GEOINFORMATICS FOR FLOOD SCENARIO RECONSTRUCTION: A CASE STUDY IN UPPER LO RIVER, HA GIANG PROVINCE, VIETNAM

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Abstract: *Geoinformatics approach have been applied very effectively reconstructing 1970 flood scenario in upper Lo River of Hai Giang Province in Vietnam . The authors have applied these methods (GIS, remote sensing, GPS, information technology and field investigations) and the fuzzy expert method, fuzzy logics, model of HES-RAS for assessing the impact of flood disaster. Study results have helped in generating a number of maps with different flood scenarios simulations and the results are confirmed to be consistent with the greatest flood in 1970.*

I. INTRODUCTION

A Flood is a hazard that can occur in many countries in the world. In Vietnam, especially in the Ha Giang Province, flood occurs annually. We used combination methods with Geoinformatics as the main method to assess flood disaster in the basin of the upstream of the Lo River, in the Ha Giang Province.

Ha Giang is a mountainous province situated in the extreme north and northeast of Vietnam. Surface topography of this area is very complex, which can be divided into 3 types: 1) Erosion and denudation relief, developed on metamorphosed sediments lying in high altitude; 2) Karstic relief, developed on carbonate rocks; and 3) Valley of rivers and streams, usually narrow with steep and asymmetrical slopes such as the Yen Ninh region, Bac Quang Districts and Ha Giang City. Flood usually happens in these areas. In this paper, we present the flood where upstream of the Lo River flow into through three areas above.

II. METHODS

Many methods of the Geoinformatics can be used to reconstruct flood events. In the following part, some methods used and developed by the authors during the study of flood disaster are summarized.

2.1. Data base: We used many type of data and they are from many sources. The data used are shown in the list below:

- Vector data (geological map, geomorphological map, land use, land cover map, road map and drainage network);
- Raster data (Remote Sensing data such as ALOS, ASTER and Landsat images,);
- Field data

On the technological side, the configuration and spatial position of objects need to be managed, evaluated and described by cartographic data. The character of these objects is described by attribute data. The model of spatial database not only determines the data model for cartographic objects and attribute objects, but also determines the association between them through the relation model using object oriented definitions, including such characters as inheritance, encapsulation and polymorphism.

2.2. GIS technology: For effectively exploiting GIS, we have been incorporated following functions (Bernhardsen, T., 1999) and (Truong, X.L., 2009): 1) Query and search; 2) Spatial analysis, including: analysis of attributes and measurement, piling, analysis of adjecency (spatial search, topography and interpolation, continuity (network, transmission, flow direction). Used digital model include the digital elevation model (DEM) and slope and flow direction.

2.3. Remote sensing: In the study, for interpreting remote sensing images, apart from free Landsat images, we have been using ALOS PALSAR and ASTER data (provided by the Osaka University, Japan) having high resolution, more appropriate for the study demands, especially the ALOS images taken in July 7, 2009 at the timing date of extensive flood happening in the North Vietnam. These are precious data, helping the establishment of DEM model and determination of slope-current directions.

2.4. HEC-RAS model: The authors have been establishing the probability model, especially using the HEC-RAS (Hydrologic Engineering Centers - River Analysis System) model. Modules in the HEC-RAS model were constructed on the basis of theories related to different calculating possibilities, using two basic equations, such as equation of energy/water power and equation of dynamic variation; besides, semi-experimental equations were also used. In the theory side, the line of water surface in the HEC-RAS model was calculated continuously from one to other sections by the solution of energy equation (or Bernoulli equation):

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_2^2}{2g} + h_e$$

Y_1, Y_2: depth of current in sections; Z_1, Z_2: altitude of river bed; V_1, V_2: average velocity; α_1, α_2: corrected coefficient of kinetic energy; h_e: damage of unit energy between two sections.

The energy equation is appropriately applied in the condition of gradual change of current. In the case of strong current or area of confluence, the above equation is unsuitable. It is more suitable when we apply the dynamic equation starting from the Newton 2 Law in current direction. This equation has the following form:

$$P_2 - P_1 + W_x - F_f = \sum \rho Q V_x$$

in which: P_1, P_2: hydrostatic pressure in the section;W_x: gravity of the water volume in the x direction; F_f: power occurring from the friction between 2 sections; Q: water discharge; ρ : specific weight of water; V_x: flow velocity of the section at the margin.

The HEC-RAS model supplies fully functions of analysis of flood, forecast of flooded areas and can completely link with GIS data for adjusting input data with the HEC-GeoRAS tool, helped by ArcGIS 10.0.

2.2.5. Expert and fuzzy expert systems: *Expert systems* consist of computer programs solving a problem demanding knowledge, skill, as well as experiences, conserved in computers and used in the solution of necessary problems. Basic composition of an expert system is the "knowledge base" (KB) and a "deductive machine". Information in the KB is established, deduced from specialists on the basis of an assemblage of logic, typical of them is the "if-then" inference structure. The deductive machine helps the expert system to draw deductions from logics defined in the KB (Kwang-Hoo Chi et al., 2003) and (Truong X.L., 2009).

Fuzzy expert consists of an expert system using fuzzy logic instead of Boolean logic. It is a series of component functions and laws used in the argument of data. Differing from other ordinary expert systems which are machines arguing mainly symbols, the fuzzy expert system concentrates in the direction of digital processing.

Laws in a fuzzy expert system have the following form:

If **x** is **low** and **y** is **high**, then **z** = **medium**

with **x, y** as input variants, **z** – output variant, **low** – component function (fuzzy small file) defined by **x**, **high** – component function defined by **y**, and **medium** – component function defined by **z**. The role of the inference between "if" and "then" is the hypothesis and premise of the logic. This is a fuzzy logical expression, describing to the level that the decision applies. The role of the law after "then" is the conclusion or result clause. This role of the law fixes a component function to one or many output variables. Almost all tools working with fuzzy expert systems allow more than one conclusion for each law. All the group of laws is concentrated as a base of law or of knowledge.

For the fuzzy logic, we consider spatial objects on the map as component function of the fuzzy logic. Component values lie in the domain of from 0 to 1. In the study, we have been establishing a sensitive map of reactivity of flood or the new formation of an area having high sensitivity with flood. Component values, receiving the value lying in the interval of from 0 to 1, were put as value of each image point or each area for each input of the informational layer. We have been calculating component functions $\mu(x)$ for each informational layer:

$$\eta(x) = \frac{EDF - R}{EDF - R + \overline{EDF - NR}}$$

in which, EDF – R is the function of distribution of experiences of areas suffering the reactivation of flood, and $\overline{EDF - NR}$ is the function of experience distribution of areas without reactivation of flood. When they have more than two information layers (thematic map of composition) with the fuzzy component function for a same assemblage, as in usual case, variables of operator can be used for associating values of component functions.

III. RESULTS

In the framework of a paper, the authors present only some obtained results.

3.1. Data base

This is, for example, database on flood frequency in villages, communes (close related to rainfall, duration of each rain); database on topography, geology, geomorphology, weathering crust, vegetative cover and population density. These data are very important premises in the assessment of flood disaster and their impact to the socio-economic situation of the Ha Giang Province.

3.2. Map of flood disaster sensitivity

The article presents results of study on flood disasters in the basin of Lo River, on the territory extending from Ha Giang City through the Vi Xuyen District to Bac Quang District. The area usually suffers flood is the most populated of the Ha Giang Province. The total area of studied region reaches 2,734 km^2. In this map, 3 pivotal areas have been selected for detailed study, namely: Ha Giang City with an area of 171 km^2, Vi Xuyen District with an area of 1467 km^2 and Bac Quang District with an area of 1094 km^2.

For operating the model of establishment of flood disaster sensitivity maps, we must take care of input integrated indexes, which depend much on parameters of each disaster. Based on study experiences in Sanyal, J. and Lu, Xixi (2010), reference of documents, test of 3-5 different variants, and specially, correlation with factual materials on flood, the optimal indexes for flood sensitivity have been selected as follows:

Flood sensitivity index = [Ftb + Fi × 0], if easy to be flooded = 0;

= [Ftb + Fi × 0.25], if 1 ≤ easy to be flooded <3;
= [Ftb + Fi × 1.5], if easy to be flooded = 3;
= [Ftb + Fi × 2.5], if easy to be flooded = 4;
= [Ftb + Fi × 4.0], if easy to be flooded = 5;
= [Ftb + Fi × 5.5], if easy to be flooded = 6;

With: Ftb: Medium flood index for the study area; Fi: Flood index for each factor in the area.

The classification of flood sensitivity indexes is summarized in (Table 1).

Table 1. Values of flood sensitivity indexes

Value interval (Fi)	Group of flood disasters
-5.16 - 0.45	Low
0.46 - 2.53	Medium
2.54 - 8.11	High
8.12 - 15.37	Very high

The index of flood causing danger to village level in the studied area is submitted with three indexes of causing flood danger as follows:

- Number of flood times in each village during 30 years;
- Population density (separated house) on an area of 1 ha;
- Possibility of evacuation of people in flood time. The evacuation area needs to be higher and without possibility of inundation by flood. This index has been calculated and taken from results of construction of DEM model.

Villages never suffering flood during 30 recent years have the danger value of 0. In this paper, the results of analysis of flood frequency of 587 villages in the studied area were used. These indexes are summarized in the (table 2).

Table 2. **Index of flood frequency**
(flood times during 30 years)

Flood frequency (fld-fqr)	Disaster index (R_fld-fqr)
0	0.00
1-3	1.00
3-6	1.20
7-9	1.75
10-12	3.00
13-15	4.00
16-18	4.50
>19	5.00

We select areas of highest possibility of flood occurrence for more detailed study; they are as follows:

Ha Giang City area, with:

- Mien River section extending from Cuom Village to Street part 11, Quang Trung Ward (Area 1);
- Lo River section extending from Street part 3, Quangtrung Ward to Me Bridge (Area 2);
- Vi Xuyen District area, including: Lo River section extending from Dong Cap 2 to Street part 24, Viet Lam Kolkhoz Townlet (Area 3);
- Bac Quang District area, including: Lo River section extending from Tan Thang Commune to the end of Tan Tao Commune (Area 4).

In a paper scale, we can only present some thematic maps on flood in the Area 2, directly related to the inner area of the Ha Giang City. Used parameters are as follows:

- Length of studied segment: 5632 m;
- Number of cross sections: 11;
- Hydrological parameters and flood frequency are used following statistics presented in the Table 3.

With the close with reality model established by us, it needs only change input data and one can calculate rapidly the results. Therefore, it is easy to establish different scenarios on flood disasters that are very significant in the protection against flood disaster. In the (Fig. 1) shown the flood scenarios in the year 1971, it represented specific flood scenarios in the study area.

Table 3. **Parameters of calculated sections in the Area 2.**

OID_	Shape_Leng	XS2DID	HydroID	Profile M	Reach Code	Left Bank	Right Bank	Ch Length	Node Name
1	350.634	7	45	13.9577	Area2	66.3362	1.6395	54.4435	4
2	451.393	8	46	14.4752	Area2	81.6650	51.8216	39.7191	5
3	594.754	9	47	13.2025	Area2	17.6522	105.0613	48.0384	6
4	533.143	10	48	12.6240	Area2	98.5708	51.1954	25.6997	7
5	440.185	11	49	11.7832	Area2	71.8552	77.1839	52.7807	8
6	388.935	12	50	11.3041	Area2	2.8151	44.8641	109.1600	9
7	397.451	13	51	10.9406	Area2	55.8379	47.2711	55.5181	10
8	412.426	14	52	9.5335	Area2	25.2084	26.3171	51.0120	11
9	366.934	15	53	8.1344	Area2	5.4457	7.4087	59.1918	12
10	413.692	16	54	6.9045	Area2	50.6768	101.9159	24.8545	13
11	511.836	17	55	5.6821	Area2	94.3207	118.6791	49.1288	14

IV. CONCLUSIONS AND DISCUSSIONS

The obtained results are as follows; a) Flood disaster database; b) Map of areas sensitive to flood disaster at 1:100,000 scale; c) Three thematic maps (river basin on the territory of Ha Giang City, Vixuyen and Bacquang Districts); d) Four thematic maps of more detailed areas.

It needs an enough long time for collecting necessary real data and for verifying. The problem on disasters of the present geological environment, especially flood disaster, is very complicated, needing to combine knowledge of many domains for obtaining full and more trustworthy results. In the study, it will be more resultant and economic if we combine with the simultaneous study of other hazards. For example, flood disaster is usually accompanied by hazards of soil-rock slide/flow and maybe also significant subsidence, erosion and accumulation.

The application of modern method association in the assessment and warning of flood disaster cannot miss the Geoinformatic system

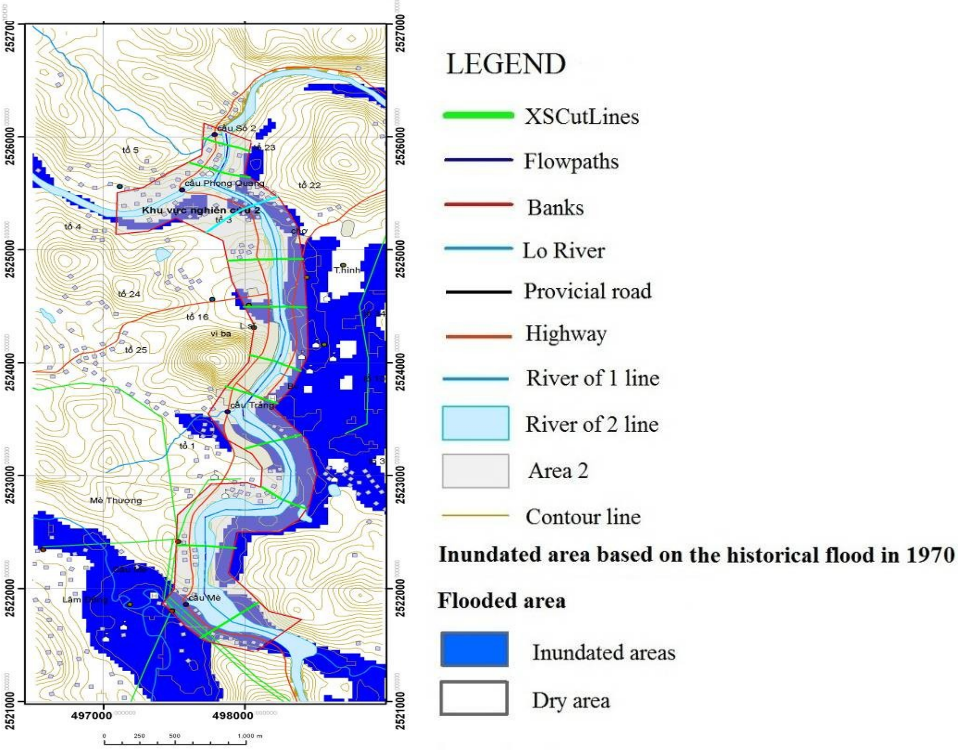

Figure 1. Map established following the flood scenario in 1971, Area 2.

With the modern mapping and information technologies, the program establishment can completely be realized for rapidly update with input as arbitrary parameters aiming to help provide timely information to people, as well as local administration, in the prevention and mitigation of natural calamity in general, and flood in particular. In coming time, it is necessary to establish the zoning map of flood following the principle of searching the shortest road from flooded residential areas to secure places (flood-proof areas) and to construct stations of flood warning. Input data of these stations need to be standardized for easily integrate with environment monitoring satellites in Asia and on the world. We propose to follow the Open Geosspatial consortium standards in future systems and are currenlty working on a service oriented collaborating many years ago. For serving the warning work, the network technology must be most thoroughly displayed.

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