INVESTIGATION AND EVALUATION OF LANDSLIDES IN TRA BONG AND VE RIVER BASINS, QUANG NGAI PROVINCE

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ABSTRACT

At the end of 1999, the provinces of Central Vietnam, including Quang Ngai, suffered catastrophic losses caused by heavy rains and floods. In Quang Ngai province alone, the floods killed more than 100 people. The value of the properties and infrastructures destroyed reached VND 212 billion. The floods also caused adverse impacts on the environment, such as topographic changes, landslides in the mountain areas, mud flows, slope collapse, river sedimentation, etc.

By using satellite images taken before and after the floods with the help of remote sensing image interpretation software programs and GIS, the authors have compiled the following maps for the three main study areas of Quang Ngai province:

1- Lineament maps
2- Lineament density zonation maps
3- Slope angle zonation maps
4- Topographic elevation zonation maps
5- Topographic dissection depth zonation map
6- Water course change map

By analyzing and synthesizing the above mentioned maps, with field data and other supporting data (on geomorphology, geology, structure, etc.) the authors provided an evaluation of the landslides in important sites, changes of the shore lines of two rivers investigated, and proposed measures for preventing and mitigating damages caused by landslides.

1 . INTRODUCTION

In November and December 1999 the central provinces of Vietnam including Quang Ngai suffered catastrophic damages due to natural calamities. The continuous rainstorm taking place within an extensive area, combined with steep slope and other geologic characteristics, entailed unprecedented flash flood and inundation in Quang Ngai province: 101 people died, 3 people disappeared, 255 people were wounded, 1,902 houses were knocked down completely or swept away, 59 classrooms were destroyed. This flood also caused very heavy losses to agriculture, infrastructures, etc. The estimated loss was up to 212,194 million VND[1] (equivalent to 14.2 million USD). The more worthy of concern were the environmental damages and deterioration after the flood. With the above briefly cited data, investigation and evaluation of environment in general and landslides in particular in the river basins of the province (the Tra Bong and Ve river basins) were very urgent [1].

2. OUTLINE OF THE STATUS OF THE STUDY AREA AND THA BASIC DATA

The study area covers about 3,140 km^2 out of the total 5,938.6 km^2 of the province.

2.1 Tra Bong river

59 km long, has basin area of 697 km^2. Its basin has an average width of 12.4 km, with an average elevation of 196 m, an average slope of 10.5 %. The drainage density is 0.43 lm/km^2, the water divide development coefficient is 1.29, the asymmetry coefficient is 0.08, the river network imbalance coefficient is 1.20, the shape coefficient is 0.22 and the meandering coefficient is 1.37.

2.2 Ve river

70 m long, has a basin area of 1,260 km^2. Its basin has an average elevation of 170 m, its slope is up to 19.9 %, its drainage density is 0.79 km/km^2, and its meandering coefficient is 1.30.

The basin characteristics of these rivers can be seen in their mountainous and plain reaches.

Within the area of the river basins are met practically all rock formations from sedimentary, metamorphic to igneous, both intrusive and volcanic, with ages from Pre-Cambrian to Quaternary.

These rivers were formed as a results of long and complicated geologic processes. They were probably formed very early and basically they coincide with (follow) the existing faults. However, in Neogene, volcanic activities made changes to their flow directions.

2.3 Basic data

Gauss system topographic maps at 1: 200,000, 1: 100,000 and 1: 50,000 scales.

Remote sensing data, comprising US Landsat-TM, Japanese ASTER WIR images, in combination with air photos taken in the 1965 - 1966 and 1998 - 2000 periods.

3. INVESTIGATION METHODS

In this paper, we refer mainly to the remote sensing and GIS methods, in combination with traditional approaches, in particular:

1. Visual interpretation and analysis of remote sensing data with the use of optical instruments
2. Interpretation and analysis of remote sensing data with the use of digital image interpretation software programs, in particular French DIDACTIM 4.0 (1993).
3. Statistical processing of lineaments with the use of Microstation software.
4. Processing of topographic data with the use of GIS-RS software programs such as Canadian PAMAP-GIS 4.2, Australian ER_MAPPER 6.0. Editing maps with the use of MapInfo.
5. Field check and ground truth survey
   a) Survey of geological and hydrological sections at the site of strong landslides along the two rivers
   b) Collection of soil samples and carrying out laboratory tests for physico-mechanical properties and grain size distribution of soil samples at the river reaches with strong landslides.

c) Carrying out permeability tests at the sites of strong landslides along both sides of the rivers.
d) Interviewing the local people about the process of river channel changes, landslides, damages that have occurred, etc.

4. RESULTS OF INVESTIGATION

4.1 Compilation of 15 maps:

4.1.1 *Lineament map of mountainous area of Quang Ngai province*

With the size of lineaments varying from 0.5 to 35 - 40 km, well developed and relatively evenly distributed. By their trend directions, the lineaments are divided into 4 groups as follows:

- NW-SE trending lineaments: accounting for 45 %, related with small local tectonic faults; some in the West are related with large extent faults.
- NE-SW trending lineaments, accounting for near 40 %, mostly related with small local faults; some in the East are related with larger faults
- Longitudinal and sub-longitudinal trending lineaments, accounting for about 10 %.
- Latitudinal and sub-latitudinal trending lineaments, accounting for about 5 %

4.1.2 *Lineament map of the plain area along the Tra Bong river.*

Here lineaments are poorly developed, with uneven distribution.. By their trend directions, the lineaments are divided into 4 groups, as follows:

- NE-SW trending lineaments, accounting for near 45 %, mostly large faults (along the Tra Bong river)
- Longitudinal and sub-longitudinal trending lineaments, accounting for 35 %.
- NW-SE trending lineaments: accounting for 15 %
- Latitudinal and sub-latitudinal trending lineaments, accounting for about 5 %

4.1.3 *Lineament map of the plain area along the Ve river.*

Here lineaments are developed at medium degree, with uneven distribution. By their trend directions, the lineaments are divided into 4 groups as follows:

- NE-SW trending lineaments, accounting for near 40%, mostly large faults (along the Ve river)
- Longitudinal and sub-longitudinal trending lineaments, accounting for nearly 30%.
- Latitudinal and sub-latitudinal trending lineaments, accounting for nearly 20%
- NW-SE trending lineaments: accounting for 10%

4.1.4 *Lineament distribution density map of mountainous area of Quang Ngai province.*

The units and parameters of the lineament density map are :

- Unit : km/km^2
- Cell area: 1km^2
- Grid spacing: 1 km
- Min value: 0.0032
- Max value: 3.2
- Mean value: 1.2
- Square error : 0.47
- Standard deviation: 0.69

On the map, 4 types of area with different lineament density levels are differentiated:

- Type 1: background area: the density value is less than 2 km/km^2.
- Type 2: grade I anomaly area: the density value is 2.0 - 2.5 km/ km^2.
- Type 3: grade II anomaly area: the density value is 2.5 - 3.0 km/ km^2.
- Type 4: grade III anomaly area: the density value is > 3 km/ km^2.

The areas with high lineament density (level 3 and 4) are usually related with tectonic faulting activities (brittle deformation).

4.1.5 *Lineament density map of the plain area of the Tra Bong river basin*

In general the lineaments in this area are unevenly distributed. In the North (at the Tra Bong river mouth), lineaments are very sparse. In the South-Southwestern part they are of high distribution density.

This area also is subdivided into 4 types with ranges of lineament density as for the above area, of which type 1 has the predominant (largest) area.

4.1.6 *Lineament density map of the plain area of the Ve river basin*

Here also 4 types of area are differentiated with ranges of lineament density as in the two above maps. Type 1 is predominant, while type 4 has very limited distribution.

4.1.7 *Topographic slope zoning map of mountainous area of Quang Ngai province.*

The topographic slope is expressed in degrees. The zoning is made automatically with the use of ERMAPPER 6.0 and PAMAP - GIS 4.2 software programs, with cell area of 1 km^2 and grid spacing of 1 km. The slope value of a cell is taken as an average. The distance between the highest and lowest contour lines is divided into 10 levels.

4.1.8 *Topographic slope zoning map of the plain area of the Tra Bong river basin*.

The slopes in this area are divided into 6 levels, with intervals of 5 degrees.

In general, the slopes in this area are re relatively uniform, with low differentiation.

4.1.9 To*pographic slope zoning map of the plain area of the Ve river basin.*

The slopes in this area are divided into 8 levels, with intervals of 5 degrees

4.1.10 *Topographic elevation zoning map of mountainous area of Quang Ngai province.*

The elevation in this area is divided into 16 levels with intervals of 20 m, from level 1 with elevation of 0 - 20 m to level 16 with elevation > 1,600 m.

4.1.11 *Topographic elevation zoning map of the plain area of the Tra Bong river basin.*

The elevation in this area is divided into 6 levels,

Levels from 1 to 5 have intervals of 20 m, while level 6 in particular has an elevation 100 - 200 m. Level 1 occupies most of the area, while the remaining levels have very limited distribution.

4.1.12 *Topographic elevation zoning map of the plain area of the Ve river basin.*

The elevation in this area is divided into 11 levels,

Levels from 1 to 5 have intervals of 20 m, while the remaining levels have intervals of 100 m. Level 1 (0 - 20 m) occupies most of the study area. Level 6 (100 - 200 m) and the remaining levels have very limited distribution, mainly in the West and SW of the study area

4.1.13 *Topographic dissection depth zoning map of the mountainous area of Quang Ngai province.*

For the study, the authors selected the nodal cell of 0.25 km^2 and the grid spacing of 250 m.

According to the depth of dissection, 4 levels of dissection depth are differentiated, with dissection depth intervals of 100 m.

+ Level 1 with dissection depth < 200 m is the background level, occupying most of the study area.
+ Level 2 (200 - 300 m) is the grade I anomaly level, is concentrated in the North, South, West and central part of the study area.
+ Level 3 (300 - 400 m) is the grade II anomaly level
+ Level 4 (> 400 m) is the grade III anomaly level

Levels 3 and 4 are of very limited distribution.

4.1.14 *Topographic dissection depth zoning map of the plain area of the Tra Bong river basin.*

Four dissection depth levels are differentiated.

+ Level 1 (with dissection depth < 10 m) is the background level, with dissection depth values relatively uniform, occupying the most of the study area.
+ Level 2 (10 - 30 m) is the grade I anomaly level, is of wide distribution area.
+ Level 3 (30 - 70 m) is the grade II anomaly level
+ Level 4 (> 70 m) is the grade III anomaly level

Levels 3 and 4 are of very limited distribution at the Eastern and SW margin of the study area.

4.1.15*Topographic dissection depth zoning map of the plain area of the Ve river basin*

Consisting of 4 dissection depth levels similar to the map No 14.

4.1.1*6 Map of river channel changes*

In general the shorelines of the Tra Bong river and its tributaries have experience some small changes after the 1999 flood. However, the river channel network of Tra Bong river in 1998 -- 2000 in comparison with the years 1965 - 1966 has clear changes in some places. The confluence between the Lap Da and the Thai Lan rivers have been clearly narrowed, the river channel there has been deepened. The erosion has become stronger, therefore more material has been transported and accumulated in the flood plains in the middle of the river channel, along the river banks, and further in the Dung Quat bay, making the sea coast here advance Northward for 100 - 200 m. A branch of the Tra Bong river, which is the Bi river, flowing from Loc stream in Binh Hiep through Binh Long, Binh Thoi has been narrowed and become much more depleted in comparison with the period 1956 - 1966. With time, the Ve river has much changed, especially in the river mouth area. In 1965 the river mouth was nearly completely filled with sediments. by 1982 the mouth of the Ve river had moved about 200 m from the position in 1965. By 1988 it had been moved Northwards 180 km from its position in 1965. By 2000 the coast line over a length of near 2 km at the river mouth had been eroded and moved inland by 200 m from its position in 1965.

4.2 Evaluation of landslide potential

Landslides on the rive bank at a location is the integrated result of many factors. These factors are arranged in order of importance as follows:

- Direction and speed of flow (flow dynamics)
- Composition and physico-mechanical properties of the rocks and soil and weathered crust along the two sides of the river.
- Slope and relative height of the river bank
- Tectonic activities
- Geological and hydrogeological characteristics
- Distribution characteristics of population and public utilities, economic activities of the community.

From the results of study and by giving points (as per the parameters: flow direction, bank height, bank slope, lithologic composition, population distribution and lineaments) a landslide potential zoning map of the two river basins studied has been compiled. Four levels of landslide potential are differentiated: Level 1: high landslide potential, with 15 points; Level 2: medium landslide potential, with 10 - 15 points; level 3: low landslide potential, with 6 - 10 points; level 4: stable, with < 6 points. In Tra Bong river basin there are 12 areas with high landslide potential and 6 areas of medium landslide potential. In the Ve river basin there are 9 and 13 areas respectively.

5. MEASURES FOR PREVENTION AND MITIGATION

5.1 Principles

1. Prediction of landslides and sedimentation (long term forecast, compilation of prediction maps)
2. Active mitigation of landslide

5.2 Landslide mitigation measures

1. Regulation of flow by two methods:
   - Strengthening the vegetation cover in the upstream area
   - Construction of dams in the upstream
2. Regulating the flow direction by two methods:
   - Construction of jetties
   - Changing the river channel
3. Reinforcing the river bank to increase its bearing capacity and reducing the direct impacts of the water on the bank, by two methods:
   - Construction of embankment along the river banks
   - Setting trees (bamboo) along the river banks
4. Planning the population settlement appropriately
5. Organizing regular monitoring and warning
6. Developing methods for taking prompt actions against landslides and mitigation of damages when incidents occur.
7. Strengthening the education and enhancing the awareness of the community.
8. Close cooperation between different sectors at various levels.

6. CONCLUSION AND RECOMMENDATION

Landslides occur not only in the concave river reaches, but also in relatively straight river reaches. As the slope of the river bed is small, therefore the longitudinal profile of the river is in equilibrium state, and also for this reason the main river bank erosion is due to the action of the surface and subsurface flow along the river banks.

First of all due attention should be paid on the landslide zoning map compiled. It is necessary to build a rain gauge station for each 100 - 150 km^2 and a meteorological station for each 200 - 250 km^2. Also, some landslide monitoring station should be established along the downstream reaches of the rivers.

7. REFERENCES

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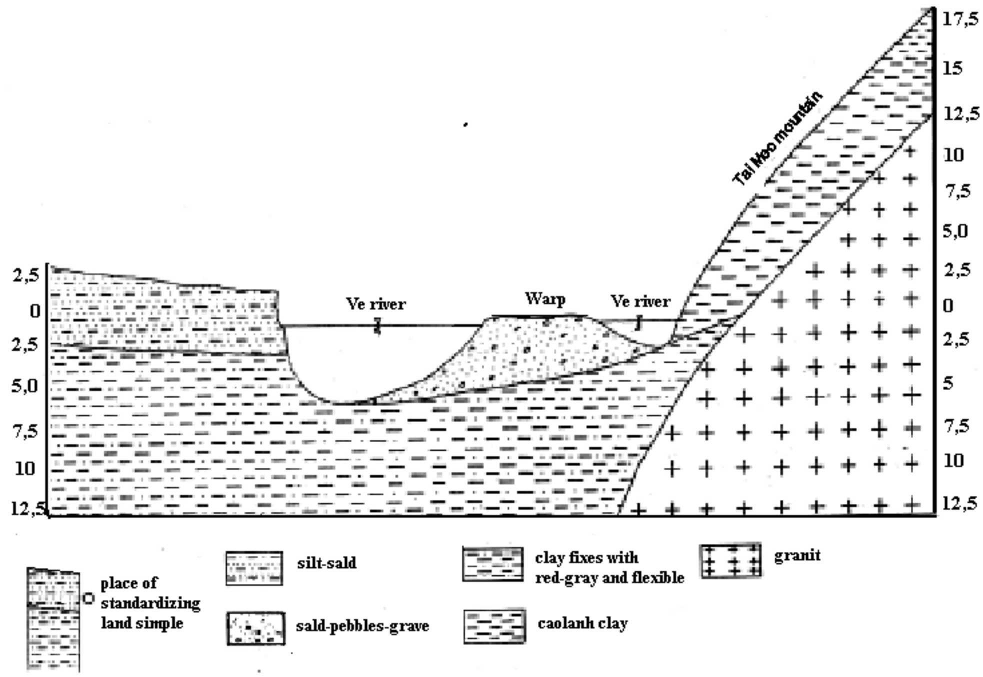
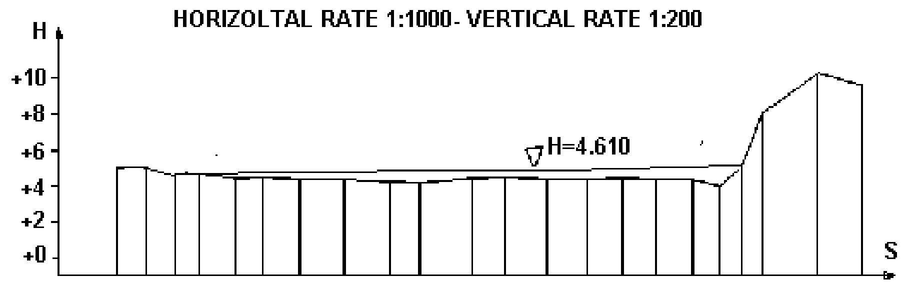


Fig 1. Cross section of the Ve river chanel



Height H(m)	4.94	5.07	4.67	4.61	4.35	4.33	4.25	4.14	4.03	3.98	4.16	4.17	4.05	4.03	4.00	3.99	3.95	3.54	4.61	7.60	9.75	9.06
Differental distance		8.00	8.00	6.00	10.00	7.00	10.00	12.00	12.00	8.00	14.00	9.00	11.00	11.00	9.00	9.00	10.00	7.00	6.00	6.00	15.00	12.00
Total of intergrated distances	(-) 0.00	8.00	16.00	22.00	32.00	39.00	49.00	61.00	73.00	81.00	95.00	104.00	115.00	126.00	135.00	144.00	154.00	161.00	167.00	173.00	188.00	200.00 (+)

Fig 2. Cross section of Ve river chanel