GIS, REMOTE SENSING AND MATHEMATICAL MODELS IN COMBINATION TO STUDY LANDSLIDE: A CASE STUDY OF THE BO RIVER CATCHMENTS IN THUA THIEN HUE PROVINCE OF CENTRAL OF VIETNAM

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ABSTRACT

Landslide is one of natural hazard causing human and material serious losses for Vietnam and other national in the world. Beside introduction and classification landslide types, together with carefully analysis capabilities to application tradition and modern study methods combination in the landslide occurs in study bring out some obtained resulted following:

1. *Bring out mainly factors of causing landslide.*
2. *Divide into areas having landslide separate susceptibility levels in studied spatial*
3. *Compare the obtained results on the model and reality.*
4. *High capabilities to application GIS, analysis remote sensing (RS) and mathematics models in studying landslide.*

I. INTRODUCTION

Vietnam, Especially in River basin, natural and landslide hazards are normally occurrence, which made many effect as human and material losses. Leads of many levels and scientists of Vietnam have been carrying about that. But it is incomprehensive in research, modern methods and has not obtained the desired results.

To use combination of the methods as Remote Sensing, GIS and mathematical models are essential. We studied to obtain good results about landslide for Cau River area (Thai Nguyen province); Ve, Tra Bong rivers (Quang Ngai province) and so on and the nearest recently is Bo river (Thua Thien Hue province).

II. METHODOLOGY

II.1 Landslide classification

Landslide takes places when material loses balance, the strength of slide resistance is smaller than restrict permit, which caused by progress of the geological dynamic, human activities, …

Up to this time, there are a lot of classifications for landslide hazards. In this paper, there are two systems have been using popularly and particularly system due to Hutchinson (1968), Skempton and Hutchinson (1969) and Varnes (1958, 1978) proposed. Classification system of Varnes (1978) was prominent 2 essential problems; transfer model and material model are moved (Table 1).

Table 1: Classical landslide systems according to Varnes (1978)

	Moving model	Materials model		
		Stone	Soil	
			The raw grain is main	The smooth grain is main
1	Fall	Fall stone	Piece of crushed fall	Falling soil
2	Topple	Topple stone	Piece of crushed topple	Toppling soil
3	Slide	Slide stone	Piece of crushed slide	Sliding soil
4	Spread	Spread stone	Piece of crushed spread	Spreading soil
5	Flow	Flow stone	Piece of crushed flow	Flowing soil
6	Mixture of the above model	Mixture of the moving types or materials types		

II.2. The main cause of the land slide

Landslide is complicated progress by the causes of which makes landslide and what type of process controlling the movement of the structure material and etc...In general, can be divided 4 main groups:

1. The causes of geo-technique

Landslide happened when appears the weak materials, weathering, materials is broken; crack, stretched, appeared the un-continuous, *not identify with disadvantage factors (fault, not accordant)....; materials are capability with good absorbent; Mixture of disadvantaged materials and so on.*

2. The causes of geomorphology

Slope of topography, active elevation, erosion, vegetation cover, etc.

3. The causes of physics

Rainfall, Flood, inundation, earthquake, volcano activity, shrink or stretch caused by weather.

4. The causes of human activity

To make hole, to be lost the legs of slopping roof, explode with boom, water out by economic activities...

The above causes are complications which are represented by 3 landslide process: increasing of stretch forces, materials intensity is low and decrease intensity of resistance force of the stretches.

II.3 Models

Information supposed for hypothesis of the landslide in the past is premise for in the future forecast. Therefore, to set up a weight mapping to classify landslide is very important for dividing zones of landslide levels. Topography factors are very important so there are 2 methods to analyze the landslide relations:

+ The method for mapping directly. Based on directly evaluation to be related to landslide and geomorphology, geological features by direct observations.

+ The method for mapping indirectly. Firstly, to establish the factors (parameters) these has capacity influence on landslide process. Secondly, analyze to determine amount of values of all parameters, to compare with event of landslide, defining correlations of topographic condition with actual state landslide and condition to happen landslide.

In order to implement the above methods, regularly use 2 technological groups to evaluate catastrophes are the relative and absolute (Harden, Viberg, 1988). The relative technology help to establish qualitative landslide maps, representing landslide can happen at various locations. Conversely, the absolute catastrophes map expresses quantitative landslide (safety factors, probability of landslide...).

In the fact, often using 3 models to evaluate landslide (Carrara, 1988; Hartlen and Viberg, 1988) is:

+ The model of white box based on physical model basis (the stable slope roof model, hydrographical model...).

+ The model of black box which not based on physical model basis that based on the statistical (quantitative) analysis.

+ The model of grey box plays an intermediary role of 2 above models.

Zoning landslide is task always conforms (ensures) the rude effecting principle with the scale of reasonable economic and results to determine economic effect base on the request of the researchers. However, the technological choice to establish this map is unlimited, depending on data collection, expenses, time and specialized experiences of researchers.

The factors is relative to landslide very diversified, from structure geological features relate to land use, which exist in the physical environment and the activities of human. So, input data for researching the landslide catastrophe have to include of large groups: Geomorphology-Topography, Engineering Geology, Geo-Technique, Land use and Geo-Hydrographs. The each of the group is divided into data layers. Each of them is showed in its own map. GIS technology helps us to easy represent that data layer by objects to describe points, lines, polygonal (zone, area) and allied necessary attributes.

II.4 GIS in the progress of landslide analysis

The destruction of sloping roof leading to landslide caused by many factors or a part of the factor has a relation with each other. It is very important for the analysis landslide to estimate the correlation between the changes condition of topography and landslide events. Sometimes, this estimation requires nearly to reappearing the landslide progress. The capacity of GIS allow to store, change the information relate with the different topography factors such as different layers, so it is a good technology to zone sloping roof stably.

To promote maximum advantages of GIS, but reduce its disadvantages, to establish a map for landslide distribution (Fig.1) and a map for landslide density (Fig.2). Apart from that, using some various methods based on foundation of GIS such as the analysis according to the experience (Fig.3); the analysis according to two dimentions geo-statistic (Fig.4), multi-objectives analysis (Fig.5) and analyze stability of sloping roof (Fig.6).

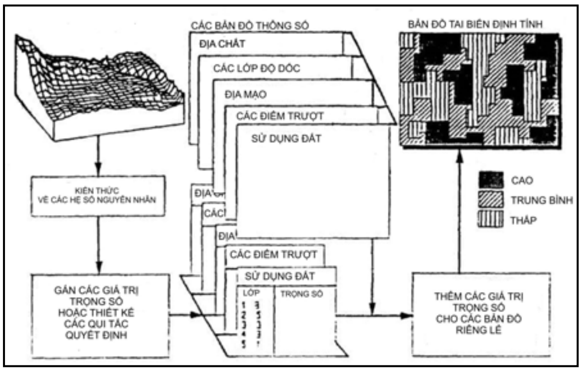


Fig 1. Landslide Distribution map

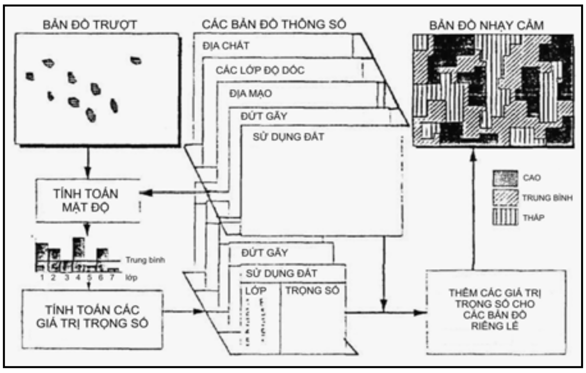


Fig 2. Landslide density map

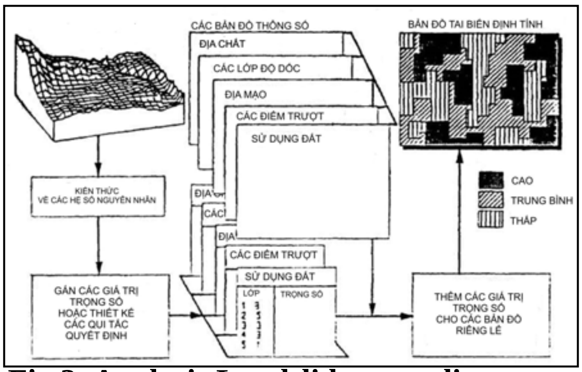


Fig 3. Analysis Landslide according to two the experiences

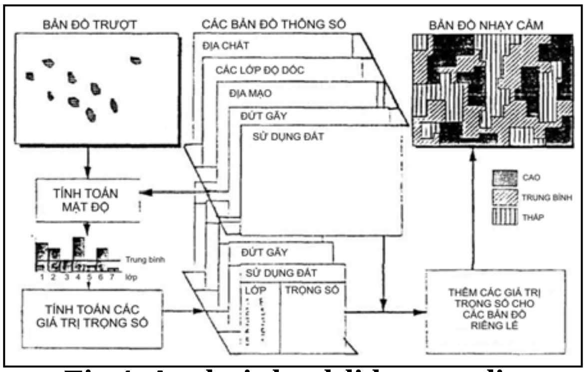


Fig 4. Analysis landslide according to Geo-Statistic dimensions

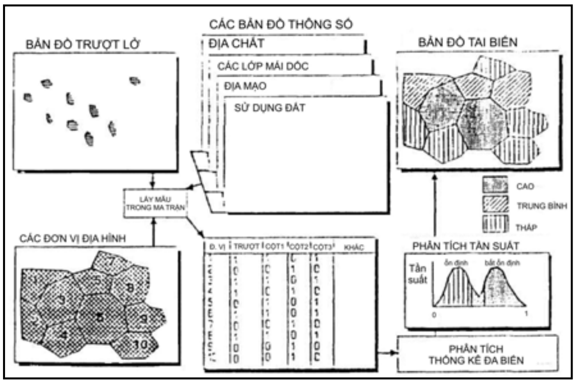


Fig 5. Multi-objectives analysis

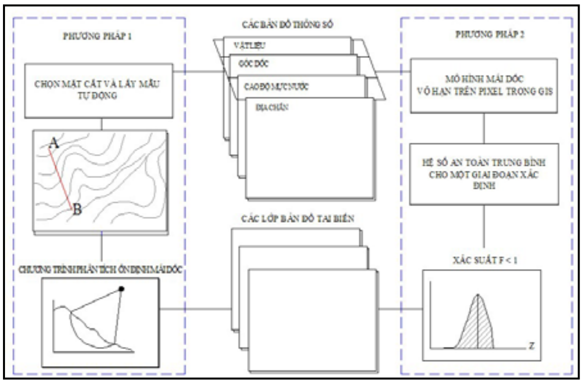


Fig 6. Analyze stability of the sloping roof

II-5 The mathematical model to build a sensitive landslide map

We used a method of confident coefficient (CF) to research. Basic principle of CF method is introduced firstly in MYCIN system (Shortiffe and Buchanan, 1975). This model is studied, applied and tested the progress of analyzing successfully landslide (Chung and Fabbri, 1993, 1998; Binaghi et.al 1998; Luzi and Pergalani, 1999). In the progress of analyzing landslide zone, researchers corrected and gave theory of confident factors (Lan and et.al, 2004). Method of CF is defined as a function of sensitive landslide probability:

$$CF = \begin{cases} \dfrac{PPa - PPs}{PPa(1 - PPs)} & if PPa \geq PPs \\ \dfrac{PPa - PPs}{PPs(1 - PPa)} & if PPa < PPs \end{cases}$$

In there, *PPa* is probability to have a landslide condition in *a* class.

PPs are the total of landslide events in researching area of A.

CF is changed in about [-1, +1]. Positive values represent the increase in confident level of the landslide potential; inversely, negative values correspond to decrease in confident level of the potential landslide, nearly values (approximately) 0 to have a specific sense for homogeneous similar to initial probability and initial condition.

The main software used is ILWIS 3.3 for windows helping to analyze landslide, calculate the values which have the capability make effect and merge data by GIS technology.

The progress of preparing the classes to input data and select them to analyze is performed in GIS foundation. The values are ability relate with potential landslide defined to overlap on landslide map and each of a data class is calculated landslide frequency. The each of subclass of a data class is delimit by calculated its influence values with the help of GIS software and the classes and then they are merge by using an integrative principle to synthesize the result of the model. Finally, including redefinition results of the prediction again, survey and check in the field to consolidate the ground control.

III. A case study

The Bo river valley is far away Hue city 20km in the west, has an area of 1124 square meters, the length of the main river is 85km, the short level of 1200m. The north is contiguous with Thai Ma river valley, the south is in the Hien Trach river valley, the west in the Xe Kong river valley and the east runs into the sea. The Bo river is one of the main branch river of Huong river, belongs to the system of Huong river, it proceeds from the mountainous region of the south-west in the Laotian-Vietnamese border that at an altitude of 1400 meters; it runs into the sea according to Thuan An and Tu Hien seaports.

The map of landslide actual state includes of 205 landslide points. The map of ground-using and fault density is determined by Landsat TM5 image taken on 3 April 2000 (Path/Row: 125/049) with ground resolution of 30 meters. The map of geology, geomorphology, topography and weathered cover are used by the researching results of Tran Tan Van (2001) and Pham Khac Tuy (2001). The slope map, elevation, river density are established by topography map. The factor map of poly-space is formated Raster with the scale of 1 pixel corresponding to 30x30 meters differ from the fact. By the GIS assistance, ILWIS software and factors leading to landslide which are set up into special maps. They are the input coefficients to supply to analyse the landslide sensitive to base on Confident principle (CF). The results of studying are shown in 11 maps as follow:

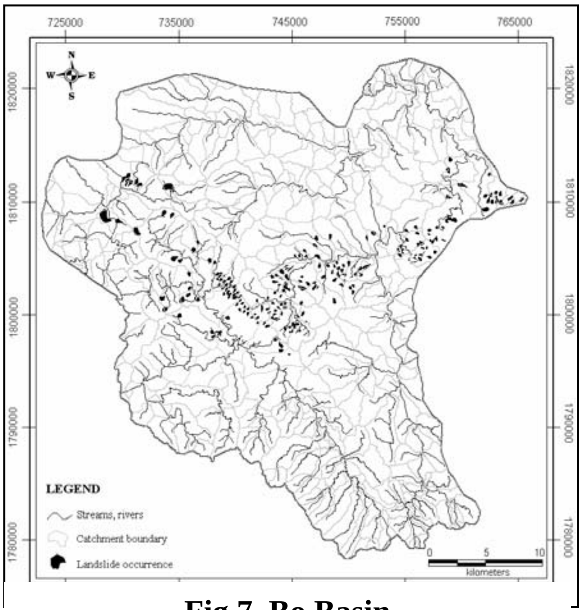


Fig 7. Bo Basin

1- The map of CF (distribution of the average rainfall in 1997s) (Fig.8)

2- The map of CF (coefficient distribute (CF) of slope) (Fig.9)

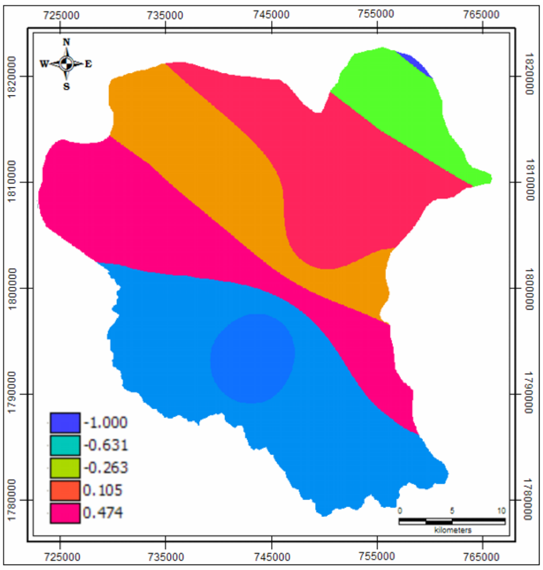


Fig 8: Distribution CF, rainfall map in 1997

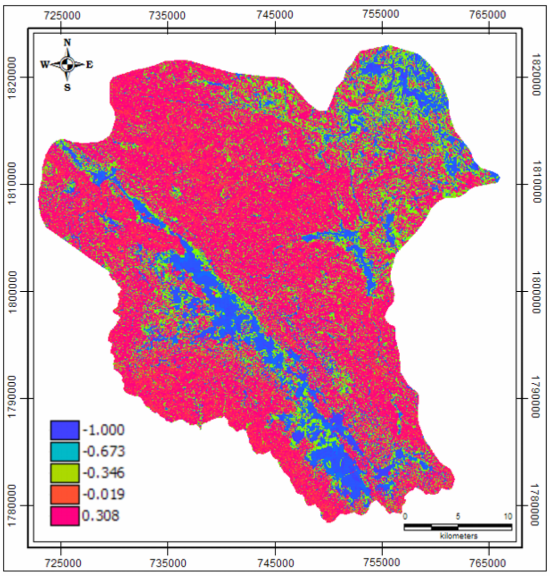


Fig 9. Distribution CF, Slope map

The slope is one of the main coefficients to create landslide. Which are divided into 5 levels. Find that, at the sloping roof is smaller than 5^0 can bring out landslide 1,4%; The sloping roof is from 5 to 15^0 can cause landslide 11,1% and bigger than 35^0 is 87% leading to landslide.

3- The map of coefficient distribution (CF) of elevation factors (Fig.10) divided into 5 different levels.

4- The map of coefficient distribution (CF) of geomorphology factor (Fig.11). In the study area, the strong slide is concentrated sloping roofs of Neogen moving the slow gravity.

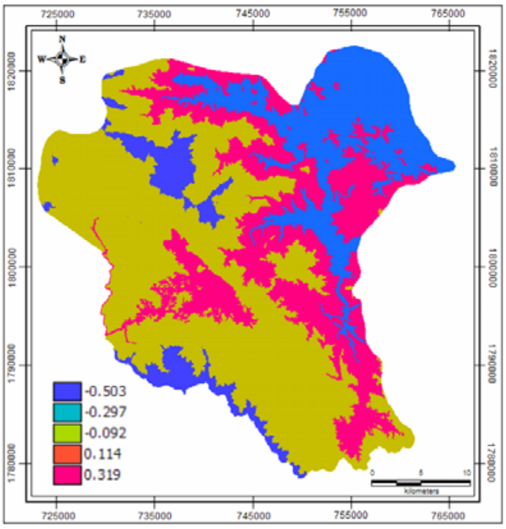


Fig 10. Elevation map with 5 levels

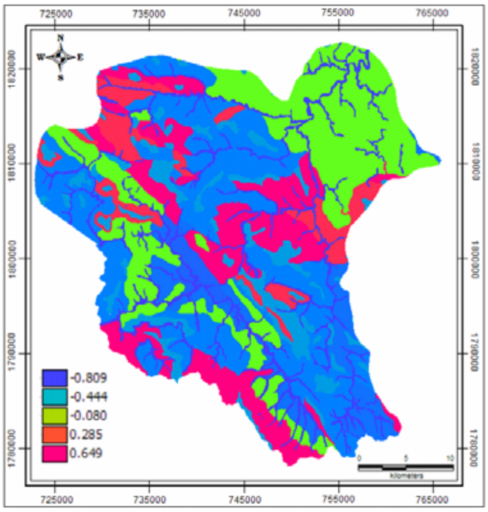


Fig.11 Geomorphology map

5- The map of confident coefficient distribution (CF) of factor landuse (Fig.12)

6- The map of confident coefficient distribution (CF) density of rivers and streams (Fig.13). The classed map of rivers and streams density is divided into 4 levels.

7- The map of confident coefficient distribution (CF) of geological factor (Fig.14). There are 9 geological formations which include of sedimentary rock, degeneration, and volcano, which divided into 17 levels according to component and the age of different geology.

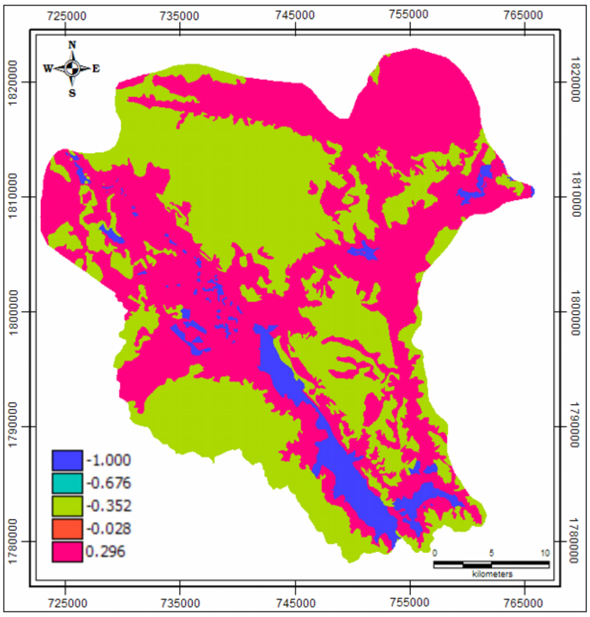
8- The map of confident coefficient distribution (CF) of fault density factor (Fig.15). The fault density is calculated to base on interpolate algorithms and combine with using Landsat image TM5. This map is divided into 4 different density classes.

9- The map of confident coefficient distribution (CF) of weathered cover factor (Fig.16) that is divided into 5 classes corresponding with 5 types of different weathered covers.

10- The map of landslide sensitive is represented in 2 forms:

10.1- To express to follow CF values varying continuously (Fig.17)

10.2- To represent to follow the classed table of CF value to correspond with the sensitive level of different landslide (Fig. 18).



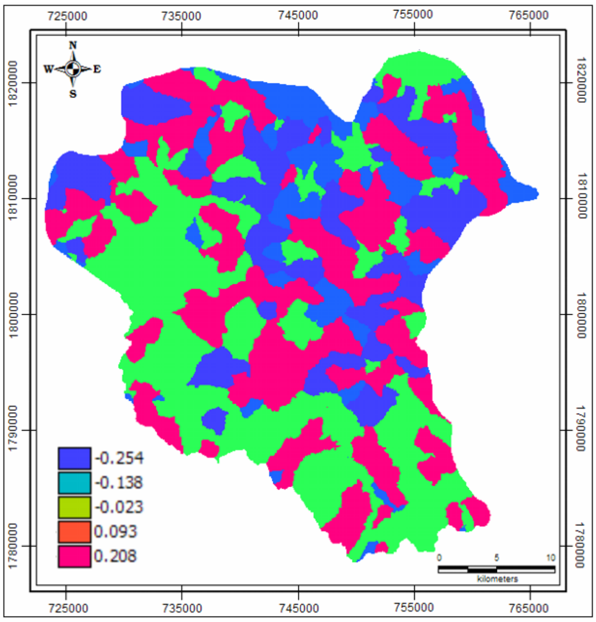
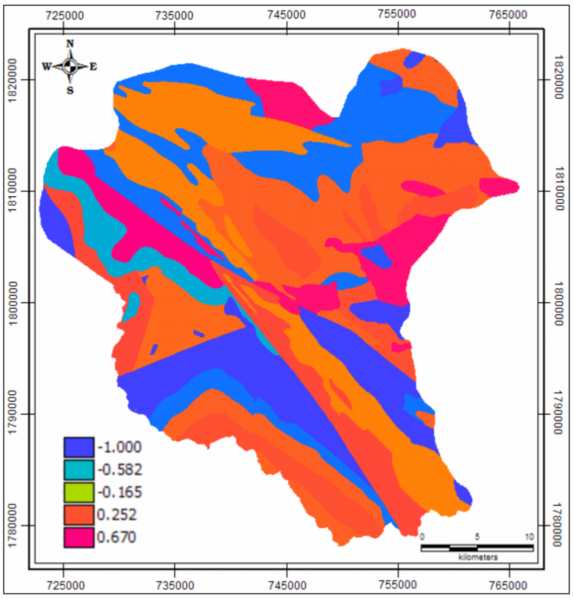


Fig.12 Land use Map

Fig.13 Density of river and stream distributed



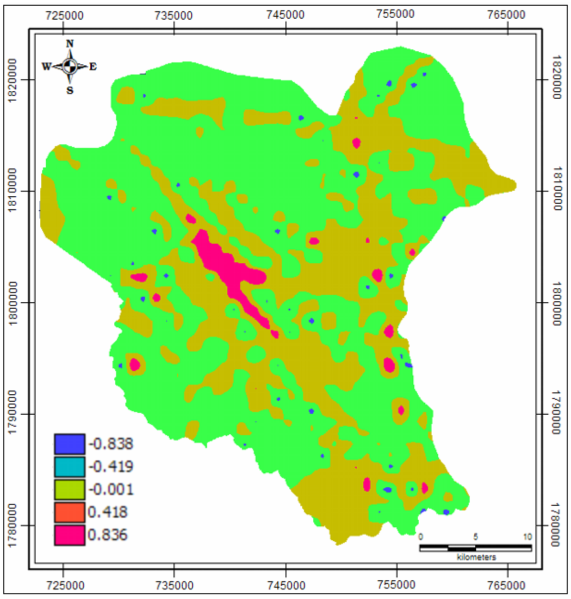


Fig 14.
Geological Map

Fig 15.
Density of fault map

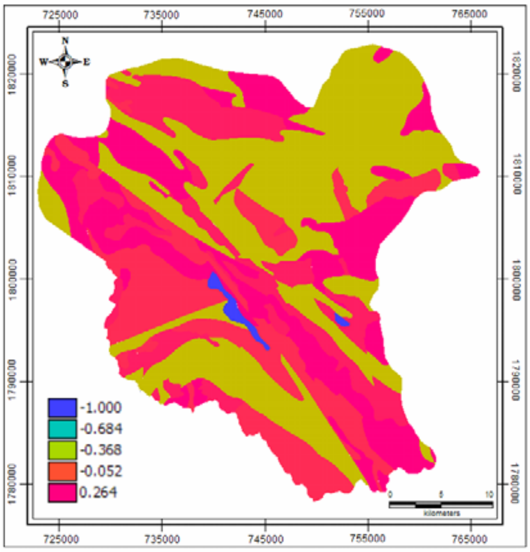


Fig 16. Weathering Distributed Map

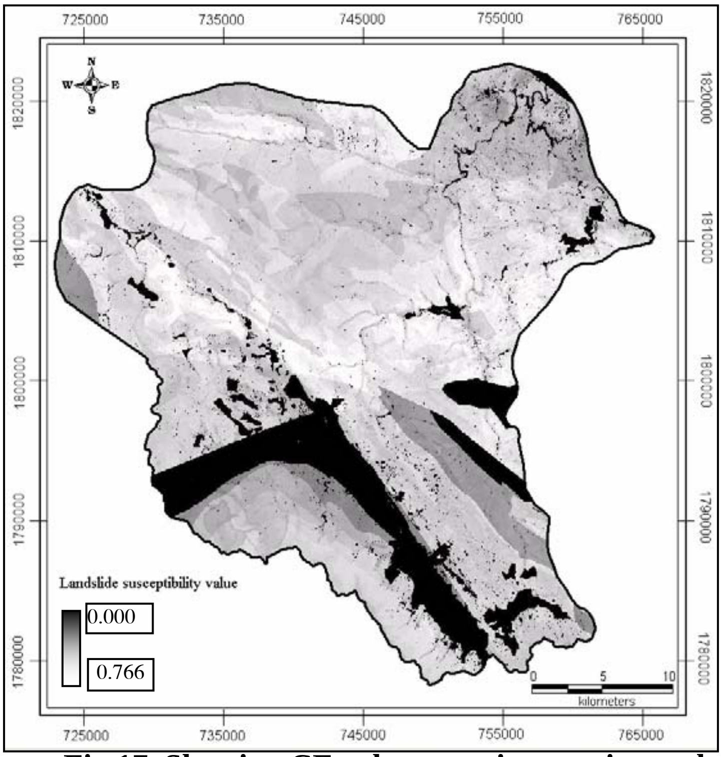


Fig 17. Showing CF values varying continuously

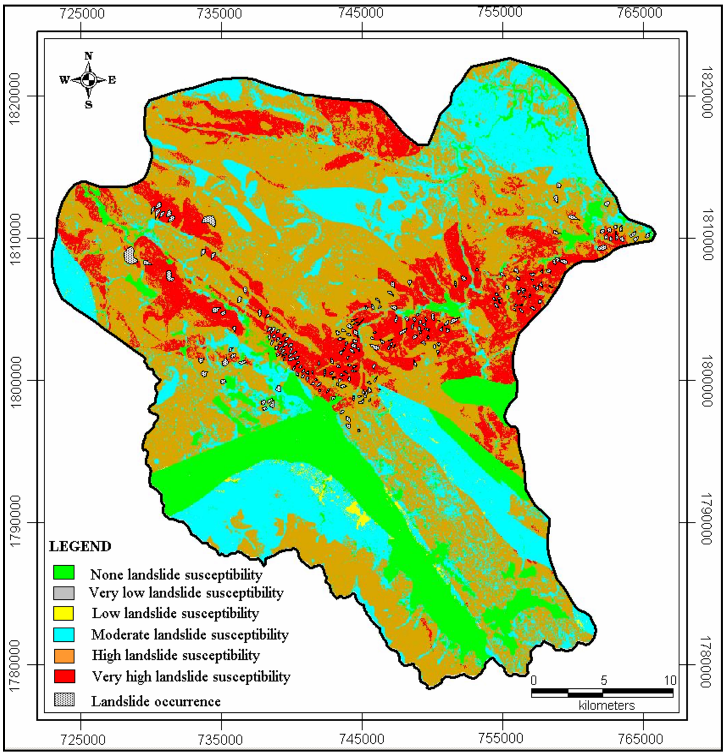


Fig 18. Showing classify table of CF values to correspond with the sensitive level of different landslide.

3. CONCLUTION

Places where have deep sloop, with the large and deep weathering layers when meet big rainfall or high intensity is highly potential landslide. And density of faults, folds those also have a big role for make up landslide potential.

RS and GIS using the mathematics models, specially is CF method with good accuracy and suitable for applying to study area. Predict landslide area has the different sensitivity had a result quite identical with the actual landslide taken on many places in study areas.

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