VNU Journal of Science, Earth Sciences 27 (2011) 219-228

Using remote sensing and geographical information system to establish the landslide sensitivity map for Son La city area

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Received 1 October 2011; received in revised form 2 November 2011

Abstract. Son La city is a social-economical centre of Son La province. It is located in the north-west high mountainous area of Viet Nam, where the majority of people is ethnic minority. This area plays an important role for development of the Son La province in particularly and also for all the north west mountainous region.

During development from a town to a city, recently, Son La has planned for quickly increasing and modernization of its infrastructure such as traffic system, public construction, new building… Those works have seriously interfered to the ancient balance of slope. Beside of natural effecting as earthquarke, slope gravity, rainfall…, constructional process has a strongly impact to break the natural balance, to appear the hidden gravitational hazard and increase landslide hazards.

By using remote sensing technique with SPOT image of scale 1:50.000 and ENVI 4.3, ARCGIS 9.1 softwares, the study try to evaluate and estimate the landslide in relations with different physical elements such as geology, geomorphology, geo-engineering, tectonics, seismology, hydrology, hydrogeology, etc. Result of the study presents a sensitivity map for landslide and different scenarios for landslide risk. These products has been used as scientific references for local government in environmental protection planning

Keywords: Landslide, parameters, easement, remote sensing and GIS, integration, scenario.

1. General introduction about natural conditions and landslide in the study area

With the area of 32.505 square hares, Son La city is a complex hilly-valley landform with various lithological formations. Due to developmental process of differentially tectonic movements, geological structure of the area is partitioned complicatedly.

The various of geological creates the various of topographical forms, weathering cover, soil type, vegetable cover, surface water, ground water, and also in geology-engineering conditions. The natural characteristic of Son La city that has existed presently is the result of active, secular changing process to gain the balance temporarily. Whenever the nature balance is broken, it will move to a new balance and that process usually generates the natural hazards. From 1979, especially during the stages from 1984 to 1989 up to now, Son La is quickly developed by a new planning with expanded city, modernize infrastructures, new traffic systems, new housing and public

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constructions. These processes are impacting to the environment and make effectively to break the natural balance. The hidden gravitational landslide and opened landslide process usually appears in rainfall season, especially in strongly flooding rain period since June to October annually. In and after historically flooding rain on June 27, 1991, the landslide occurred seriously, especially in eastern and northern part of Khau Ca - Khi Tuong hill - a central hill of the city, where number of governmental and historical buildings located. The landslides also occur in other places of the city. Contractly with landslide, the surface depression phenomena cause ground split, break the man made constructions for welfare of the people as houses, school.... in dry season only.

The gravitational landslide process has strongly effected to constructional sites. It situation bring requests to employ the basic study activities to reduce and manage the landslide. To solve these problems, since1991 several projects have been conducted to find out the impact of hazard and cause of the gravitational landslide in the Son La tow area.

2. Conception and methodology of the study

♦ Conception

Study "*Using Remote sensing and geographical informative system for studying and predicting of landslide in Son La city*" has been conducted base on the scientific conception as follow:

The normal landslide is shown on many differential layers that are characterized by differential landslide levels. The same regions are listed, divided in the same property, in the same hazard level. The landslides show the massive movement to occur apparently along slice surface and it belong to some massive movement type as: ground landslide, escarpment landslide, broken escarpment, rolling and collapsed rock. Related factors to landslide can be directly recognized by measuring difference forces under geo-engineering concept, but it can be indirect studied under the geo-geographical conception by accessing the relationship between landslide and several related factors: both geological factors and geographical factors such as rock type, rock sloping, fault, breaking, land cover, weathered cover, soil type and soil thickness, slope of landform, ground water table... The scientific research focuses on scope of indirect assessment by using spatial modeling of GIS technology. Result of the study is the hazards have been assessed relatively into quantity or semi quantity as: low, average and high hazard etc…with ranking from level 1 to 5 or from 1 to 10.

Conception of the study can be explained as below:

- Natural hazard - H: Occurred frequency of potentially hidden deformation in a long time

and in the area. The natural hazard level is a cumulative level of vulnerability levels.

- Vulnerability - V: the level loss of an element or series of elements occur in damaged places the level of damage can range in scale from 0 to 1 (0- without loss and 1 is maximum loss).

- Specific risk - RS: Loss level of special phenomenon that show is the product of H and V, it can be mapped (existing landslide map).

- Element at risk - RT: is calculated as residences, properties, economic activities, public sites etc, based on the damage site.

It is the rule that if the hidden hazards estimated, solutions can be planted to manage and to reduce the dangerous hazards in future.

♦ **Methodology for study**

From satellite images combine with limited field checks, data base of landslide positions was constructed and natural factors which related to hazard can be extracted and mapped. Detail of maps depend on the characteristic of each type of image.

+ With field checking, and interpretation on SPOT 4 image ,the landslide situation in Son La city is mapped on scale 1: 50.000.

+ Information of weathering crust, soil, water, vegetable, geology, topography, hydrogeology, etc. and other tectonic elements are extracted by integrated process between visual interpretation and digital processing, mapped on scale 1: 50.000.

+ The preference, field test of landslide location has been deployed in March 2000 - 2007.

+ The referenced documents includes: geology, geomorphology, geology-engineering, tectonics, seismology, hydrology, exploration drill, hydrogeology.etc... Those data has been conducted by several several previous research.

The landslide is formed and occurred in several relations with different naturally elements [1,2]. With multi-criteria analysis method (MCA) in GIS technique, the natural relation between landslide and related factors of natural condition can be processed and mapped. The software used includes: ARC/GIS, ILWIS, SUFFER, EXCEL, MAPINFO [3].

3. Mapping out the hazards and analyzing related factors

3.1. Characteristics of landslide situation in Son La city

♦ **Landslide situation in Son La city area**

The slide traces have been recognized on the images and can be divided into difference types as follow (figure 1).

+ The newly slide massive area occurred along sloped surface: it has just occurred with length from 10 meters to 100 meters and areas are larger than $30m^2$. In the image, it's appeared with light tone traces or points that located sparsely and occurred the slope surface or escarpment foot. Although, we need to distinguish it with the bare soil on the top or at the foot that caused by shifting cultivation. The bare grounds that usually exist in special locations with typical structure of shifting cultivated habitant. The dry rice fields on the mountains and the slide traces of landslide are difficulty to differentiate, so it is needed to confirm by the field checking.

+ The falling slide traces in steep slope of the karst stone. The falling that usually appears in the limestone mountains along faults zone with very steep slope.

+ The slide arcs: They are located in long belts along the escarpment foot. The escarpment is about 25^0 - 35^0. The arcs compose of the newly integrated slide traces mixed with the old or the arc cracks that show flux slide traces. The arc that forms due to the differential causes, basically due to water table of the surface layers to rise up during raining. The arcs are easily discovered by the accumulative topography and escarpment foot accumulative.

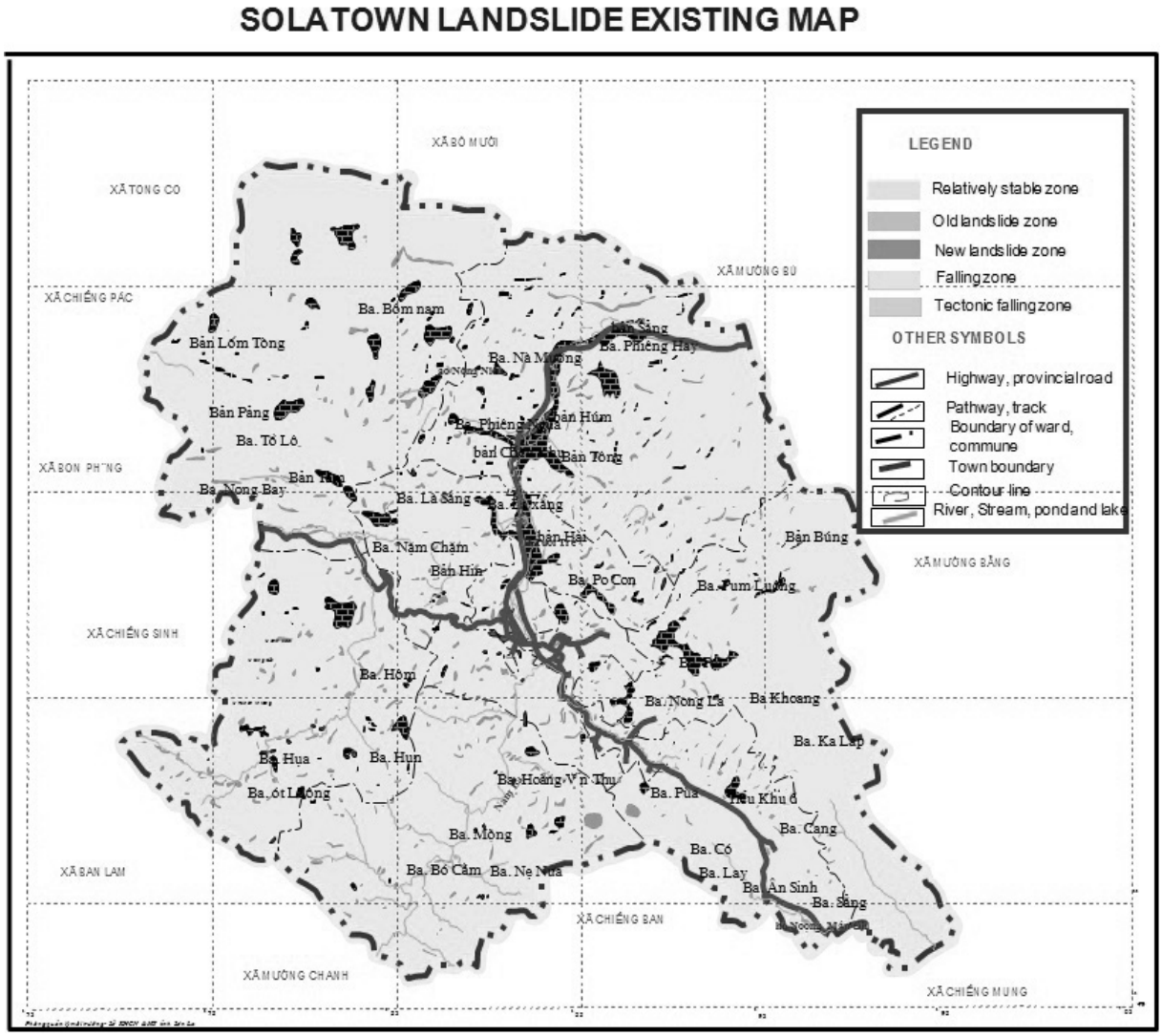

Fig. 1. Existing landslide map of the Central Son La City.

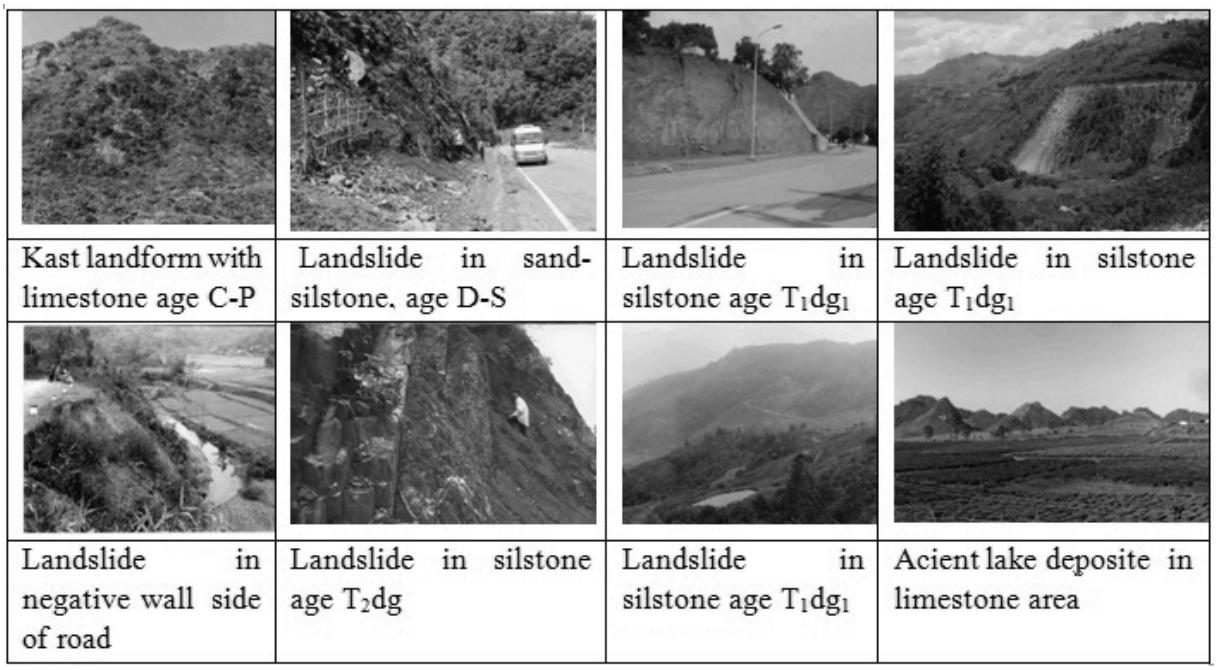

Fig. 2. Landslide in different type of landform and lithological condition.

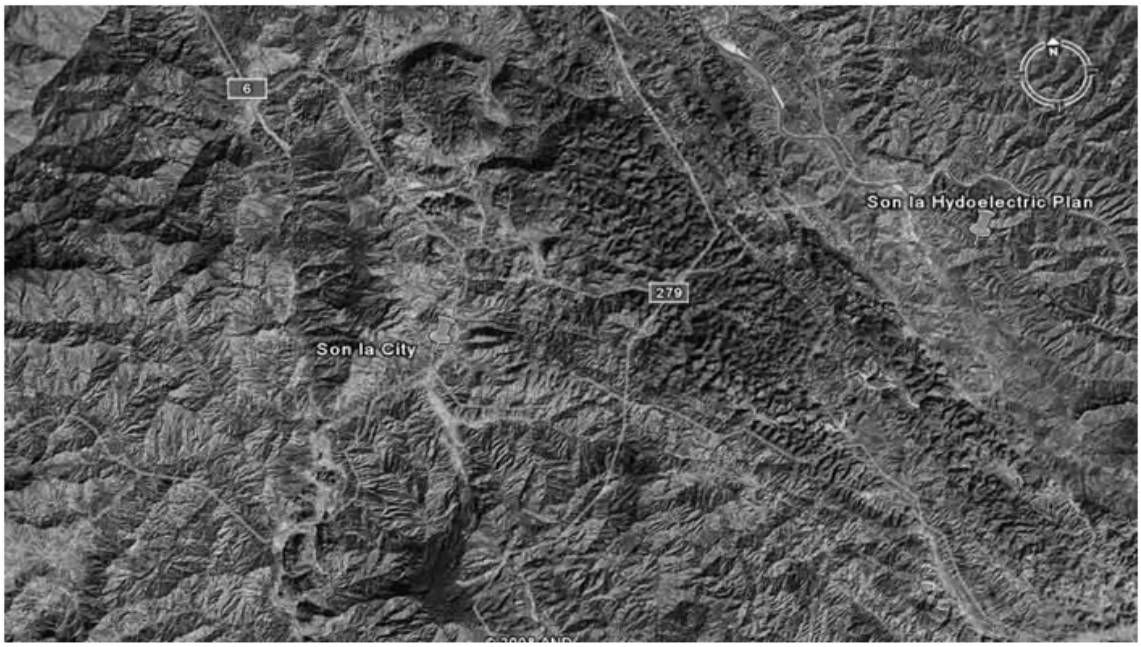

Fig. 3. Landsat satellite Image of Son la city, clearly to difference Limestone and others rocks.

3.2. Causes of the landslide

In Son La, the landslide occurred due to the slope load is caused by nature and artificial activities with three important types such as [4]:

1) Infrastructural constructions locate on the sloped sites, both at the foot and at the slope surface.

2) Water is increasingly percolated through the weathering crust. The landslide process that can be occurred slowly related closely to the highly water table level zone

3) Weathered material is thickly accumulated on the top hills and on slope surface.

These phenomena are signatures for assessment the relationship between landslide and natural factors.

4. Estimating landslide hazard by GIS processing

The relative informative layers such as geology, geomorphology, slope, weathering crust, land use and vegetation cover etc ..are processed and classified with landslide relation

It is discovered that almost the landslide slide are result of techtonical movement in .the past or in present. During GIS processing, some extracted layer also created such as lineament density, buffer of faults…

Result of the processing is a predicted map showing locations where landslide can be happened with highly probability.

Main research steps can be descripted as follow [3]:

a) The landslide parameters are evaluated correctly by aerial images and tested by field survey.

b) Mapping of landslide , analyzing , classification landslide types base on its structure, characteristic, occurred situation ...

c) Analyzing direct quantities or indirect quantities of the number of geological, geomorphological information etc.., that relates closely to the landslide.

d) Analyzing by statistics method : From the analyzing of statistic data base on crossing maps between existing landslide map, the weighted value can be calculated separately which showing the relationship between each factor to landslide.

e) Collect the relative parameters as earthquake or rainfall and process it into data base layers

f) With integrated function named multilayer overlay technology in GIS, all layers and their weigh are processed for bring out the prediction landslide map. With difference level of assessment, the result map can be various such as various scenario.

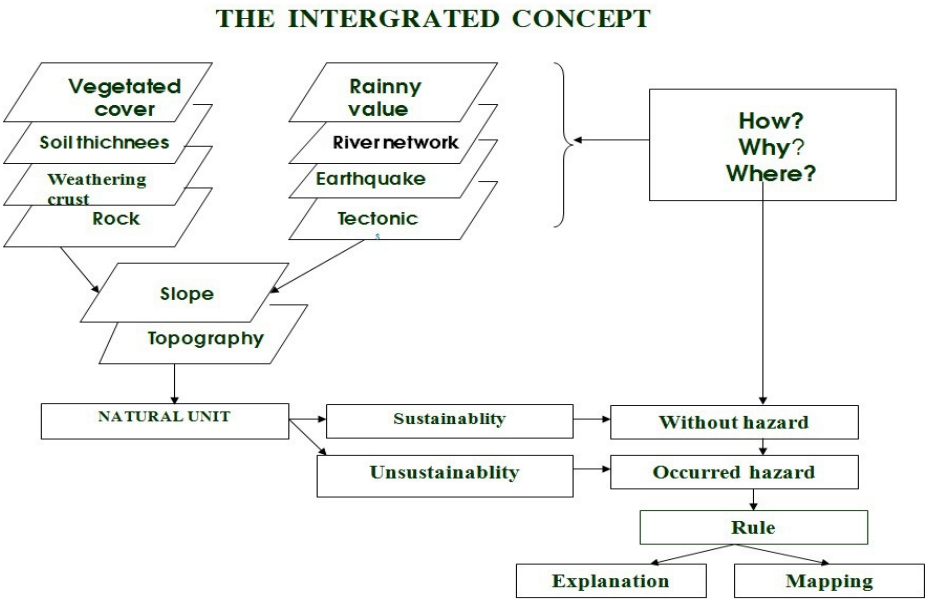

Fig. 4. The chart for studied conception.

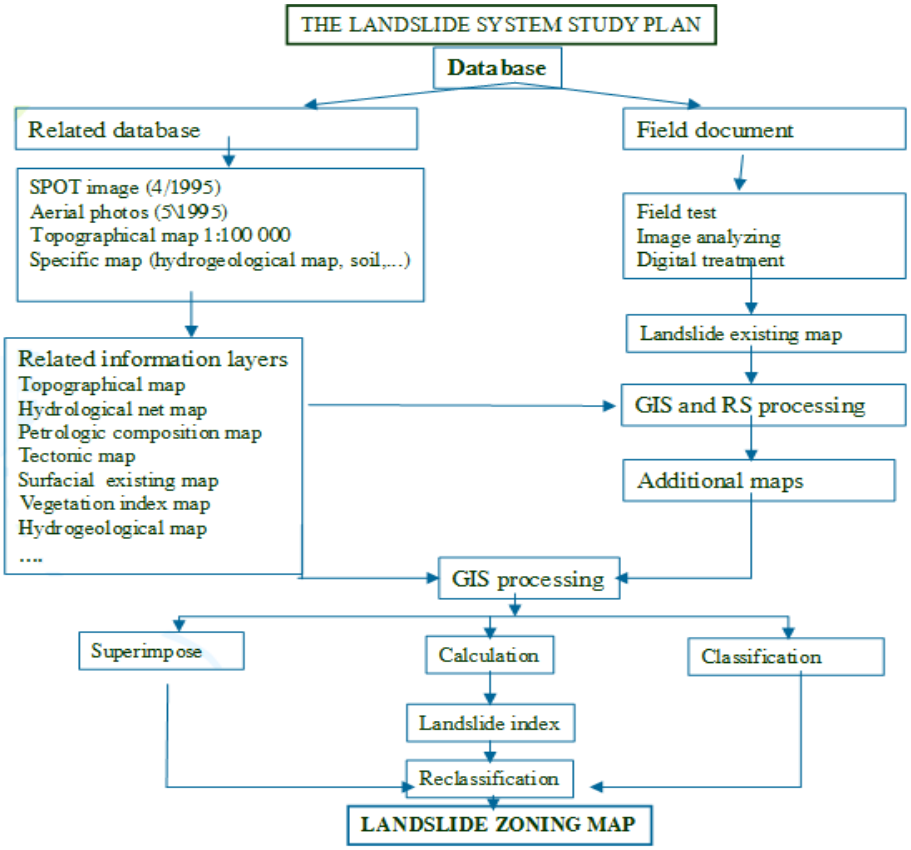

Fig. 5. Flowchart of studying.

♦ **Image processing**

With the FCC of SPOT images, landslide areas can be clearly determined and filter techniques are applied to show all fault directions. A part from filtering techniques, the land use and vegetated covers are easily recognized by vegetation index and by supervised classification.

♦ **Weighting the correlation between relative factors to landslide by GIS**

Weighting is the most important work to map out the estimated areas of landslide. The work is developed in steps as following:

- Counting statistically the units of modern landslide maps.

- Crossing the modern landslide maps with naturally compositional maps such as: geomorphology, vegetation cover, hydrological net, fault etc. From the crossed maps the relationship between related factors to landslide to be distinguished.

- Numerable importance that is calculated as the relationship to the landslide as following formula [5]:

$K = (Si / \Sigma Sn)$ %

Where:

Si: Area of hazard type (i)
Sn: Area of layer unit (n)
K: Weigh value of each unit

The numerable important level is calculated to figure out:

Probability level 1,2,3,4,5 with K range as : k >= 20 %.15%.10%.5%.- k = 1%.

By CROSSING method (cross mapping), these weighs are calculated and the relation of naturally elemental layers is analyzed by gravitational hazard via the numerable important values as below description.

- **The relationship of lithological to landslide relation.**

Based on studying and statistic calculation, the relation of lithological units with land slide hazard is found as follow.

- The collapse phenomena: They are only found in massive limestone area at the age of T_2dg_1, C - P limestone, continental sediments age T_2 dg_2.

- The underground karstic subsidence phenomena often occurs in limestone sedimentary areas at the age of T_2 dg_2, T_2dg_1. Apart from, the underground subsidence is found in limestone at the age of C - P.

The landslide phenomena: normally occurs in the non-carbonate sedimentary rocks age of T_2 lnt, T_1, lava sediment age P_2. Apart from, the landslides are discovered in the metamorphic rocks at age of C_2sm, C_3 and D_2mt [1,2].

- The relationship of weathering crust.

The landslide phenomena that occur strong in the thick weathering layers and reducing in the thin weathering layers. The thick weathering layers are formed normally in non-carbonate rocks.

The subsidence phenomena occur in the thick weathering layers but bedrock is limestone and alluvial sediment at the old lakes.

- **The relationship of fault density**

Apart from the main faults run in Northwestern - Southeastern direction in study area that contains lineament system, faults to run in NE-SW, SN direction to form the thick lineament system to control geomorphological and structural elements and underground karstic system such as (inlet system of Ban Lau, Chieng Te commune, Bun Hum of Chieng Xom commune, etc.). In general calculation, the fault density that is divided into several levels as: 1,

2, 3, 4, 5 with value range as: >=0.6 km/km^2. 0.5 to 0.6-0.4 to 0.5-0.3 to 0.4 and 0.2 to 0.3 km/km^2.

In general, the rule that is where having high lineament dense is easy to cause the large number of landslide.

- **The relationship of road system.**

According to the general rule, when the road that is opened, it changes slope surface, is easily causing landslide. Along the road, landslide always occurred, but it is only seriously happened at positions taluso... where the rock dip slope are the same direction of road slope talus. In other place along the road talus, landslide occur rarely.

- The relationship of hydrological networks

In this area, where the hydrological network of high density in non carbonate rock region, special in the first or second order of river or stream, landslide are highly concurrent. In the limestone regions, the rule is difference because hydrological network is hidden.

- The relationship of slope:

According to the general rule, the landslide phenomena increase with the increasing of slope. In opposite, underground subsidence appears only at the gentle slope areas. In the field, where topographical slope ranging from 30^0-45^0 is easy to appear landslide.

- The relationship of vegetation cover

From crossing map between the land cover map and landslide map, areas of high probability of landslide are taken place at some type of land cover such as: grass land, bushes, new plantation, bare land. Where the thick vegetated cover is affected actively for reducing collapse phenomena. Whereas, good covered of wooden or bamboo plant in limestone mountains will reduce the collapse process.

♦ **Calculate and mapping of the landslide sensitivity map - the estimated maps**

Mapping with the areas that have high probability of hazard are the highly important. The map was calculated from the below equation:

$$E = 1/n (\alpha A + \delta B + \gamma C...)$$

Where:

E: The high probability hazard map - output layer with maximum value of probability to landslide

1.....n: information n^0 (from 1-n)

α, δ, γ...: weighted values of separated layer

A, B, C…: layers of separated factors.

In the map, there are hazard types was divided as: collapse, underground subsidence and landslide in range from 1-5 level. Every type has 2 levels of high and average probability (level 5 and 4 in the considered levels). Particularly, the zones that cause the collapse highly and normally are the carbonate areas and differ from this particular point to the other. Fault density, slope and a vegetated cover is the same, the landslide relates closely to the fault system. In another word, the landslide is a function of slope, thick weathering layer, high fault density, and vegetated cover.

Table 1. The hazard area with highest probability according to the scenario

Type of hazard	NPix	Area (m^2)	Area (ha)
High collapse	7254	4533750,2	453.37502
High falling	7446	4653750,2	465.37502
High landslide	6849	4280625,2	428.06252
Stable area	480501	300313138	30031.3138

According to the estimated maps, three areas with high probability of gravitational falling slide types shown in the city are:

♦ High probability to sloped landslide hazard area:

It concentrates in W and SW part, South part of Hua La, Chieng Co commune, the city centre.

♦ The high probability to subsidence hazard area: that is distributed in Chieng Co, Chieng Sinh commune, Quyet Thang ward along NW-SE lines.

♦ The high probability to falling landslide hazard: distribute at composes of Chieng Xom, Chieng Den, Chieng Ngan, and Chieng An communes.

5. Conclusions

❖ Application of the results of study

1) To establish the database of environment and mineral resources, not only for the gravitational landslide hazard study but also for many goals of territory management and environment.

2) The objective information of quantitative and qualitative is shown in the estimated map. It will be the most effective information to protect and to manage environment.

3) The results of the study shown up a orientation for planning activities and manage environment in Son La city such as: making constructions for protecting landslide, moving houses of people to new safety place, plan for special types of plantation etc..

❖ Advanced of the methodology

By using remote sensing and GIS techniques, landslide can be mapped and the relationship between landslides also can be assessed. For prediction of landslide, weighted values and rating for map units are very importance values, these parameters can be directly calculated by spatial analysis tool in GIS.

Comparison with the geo-engineering methods, the remote sensing and GIS method is an advanced tool for quickly and early apply for assessment of landslide hazard in mountainous area, where the traditional method can be applied when needed for preventing of landslide.

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