

THE PROGNOSIS OF LANDSLIDE IN THE LAO CAI-SA PA REGION BY USING GIS AND REMOTE SENSING TECHNIQUE

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ABSTRACT

The Lao Cai – Sa Pa region with the towns of Lao Cai and Sa Pa is very famous in Vietnam for tourism. This region is located in the Hoang Lien Son highest mountain belt of Vietnam. In summer time many tourists come to this region for a rest and sightseeing. But in this region there are have been occurred many landslides. The landslide geohazard is very dangerous for local, native peoples and tourists.

By integration of some parameters such as: DEM, slope, geomorphology, landscape, weathering crust, vegetation, petrography, geology, structure... the authors have divided the study region into areas with 5 different possibility levels for landslide hazard occurring as following: Areas of I level: Very high landslide hazard possibility; Areas of II level: High landslide hazard possibility; Areas of III level: Medium landslide hazard possibility; Areas of IV level: Low landslide hazard possibility; Areas of V level: Non landslide hazard possibility

The studied results may give useful contribution for local administration for making urgent decisions for reducing the damages caused by landslides every year in this region.

1. INTRODUCTION

The Lao Cai - Sa Pa region is located in the North western part of Viet Nam, near the Viet Nam - China border. Sa Pa town is one of the most famous places for tourism in Viet Nam. It's located near the Phang Si Pan mountain peak that belongs to the highest and greatest mountain range in Viet Nam. Every year many foreign and home tourists come to Sa Pa for a rest, for sight seeing and for intruding in to the interesting light of ethnic minority people living in this area. However, in recent years in this region had happened in increasing direction some geological hazards, especially landslides and rock - falls. Landslides had caused both material damages and human life loses. The native local people and tourists are very worried about the sudden occurring of landslides during summer and autumn seasons time. That is why the prognosis of areas in which there may be occurred landslides is very urgent, practical and important problem.

During 2001 year, the Remote Sensing Center for Geology (Department of Minerals and Geology of Viet Nam, the Ministry of Industries) in cooperation with Division of Geodesy and Topographic Mapping (Department of Minerals and Geology of Viet Nam, the Ministry of Industries) had carried out one scientific research work titled “ The prognosis of

landslide in Lao Cai - Sapa region using GIS and remote sensing technique". The results of the carried out work was transferred to the local authority for taking necessary measures for protecting people against landslides and mitigating the damages and losses caused by landslides.

2. THE CHARACTERISTICS OF RESEARCH REGION

Lao Cai - SaPa is 20 km long and 4 km wide and it has the rectangular shape with the area of 80 km². The coordinates of the four peak points of rectangle are as following:

Number of peak point	Geodesic coordinates	
	X _G	Y _G
1	2487500	18390800
2	2485000	18394000
3	2469000	18381600
4	2471500	18378500

This region belongs to topographic sheet at the scale of 1:50.000 as 5753 - I (UTM projector) and F-48-52-D, F-48-52-B (Gaussian Projector).

This region is striking along highway N^o 4B by North - Eastern to South - western direction from S - SW part of Lao Cai town to SW part of SaPa town.

The relief of the region is high mountainous with the average height of about 1400 m (From 800 m to 2000 m). The differentiation and cutting of the relief are from medium to high. There many places are full of obstacles and difficulties to access with very strong deep (vertical) and horizontal cutting. The slopes of the region relief are from medium sloping to very steep (the sloping values are from 20^o to 90^o).

The hydronet contains mainly unpermanent streams (by season) with the density from medium to high. The streams has two dominant directions NE-SW (Ngoi Dum, Ngoi Xam) and NW-SE (Ngoi Bo, Suoi Coc San).

The vegetation cover is rather dense and it mainly consists of wooden trees in alternation with brushwood, grass. In some places there are newly planted forest. In many places the forest had been being destroyed by local people for growing rice, maize, sweet potatoes, manioc...This deforestation is one of the main reasons for increasing of landslide, surface erosion, sweeping flood and debris flood occuring in this region.

The soil cover is very thin. However in some concrete places the weathering crust cover is very thick (over 5m - 6m).

In this region there are many ethnic groups (mainly the ethnic minority groups), such as: Viet, Chinese, Dao, Mong, Giay...The population density is very low. Many villages are located directly on steep mountain slopes. It is very dangerous for avoiding the sudden landslide and sweeping, debris floods.

The main economy activities of the region are agriculture, forestry and tourism. The instruments for agriculture are very sudimentary.

The highway N^o 4B is striking from NE part to the SW part is the only one in the region. The local people always go on foot on trails from village to village...

In the research region there are several geological units as following:

- Quaternary sediments (Q) consist of alluvium-proluvium formations; pebble, gravel, sand, clay, soil and distribute along narrow valleys. The thickness of the sediments is about 1m - 5m.
- Lower and Middle Devonian formations (D₁₋₂) contain limestone, silicious limestone, clayish limestone with the thickness of about 750m-950m and distribute in the southern part of SaPa town.
- Lower Devonian (D₁) formations consist of clayish shale, sandstone, limestone with the thickness of 400 m and distribute in the southern part of SaPa town.
- Lower Cambrian (ϵ_1) formations consist of gravelite, shale, sandstone, conglomerate, phyllite, limestone, apatite with the thickness of about 225 m to 400 m and distribute in eastern part of Lao Cai town, northern and southern parts of SaPa town.
- Upper Proterozoic-Lower Cambrian (PR₃- ϵ_1) formations consist of marble, limestone, dolomite with the thickness of about 100 m to 1000 m and distribute in northern part of SaPa town, Sa Sen village, Nam Tong Chu village. The limestone and marble are strongly divided into small blocks. That is why there often occurred rock falls among these above-mentioned formations.
- Lower and Middle Proterozoic formations (PR₁₋₂) contain of granitogneiss, biotite amphibolite, two-mica schist, amphibole schist, biotite quartzite with the thickness of 1300 m – 1450 m and distribute in small place in Luong Do village.
- Lower Proterozoic formations (PR₁) consist of granitogneiss, amphibolite, biotite-amphibole gneiss, amphibole schist, biotite quartzite with the thickness of 300 m and distribute in a small place of North – western part of Lao Cai town.
- Paleogene magmatic complex (P) contain of granosyenite, biotite granite aplite, pegmatite and distribute in one rather large place of south-western part of SaPa town.
- Paleozoic magmatic complex (PZ) contain of tonalite, granodiorite, gneiss-shaped granite and widely distribute around SaPa town, Tong Sanh village, Trung Chai village, Giay Tre, Luong Do villages. In some places the rocks of this complex are strongly weathered (the weathering crust cover is over 5 m in thickness). The slope with this type of weathering crust is very potential for landslide happening.

This region is situated inside the Red River faulting zone (shear zone). The faulting neotectonics is very strong. The faults have two directions: NW - SE and NE-SW. The neotectonic activities are strong and multiphase. The geomorphology of the area is typical for high mountains of mainly slopes of various sloping values.

In this area there occurred many geohazards such as: landslide, rockfall, sweeping floods, debris floods, soil cracking and earthquakes, these geohazards caused by many endogenetic and exogenetic reasons.

Some geohazards occurred in recent years:

- Sweeping floods occurred in the years of 1996, 1998, 2000, 20001 in southern part of Lao Cai town. They caused serious damages both in materials and in human life.
- Landslides occurred in 1992, 1994, 1996, 1998, 2000, 2001 along highway N^o 4B and south part of SaPa. They caused big damages (20 billions of VND, 28 persons died).
- Soil cracking occurred in 2000 Tan Son village (small damage).

The reasons of above-mentioned geohazards are: slopes with high sloping value, thick weathering crust, active fault and human activities (deforestation, road making...).

Besides the above mentioned geohazards in the area there may be occur other geohazards such as: earthquake (may reach to 6 gr. of Richter), soil erosion, rock fall, rock rolling...

3. THE RESEARCH METHODS

3.1. Making digital imagery topographic base of the study region by Photomod software.

PHOTOMOD is one product of Russia for digital imagery processing of panchromatic remote sensing films and photographs that were taken with vertical and horizontal overlap (with stereo effect). The multi - spectral remote sensing data are digitally processed by DIDACTIM software (Product of France).

The imagery digital topographic base consists of: Imagery digital topographic map at the scale of 1: 25.000; Imagery digital topographic map at the scale of 1: 10.000; Digital terrain model; Stereo – topographic model.

These maps and models are established on the basic of: Topographic map at the scale of 1:50.000 in Gaussian and UTM projection; Government topographic control points (3 point of II level and 2 points of III level); Aerial films and photographs at the scale of 1: 35.000 (30 photos, taken in 1995, in 6 flight lines).

Making digital topographic base is carried out through following steps: Design photographic spatial triangle; Field measurement between photographic control points; Interpretation of aerial photographs; Imagery processing by Photomod software; Hardcopy printing of photographic map and making CD-ROM.

3.2. Making maps of typical relief characteristics.

Digital terrain model is processed by PAMAP-GIS (Canada), Microstation and Surfer softwares for making the following maps: Map of DEM, Map of SLOPE, Map of ASPECT, Map of horizontal relief cutting, Map of vertical relief cutting.

3.3. Image interpretation.

- Visual Interpretation of aerial photographs by stereo scope.
- Visual Interpretation of imagery digital models processed by PHOTOMOD.
- Interpretation of multispectral images by DIDACTIM software.

3.4. Using GIS technique.

GIS technique is applied for establishing final result maps of prognosis of landslide through PAMAP - GIS software

3.5. Field checking.

After final establishing the map of prognosis of landslide some field trips are carried out for checking the results of research. After field checking the established map is revised before transferring to users.

4. RESULTS OF RESEARCH

4.1. Maps of typical relief characteristics.

4.1.1. Map of DEM of Lao Cai - SaPa region at the scale of 1:25.000.

In the map there are 26 elevation levels divided by 100 m and 50 m intervals. They are from 0m-50m to 1800 m to 1900 m.

These levels are used for determining the prognosis areas of possible landslides.

4.1.2. Map of slope of Lao Cai - SaPa region at the scale of 1:25.000.

This map is established directly from DEM map. The slope values depend on changing of elevation values.

In the study region there are 10 slope levels divided by the intervals of 10 degrees and 5 degrees. They are from 0-5 degree to 80 - 90 degrees.

Each level is expressed in the map by one typical colour. Slope value is very important fact for prognosis of possible landslides areas.

4.1.3. The Aspect map of Lao Cai - Sa Pa region at the scale of 1:25.000.

This map is established from DEM map. There are in the study region 9 types of areas with different direction of slopes they are: Gentle area, Area with NW direction slope, Area with W direction slope, Area with SW direction slope, Area with S direction slope, Area with SE direction slope, Area with E direction slope, Area with NE direction slope, Area with N direction slope. Some types of areas have close relationship possible landslide areas.

4.1.4. Map of vertical (deep) relief cutting of Lao Cai - Sa Pa region at the scale of 1:25.000.

By processing 3 D vector data (lines, points) in PAMAP – GIS software the TXT type file is created. This file describes the height differences between the lowest and highest points per 1 km². Using surfer 6.03 software we can get isolines of values. The parameters of processing are: Calculation unit: m; Transfer window: 1000 m; Transfer step: 500 m; Maximum value: 500 m; Minimum value: 50 m; Medium value: 300m; Variance: 2; Standard deviation: 1.2.

There types (levels) of areas with different vertical cutting may be classified. They are: Area of I level: 150 - 250 m; Area of II level: 250 - 400 m; Area of III level: > 400 m. Each type of areas has different relationship with landslide possibility.

4.1.5. Map of horizontal relief cutting of Lao Cai - Sa Pa region at the scale of 1:25.000.

By processing through PAMAP - GIS 2 D vector data (river, streams, springs, and drainage network) determined by photomod software, one TXT type file is created. This file contains of information about total length of hydronet and drainage network per one km². Using SURFER 6.03 and Map Info softwares we can get isoline of values. The parameters of processing are: Calculation unit: km; Transfer window: 1 km²; Transfer step: 0.5 km; Maximum value: 0.0122; Minimum value: 7.73; Medium value: 3.13; Variance: 3.5; Standard deviation: 1.5. Four types (levels) of areas with different horizontal relief cutting may be classified. They are: Area of I level: < 3 km; Area of II level: 3 - 5 km; Area of III level: 5 - 6 km; Area of IV level: > 6 km. This map is very useful additional information for determining the possible areas of landslides.

4.2. Geomorphological map of Lao Cai - SaPa region at the scale of 1:25.000.

This map is established by the interpretation of aero-photographs using stereoscopes and by interpretation visually the relief digital models gained from the processing through photomod software directly on the computer monitor. In this map the following factors are expressed: The surface of alluvium - proluvium sediments; The surface of deluvium – proluvium; The surface of denudation – accumulation; The surface of evenness process; The surface of karst – erosion; The surface of denudation and washing out; The surface of combinational denudation; The surface of denudation - erosion. Besides the above - mentioned factors in the map the authors also express: tectonic faults, water dividing lines, proluvium cones, erosion drainage...The geomorphological factors are very useful and important information for making prognosis of landslides.

4.3. The map of zoning and prognosis of landslides of Lao Cai - SaPa region at the scale of 1:25.000.

The main principle of landslide zoning is the intergration of different factors or parameters that may cause landslides in general. These factors may be called as “landslide factors”. In our opinion, in the study region there several landslide factors. They are as following (in priority): Slope value; DEM value; Weathering crust; Soil cover; Petrographic composition (kind of bed - rocks); Tectonic faulting (active faults); Vegetation cover; Geomorphological factor; Structure and texture of bed – rocks; Rain fall factor; Man - made factor (road making, forest destroying...). By analyzing and integration of mentioned - above factors (parameters) the authors have divided the study region into areas with 5 different possibility levels for landslide hazard occurring as following: Areas of I level: very high landslide hazard possibility; Areas of II level: High landslide hazard possibility; Areas of III level: Medium landslide hazard possibility; Areas of IV level: Low landslide hazard possibility; Areas of V level: Non - landslide hazard possibility. Among these 5 levels the

two first ones are must be pay special attention because in the areas of these two levels the landslide hazard may be occurred at any time, especially in summer and autumn time of the year. These areas mainly concentrate along the highway N^o 4B, around Tan Son village and SaPa town. On the basic of landslide zoning and checking in the field the authors have established “The map of zoning and prognosis of landslides of Lao Cai - SaPa region at the scale of 1:25.000”. In this map besides the areas of 5 levels of landslide hazard possibility the authors also express some additional features such as: Position (location) of already occurred landslides in the past; tectonic faults; location of already occurred rock - falls; some geomorphological elements.

5. CONCLUSION

Lao Cai - Sa Pa region is potential for high landslide hazard occurring. The landslide occurs not only along the highway (automobile road) but also in faraway areas where there are not any man - made activities. The Landslide hazard in the study region has following main properties: They often occur in the areas of high values of slope and DEM; They occur in the areas where the weathering crust is rather thick (over 5 m); They often occur in the areas where the vegetation cover is strongly destroyed; They usually occur along tectonic faults; They often occur in high rain fall time (summer and autumn). The studied results may give useful contribution for the local administration for making urgent dicissions for reducing the damages caused by landslides every year in this region.

6. REFERENCES

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