Using GIS to Assess Natural Hazards in NW Vietnam

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Abstract: Natural hazards occur annually and are expected to become more frequent with more losses of life and property under a changing climate in different geographic regions and provinces of Vietnam, a tropical, populous and mountainous country in SE Asia. In such context, assessments of natural hazards using geoinformatics in Vietnam have really attracted an increasing attention of many scientists and managers. This paper provides an example of GIS application to assess earthquakes, flash floods and landslides as major types of natural hazards reported in three mountainous provinces of Hoa Binh, Son La and Dien Bien in NW Vietnam. The reported natural hazard data were collected online and offline from a variety of sources. The collected data were reviewed and entered to develop a natural hazard database for all the three provinces. Selected GIS analysis techniques were applied to derive new information on the location, extent, causes and consequences of natural hazards based on data integration. This GIS analysis model proves the utility of GIS as an effective tool for systematic assessments of natural hazards at provincial and regional levels. It can be applied to other provinces and regions in Vietnam for natural hazard research and management for sustainable development in the context of climate change.

Key words: GIS, natural hazards, earthquakes, flash floods, landslides

1. Introduction

Natural hazards are physical geographic processes or phenomena with potential adverse impacts on human and natural systems. To better understand and effectively manage natural hazards for sustainable development, natural hazard assessments need to be conducted and integrated into development planning with the aid of advanced spatial information technologies such as remote sensing and geographic information systems (GIS) [1].

GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information [2]. This system allows users to perform very difficult, time consuming, or otherwise impractical spatial analyses to support spatial decisions for planning and management. The benefits of using GIS have been proven in the

studies by Babinski et al. (2012) [3]; Graham et al. (2011) [4]; and Taupier (1998) [5]. The use of GIS in natural hazard assessment is justified by it great power in data input, management, analysis and output [6-16].

According to the International Council for Science Regional Office for Asia and the Pacific (ICSU ROAP), (2008), the impact of natural and human-induced environmental hazards and disasters on humans and the environment continues to rise and the Asia and Pacific region accounts for more than one-half of the world population, and about 80% of all losses due to natural hazards globally. A Science Plan on Hazards and Disasters was proposed to address research needs in three categories of hazards and disasters, namely earthquakes, floods and landslides.

Vietnam is a tropical, populous and mountainous country in SE Asia. It is highly vulnerable to natural hazards due to its geographic location and socioeconomic conditions. Natural hazards occur annually and are expected to become more frequent with more losses of life and property in different geographic regions and provinces of the country under

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a changing climate. In such context, assessments of natural hazards using geoinformatics in Vietnam have really attracted an increasing attention of many scientists and managers for scientific and disaster management purposes. This paper presents a case study of GIS application to assess earthquakes, flash floods and landslides as major types of natural hazards reported in three mountainous provinces of Hoa Binh, Son La and Dien Bien in NW Vietnam. The tested value of the GIS data and analysis techniques provides a strong basis for further GIS applications to support making decisions for future regional development.

2. Study Area

The study area is located between 20°18'23" and 22° 32'57" latitudes and, 102°8'31" and 105°51'29" longitudes. It includes 3 large provinces in NW Vietnam (Fig. 1), covering a total area of about 28219.91 sq. km.
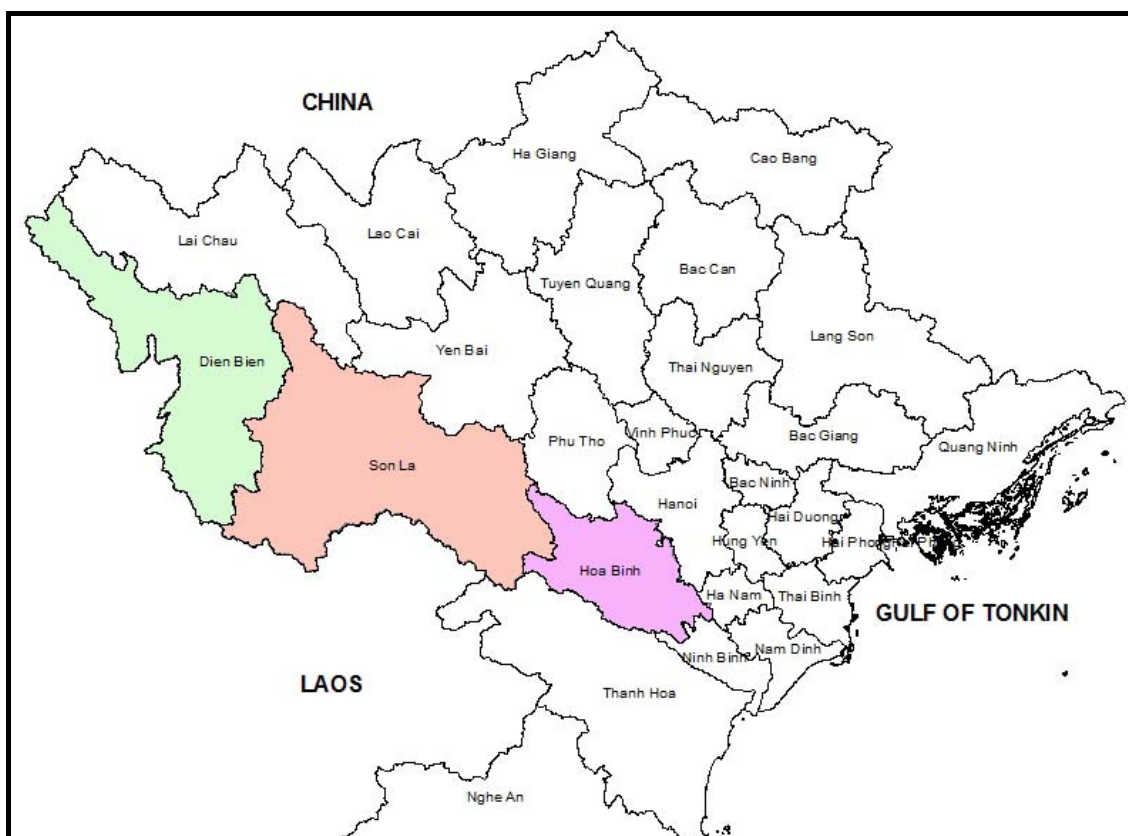

Fig. 1 Location of Hoa Binh, Son La and Dien Bien provinces.

Hoa Binh province borders Phu Tho and Son La provinces to the Northwest, Hanoi to the North and Northeast, Ha Nam province to the Southeast, Ninh Binh and Thanh Hoa provinces to the South. Hoa Binh is subdivided into 11 district-level sub-divisions: 10 districts (Cao Phong, Da Bac, Kim Boi, Ky Son, Lac Son, Lac Thuy, Luong Son, Mai Chau, Tan Lac, Yen Thuy) and provincial capital (Hoa Binh city). They are further subdivided into 11 commune-level towns (or townlets), 191 communes, and 8 wards. Major ethnic groups in Hoa Binh include Vietnamese, Muong, Thai, Tay, Dao.

Son La province borders Dien Bien province to the West, Lai Chau province to the North, Yen Bai and Phu Tho provinces to the East, Hoa Binh, Thanh Hoa provinces and Laos to the South. Son La is subdivided into 12 district-level sub-divisions: 11 districts (Bac Yen, Mai Son, Moc Chau, Muong La, Phu Yen, Quynh

Nhai, Song Ma, Sop Cop, Thuan Chau, Yen Chau, Van Ho) and provincial capital (Son La city). They are further subdivided into 9 commune-level towns (or townlets), 188 communes, and 7 wards. Major ethnic groups in Son La include Vietnamese, Thai, H'Mong, Muong, Dao.

Dien Bien province borders Lai Chau and Son La provinces to the East and China to the North, and Laos to the West. Dien Bien is subdivided into 10 district-level sub-divisions: 8 districts (Dien Bien, Dien Bien Dong, Muong Cha, Muong Nhe, Tua Chua, Tuan Giao, Muong Ang, Nam Po), 1 district-level town (Muong Lay town), and 1 provincial city (Dien Bien Phu city). They are further subdivided into 5 commune-level towns (or townlets), 116 communes, and 9 wards. Major ethnic groups in Dien Bien include Vietnamese, H'Mong, Dao, Thai.

These three hilly and mountainous provinces are linked to Hanoi by National Highway 6 (NH 6), also known as Asian Highway 13 (AH 13). They were selected for this GIS study for their socioeconomic conditions, ecosystem services and high vulnerability to natural hazards.

3. Data and Methods

3.1 Data Collection

The reported natural hazards and related data for use in this study were collected online and offline from a variety of sources, including official web pages at provincial, national and international levels, education, research and management institutions under Vietnam National University (VNU), Vietnam Academy of Science and Technology (VAST), Ministry of Natural Resources and Environment, Ministry of Agriculture and Rural Development, Ministry of Transportation and Communication.

3.2 Database Creation

The collected analog and digital data in the form of archived and published documents were reviewed, edited, digitized and standardized to the ArcGIS software format (ESRI File Geodatabase) to develop a natural hazard GIS database for all three provinces for better data management, analysis and output.

ArcGIS is an advanced GIS. It includes tools for data input, storage, management and output. The use of ArcGIS is justified by its completeness, power and popularity [17, 18].

The ArcGIS database for natural hazard assessments consists of spatial and attribute data in the form of feature datasets and feature classes related to hazard inventories, environmental factors, triggering factors and elements at risk

3.3 Data Analysis and Output

The created GIS data layers were further analyzed using different established GIS techniques such as mapping, statistical, geometrical and overlay analysis [15, 19]. All the above mentioned operations allowed to derive new information on the geographic location, extent, causes and consequences of natural hazards in the study area.

4. Results and Discussion

The GIS database for earthquakes, flash floods and landslides in the provinces of Hoa Binh, Son La and Dien Bien is illustrated in Fig. 2. It is essential for provincial and regional assessment of natural hazards using their spatial and attribute data.

Fig. 3 shows the spatial distribution of earthquake events recorded between 1996 and 2015 in the three mountainous provinces along NH 6 by the national seismic stations. A total of 201 earthquake epicenters were recorded: 16 in Hoa Binh, 106 in Son La and 79 in Dien Bien.

In Hoa Binh, earthquake epicenters are concentrated on the Da River Fault. In Son La, major earthquakes were reported in 1983 (Ms = 6.8 on the Richter scale) on Song Ma fault zone, 2014 (4.3) on Muong La-Bac Yen fault, 2015 (3-3.9). The strong earthquake epicenters are located in the Song Ma district, Thuan Chau, Yen Chau, Moc Chau districts and Son La Town.

In Dien Bien, major earthquakes were reported in 1935 (Ms = 6.8 on the Richter scale), 1983 (6.7), 1996 (5.0) and 2001 (5.3). They are related to the Dien Bien-Lai Chau fault, one of the active faults capable of generating the strongest shocks in the country. The strong earthquakes in Dien Bien may also be explained by its geographic closeness to the seismic belt in Asia.
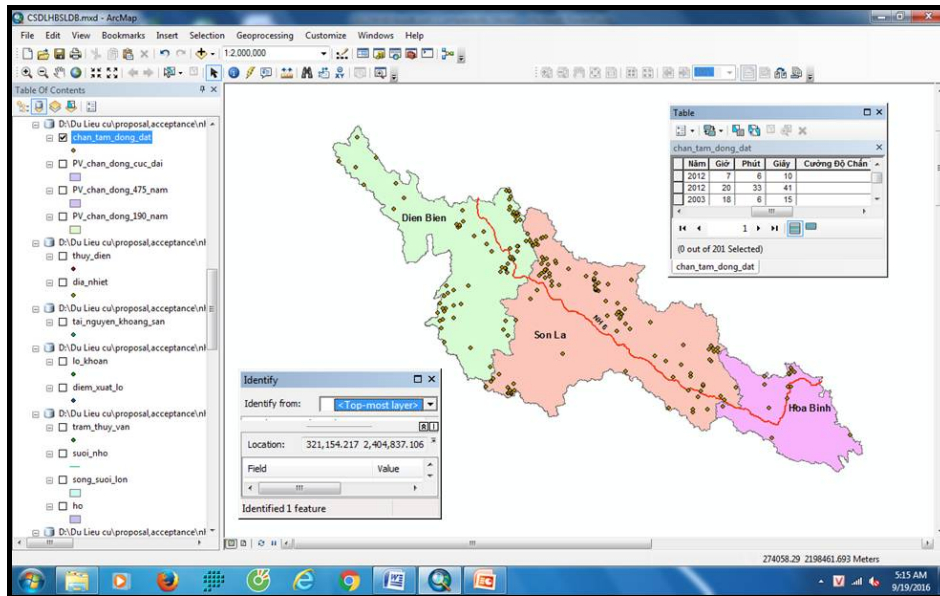

Fig. 2   An illustration of GIS database of earthquakes, flash floods and landslides in the study area.
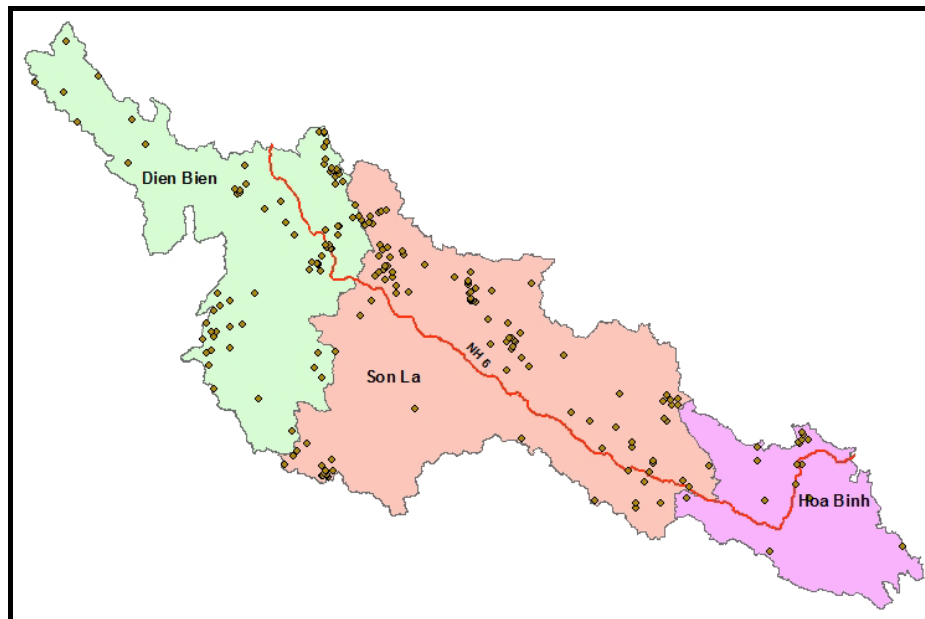

Fig. 3   Spatial distribution of earthquake epicenters in Hoa Binh, Son La and Dien Bien provinces.

Flash floods can be generated by rainfall, slope, hydrological network, bedrock features, weathering crust, vegetation and human activities. The spatial distribution of reported flash floods in the study area is indicated in Fig. 4. A total of 29 flash flood positions were mapped.

It is evident that no large flash floods were mapped in Hoa Binh while there is a spatial concentration of flash floods in Son La and Dien Bien. In Son La, flash floods often occur from from June to October every

year. There were notable flash floods in 1991 in Nam Bu, Nam Pan and Nam La streams of Yen Chau, Mai Son districts and Son La city. In 1994, large flash floods occurred in Song Ma, Thuan Chau, Muong La, Yen Chau, Moc Chau districts and Son La City. The 1999 flash floods were reported in Muong La district and Son La city. The flash floods reoccurred in 2007 in Yen Chau, Moc Chau, in 2008 in Mai Son district and Son La city, and in 2012 in Muong La district. In Dien Bien, flash floods also occur frequently, causing damages to people and property. Notable flash floods were reported in Muong Lay, 1990, 1991, 1994, 2000; Muong Cha, 1994; Dien Bien, 1994. The region needs to be

investigated in detail to take appropriate measures for warning to minimize the damage caused by flash floods.

Landslide events were reported in all three provinces. Their spatial distribution is shown in Fig. 5. A total of 177 landslides were mapped between 1996 and 2015 with 28 cases in Hoa Binh, 67 cases in Son La and 82 cases in Dien Bien. These landslides were mainly triggered by rainfall. The traffic safety on NH 6 is seriously affected by landslides during the rainy season. The landslide in Dong Bang commune, Mai Chau district, Hoa Binh in Feb. 2012 is an example of the deadly landslides.
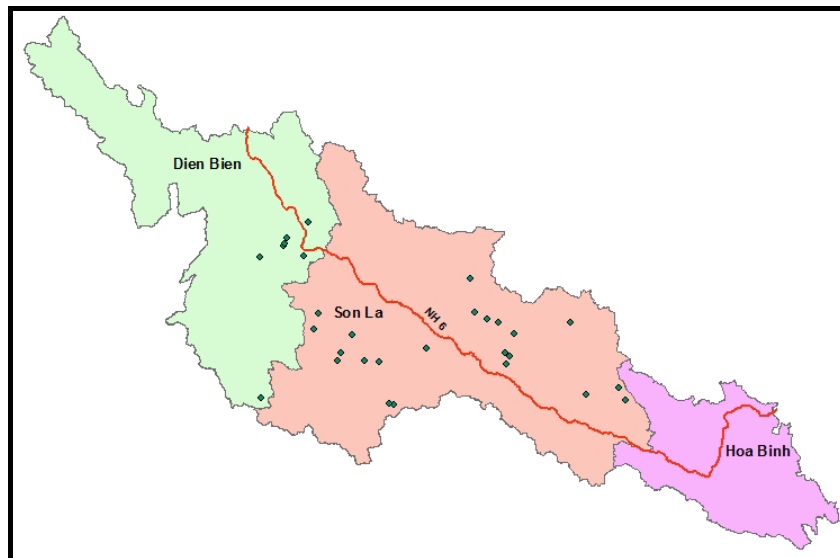

Fig. 4   Spatial distribution of flash flood events in Hoa Binh, Son La and Dien Bien provinces.
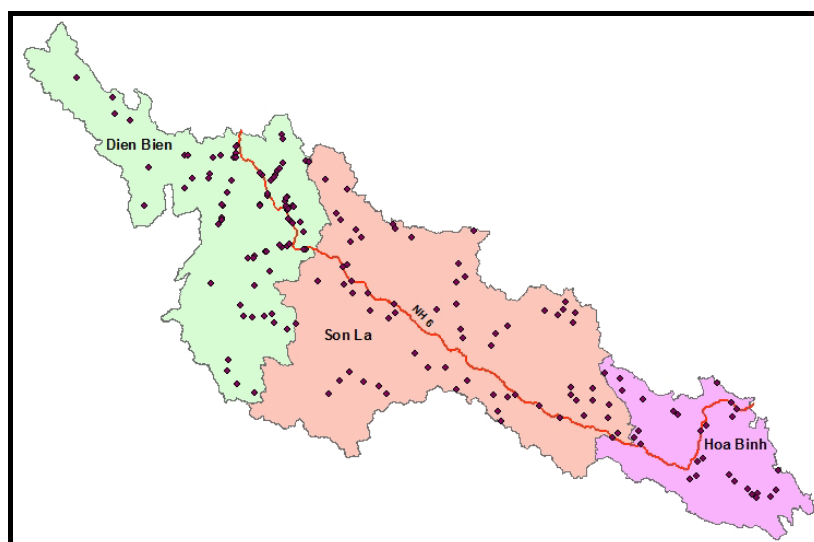

Fig. 5   Spatial distribution of landslide events in Hoa Binh, Son La and Dien Bien provinces.

5. Conclusions and Future Work

GIS is an effective tool for mapping and assessment of natural hazards in Hoa Binh, Son La and Dien Bien provinces in mountainous Vietnam to derive new information from existing data for scientific research and management of natural hazards in the context of climate change.

All three provinces are exposed to earthquakes, flash floods and landslides. Dien Bien is better known for destructive earthquake, Son La for flash floods and Hoa Binh for landslides along NH 6.

The created ArcGIS database can and should be exploited, updated and enriched as new data and techniques become available. Further studies can focus on comprehensive and detailed inventories, predictive modeling and assessment of vulnerability to natural hazards, especially flash floods and landslides in the study area using remote sensing and GIS in combination with ground investigations. The presented GIS multi-province, multi-hazard assessment model can be applied to other provinces and regions in Vietnam.

Acknowledgements

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