 2007 studied and presented some features of flash floods in our country based on statistical analysis of flash flood data in the past; (4) Nguyen Viet Thi, in 2006 studied flash floods that occurred in Vietnam from 1991 to 2005; (5) Nguyen Viet Thi, in 2007 made a presentation on rain and flood forecasting system in Vietnam at the workshop "Research on flash flood and solutions"; (6) La Thanh Ha, An Tuan Anh, and Tran Anh Phuong, in 2007, have applied field methods, hydrological and hydraulic models and GIS to simulate massive historical flood caused great harm in people and property; (7) Nguyen Huu Khai, in 2004 applied artificial neural networks (ANN) to simulate and forecast flash floods for some minor basins such as Dinh river (Binh Thuan province), Nam La (Son La), Ve river (Quang Ngai); (8) Nguyen Ngoc Thach and nnk, in 2011 studied and built disaster management software (landslides and flash floods) and

supported to make decision (DSS) and applied them in Vinh Phuc and Bac Kan provinces.

Generally, most of the researches from the government state, ministry, provincial or donor levels have shown specific and detailed causes. Therefore, these researches have made several valuable recommendations in continuing to conduct studies on solutions to the disaster reduction in specific areas; however, they have not been summarized into the law. The study mainly focused on some northern provinces of Vietnam and the study on small scale, the forecast still has limitations.

The Researches related to the subject in Quang Nam province

Most of the researches in this area are the study on floods in basins, typically researches: (1) Can Tho Van conducted research on establishing scientific basis of vulnerability assessment in basins of Vu Gia - Thu Bon to plan for disasters protection; (2) Ngo Le An and his colleagues studied the simulation and forecast of flood flow in Vu Gia - Thu Bon; (3) To Thuy Nga and his colleagues presented an approach to operating reservoir system during that time in basins of Vu Gia - Thu Bon; (4) To Thuy Nga (2014), (2015) continued to study on operating large reservoir system in Vu Gia - Thu Bon for flood protection; (5) Tran Van Tinh has successfully applied the Hec - GEORAS model to calculate and simulate in basins of Vu Gia - Thu Bon floods, through the GIS to build a map system for floods in 2009, floods 1%, 5% and 10% respectively; (6) Dao Van Khuong, Nguyen Manh Linh applied the SWAT model to assess impact of forest on floods in Vu Gia; (7) Dang Thanh Mai (2009) studied the application of wetspa and hecras models to simulate flood forecasts in the Vu Gia - Thu Bon river system on the basis of connection three models: WETSPA, HECRAS and GIS hydrological one in scheduled 24 hours and 36 hours warnings; (8) Vu Thi Thu Lan conducted research through field surveys, remote sensing and GIS combinating with hydrographic - hydrological models in the Vu Gia - Thu Bon river system.

The aforementioned projects focus on the downstream of the river or on a large territory of the Government state level. The contents stop at solving flood problems in the downstream, mainly build models for the construction of a flood warning system in downstream areas, particularly in the Vu Gia-Thu Bon basin. Therefore, studying and assessing the risk of flash floods in mountainous districts of Quang Nam and proposing solutions for minimizing damages is an essential issue now.

1.2. Theoretical basis for flood risk study in mountainous districts of Quang Nam

1.2.1. The definition of flash floods

Even though scientists agree on the severity of flash floods, the definition of flash floods has not been unified.

According to some scientists' perspectives in Vietnam and in other countries:

- According to Ngo Dinh Tuan, flash floods are floods that have very high speed (sweep), occur unpredictably (usually occurs at night when it has rain, flood ...) in a small area or large, maintain in a short or long time (depending on the floods), bring a great deal of mud and sand, cause enormous destruction.
- According to Cao Dang Du, La Thanh Ha and many other researchers in Vietnam all agree that: *flash floods are often large floods, occur unpredictably, exist in a short time (rapid rise, rapid fall), high streams flowing solids with enormous destruction.*
- According to WMO, flash floods often occur on a narrow area and in short time (less than 6 hours), sharp charts, unpredictable water floods, and rapid rise and fall. The basic

difference from normal floods is usually the sudden appearance and the very short time from the phenomenon to the flood.

According to Frederik C.C, flash floods are the result of a rapid gathering of rainfall in a high hill area. The danger of flash floods is created by its speed and damage.

1.2.2. Basic features of flash floods

- *Surprising:* The duration from the rise of water level in the river to flood peak lasts very short.
- *Short-term and fierce:* flash floods usually last in a short time, usually end in 10-18 hours, rarely in more than one day, large floods cause erosion, Slope a great deal of materials in mountain slopes becoming streams of mud - water - solid together almost simultaneously and rapidly.
- *Density:* Flash flood streams are different from normal floods because of the large solids percentage.

1.2.3. How to recognize the flash flood

Due to the aforesaid features, to identify whether the flood is a flash flood or not, attention should be paid to the following observable phenomenon such as the amount of time flood reaches peak extremely rapidly, peak is higher than normal flood peak in the same condition (equivalent rainfall); Alluvial deposits are larger than normal, pulling solids; Flood streams create loud noise due to carrying soil, rocks, trees, etc.

1.2.4. Flood classification

Similarly to the definition of flash floods, scientists hold different points of view about identification and classification. Having combined all the existing classifications, according to Uong Dinh Khanh: the Thesis of Flash Flood Classification was divided into 4 types (1) Block flow flash flood, (2) Side flash flood, (3) mixed flash flood, and (4) Mud rock flood. Block flow flash floods (either natural or artificial) and mixed floods are not as common as side flash floods, but are often large, unexpected, cause great destruction and difficult to simulate and predict. Rock mud floods are usually caused by landslides with very large amounts of rocks and soil in the upstream or downstream rivers during flood time. Landslide occurs when the soil structure is broken down for many reasons including the effects of heavy rain and/or prolonged rain, and sometimes after a long or moderate precipitation. These floods are rare but extremely enormous, unpredictably, causing the greatest damage and also the most difficult floods to simulate and forecast.

1.2.5. Factors involve in flash flood formation process:

a. Group of factors involve in the dynamics process of flash flood risk

b. Group of factors affect the formation of flash floods

1.3. Research perspective, research approach

1.3.1. Viewpoints

a) The system-synthesis-territorial viewpoints applied in the implementation of the project are:

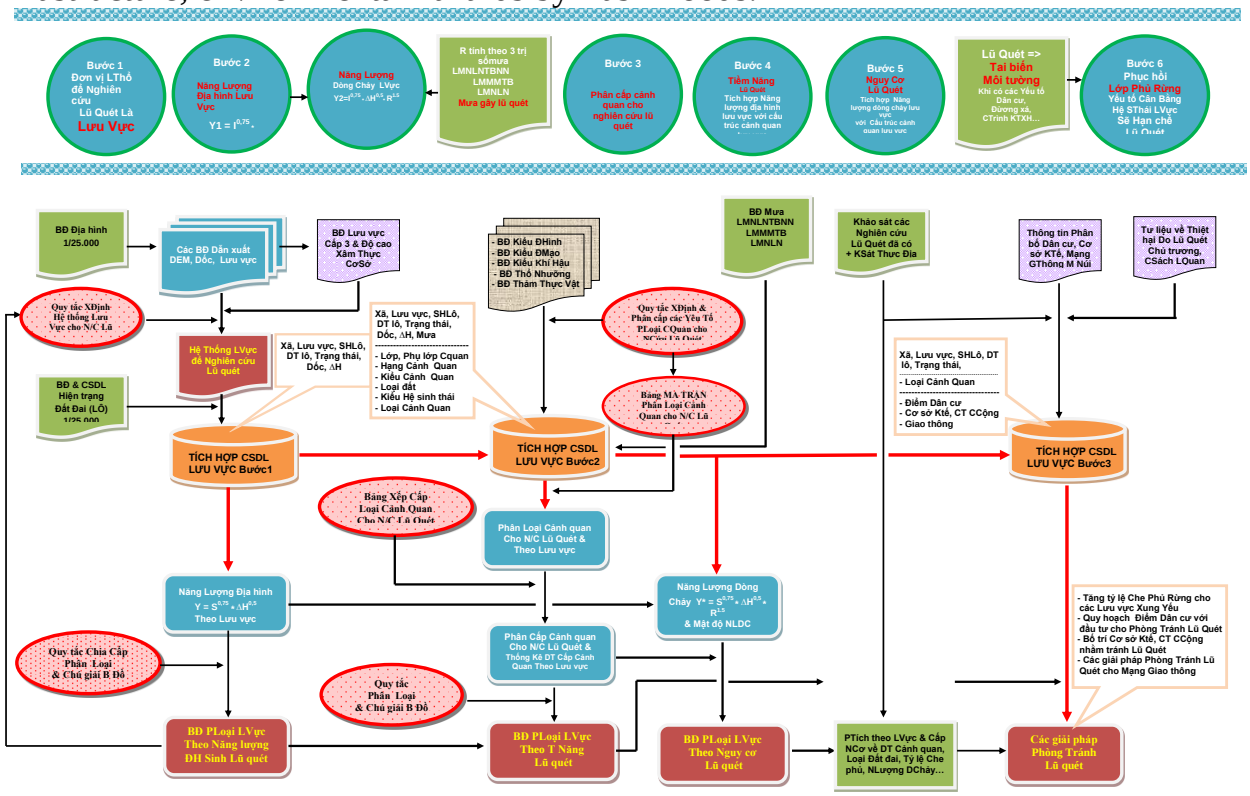
- The territorial system studied is basin (sub-basin - level 3).
- The flash flood process is a dynamic system of exogenous geodynamic processes (dynamic geomorphology, dynamic hydrodynamics, etc.), interactions between rain, flow, slope surface, buffer surface landscape, etc.).

b) Historical perspective – arising viewpoints applied to explain the history of formation, common features, features of natural ingredients, natural geographic distribution of studied areas, flash flood formation factors.

c) Ecological environment viewpoints: The balance of natural processes: material balance, energy, water balance in the basin ..., and ecological balance.

1.3.2. Research approach (Research diagram)

Conducting process: Step 1: Dividing sub-basins; Step 2: Classifying basins according to topographic energy and flow energy; Step 3: Establishing landscape map for flash flood study, assessing landscape classification according to level of impact on flash flood risk; Step 4: Assessing the potential for flash floods; Step 5: Assessing the risk of flash floods; Step 6: Analysing of land use actuality, forest cover, population distribution, infrastructure; environmental hazards by flash floods.



Picture 1.1 Map of steps in conducting process approaching the thesis topic

1.4. Research methods:

1.4.1 Research methodology

The topic uses the following research methods to complete the planned contents:

- Data collection, analysis and synthesis methods: The documents that need be collected are divided into these groups: Research projects, research reports related to the thesis and study area as well as maps, statistics. Summarizing collected materials allows to access to exist research results, update new issues in Vietnam and in other countries.

- Geographic Information System method (GIS): GIS and remote sensing software applied in the thesis: ArcGIS 10 (spatial process and analysis), MapInfo 11.0 (edition, thematic maps establishment).

- Expert method: Collecting, summarizing and analyzing expert opinions creating a basis to support the scientific basis and the research results; consulting the experts in the research approach, assessment of flood risk in mountainous districts of Quang Nam.

- Field method: It is the traditional method of geography. Although field method is not the primary method in the implementation of the topic, it is a significant one.
- Statistical method: creating the highest isotropic graph line in this year according to data in the previous years for the study area;
- Quantitative model methods.
- Analysis and assessment landscape methods.
- Modeling method.

1.4.2. Specific methods

a. Basins classification method for study on flash flood in mountainous districts of Quang Nam

- Creating component maps

DEM (Digital Elevation Model): created from the contour maps with the same height of 20m; High altitude map has been entered altitude values. The processing and interpolation are conducted by the software called ArcGIS 10.0. The spatial resolution for the map layer is 30m (pixel size).

Slope model: The slope model is calculated from the aforementioned DEM model using the ArcGIS 10.0 Spatial Analyze Tool. It represents the angle of inclination of the topographic at the viewing point with the horizontal surface.

Slope length model (L): The slope length is calculated according to the absolute height of each land unit and the level of erosion in each basin level 3.

River basin level 3

The basis unit of assessment the potential flood risk and flood risk is basin level 3 because each level 3 basin is a relatively closed area for flow processes. Flow process is systematic and continuous in the whole basin. The surface features of the basin including the topographic slope, the slope length (topographic elevation) create topographic potential for flow.

b. Modeling of topographic energy and flow energy

Applying the model of I. A. Kornev and A. D. Ivanovski, caculating slope (I), topographic elevation (h) with rainfall causing flash flood (P): $Y = I^{0,75} h^{0,5} P^{1,5}$, Y is the surface flow energy, where Y1 = I0,75 h0,5 is the topographic energy. P is the quantity of rainfall: the highest average annual rainfall, the average rainfall in the rainy season, the highest daily rainfall. The quantity Y will be cumulated on the basin surface. Cumulative Y flow energy is the unit to assess the risk of flash flood according to basin level 3.

Topographic energy estimation method (Y1 calculation model)

To assess the potential of flash floods, the project has conducted the model of calculation according to a step-by-step approach:

+ Measure relatively topographic energy: $\mathbf{Y_1 = I^{0,75} * \Delta H^{0,5}}$

In which: Y1: Topographic energy; **I:** slope; **ΔH**: Topographic difference

* Step 1: Classify the basin according to the quantity $\frac{\overline{y_1}\,max - \overline{y_1}min}{5} = \Delta\overline{y_1}$

* Step 2: Classify the basin according to the quantity : $\frac{\sum y_1 max - \sum y_1 min}{5} = \Delta \sum y_1$

* Step 3: After arranging levels for $\overline{y}_1$ and $\sum y_1$, building the link hierarchy table for $\overline{y}_1$ and $\sum y_1$ according to the total point.

* Step 4: Ranking Y_1 for ($\overline{y}_1$ and $\sum y_1$) according the calculated total point

* Step 5: Calculating the area of levels of Y_1

Flow energy estimation method

* Step 1: Classify the basin according to the quantity $\overline{y}_{2:}$ $\frac{\overline{y_2}\,max-\overline{y_2}min}{5} = \Delta\overline{y_2}$

* Step 2: Classify the basin according to the quanity $\overline{y}_{2:}$ $\frac{\overline{y_2}\,max-\overline{y_2}min}{5} = \Delta\overline{y_2}$

* Step 3: After arranging levels for ($\overline{y}_2$ and $\sum y_2$), building the link hierarchy table for $\overline{y}_2$ and $\sum y_2$ according to the total point.

* Step 4: Rank Y_2 for ($\overline{y}_2$ and $\sum y_2$) according to the calculated total point point.

* Step 5: Calculate the area of levels of Y_2

Table 1.1. The link hierarchy matrix for $\overline{y}_1$ and $\sum y_1$ according to the total point

	1	**2**	**3**	**4**	**5**
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10

Point	**Level**	
2	I	Very low
3	I	
4	II	Low
5	II	
6	III	Average
7	IV	High
8	IV	
9	V	Very high
10	V	

The thesis has calculated, linking $\overline{y}_1$ and $\sum y_1$ to determine the torographic energy in the basin, because $\overline{y}_1$ and $\sum y_1$ depend on the basin area. Two basins have the same numerical value $\sum y_1$, depending on the basin area, the basin has small area and then $\overline{y}_1$ is large; by contrast, the basin has large area and then $\overline{y}_1$ is small . $\sum y_1$ also depends on the basin area, the basin has small area and then $\sum y_1$ is small; by contrast, the basin has large area and then $\sum y_1$ is large.. Likewise, with the flow energy quantity y2, is determined by connecting $\overline{y}_2$ and $\sum y_2$.

c. Developing a landscape map for study flood and assessment landscape for flood risk classification.

Assessment methods

- *Classifying landscape factors are influenced by the degree of impacts on flash floods*

In order to assess landscape according to the the impact of flash floods, it should be connected with the history of the most typical flash floods in many years. In order to classify the landscape factors according to their sensitivity of flash floods, grade the risk of human and socio-economic values loss in flash floods, as well as classify according to factors influencing flash floods. In which: Level I: 1 point - weak; Level II: 2 points-average; Level III: 3 points-quite strong; Level IV: 4 points - strong.

Step 1: classifying danger level (damage level) at 21 flash flood areas.

Step 2: classifying of landscape factors to the risk of flash flood:

* Topographic type (sub-class landscape): medium mountain (height> 1000m): 4 points; Low mountain (500-1000m): 3 points; High hill (100-500m): 2 points; Low mountain valley, mid valley (<100m): 1 point.
* Geomorphological group : grade landscape denuded synthetically, surface sides: 4 points; Togographic advantages of synthetic denudation, flat surface: 2 points; volcanic togophraphy : 1 point; landscape flow topography: 3 points
* Soil groups:
- Soil group with weak permeability, high surface flow, high flash flood risk (Fs, Fk, Fe, Fv): 4 points
- Soil group with relatively weak water permeability, relatively high surface flow, high flood risk (Fa, Ha, Hs, Hq): 3 points
- Soil group with average permeability, average surface flow (Fq, X, Xa, Fp, D, Pc, Ff): 2 points
- Soil group with low surface flow (C, Cc, Pcb, Pf, Py): 1 point
* Vegetation cover: less affected ecosystem: 1 point; Planted forest ecology, secondary: 2 points; Soil ecosystem, shrubs: 3 points; Agricultural land, milpa: 4 points.

- *Determine the weight for landscape factors*

Using the hierarchical classification method, the correlation between the level of damage caused by flash floods (based on flash flood status) with the level of factors (topographic, geomorphology , soil, vegetation) to assess the difference in each factor.
Spearman coefficient correlation method (relationship between qualitative signs)
Table 1.2. Correlation between flood damage level and factor levels

Data at flash flood point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	**∑Δ2**
	4	4	4	4	4	1	1	3	3	3	4	3	2	4	3	2	2	3	3	3	2	
Types of topography	3	3	4	2	3	2	2	4	4	4	1	3	3	1	2	1	2	4	2	2	2	
Δ	1	1	0	2	1	-1	-1	-1	-1	-1	3	0	-1	3	1	1	0	-1	1	1	0	
Δ²	1	1	0	4	1	1	1	1	1	4	9	0	1	9	1	1	0	1	1	1	0	**39**
Geomorphological group	2	4	4	3	2	2	4	2	2	4	2	4	4	2	4	4	4	4	2	2	2	
Δ	2	0	0	1	2	0	-3	1	1	0	2	-1	-2	2	-1	-2	-2	-1	1	1	0	
Δ²	4	0	0	1	4	0	9	1	1	0	4	1	4	4	1	4	4	1	1	1	0	**45**
Soil types	3	4	4	1	4	4	4	3	4	2	2	2	4	4	3	2	3	4	1	3	4	
Δ	1	0	o	3	0	-3	-3	0	0	1	2	1	-2	-3	0	0	-1	-1	2	0	-2	
Δ²	1	0	0	9	0	9	9	0	0	1	4	1	4	9	0	0	1	1	4	0	4	**57**
Vegetation cover	2	3	2	2	2	3	3	1	1	1	4	3	1	2	3	1	3	1	4	2	2	
Δ	2	1	2	2	2	-2	-2	2	2	2	0	0	2	2	0	1	-1	2	-1	1	0	
Δ²	4	1	4	4	4	4	4	4	4	4	0	0	4	4	0	1	1	4	1	1	0	**53**
∑Δ2																						**194**

As can seen in the correlation table:
Topography: ΣΔ ^ 2 = 39; Geomorphological groups: ΣΔ ^ 2 = 45;
Type of soil: ΣΔ ^ 2 = 57; vegetation cover: ΣΔ ^ 2 = 53

ΣΔ ^ 2 = 194

The basis of this approach is: comparing the pairs of rankings between the damage level (21 actuality points) and the risk factors for flash flood (xi). The smaller two srings of numbers sums of Δ^2 have, then the fluctuation of the pair around the equation is smaller, the stronger the correlation is, the higher the weight is.

Consider the smallest sum Δ^2 to be 1 to compare with other factors:

Topography: 39/39 = 1; geomorphological group: **39/45 = 0.866;**

Type of soil: **39/57 = 0.684**; vegetation cover: **39/53 = 0.735**

Σ = 3,285

The sum of the four factors is 1. Therefore, the weights of: Topography (D1): 0.304; Geo-morphological group (DM2): 0.264; soil (TN3): 0.208; vegetation cover (TTV4): 0.224

In conclusion, topography is the most important factor in terms of flash flood assessment, the next orders: geomorphological group, vegetation cover, types of soil. (Table 1.3)

c. *Comprehensive assessment-Classification of landscapes according to the level of impact on flash floods*

Based on the decentralized points and the weighting of the factors, it is the basis for assessing the impact of the risk of flash floods. Calculating the total points for each type landscape:

$$\sum D = (\text{point}(ĐH) * D_1) + (\text{point}(ĐM) * DM_2) + (\text{point}(TN) * TN_3) + (\text{point}(TTV) * TTV_4)$$

The main point of assessment here is that the higher the rating of the landscape, the more advantageous the landscape for the risk of flash flood (high risk level) and the lower the rating of the landscape, the less advantageous the landscape for the risk of flash flood. Each level corresponds to the ranges of the common assessing point. The point ΔD of the levels in all equal cases is calculated according to the formulation:

$$\Delta D = \frac{Dmax - Dmin}{M}$$

In which: Dmax: highest common assessing point; Dmin: lowest common assessing point; M: number of assessing levels;

Dmin = 1.49; Dmax = 3.78; ΔD = 0.46

Level I: very low: 1.49 - 1.95; Level II: low: 1.95 - 2.41; Level III: average:> 2.41 - 2.87; Level IV: high 2.87 - 3.33; Level V: very high: 3.33 - 3.79.

d. Summarizing topographic energy research results with landscape to assess the potential of flash floods

Assessment methods

(This method accounts for the potential of flash flood (Y1) and the risk of flash flood (Y2).

- Step 1: Defining average points of landscapes in each basin (X1)
- Step 2: Defining the effect of landscape on Y1, Y2. (X2)
- Step 3: Defining the normalization marks of Y1, Y2, after taking into consideration the impacts of landscape (X3)

-Step 4: Arranging potential of flash flood arising (Y1), (flash flood risk (Y2) based on data of series X3 of 77 standard basins.) Each influence level, increases or decreases flood potential corresponding to the values of the common assessing point (Appendix 11, 12).

- ***X1: (Step 1: defining the average points of the landscapes in each basin):*** The average point of landscapes in each basin is calculated according to average weighted grading formula (*weighted index is the area of landscape*):

$$D^A = \frac{1}{n}\sum_{i=1}^{n} Ki\ Di$$

In which: D^A: Average assessing point according to the landscape in basin; Di: assessing points of landscape; Ki: area corresponding to landscape level; i: order landscape, i = 1.2 ... n.

Each basin has a combination of landscape level levels that affect the risk of flash floods. Calculate the average landscape level in each basin by the weighted average basis. Grading levels: Level 1: 1 point; Level 2: 2 points; Level 3: 3 points; Level 4: 4 points; Level 5: 5 points. S1, S2, S3, S4, S5: area corresponding to each level in the basin

Average point levels of each LVS (X1).

$$X_1 = \frac{\text{Point } S_1 \text{ x } S_1 + \text{point } S_2 \text{ x } S_2 + \text{point } S_3 \text{ x } S_3 + \text{point } S_4 \text{ x } S_4 + \text{point } S_5 \text{ x } S_5}{\sum S}$$

For example, calculating X1 for LVG 110 in basin Y1-level 1, in LVG 110 including level 1,2,3,4. We have: (1 * 816) + (2 * 2,540) + (3 * 3,517) + (4 * 921) / 7,795 = 2.58 (S1 = 816ha; S2 = 2.540ha; S3 = 3.517ha;)

- X2: (Step 2: Defining the impacts of landscape for Y1, Y2): The assessing point of the effect of the quadratic for Y1 or Y2. If the landscape is at level 3 - the average level does not change the level number Y1, Y2. If less than 3, it limits the effect, greater than 3, then increases the effect of landscape to Y1, Y2 (topographic energy, flow energy)

For example, calculating X2 for LVG 110 (in the above example), average point of landscape level is 2.58, the effect of landscape on Y1 is -0.42.

- X3: (Step 3: Defining Y1, Y2 normalized points, after taking into consideration the effect of landscape): Standard value of Y1 including the effect of landscape. Calculating coefficient of impact of landscape on topographic energy and flow energy in each basin (adjustment coefficient X2). It is argued that landscape: X1 = 3 does not decrease or increase topographic energy or flow energy.

X1 <3 impacts of landscape decrease topographic energy or flow energy. The adjustment coefficient is X2 = X1-3 -> X2 (-).

X2 = 1 - 3 = -2 -> X2 = [0 -> -2]

X1> 3 impacts of landscape increase topographic energy or flow energy. The adjustment coefficient is X2 = X1-3 -> X2 (+).

X2 = 5 - 3 = 2 -> X2 = [0 -> + 2]

The adjustment coefficient showing the effect of landscape on topographic energy and flow energy will be X2 [-2 -> +2].

For example,calculating X3 for LVG 110 (in the above example), X2 value is -0.42, with Y1 - level 1, the effect of landscape on Y1 is 0.58.

(Step 4: Arranging flood potential (Y1), flash flood risk (Y2) based on standardized data series X3 of 77) Each level influencing, increasing or decreasing potential of flash floods corresponds to the range of values of the common assessing point. The point ΔD of the levels in the equal case is given by the following formulation:

$$\Delta D = \frac{Dmax - Dmin}{M}$$

In which: Dmax: highest common assessing point; Dmin: lowest common assessing point; M: number of assessing levels; Dmin = 0.58; Dmax = 5.33; ΔD = 0.95

Level I: very low: 0.58 - 1.53; Level II: low: 1.53 - 2.48; Level III: average: 2.48 - 3.43; Level IV: high 3.43 - 4.38; Level V: very high: 4.38 - 5.33

e. Summary of flow assessment with landscape to assess flood risk in mountainous districts of Quang Nam.

Classification of river flood risk in basin to calculate the flow energy according to the highest average annual rainfall in many years (1975-2015) (Appendix 14)

The method of flash flood risk assessment is similar to the one presented for potential floods above (see appendix 13, 14).

The point ΔD of the levels in this case are evenly spaced by the formula: ΔD = (Dmax-Dmin) / M

In which: Dmax: highest common rating; Dmin: lowest common rating; M: number of rating levels;

Dmin = 0.58; Dmax = 6.44; ΔD = 1.17

Level I: very low: 0.58 - 1.75; level II: low: 1.75 - 2.92; level III: average: 2.92 - 4.09; level IV: high 4.09 - 5.26; level V: Very high: 5.26 - 6.43

Classification of flash flood risks in river basins calculated the flow energy according to the annual rainfall intensity in rainy season in many years (1975-2015).

Assessment methods

The method of flash flood risk assessment is similar to the one presented for potential of flash floods.

The point ΔD at all levels in this case are equally calculated according to the formulation:

$$\Delta D = \frac{Dmax - Dmin}{M}$$

In which: Dmax: the highest common assessing point; Dmin: lowest common assessing point; M: number of assessing levels;

Dmin = 0.58; Dmax = 0.56; ΔD = 0.98

Level I: very low: 0.58 - 1.56; level II: low: 1.56 - 2.55; level III: average: 2.55 - 3.53; level IV: high 3.53 - 4.52; level V: Very high: 4.52-5.56

The point ΔD at all levels in this case are equally calculated according to the formulation:

$$\Delta D = \frac{Dmax - Dmin}{M}$$

In which: Dmax: the highest common assessing point; Dmin: lowest common assessing point; M: number of assessing levels; Dmin = 0.58; Dmax = 5.56; ΔD = 0.99

Level I: very low: 0.58 - 1.58; level II: low: 1.58 - 2.57; level III: average: 2.57 - 3.57; level IV: high 3.57 - 4.56; level V: Very high: 4.56 - 5.56. The results of flood risk classification in the basin with the highest daily rainfall.

f. Analysing of land use actuality, forest cover, population distribution, infrastructure, environmental hazards caused by flash floods.

CHAPTER 2 FEATURES OF FACTORS CREATING FLASH FLOODS IN MOUNTAINOUS DISTRICTS OF QUANG NAM

2.1. Geographic location and natural factors

2.1.1. Geographical location

Quang Nam is located in the middle of Central of Vietnam, with an area of 10,438,37 km sq. with the geographical coordinates: 14057'10 "- 16003'50" N latitude; 1070 12'50 "-108044'20" East longitude. To the north, it is surrounded by Thua Thien Hue and Da Nang, to the West, it has border with the Lao People's Democratic Republic and Kon Tum province, to the South it is bordered by Quang Ngai Province, and to the East it has border with the East Sea.

2.1.2. Natural factors

a. Geology: The study results show that the sedimentary formations of Paleozoic terrigenous rocks with weathering products from rocks have several ingredients such as sandstone, siltstone, shale, coal clay, siliceous slate. These rocks are easy to be weathered and discreted, weak connection and easily permeable to water. It is clear that the rock formations in Quang Nam or the pristine conditions (sedimentary rocks, eruptive rocks) or secondary conditions (strong weathering processes) are advantageous for landslide during flash floods process.

b. Topography: In general, mountainous area in Quang Nam is steep, steep slopes, is one of the conditions of flash floods. According to study on flash flood areas, it shows that the basin where flash flood occur are usually in the form of concave, topography is strongly separated, mountain sides are steep, the average slope of basin used to have flash flood from 2005 to 2015 is relatively high (from 11° to 30°). The flash floods occur in high hills (100m-500m), next in average mountainous topography (> 1000m), low mountains (500m-1000m) and low hills and valleys (100m-500m) happen relatively.

c. Rain: The total amount annual rainfall fluctuates from 2000 to 4000 mm. Midlands and mountains, to the west of Nam Giang district has the amount of rainfall from 3200 to 4000 mm. The southwest and northwest of the province have average amount of rainfall from 4500 to 5500 mm. This climate features have created the conditions for all three weathering processes to create thick weathering crusts, which are crumbly – the material features is very beneficial for transportation. The rain causing flash floods usually gathers in one to two hours, with heavy rain density, from 240mm-410mm.

d. River networks: Rivers in the upstream often flow between the ravines, cross sections are usually deep and narrow V-shaped. Flash flood basins in Quang Nam are generally small (area <500 km2), rivers and streams originate from high peaks (about 1,000 - 2,000 m). The expanding of river valleys usually have large spillway, have group of population, strong economic development are also often affected by floods and flash floods.

e. Soil: From the basis of weathering crust and soil formation conditions, there are two soil types in mountainous areas in Quang nam province: (1) feralit soil type and (2) alluvial soil type. Feldite soil is popularly distributed in the study area and depends on the rock structure. This feralit soil type is divided into many different small types. Flash floods occur in weakly permeable soils (Fs, Fk, Fe, Fv, F), soils with average permeability (Fq, X, Xa, Fp, P, Pc, Ff).

f. Vegetation cover: Vegetation cover is a slow changing factor, but due to human impacts, degradation reaches the limitation that the protective role of the forest no longer

exists, combining with other factors that flash floods appear more regularly. The flash floods occur mainly in less affected forest ecosystems, secondary forest ecosystems, scrubland soil ecosystems.

Assessing the actuality of flash floods for the purpose of eliminating natural disasters and helping people in mountainous areas of Quang Nam to understand the rules of flash floods, responding to flash floods by using the map, this s the most practical solution to not only the realities of life but also the socio-economic development of the region.

2.2. Conditions and socio-economic factors

2.2.1. The overview of socio-economic features

According to statistical data from Quang Nam Statistical Office, the average population in 2017 is estimated about 1,494 thousand people, including 761.1 thousand females accounting for 51%, urban population has 362.1 thousand people, accounting for 24.2%, the number of people in working age is 890,300 people, making up about 60.4%. The average population density is 142 people/ km², compared to 274 people/ km² of the country.

Gross Provincial Product (GRDP) in 2017 (at compared prices with 2010) is estimated at 63,003 billion, increases 5.09%. The economic structure continued to change but the rate was slow, including agriculture, forestry and fisheries account for 11.6%; industrial construction accounts for 35.8%; service zone makes up 52.6%.

2.2.2. Economic development activities affect the flash flood disaster

+ Agro-forestry production: Agro-forestry production plays a signigficant role in Quang's economy. In 2017, Agriculture, forestry and aquaculture accounts for 17% of GRDP, and employs 52.6% of total of employment in economic zone.

+ Infrastructure construction

+ Minining activities

+ Hydropower development

2.3. Actuality of flash flood hazards in mountainous districts of Quang Nam

Steep topography, large river slope, heavy rainfall are the basic factors to allow flash flood to develop there. In the mountainous area of Quang Nam, swamp floods and mudflat floods are the primary types, more common than blocking flow flood and flash floods.

In Quang Nam, flash floods distribute almost every districts including Nam Giang, Dong Giang, Tay Giang, Bac Tra My, Nam Tra My, Nong Son, Phuoc Son and Hiep Duc, particularly in Tay Giang and Bac Tra My. The majority of flash floods occur in the rainy season, from September to December, and in places having the average annual rainfall > 2800 mm / year. The highest rainfall in a day is usually in the month of X or XI (reaching 455 - 666 mm) which is the consequence of strong storms and tropical cyclones activities and flash floods as well. In November, 7 out of 21 flash floods occur.

CHAPTER 3.
THE RISK ASSESSMENT OF FLASH FLOODS IN MOUNTAIN DISTRICTS OF QUANG NAM PROVINCE

3.1. Division of basins in mountainous districts of Quang Nam

Basin - basic unit for study on flash floods:

The basin which is a relatively closed natural topographic system for the flow of water created by rainfall that gathers on the surface of the basin and enters the estuary.

Results of basin division for study on flash flood in mountainous districts of Quang Nam: After establishing the basin map of 441 basin of level 3, to analyse and identify the potential basins in different abilities, gathers 77 basins of level 3, for the purpose of classification of basins according to topographic potential.

Table 3.1. 77 basins lumped from 441 sub basins

Lumped basin code	**Area**	**Lumped basin code**	**Area**	**Lumped basin code**	**Area**	**Lumped basin code**	**area**
1	7.165	**110**	10.407	**196**	10.199	**331**	16.079
3	10.692	**112**	5.575	**197**	3.865	**339**	19.587
16	11.672	**115**	2.796	**198**	27.228	**350**	4.137
26	10.370	**128**	12.172	**211**	9.884	**352**	10.104
38	12.647	**129**	8.356	**243**	15.008	**354**	8.687
42	8.318	**130**	5.698	**248**	9.674	**366**	8.891
44	15.341	**132**	1.736	**255**	12,080	**367**	2.751
47	9.295	**142**	8.113	**257**	17.616	**382**	13.444
48	19.562	**148**	4.985	**259**	9.248	**383**	8.251
54	4.494	**149**	5.055	**262**	5.348	**391**	5.269
55	7.572	**158**	5.761	**277**	9.410	**393**	15.130
66	6.828	**164**	7.061	**287**	9.507	**399**	5.512
71	7.947	**165**	7.428	**292**	10.788	**402**	7.633
75	10.595	**167**	13.697	**304**	7.911	**409**	8.390
83	2.743	**173**	11.120	**310**	8.755	**411**	5.540
90	6.148	**177**	11.530	**311**	17.196	**415**	14.191
92	8.083	**179**	18.488	**319**	8.825	**417**	6.385
93	20.705	**185**	11.484	**327**	20.940	**419**	11.677
102	16.317	**193**	22.554	**330**	4.378	**425**	20.399
108	4.932						
Total	**785.361**						

3.2. Assessment topographic energy in the river basins

3.2.1. Topographic energy - a factor of the potential for flash floods formation

The topography of the basin decides surface flow energy. The sloping topography has high slope, high difference will have large topographic energy, large surface flow is advantageous for flash flood.

3.2.2. Results of topographic energy assessment in the river basin

Topographic energy is represented by two quantities: the average energy quantity Y1 and the total topographic energy quantity Y1

a) The average of topographic energy quantity

The results show the average topographic energy values of each basin. Then, the classifications for the basins are different according to the slope and altitude difference. $\overline{y}_1$ shows basins having large area but low topographic energy levels, such as LVG: 198; 93; In contrast there are the LVG: 132; 391; which have small area but high topographic energy. Only a few LVGs have large area, high topographic energy. In conclusion, the slope and high difference of topography are important factors in the basin participating in flash floods.

b) Total topographic energy:

Taking into account LVG 77 at volume $\sum y_1$, the levels change due to the change of total topographic energy value. The LVG: 3; 108; 66; 47; has small area but large total topographic eenergy, slope and high altitude difference.

c) Results of topographic energy assessment:

After analyzing quantitesin the basin step by step, the basin's topographic energy has been determined, indicating basin have the potential of high flash floods due to topographic factors and where they are distributed. Mountainous district, Level I, II (low), accounting for 69.3% of the area, distributing in 9 districts. Level III basins (average) accounting for 15.6% of the total area, distributing mainly in Nam Giang, Phuoc Son, Tay Giang. Level IV and V basins (high potential) making up 14.6% of the area, distributing in Dong Giang, Nam Giang, Nam Tra My (highest risk), Tay Giang, where elevation is from 674m -1566m, slope from $21° - 30°$, belong to the low and medium mountains, belong to the LVG: 44; 47; 55; 66; 90; 393; 415; 92; 419 and 425, potential basins of flash floods formation.

3.3.Assessment of river flow energy in the basin:

3.3.1. Results of assessment of river flow energy according to basin:

a. The results of assessment of river flow energy in 9 mountainous districts of Quang Nam - Y2 calculated according to the highest average annual rainfall in many years

After calculating potential, topographic energy, taking the rainfall factor (highest average annual rainfall in many years) into the Y2 calculation model in 77 basins from 441 basins. Basins with different flow rates at risk level are input factors for flood risk analysis with landscape factor. The whole mountainous district, level I, II (low) accounting for 83.5%, distributes in 9 districts. Grade III (average) accounting for 8.7%; basins distributes in Bac Tra My, Nam Giang, Phuoc Son, Tay Giang where the average rainfall is 2789mm-4158mm, average daily rainfall: 360mm-440mm. Level IV, V (high) accounts for 7.8% of the area, distributes mainly in Nam Tra My (highest risk), where the average rainfall is 4158mm, the highest average rainfall is 420mm -520mm, the highest rainfall day: 493mm, belonged to basins having large flow energy such as LVG: 393; 415; 419; 425.

b, Results of flash flood flow assessment in 9 mountainous districts of Quang Nam - Y2 in terms of annual rainfall in rainy season in many years

After calculating potential, topographic energy, taking the rainfall factor (highest average annual rainfall in many years) into the Y2 calculation model in 77 basins from 441 basins. The whole mountainous district, level I, II (low) accounting for 78.9%, distributes in 9 districts. Grade III (average) accounting for 12.2 basins distributes in Bac Tra My, Nam Giang, Phuoc Son, Tay Giang where the average rainfall is 2789mm-4158mm, average daily rainfall: 360mm-440mm. Level IV, V (high) accounts for 8.9% of the area, distributes mainly in Nam Tra My (highest risk), where the average rainfall

is 4158mm, the highest average rainfall is 420mm -520mm, the highest rainfall day: 493mm, belonged to basins having large flow energy such as LVG: 393; 415; 419; 425.

3.4. The result of assessment of the flow energy affecting the risk of flash floods approaching the landscape

3.4.1. Establishing a landscape map for study on flood risk in mountainous districts of Quang Nam

Table 3.2. Landscape units in 9 mountainous districts:

Landscape units		**Targets**			
Landscape class	**Landscape sub class**	**Number of types of landscape**	**Number of records**	**Area (ha)**	**Percentage (%)**
		175	**37.400**	**786.066**	100
Mountain	High, average mountain >1000m	17	75	84.783	10,8
	Low mountain 500 - 1000m	47	3.286	230.092	29,4
Hill	High hill 100-500m	64	28.140	325.448	41,1
	Low hill 25-500m	37	3.484	37.919	4,8
valley	Valley	9	283	74.346	9,6
Other types	Other types	1	2.132	33.478	4,3

3.4.2. Assessing the landscape according to the extent of impacts on flash floods

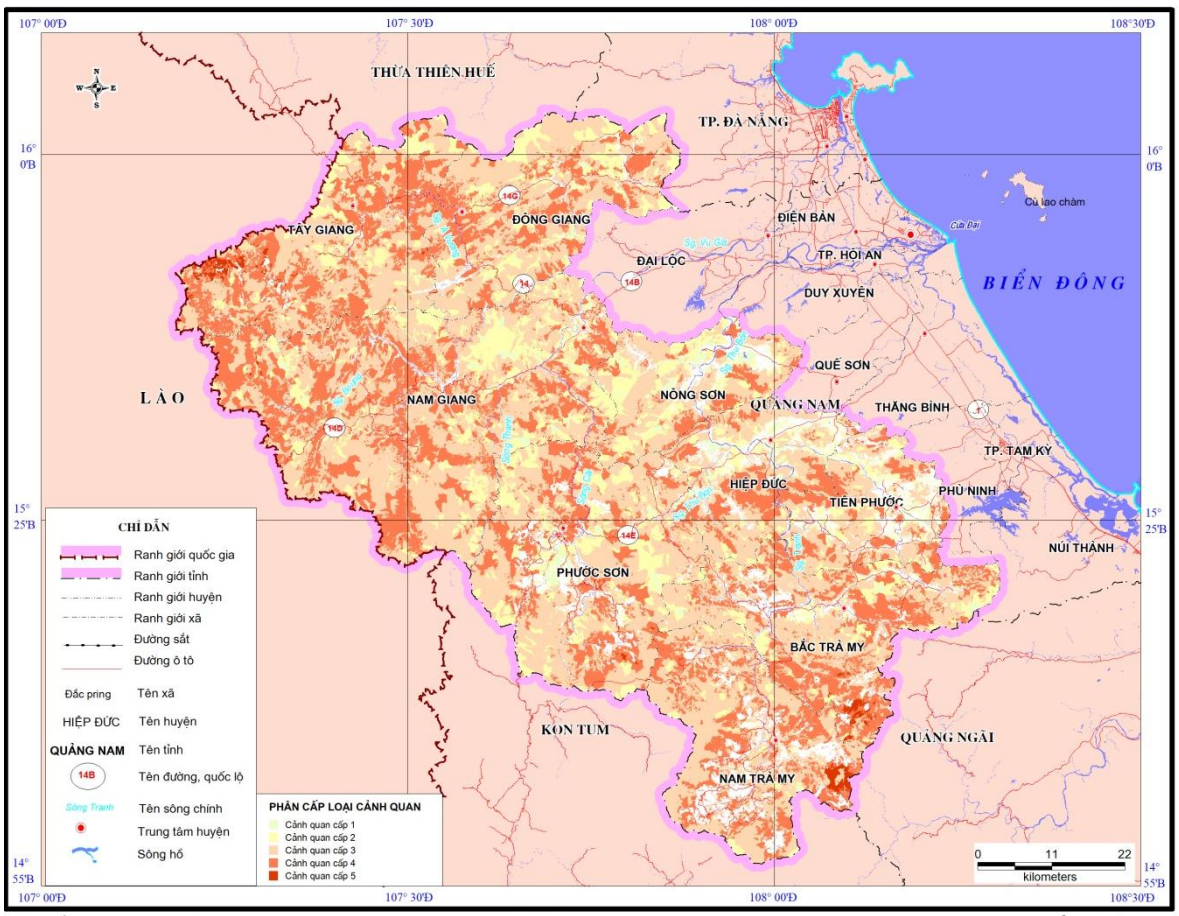
Factors influencing the flash floods formation, such as types of soil, water permeability, erosion resistance and ecosystems, in terms of surface flow reduction, are considered in topographic and geomorphologic types as information layers. Establishing a landscape map for flash flood research. Comprehensive and decentralized classification of forest types according to the danger level of flash flood, divided into 5 levels: Category I includes 28 landscape types, covering an area of 10,521 ha (1.5% of the area); level II includes 60 landscape types with an area of 106,239 ha (accounting for 14.8%); level III includes 56 landscape types with an area of 375,365 ha (accounting for 52.6%); Level IV includes 24 landscape types with an area of 217,754 ha (accounting for 30.5%), Level V comprises 6 landscape types with an area of 4,070 ha (accounting for 0.6%).

3.5. Assessment the potential of flash flood in mountainous districts of Quang Nam

3.5.1. Theoretical basis for assessment of flash flood potential

Definition of flash flood potential: in a basin, topographic, elevation and gradient factors create topographic energy as a sustainable factor, the dynamics of flash floods. Topographic energy is controlled by landscape.Therefore, to assess the potential of flash floods, it is necessary to integrate topographic energy with landscape structure and classify them according to the degree of impact on flood risk in each basin.

3.5.2. The results of the assessment of the potential of flash floods in basins

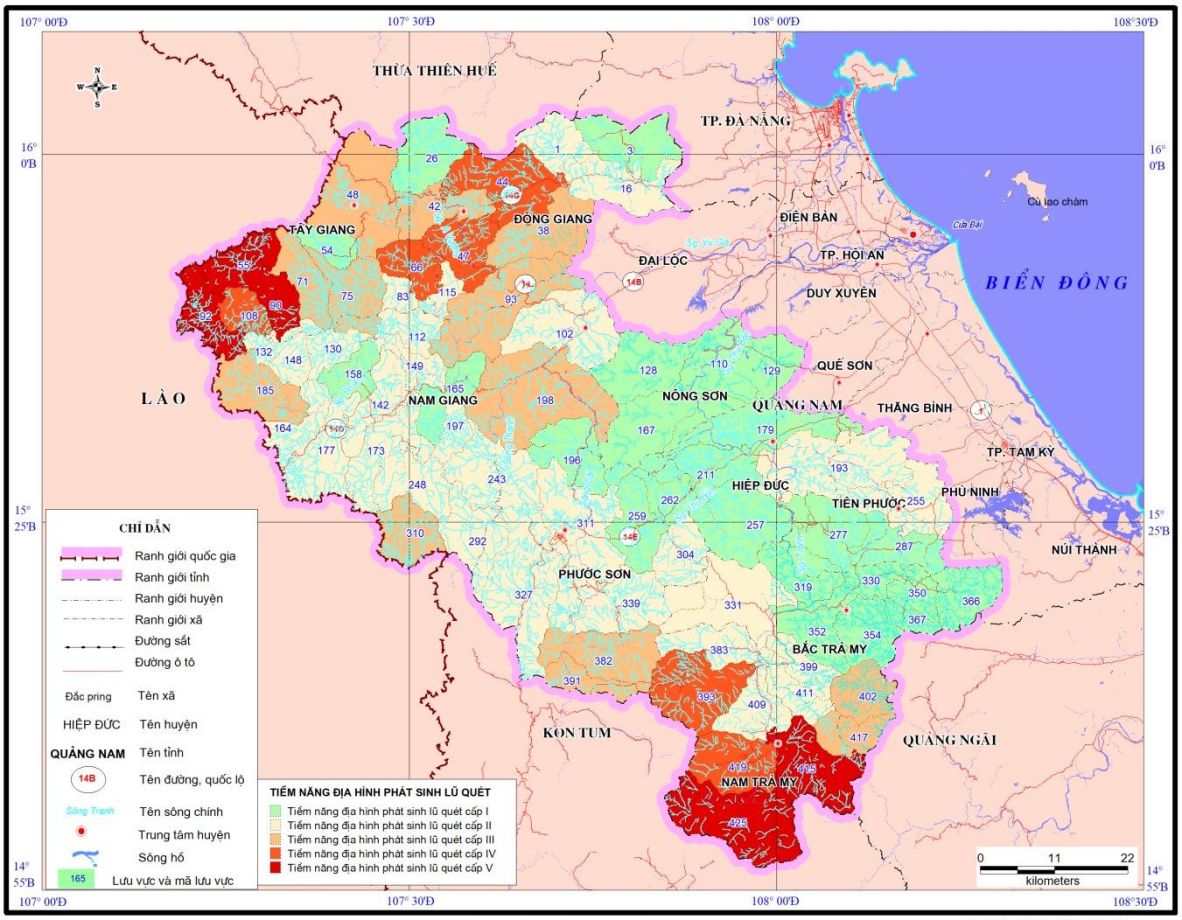


Nguồn dữ liệu: - Bộ Tài nguyên và Môi trường
- Viện Điều tra, Quy hoạch rừng

Thu nhỏ từ tỷ lệ 1/50.000

Thành lập: NCS Nguyễn Thị Thu Hiền
GVHD: PGS.TS Nguyễn Thị Kim Chương
PGS.TS Nguyễn Ngọc Thạch

Hình 3.6. Bản đồ cảnh quan phân cấp theo mức ảnh hưởng đến nguy cơ lũ quét 9 huyện miền núi tỉnh Quảng Nam



Thu nhỏ từ tỷ lệ 1/50.000

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GVHD: PGS.TS Nguyễn Thị Kim Chương
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Hình 3.7. Bản đồ tiềm năng phát sinh lũ quét 9 huyện miền núi tỉnh Quảng Nam

Comprehensive assessment of landscapes, classification of landscapes by levels of affects on the risk of flash floods. Integrating topographic energy with landscape level affects the risk of flash floods in each basin, to define the potential of flash floods. Assessment results: Indicating that basins at different levels, including landscape factors classified potential of flash floods. This is a comprehensive and overall picture for each basin in flash floods. Landscape factor increases or decreases the potential of flash floods floods. In the mountainous districts of Quang Nam, the potential of flash floods at I, II (low and very low) occupies for 505,800 ha (accounting for 64.4% of the district's total area). Distributing in all districts, the largest area is in Nam Giang then North Tra My, Hiep Duc, Nam Giang, Phuoc Son. Level III (average) occupies 160,389 ha (occupying 20.4% of the total area of the district), distributes mainly in Dong Giang, Bac Tra My, Nam Giang, Phuoc Son, Tay Giang. Level IV, V (high and very high) accounts for 119,879 ha (occupying 15.3% of the total area of the district), distributes in the districts of Nam Tra My, Dong Giang and Tay Giang. Ranked 11th LVG: 108; 66; 393; 47; 44; 419; 90; 415; 55; 425; 92. In Hiep Duc, Tien Phuoc and Nong Son are mainly low potentiality levels.

3.6. Assessing flash flood risk in mountainous districts of Quang Nam

3.6.1. Theoretical basis for flood risk assessment

The potentiality of flash floods becomes a flash flood hazard if there is sufficient precipitation that forms a cumulative surface runoff energy on the basin surface. Surface flow energy is controlled by landscape factors, especially buffer surface factors (vegetation cover, soil). The effects of surface flow energy are the processes of erosion, soil erosion, landslide on the slopes creating material for the flash floods formation.

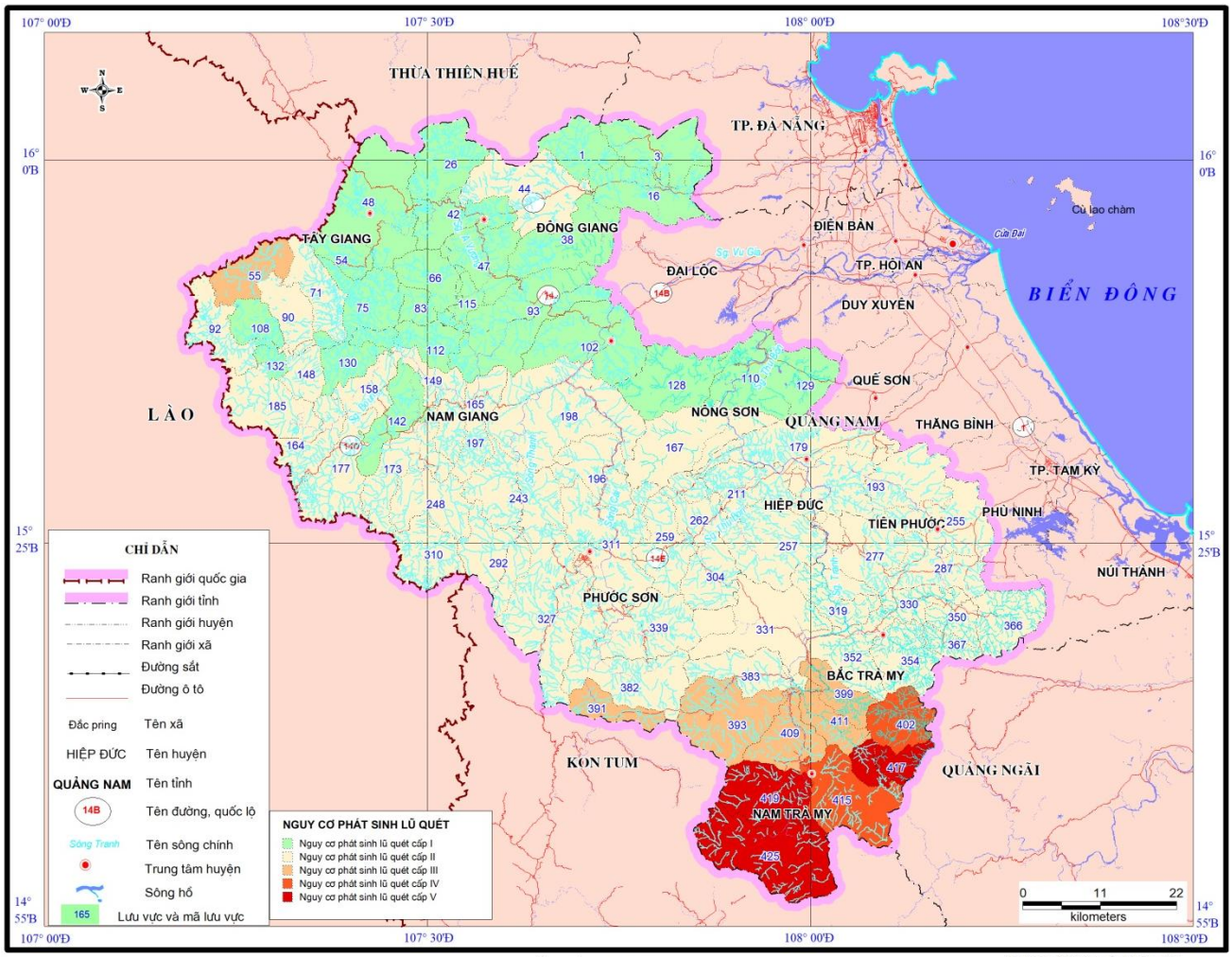
3.6.2. The result of the assessment of flash flood risks in river basins

3.6.2.1. Classifying the flash flood risks in river basins and calculating the flow energy according to the highest annual average rainfall from 1975 to 2015

The result of the assessment of flash flood risks in river basins and calculating the flow energy according to the highest annual average rainfall show the watershed area, location of place may have high risk of flash floods. The study meaning: Along with climate change, the risk of flash floods with the highest amount of precipitation will occur where it is forecasted. Low risk level, level I and II: occupy 685,235 ha (accounting for 87.3% of the total area of the district). Typically, Dong Giang, Nam Giang, Tay Giang occupy a large area, then Nong Son, Hiep Duc. Level III (medium) occupies 39,841 ha (occupying 5.1% of the total mountainous districts), while Nam Tra My accounts for more than 50%, to Bac Tra My and Phuoc Son. Level IV, V (high risk and very high) occupy 60,285 ha (accounting for 7.7% of the total area of the district, mainly distributes in Bac Tra My and Nam Tra My.) LVG: 402, 415, 393 415, 419, 425. Theses districts have asynchronous socio-economic development.

3.6.2.2. Classifying of flash flood risks in river basins, calculating the flow energy according to the annual average rainfall intensity (1975-2015)

The results show that low risk level, level I and II: account for 634,769 ha (accounting for 80.8% of the area of the mountainous district). Nam Giang occupies a large area, then Nong Son, Nam Giang, Hiep Duc. Level III (medium) occupies 67,605 ha (occupying 8.6% of the whole district), including Tay Giang occupies over 30%, to Nam Tra My, Dong Giang and Phuoc Son. Level IV, V (high and high risk) account for 82,988 ha (making up 10.6% of the total area of the mountainous districts).



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Hình 3.14. Bản đồ cảnh báo nguy cơ lũ quét ở 9 huyện miền núi tỉnh Quảng Nam (tổng hợp kết quả hai trị số lượng mưa trung bình năm)

Comparing the calculated results with the average annual rainfall of 5 LVGs with high potential of flash flood (402, 415, 417, 419, 425) with 50,212 ha (accounting for 7.0% of the total area of the mountainous districts). This is the basis for the proposal to prevent and address the damage caused by flash floods. According to the basin classification based on the annual average rainfall, the priority is given to and repeating two rainfall values.

9/102 high risk communes account for 8.8% of total communes in 9 mountainous districts of Quang Nam. In Bac Tra My district, there is a high risk of flash floods in 2/13 communes, accounting for 15.4% of the total number of communes in the district, including Tra Giap and Tra Ka. In Nam Tra My district, there is a high risk of flash floods in 7 out of 10 communes, accounting for 70% of the total number of communes in the district, including the communes are in the high warning level: Tra Cang, Tra Don, Tra Nam, Tra Mai and Tra Van, Tra Vinh, Tra Tap.

3.8. Proposing solutions to prevent and eliminate environmental hazards caused by flash floods in mountainous districts of Quang Nam

3.8.1. Proposal Basis:

3.8.1.1. Results of flood risk assessment

a. The summarized results of the assessment of flood risk in three average rainfall values: the highest average annual rainfall, the average rainfall in the rainy season and the average annual rainfall.

b. Assessment results of flash flood risks:

c. Quang Nam is the center of heavy rain of the Central Vietnam and the whole country

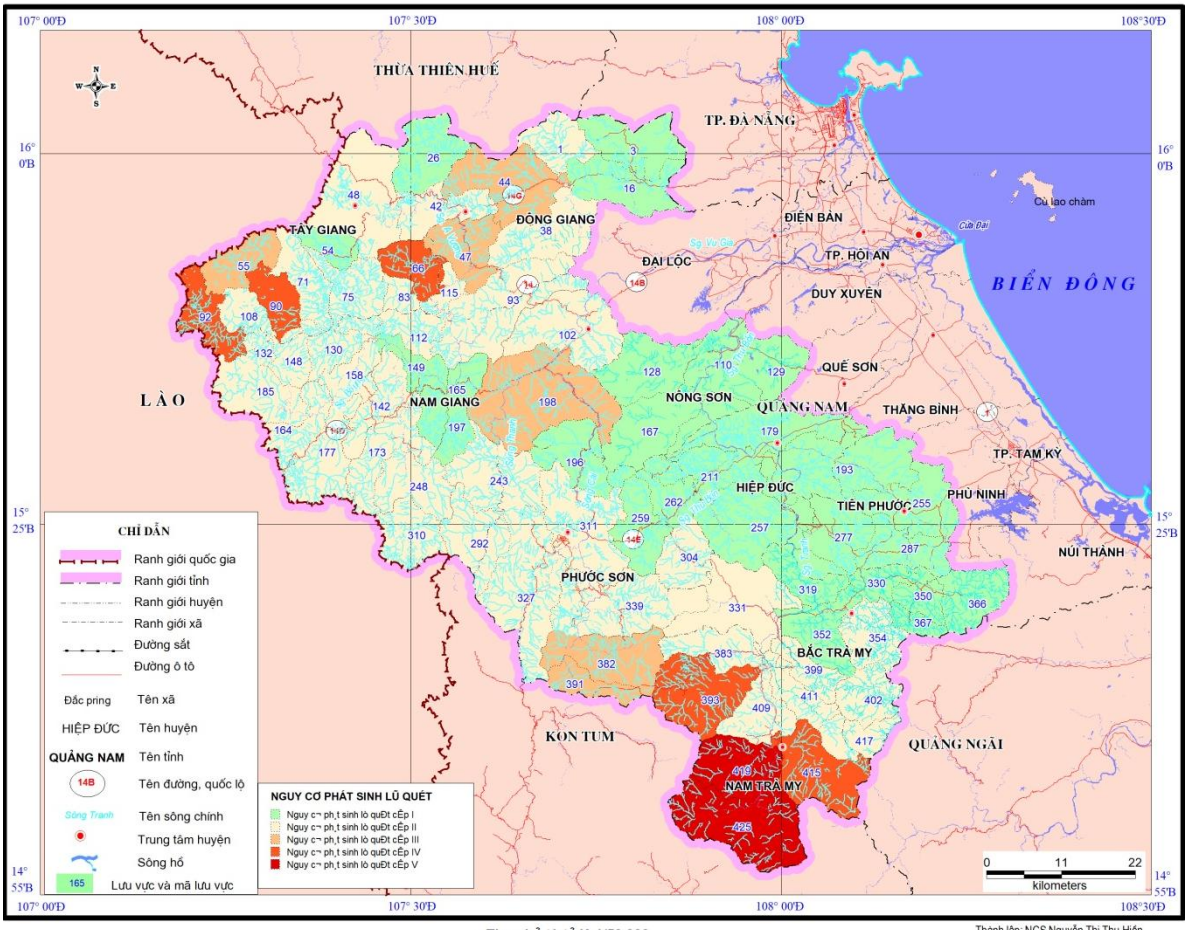
3.8.1.2. The Assessment results of flash flood risks calculates the flow energy in two days of maximum rainfall

a. Comments on the necessity and importance of flash flood risk assessment with heavy rainfall in extreme weather and climate conditions.

Under extreme climate and weather conditions, intense rainfall occurs at the stations with the highest annual average amount and the maximum daily precipitation is the basis for defining the potential of flash floods. In climate change, the frequency of heavy rains increases gradually. Therefore, the results of calculating the risk of flash flood according to the aforementioned rainfall factors can be able to forecast flash flood risks.

b. The results of the assessment of flash flood risk on the highest daily rainfall.

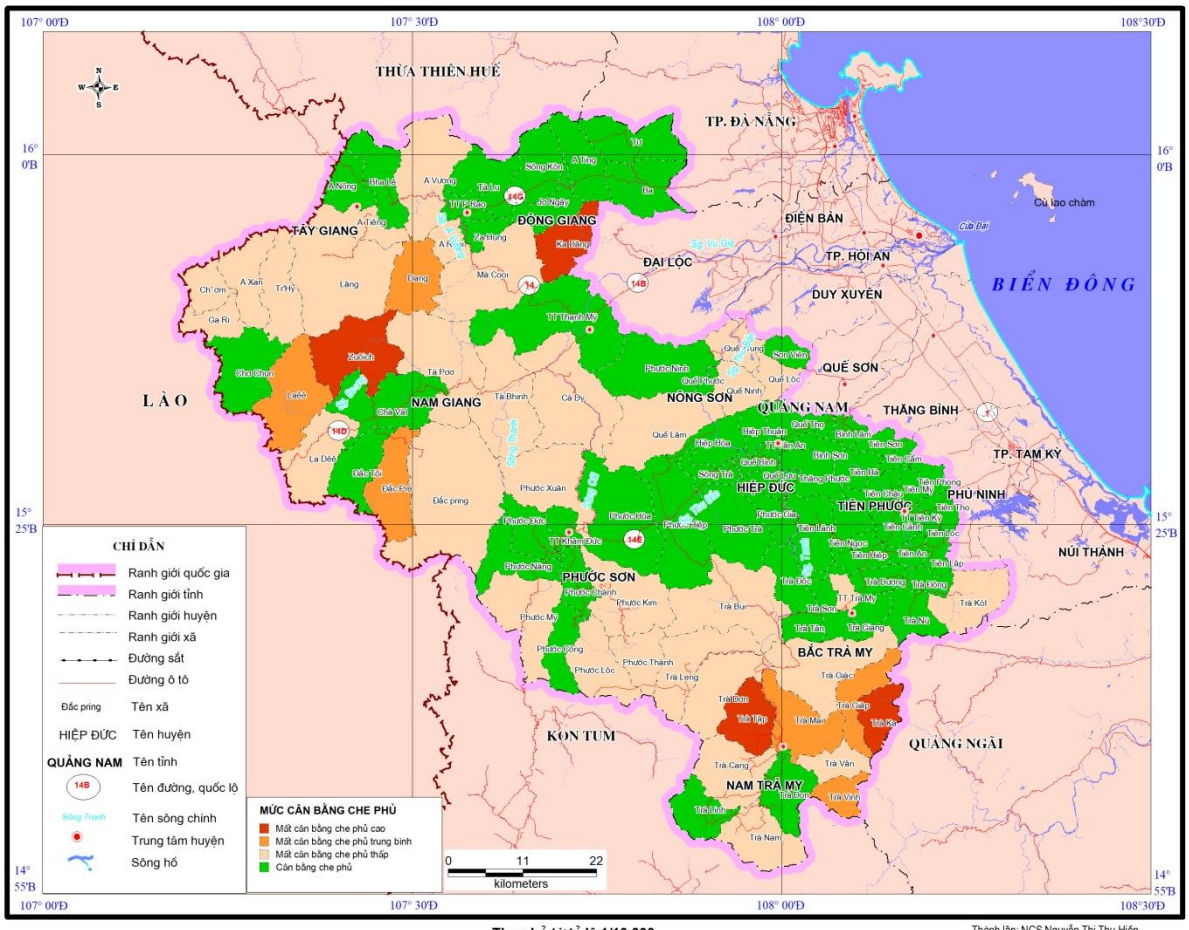
In each basin, level IV, V (high and very high risk) occupy 82,457 ha (occupying 10.5% of the total area of mountainous districts) Level IV (high potentiality) accounts for 50,381 ha (6.4%) in South Tra My (58.2%), Tay Giang (37.0%), Nam Giang (4.0%). The highest rainfall of 368 mm - 451 mm is likely to occur high flash floods. Level V (very high potentiality) occupies 32,076 ha (accounting for 4, 1%) distributes in Nam Tra My (100%), in 2LVG: 415.425. The highest daily rainfall: 449mm is likely to happen very high flash floods. The risk of flash flood is very high, compared to the high potentiality of flash floods, indicating that 11 basins have a high potentiality of flash flooding with an area of 119,879 ha. occupying 15.3% of the whole mountainous district), at the highest rainy day, the risk of flash floods is very high and shows 7 basins occupying 82,415ha (occupying 10.5% of the total area of MN. This is the warning signal for climate change and extreme weather not only in the country but also Quang Nam for flash floods in mountainous districts to prevent and reduce losses caused by external hazards.



Thu nhỏ từ tỷ lệ 1/50.000

Thành lập: NCS Nguyễn Thị Thu Hiền
GVHD: PGS.TS Nguyễn Thị Kim Chương
PGS.TS Nguyễn Ngọc Thạch

Hình 3.16. Bản đồ nguy cơ lũ quét ở 9 huyện miền núi tỉnh Quảng Nam với lượng mưa ngày lớn nhất



Thu nhỏ từ tỷ lệ 1/10.000

Thành lập: NCS Nguyễn Thị Thu Hiền
GVHD: PGS.TS Nguyễn Thị Kim Chương
PGS.TS Nguyễn Ngọc Thạch

Hình 3.19. Bản đồ cân bằng che phủ theo xã của 9 huyện miền núi tỉnh Quảng Nam

**** Communes at high and very high flash flood risk:***

The results of the high risk of flash floods in 77 basins with the highest number of rainy days in the rainy season illustrate that 17 out of 102 high risk communes account for 16.7% of the total number of communes in 9 districts mountainous province of Quang Nam. There are 14 out of 102 communes face high risk, 13.7% are very high and 6 out of 10 communes account for 5.9% of total communes in 9 mountainous districts of Quang Nam.

In Nam Giang district, there is a high risk of flash floods in 1/12 of communes, accounting for 8.3% of the total number of communes in the district. In Nam Tra My district, there is a high risk of flash floods. 10/10 communes account for 100% of the total number of communes in the district, particularly, the typical communes are in the high warning level: Tra Cang, Tra Linh, Tra Don, Tra Leng ... In Tay Giang district, there is a high risk of flash flood that 6 out of 10 communes account for 60% of the total number of communes in the district, including high risk warning in the communes such as Tr Hy, Dang.

3.8.2. Proposing solutions to prevent and eliminate the damages caused by flash floods in the mountainous districts of Quang Nam

3.8.2.1. Group of non-workload solutions

a. Establishing a map of high risk of flash flood.

b. Proposing solutions for forest cover restoration

- High level of imbalance: the communes have coefficient of imbalance <0.6. Ka Tra (Northern Tra My), Zuôich (Nam Giang). Totally, there are 2 out of 102 communes having a high level of forest cover imbalance, account for 1.96% of the total number of communes in mountainous districts of Quang Nam.

- The average level of cover imbalance: communes having the average cover imbalance index 0.6-0.7 are: Ka Band, A Rooi (Dong Giang), Tra Giap Tra Nam, Tra Co, Tra Dang, Tra Nam, Nam Tra, Tra Dang, Ga Ri, Chom, A A class, A Xan (Tay Giang). There are 16/102 communes with high level of forest cover imbalance, accounting for 15.7% of total communes in mountainous districts of Quang Nam.

c. Redistributing population to avoid high risk of flash flood (by district, commune)

In communes and districts that are at high risk of flash floods, it is necessary to propose solutions to distribute population, actively relocate people to safe areas during heavy rainy days. Particularly, giving priority to communes with high risk of flash floods, frequency of occurrences when evaluating and analyzing at different rainfall values, such as Tra Cang, Tra Van, Tra Tap, Tra Mai and Tra Vinh. Tra Dang, Tra Giap, Tra Dang, Ga Ri, Ch'om, A Xan, Lang, and Tr'Hy (Tay Giang).

+ Selecting areas, upland places not affected by flash floods, building some solid houses to gather properties, food and human in case of flash floods.

+ Having plans to relocate people to upland and safe places, especially the elderly and children.

+ Relief and rescue for poor households and disadvantaged areas.

d / Planning production and plant varieties appropriates to each area

e / Conducting of flood forecasting and forecasting plans plays an important role in the prevention and reduction of natural disasters.

e / Educating, communicating, and raising the awareness of locals about flood hazards.

g / Applying disaster prevention to all socio-economic, environmental development policies, programs and plans from the provincial to basic local levels.
h / Consolidating the whole system of organizations in natural disaster prevention *and mitigation.*

3.8.2.2. Group solutions works

+ Building a system of lakes division for flood reduction in basins.
+ Groups of constructions leading to flash floods
+ Installing the warning system, communication system to village level.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion on study results

1. The study process shows the brief results and application the study point, the thesis has established theoretical basis and method of research on flood risk in the mountainous districts of Quang Nam, based on the application of basin analysis model in combination with landscape analysis and assessment of flash flood study.
2. Sub-Basin Division: After establishing a map including 441 basins of level 3, 77 basins of level 3 have been lumped to classify basins of topographic potential.
3. Basin division of topographic energy and flow energy:

The research shows that the whole mountainous district has topographic capability: The basins of level IV and V (high potential) occupy 14.6% of the area, distributes in Dong Giang, Nam Giang, Nam Tra My (highest risk), and Tay Giang.

The basin after calculating the potential, topographic energy, taking the rainfall factor (the highest average annual rainfall) into the Y2 model shows that levels IV, V (high potential) account for 7.8 % of area, distributes mainly in Nam Tra My (highest risk).

The rainfall factor (rainfall in the rainy season with many years average) was calculated as Y2: level IV, V (high) accounting for 8.9% of the area, distributes mainly in Nam Giang, Tay Giang and Nam Tra My (the highest risk).

4. Establishing a map for study on flash floods, assessing landscapes division according to the level of impacts on flash flood risk:

On the basis of the 4 types of soil combined with 5 types of the ecosystem which is divided into 174 types of landscape, including one type landscape of is not evaluated for the risk of flash flood is other type. The landscapes in mountainous districts of Quang Nam are divided into 34,400 zones, with the average area of about 20.1 ha. On average, each landscape has 197 zones, divided into 2 landscape classes: mountain landscape classes have 64 types of landscape (average mountain landscape sub classes, mountain landscape classes have 47 types of landscapes); Hill classes have 101 types of landscape.

Assessment potential of flash floods:

In the mountainous districts of Quang Nam, the potential of flash floods at level IV and V (high and very high) accounts for 119,879 ha (occupying 15.3% of the total area of the district), distributes in the districts of Nam Tra My , Dong Giang, Tay Giang.

6. Flood risk assessment:

The results of the classification of risk show that the risk of flash floods at level IV, V (high and high risk) accounts for 60,285 ha in terms the highest average annual rainfall (accounting for 7.7% whole district MN), mainly distributes in Tra My and Bac Tra My. The results also show that the average area of rainy seasons is high: 82.988 ha (accounting for 10.6% of the total area of mountainous districts), distributes in Bac Tra My, Bac Tra My and Tay Giang districts.

- Assessing the risk of flash floods in extreme conditions of climate and weather with calculating the flow energy according to the maximum daily rainfall to propose priority communes to have solutions in order to prevent and reduce flood hazards. There are 7 basins at level IV, V (high risk and very high), occupying 82,457 ha (occupying 10.5% of the area), level IV (370%), Nam Giang (4.0%). Level V (very high) is 32,076 ha (accounting for 4.1%) distributes in South Tra My.

7. Analysing of land use actuality, forest cover, population distribution, infrastructure; Environmental hazards caused by flash floods: To propose solutions to prevent and mitigate damages caused by flash floods. Important measures to prevent and minimize flash floods in long-term are restoring the coverage and redistributing the population.

2. Recommendations

* Theoretical side:

The direction of study on flood risk assessment, based on the connection between basin analysis about flash flood dynamics factor and landscape analysis and assessment of factors affecting the risk of flash floods in the sub-basin, is necessary to continue to apply to basins in other territories in order to supplement and improve the research methodology and methods of assessment of flash flood risks.

* Practical side:

Local authorities can consult to the results of the thesis in preventing and mitigating damages caused by flash floods, especially based on flood risk assessment results in extreme conditions of climate and weather in calculating the flow energy according to the annual maximum rainfall for weather forecasts in rainy days, suggest that priority communes should have remedies to prevent and reduce the flash floods.

The restoration of forest cover and population redistribution should be prioritized according to administrative units in the study area.

Local residents who are at risk of flash floods should be guided how to read disaster maps, given visual materials (maps), this can decrease the impact of natural disaster damages, especially locations having limited informative media.

A database should be established to prevent damage caused by flash floods, manage and plan the territory more effectively.

Authorities should invest in creating a network of rain calculation stations in localities, particularly in areas with heavy rains leading to flash floods such as Tay Giang, Dong Giang and Nam Tra My.

A LIST OF PUBLICATIONS OF AUTHOR RELATED TO THE THESIS

1. Do Quang Thien, Nguyen Thi Thanh Nhan, Hoang Ngo Tu Do, Tran Thi Ngoc Quynh, La Duong Hai, Nguyen Huu Huy, Nguyen Thi Thu Hien (2015), Assessment of Landslide, Flash Floods and Debris Flow along Ho Chi Minh Route From Cong Troi Pass to Lo Xo Pass, *Proceedings of The 2nd International Conference Hanoigeo 2015, Engineering Geology in Respond to Climate Change and Sustainable Development of Infrastructure. Publishing House for Science and Technology, Hanoi, Vietnam, 2015, pp: 239-246.*

2. Nguyen Thi Thu Hien, Do Quang Thien, Hoang Ngo Tu Do, Nguyen Thi Thanh Nhan, La Duong Hai, Dennis Gross (2016), Appreciation of Mud-Debris Flow Intensity in Strongly Dissected Mountainous Territory (Case research of Vu Gia-Thu Bon River Basin), *The 2nd National Conference on Transport Infrastructure with Sustainable Development, Construction House.ISBN:978-604-82-1809-6, pp: 401-408*.

3. Nguyen Thi Thu Hien (2017), Features of flash floods actuality in the mountainous districts of Quang Nam province, *Science Journal (Hue University*), Thua Thien Hue.

4. Nguyen Thi Thu Hien, Nguyen Thi Kim Chuong (2018), Establishing landscape map for the research on flash floods in the mountainous districts of Quang Nam, *Summary Record of National Geography Science Conference X, book 1, ISBN ISBN 978-604-913-693-1, Da Nang.*

5. Nguyen Thi Kim Chuong, Nguyen Thi Thu Hien (2018), Approaching system in flash floods research, *Summary Record of National Geography Science Conference X, book 1, ISBN ISBN 978-604-913-693-1, Da Nang.*

6. Nguyen Thi Thu Hien (2018), Flood risk assessment of mountainous districts of Quang Nam, *Proceedings of the National Conference on Geosciences, Institute of Geography, pp. 126 - 137, ISBN 078-604- 913-773-0.*

7. Nguyen Thi Thu Hien, Nguyen Ngoc Thach, Đo Van Thanh (2019), Assessing the potentiality of flash flood in mountainous districts of Quang Nam province, *Summary Record of National Geography Science Conference XI,* Thua Thien Hue.