LANDSLIDE VULNERABILITY ZONATION MAPPING USING GIS AND REMOTE SENSING METHODOLOGY: A CASE STUDY ON HIGHWAY 6, HOA BINH PROVINCE

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ABSTRACT

This paper presents the creation of a landslide vulnerability map on Highway 6, Hoa Binh Province by using Geographic Information Systems (GIS) and Remote Sensing. Nine separate maps are collected from different sources, that include lithology, land cover, hydrographic network, vegetation cover, geomorphology, altitude, orientation and slope gradient in the study area. Then, these maps are calibrated with weighting factors and combined with a linear method. In the final map, three landslide vulnerability zones on Highway 6 – Hoa Binh province, low, medium and high, are represented. This total map may not only provide in credible future location of infrastructure, identification of vulnerable areas on Highway 6 but also select the most appropriate and safer land use in the region.

1. INTRODUCTION

The landslides are usually triggered by the neo-tectonic movements, earthquakes, heavy precipitation and those induced due to land-use changes such as felling of trees, agriculture, mining and road cutting in hilly terrain. Landslide is a general term used to describe the down-slope of soil, rock and organic material under the influence of gravity .

National Highway 6 in Hoa Binh province is the only route which links North-West areas with Hanoi capital, serving the socio-economic development of the whole region as well as security and national defense. However, because of the complicated geological conditions and the high slope, this highway has been many points of seriouslly landslides which have damaged the infrastructure of the road and caused damage to people and property, especially in the rainy season. Therefore, this highway has been received much attention from the government, the transport ministry and related departments. The content of these studies assessed the vulnerability of this highway based on the road surface material (United Nations Development Program, 2015) or focused on statistics landslide positions along the route (Ministry of Transport, 2013) or identified high risk areas for landslides by DEM analysis (Nguyen Thi Hong, Do Minh Ngoc, Nguyen Manh Hieu, 2015).

This study proposes the strategy for Landslide vulnerability zonation mapping to formulate an efficient methodology to identify the landslide vulnerability areas on Highway 6. Integration of remote sensing and GIS not only allows most accurate and most updated database on land information but also seems an useful tool in combination with spatial data and very useful deriving the ideas for efficient management and mitigation during the landslide disaster (Van Westen et al., 2008).

2. STUDY AREA

National Highway 6 in Hoa Binh province has about 115km length, which connects Hanoi capital with the North-West and Thuong Lao areas. It starts from K38 to K153. Because of the medium mountainous terrain, complicated geology, high slope so the phenomenon of landslide happens quite often, especially in the rainy season.

3. MATERIALS AND METHODOLOGY

3.1 Materials

There are many factors that can cause the landslide. As Schuster (1996) suggusted, at least 20 factors cause the landslide. Depend on the size and area of the study, researchers have chosen necessary factors for the evaluation process (Schuster, 1996). However, it is very difficult to collect these factors fully, simultaneously, the analysis process in GIS is also very complex. In this study, the following nine factors are used to produce the final vulnerability map (Tab.1):

Table 1. Nine factors are chosen for landslide vulnerability zonation mapping.

No	Factors	Source	Scale
1	Slope	Topographical maps	1:50 000
2	Lithology	Geological maps	1:200 000
3	Vegetation	Forest maps and Spot-5 satellite	1:50 000; 10mx10m
4	Weathering crust	Weathering crust maps	1:100 000
5	Geomorphology	Geomorphological maps	1:100 000
6	The average rainfall	The data of rainfall stations	1:50 000
7	Lineament	Satellite image combining DEM	1:50 000
8	Line Density	Topographical maps	1:50 000
9	Deep Density	Topographical maps	1:50 000

3.2 Methodology

3.2.1 *Calibration of the factors*

The abovementioned factors correspond to individual vulnerability maps that were created after their characteristics have been calibrated. In which, level 1 corresponds to a very low probability of landslides, level 5 corresponds to exceptionally high probability (Tab.2).

Table 2. Calibration of nine factors' characteristics.

Factors	Characteristics	Vulnerability Level	Factors	Characteristics	Vulnerability Level
Slope	* $0^0 – 5^0$ * $5^0 – 14^0$ * $14^0 – 23^0$ * 23^0 -35^0 * >35^0	1 2 3 4 5	Geomorphology	*Mountains; High valley deltas. * Folded hills. * Trenches; V Valleys; Folding blocks destroy parts. * Low wet plains; Crushed limestone mountains; Folded mountains; Karst deltas.	5 3 4 2
Lithology	* Sedimentary rocks of Quaternary. * Quaternary sedimentary rocks rich alumosilicate. *Depleted sedimentary rocks. * Mafic rocks and their tuff. * Metamorphic rocks rich alumosilicates. * Magma-neutral rock. * Magma mafic - super mafic.	3 5 2 4 4 2 1	The average rainfall (mm/year)	* 1200 – 1400 * 1400 – 1600 * 1600 – 1800 * >1800	2 3 4 5
Vegetation	* Forests. * Sparse forests. * Bush forests.	1 2 3	Lineament (km/km^2)	* <0,5 * 0,5 – 1 * 1 – 1,5 * 1,5 – 2 * >2	1 2 3 4 5
Weathering crust	* Ferosialit. *Ferosialit–Sialferit. * Sialferit. *Sialferit– Sialit.	3 1 4 2	Line Density Split (km/km^2)	* 0 – 0,5 * 0,5 – 1,5 * 1,5 – 2,5 * 2,5 – 3 * >3	1 2 3 4 5
			Deep Density (m)	* <100 * 100 – 200 * 200 – 300 * 300 – 400 * >400	1 2 3 4 5

3.2.2 *Creating intermediate thematic maps*

For each thematic map of vulnerability zones, containing the calibration coefficients of individual charactertistics, was created in ArcGIS 10.2 in order to each factor has a three level.

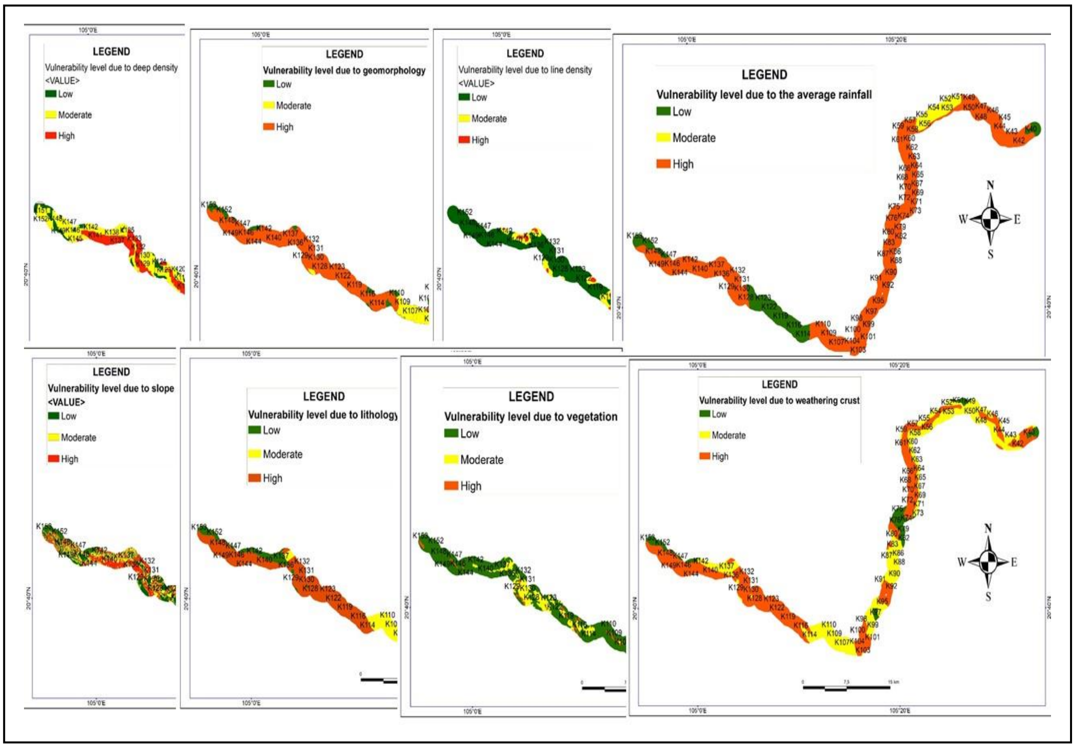

Figure 1. Vulnerability map due to slope, lithology, lineament, geomorphology, vegetation, the average rainfall, deep density, line density, weathering crust.

3.2.3 *Linear combination of individual thematic maps*

Each factor influences the landslide risk occurrence to a different extent. For the nine sub-factors, weighting coefficients, depending on their vulnerability to landslide occurrence, are provided. As Nguyen Ngoc Thach et al (2012) suggested, the highest weighting coefficients appear in the slope, the average rainfall and lithology (Nguyen Ngoc Thach et al, 2012). Nine factors and their weighting coefficients are illustrated in table 3.

Table 3. Weighting coefficients of the nine sub-factors.

No	Factors	Weighting coefficients	Percentage
1	Slope	0,25	25%
2	The average rainfall	0,25	25%
3	Lithology	0,20	20%
4	Geomorphology	0,10	10%
5	Lineament	0,06	6%
6	Line Density	0,05	5%
7	Deep Density	0,05	5%
8	Vegetation	0,02	2%
9	Weathering crust	0,02	2%

Next, the nine individual maps are placed into the linear function (1) in order to provide the cumulative vulnerability map:

$$R_a = \sum W_i.X_i \tag{1}$$

R_a = Landslide risk in the a pixel.
W_i = The weighting factor of agent i.
X_i = The value of the factor i risk level in the a pixel.

4. RESULT AND DISCUSSION

The final landslide vulnerability map is the result of the reclassification process and illustrates three landslide vulnerability levels (Fig.2). The green color represents the low risk segments, the yellow color represents the moderate risk segments while the orange color represents the high risk segments.

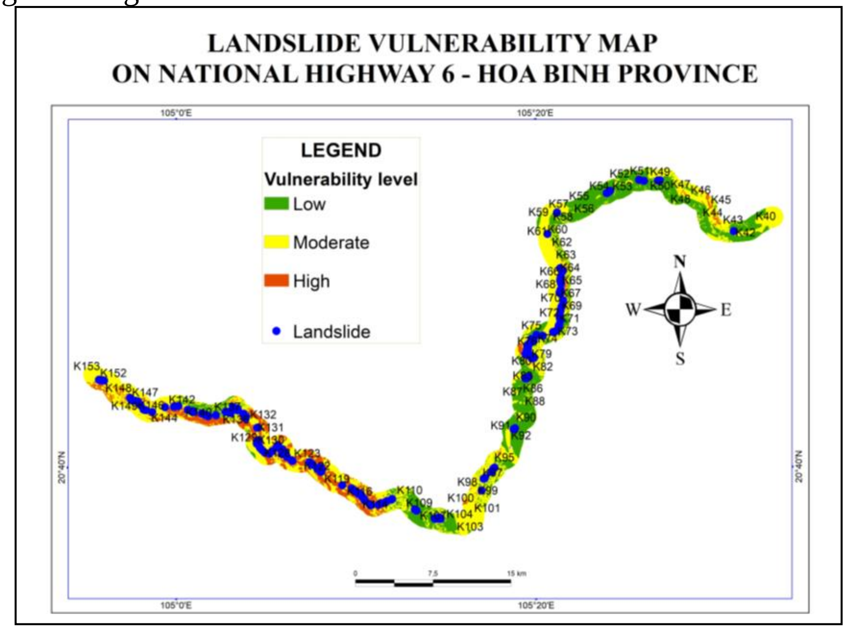

Figure 2. Landslide vulnerability map on National Highway 6, Hoa Binh province.

This final map is compared with the historical data to test the results, see easily that:

- The low risk segments include K40-K42; K51-K56; K83-K92; K103-K110. Because the slope of these segments are low, ranging from 0^0 to 10^0 and the lithology components are mainly magma-neutral rock and magma mafic - super mafic. Their stability with landslide are quite high. Although the average rainfall is much, the phenomenon of landslides rarely occur on these segments.

- The moderate risk segments include K38-K40; K43-K51; K57-K82; K93-K103. These are the medium slope segments, ranging from 10^0 to 30^0 and the major ingredients of the lithology are mafic rocks and their tuff, metamorphic rocks rich alumosilicates and sedimentary rocks of quaternary. Their stability with landslide are quite low. In addition, the average rainfall is quite high, so the landslide occur on these segments quite often.

- The high risk segments include K110-K142; K144-K152. These are the high slope segments, above 30^0 and and the major components of the lithology are sedimentary rocks of quaternary, metamorphic rocks rich alumosilicate and mafic rocks and their tuff. The landslide occur on these segments quite often every the heavy rain.

5. CONCLUSION AND RECOMMENDATION

Landslide vulnerability zonation mapping using GIS and remote sensing methodology not only helps identify risk segments on highway 6 easily but also is a low cost research method. The result of this reserch may help planners, managers for the landslide evacuation plan before each rainy season, for the development of a province, regional planning and for planning technical works. In addition, information concerning landslide vulnerability mapping can be tested with the historic data in order to confirm the effectiveness of the method as well as give the rightest conclusions.

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