The Role Of Relative Slope Length In Flood Hazard Mapping Using Ahp And Gis (Case Study: Lam River Basin, Vietnam)

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RESEARCH PAPER

THE ROLE OF RELATIVE SLOPE LENGTH IN FLOOD HAZARD MAPPING USING AHP AND GIS (CASE STUDY: LAM RIVER BASIN, VIETNAM)

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ABSTRACT. In addition to the five main factors affecting the formation of floods including slope, rainfall, drainage density, soil, and land cover, the relative slope length factor has also been considered to be one of the fundamental causes that contribute to flood hazard. The paper analyzes the theoretical basis for choosing the relative slope length criterion when zoning flood hazard in Lam river basin. The important role of this factor was evaluated by the results of the flood risk zoning map established by the method of integrating AHP and GIS technology in two cases: using 5 flood influence criteria and using 6 flood influence criteria. Flood hazard zoning maps for 2 cases were tested with 3 historic floods occurring on Oct 2010, Oct 2013 and Oct 2016. The results showed that the map established with six influence factors is more detailed and accurate than the one created with five factors affecting flood hazard because of the similarity with the reality of that map. The results of the study are applicable to other river basins which their geographical features are similar to characteristics the Lam river basin.

KEY WORDS: Relative slope length, slope length, flood hazard zoning, AHP algorithm, Lam river basin

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INTRODUCTION

Floods are among the most common and most destructive natural disasters in Vietnam causing serious consequences (El Alfy 2016; Chau et al. 2013), threatening people's lives and slowing down the progress of socio-economic development. In period 1989 to 2014, floods caused considerable losses including at least 14,867 dead and missing people, asset damages equivalent to 1% of GDP for Vietnam (Chinh et al. 2018) and especially in agriculture, the extreme flood can affect more than 40% of wet rice production (Chau 2013). Floods also bring sediments with it (Bastawesy et al. 2009) and more sedimentation can result in clogging of drainage systems (El Alfy 2016). Widespread flooding with dramatic damages has shown the importance of flood mitigation and disaster response. In order to solve this problem, the first important mission is that building the flood hazard-zoning map, one of the powerful tools to identify flood-prone zones. The production of flood hazard maps is an important component of flood risk assessment and management activities (Chau et al. 2013; Luu et al. 2018).

There are many methods to establish the flood hazard zoning map such as the Hydrological method, Analytic Hierarchy Process (AHP) method, Statistic method, etc., but the AHP method is one of the most effective procedures because of its easy usage and high flexibility (Minh 2017a). In Vietnam, this approach has appeared in the early years of the previous decade with some typical studies in Vu Gia – Thu Bon river (Tu et al. 2013), Hương river (Phương et al. 2015), Lam basin river (Minh and Dung 2017), river system in Quang Nam province (Chinh et al. 2018; Luu et al. 2018). AHP is a mathematical model for assigning the weight and rank to each factor used in the multi-criteria decision-making process (Souissi et al. 2019). When developing a flood risk zoning map using the Analytical Hierarchy Process (AHP) method, the selection of the factors leading to the formation of floods will determine the accuracy of the research results. Using AHP technique, the criteria that have a significant influence on flood formation in the river basins and other geographical areas have been published by many scientists in research of the different geographical areas including rainfall, slope, soil, land use, drainage density, land cover, irrigation system, etc. (Radwan et al. 2019; Seejata et al. 2018; Vojtek and Vojteková 2019). In fact, there are many various factors affecting flood generation such as physical geography, socio-economic, infrastructure factors (Elkhrachy 2015; Kazakis et al. 2015; Rahmati et al. 2016). According to (Tran et al. 2008), the flood is not a pure risk disaster but this phenomenon has deep roots in social vulnerabilities and inappropriate environment management. For each geographical area, the criteria as well as the level of impact on the flood are also different and there are no specific factors for flood susceptibility (Rahmati et al. 2016).

In the Lam river basin, apart from the aforementioned factors, the slope length factor is also one of the main causes affecting the flood risk. Slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases to the extent that deposition begins or to the point where runoff enters a defined channel (Zhang et al. 2017). This factor is known as one of the key factors that impact the flow volume (Yongmei et al. 2011) and runoff velocities (Gilley et al. 1987). The slope length has been studied a lot when assessing its effect on erosion. The effect of slope length on erosion occurs through an increase in the volume and the speed of runoff, resulting in increased capacity of the runoff to disaggregate and transport sediments (Bagarello and Ferro 2010). The research of (Bagio et al. 2017) revealed that the increase in erosion with the length of the slope is explained by the greater erosive power of surface runoff, determined mainly by the increase in the volume and speed of runoff (Bagio et al. 2017). Therefore, the longer the slope length, the higher the flow velocity and the greater the runoff volume. This leads to the slope length also significantly affecting the flood formation. There are two kinds of slope length: absolute and relative slope length. However, it is not easy to implement the absolute length hierarchy of all slopes in the study area by AHP, so the latter one will be mentioned in this study. The objective of the current study is to analyze the importance of relative slope length factor in making a flood hazard zonation maps using AHP associated with GIS techniques.

RESEARCH AREA

The Lam river system is located within 103°14' to 106°10' E and 17°50' to 20°50' N, lasts approximately 350 km in the NW-SE direction (Fig. 1). In Vietnam, more than 80% of the area is mountainous (Kieu 2011). The topography of the Lam river basin is complex distribution, the upstream and middle areas are steep terrain, while the terrain of downstream areas is quite flat. The terrain of the river basin is like a sloping roof that the peak is the Truong Son mountain range in the west and descending to the east. This makes it easy to concentrate the flow downstream quickly to create large floods. The average annual rainfall in the Lam river basin in the period 1961 – 2017 measured at Muong Xen station is 1,039,883 mm (lowest) and at the Ky Anh station is 2,899,900 mm (highest) (Kieu 2011).

As one of the nine major river systems of Vietnam, the Lam River system has two major tributaries, the Ca river and the La River. The drainage density of the Lam river basin is approximately equal to that of the central rivers (0.67 km/km2). The soil in the mountainous area of the Lam river basin is quite good, the thickness of the soil layer is more than 50 cm, the good soil structure consists of 38 different soils which are unevenly distributed throughout the basin and can be divided into the main land groups including alluvial soil, red yellow feralit soils, coastal sand groups, and mangrove groups. The Lam river basin is rich in land cover including broadleaf evergreen forest, renew forest, mixed bamboo forest, residential land, shrubs, agricultural land, bare lands, cultivated aquatic land, other lands. Currently, the area of vacant land, bare hills on the Lam River basin is quite high, about 20% of natural land area (Kieu 2011).

Thus, with such natural conditions, the factors which can cause flooding in the Lam river basin including heavy rainfall on large areas, rich soils, thick drainage density, steep slope, land use for many purposes. These are the most important factors for the formation of the floods when heavy rainfall occurs for long periods. However, the watershed line of the southern and southwestern regions of the Lam river basin passes through mountains with an average elevation of 1,300-1,800 m. Also, the average slope of the sub-basins of the research area varies from 1% to 40%, so the slope length will be relatively great leading to higher risks of flooding. In the mountainous areas, the slope is different, the value of slope length is different, that means flood hazard also different. Therefore, it is necessary to consider the slope length element or the distance from the watershed line to the location where assessing the flood hazard (Minh 2019b).

DATA AND METHODS

Analyzing the effects of slope length on flood hazard

The concept of slope length

Slope length is the distance from the origin of overland flow along its flow path to the location of concentrated flow or deposition. According to (Widchmeier and Smith 1978), slope length has been defined as «the distance from the starting point of overland runoff (the top of the hillslope) to one of two following locations: (a) the point where the slope decreases sufficiently for deposition to occur, (b) the position where flow concentrates a clearly-defined channel (wet or dry) that may be a part of a drainage network or a constructed channel such as a terrace or diversion» (Wischmeier and Smith 1978). Thus, this length is equal to the distance calculated from the watershed line to the valley line. A watershed is an area of land that drains to a

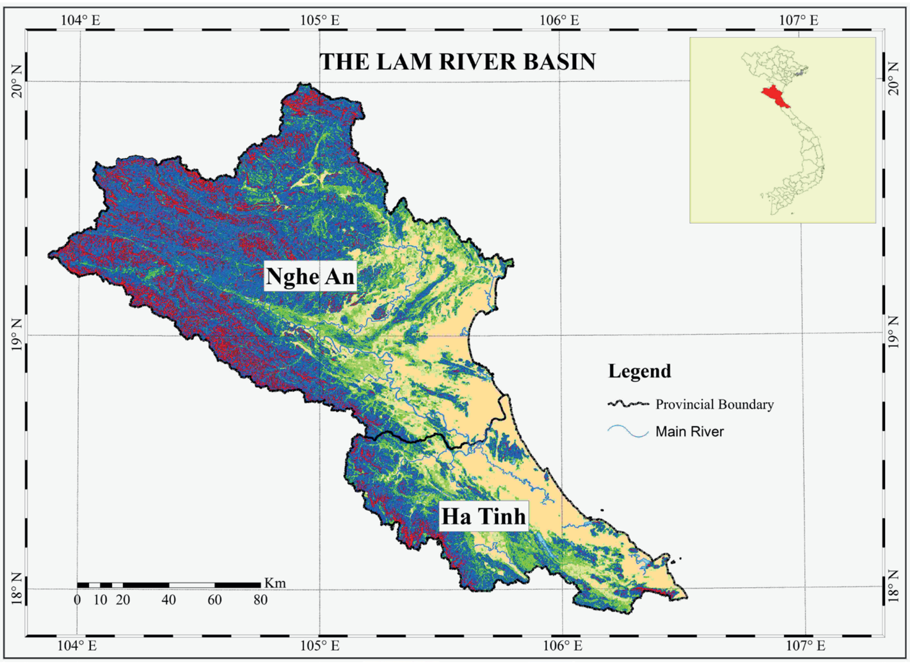

Fig. 1. The Lam river basin

From the study results, it is observed that AHP provides a flexible, simple, step-by-step and transparent approach of analyzing complex problems in a multi criteria decision analysis (MCDA) environment based on experts and end-user preferences, knowledge, experience, and judgments. Further, the AHP- GIS based method to flood hazard assessment as utilized in this study is seen as a relatively inexpensive, easy to use, and more importantly, permits interactive implementation by flood managers for continuing improvement. Therefore, it was found that the changes in the set of criteria contributing to flood creation significantly affect the result of the hazard zoning map, and the changes were reasonable and acceptable. The results prove that adding the relative slope length parameter to calculate the model will increase the reliability of the research method. Also, the different results obtained from these two cases indicate the importance of the relative slope length factor in mapping flood hazard zoning.

These results also introduce a way to improve the accuracy of developing flood risk zoning map with AHP by adding a factor leading to the formation of floods when calculating the model. However, it is carefully considered to decide which factors can be supplemented and the matching capacity of these elements on the hierarchy and computation by the AHP algorithm. In addition, it is not recommended to add too many criteria, only a maximum of 9 criteria is sufficient because psychologists conclude that, nine objects are the most that an individual can simultaneously compare and consistently rank (Pawel 2010).

CONCLUSION

When studying flood hazard zoning by the AHP method, the criteria affecting the flood may change depending on data collection. However, besides using the common factors contribute to flooding in most terrain and geographic areas such as rainfall, slope, drainage density, land cover, and soil, it is advisable to add the relative slope length parameter as input data. This is the important criterion when studying the flood risk zoning for many basins in general and the Lam river basin in particular. This factor affects the volume of water, water accumulate ability, and flow velocity, thereby this contributes to flood risk . Results of flood hazard zoning using the relative slope length are more specific and accurate, thus accuracy and reliability of the warning work will be improved significantly. Especially for river basin with high flood frequency, areas with high elevations, high slope, and area with a long distance from the watershed line to the valley line, using the slope length in the flood risk study is necessary.

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