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Full Length Research Paper

Factors Affecting the Occurrence of Mass Movements in Naroun Area, Baluchistan, Iran

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Abstract

This research provides a comprehensive analysis of landslide distribution in the Naroun area, Sistan and Baluchistan Province, South east of Iran. GIS data was applied in order to analyze the spatial distribution of landslide by using lithology, geomorphology and lineament parameters. According to the satellite image analysis430 landslides were inventoried which more than 300 of these landslides are belong to single movement group. Rock falls, slides, flow and debris flow are more common type of landslide in the study area. Landslides are distributed on a limit range of slope gradient and lithological characterization of the area. Most of landslide happened on slope gradient ranging from 10˚C to 25˚Cwhich are usually due to the present of unconsolidated hydrous tuff layer beneath Andesite layer and manmade activity in the roadway construction in the area.

Keywords: *Naroun, Landslide, Rockfalls, Tuff, Andesite, slope*

Introduction

A natural disaster like landslide is the outcome of combination of a natural hazard and human activities. Landslides cause a lot of casualties in a year especially those cities sited nearby foothills are more vulnerable to landslides. Depending on triggering factors, landslides vary in composition as well as in the rate of movement. Landslides in vulnerable zones in Baluchistan lead to small scale.

Therefore, identification, mapping and monitoring of landslide susceptible zones would help in the mitigation and rehabilitation. GIS identified as strong tools to integrate and analyze data from various sources as well as to mitigate landslide hazards and improve decision making processes associated with landslides management. (Western et al. 2005; Van Westen et al. 2005).The process of zonation of landslides comprises of preparation of different maps base on the factors influencing the occurrence of landslide with the help of aerial photographs, satellite imagery, topographic maps and geographical maps. Landslides occur due to several factors such as; Quasi-static variables, which contribute to landslide susceptibility, such as geology, slope characteristics (gradient, slope aspect, elevation, etc.), geotechnical properties, long-term drainage patterns, etc. and Dynamic variables, which tend to trigger landslides, such as rainfall and earthquakes.(Dai, F.C., Lee, C.F., 2001; Hutchinson JN,1995; Varnes DJ, 1984).

Monitoring, mapping and modeling of landslides are based upon a few, widely accepted principles or assumptions (Varnes et al., 1984; Carrara et al., 1991; Hutchinson and Chandler, 1991; Hutchinson,. 1995; Turner and Schuster, 1995) these principles are;

- Landslides are controlled by mechanical laws that can be determined empirically, statistically or in deterministic fashion. (Dietrich. et al., 1995).
- The past and present are keys to the future (Varnes et al., 1984; Carrara et al., 1991; Hutchinson, 1995) as slope failures in the future will be more likely to occur under the conditions which led to past and present instability.
- Landslide occurrence, in space or time, can be inferred from heuristic investigations, computed through the analysis of environmental information.

Monitoring is defined as the comparison of landslide conditions like areal extent, speed of movement, surface topography, and soil humidity from different periods in order to assess landslide activity (Mantovani et al., 1996).

Mapping: Evaluation of landslide hazard requires the preliminary selection of a suitable mapping unit. The term refers to a portion of the land surface which contains a set of ground conditions which differ from the adjacent units across definable boundaries (Hansen, 1984).

Material and Methods

This research deals with the spatial distribution of landslides and their relation to terrain factors such as lithology, lineaments, slope, elevation, drainage network and road path, to identify different landslide prone zones in areas under investigate using GIS and RS to describe the landforms that are developed and analyze the relationship of the landforms to landslide, identification of causal factors of landslides using information collected from fieldwork, government agencies and remote sensing, Spatial mapping of lithology, Slope, topography and landslide prone zones in *Naroun* area.

The purpose of this study cover Physical geography, lithology variations and soil characterization is to map landslide susceptible zones according to regional traverses, GIS and Remote sensing techniques. It includes pre-field work such as Review of literature, collected of previous data and topography sheets on scale 1:50000 as well as identified and coordinated landslides area. The data was supplemented by geological survey map of *Naroun* area on scale 1:250000 scanned and dotted Per Inch (DPI=100), digitized using Arcview 9.3 for image analysis, Geo-referencing of map and image, for further correction of data. Field trips to collect data, ETM+ Land sat image. During the course of field work, field characteristics of different landform feature identified and their characteristic compared to satellite photo and noted.

With the help of ArcGIS software morphometric analysis including altitude, relief and slope analyses of the most important part of areas on scale of 1:55000 were undertaken from the topography sheets. Landsat ETM^{+} holding following parameters"WGS84" (Reference _ Datum) and "UTM" :(Map_ Projection), Zones, 41R, applied to provide geomorphology, landslide zoning maps.

For the purpose of drawing landslide prone zone map in Arc GIS suitable map layers regarding to physiography, lineament, soil, lithology and climatology of area were considered by giving relative weightages of susceptibility to the classified objects of these maps. Each layer weighted individually with relation to their influence on landslide occurrence. The effect of Slope depend upon its degree similarly aspect factor considered according to its steepest downhill faces. By taking into consideration the effect of soil and lithology, unconsolidated, weathered and accountable rock in joints and fault zones nominated for higher rank moreover the fine grain particles like clayey received high weight value in the landslide prone zone classification.

The various layers, which were finally used for assigning weights for ranking, are; slope, aspect, lithology, soil characteristics, drainage density, lineament density and Rainfall intensity.

The parameters are prioritized based on the hazard potential i.e. higher the ranking higher is the area prone to landslide. The rankings of landslide magnitude given to various factors are:

Rank 1 (Very Poor): No damage to infrastructure because of low-lying areas.
Rank 2 (Poor): Injury, burial or death of people is likely.
Rank 3 (Very Moderate): Destruction of smaller trees, power lines, damage to houses possible, and removal of roadways are likely.
Rank 4 (Moderate): Destruction of large trees, and burial of small houses possible.
Rank 5(High): Destruction of large infrastructure, and derailment of trains likely.
Rank 6(Very High): Destruction and burial to multiple infrastructures, parts of towns and villages.

Results and discussion

Study area

Naroun area situated on *Khash* district, Northern *Baluchistan* part of *Iran* with a very rough topography; elevation varies from 2200 to 3100 meter throughout the area (Figure 1). The quadrangle location of *Naroun* area shown in table 1 and it covers about 50 km^2. Climatologically the area is a desert climate. There is no more rainfall in *Naroun*. The average rainfall in about 120 mm .The temperature varies from -5 °C in winter to 35 °C in summers. High undulating hilly ranges are usually common in both northern and southern areas. In this case study area the major manmade evidence are mainly road path construction and *Naroun* village anthropogenic which effect on rock fall and landslides. *Naroun* village is fall in this study with an about 1000 people by population. The common natural phenomenon in the area is an active Strato volcano known as *''Taftan''*; it is elevated 4050 meters above sea level with a highly active, Taftan summit cover by sulfur fumaroles.

Soil Characteristic

Weathering is the main element of soil production from available heterogeneous rocks in the area which are andesitic rocks. Large amount of fine to medium mixture of soil particles extend over the area. The more existing soils in the area are Sandy clay and clay.

According to XRF analysis Aluminum Oxide (Al_2O_3) is about 20%, Ferric Oxide (Fe_2O_3) contain less than 4%, the average of Sodium Oxide (Na_2O) and Potassium Oxide (K_2O) varies between 4 to 8%, Sulfur Trioxide (SO_3) 1%, Magnesium Oxide (MgO) 2%, moreover XRD analysis shows that montmorilonite is a very common mineral in the area which indicate more amount of Bentonite and less amount of Kaolinite in the soils. Soils play a vital role in deciding the susceptibility of a probable landslide mostly in humid and high amount of precipitation area but in *Naroun* area due to dry and low amount of rainfall is not very significant.

Table 1. Geographic coordinates of *Naroun* area

A	B
28°38'5''-60° 57' 43''	**28°39'19''-61 ° 01' 7''**
C	D
28°57'49''-61° 57' 49''	28o37 30-61 o 1' 26''

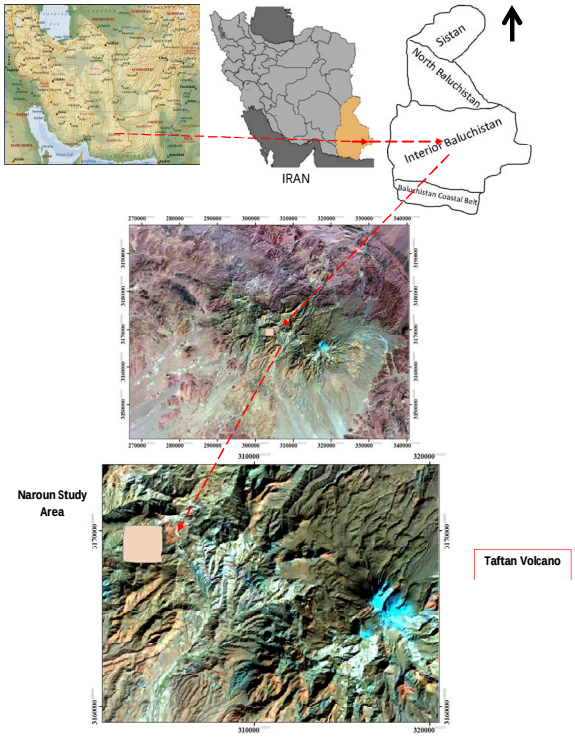

Fig. 1 Location of *Naroun* area

Lithological distribution

Naroun district sited in Khash geological map 1:250000 series sheet L12 of geological survey of Iran. High undulating area almost characterised by Andesitic flow along with Minor basaltic Andesite, Hornblende Andesite, hypersthene and Olivine basalt appeared in major part of the area , Conglomerate and Lapilli tuff with andesitic and dacitic components spread in northeast while Older Andesitic flow ,extrusive dome with minor detrital boulder breccia observed in southern part of the area . Figure 3 depict lithology of *Naroun* area. (Table 2)

Table 2. Criteria for ranking base on lithology

Number	Lithology	Rank	Share%
1	Conglomerate	4	
2	Lapilli Tuff	6	
3	Andesite	6	
4	Dacite	5	50
5	Basaltic Andesite	5	
6	Hornblende Andesite	5	

It is a common belief that factors which effect on landslide in these areas are different to other part of Baluchistan area due to lithological characteristic and distribution, for instance distribution of large quantity of hydrous tuff beneath Andesite layer may increase the occurrence of landslide base on the degree of dip, gravity and the amount of precipitation in the area.

Drainage Analysis

There is no significant drainages in the area therefore, the existence drainage in the area experience dendritic pattern. They are usually intermittent and contain water in very short period especially during rainfall. Sardarya is the only lake in the north Baluchistan with an area about 10 Km^2

Rainfall analysis

Precipitations in the region are in the form of rainfall and snowfall in the winter. The average rainfall in the area is 230 mm.

Lineament

According to the distance of fault to the susceptible zone it is acceptable that the Lineaments in the area have no direct effect on landslide but it does not mean they are not one the parameters which increase the occurrence of landslides in the area.

Terrain analysis

Digital Elevation Model is the third dimension of coordinate system (Z) which shows the height variation against surface (X,Y) in an area . Digital Elevation Model (DEM) of study area produced by using GPS to procure X, Y and Z value of study area. DEM is responsible for topographic map of *Naroun* area which ranging from 2200 to 3010 meter of mean sea level. Figure 5.18 show the DEM and Topography map of *Naroun* area.

Location of landslide in *Naroun* area

According to the activity of landslides including state, distribution, style and effect factors the susceptible zone divided into two different parts known as I and II. Part I of landslide indicate only a single effect parameter either weathering or other factors in a very small or almost in situ area without any noticeable displacement therefore, in such part of landslide the shear strength is more or less equal to material strength and there is a very uncommon relation between effecting factors and landslides. Base on Cruden and Varnes (1996) landslide classification this part of landslides experience dormant state, confined distribution and single style. They are harmless, usually triggered due to existence material and geomorphic attribute. An example could be rock fall to a limit run out distance of 0 to 10 meter or soil slide usually during precipitation, earthquake, freeze-thaw processes and root growth or leverage by roots moving in high winds.

In the part II of landslide more factors involve to displace soil and rocks. Shear strength is always exceeds strength of material. Slope morphology and geotechnical parameters of material in conjunction to available forces issue by triggering mechanism such as precipitation, wind, earthquake, water and etc. are responsible for different occurrence type of landslide. Base on the geomorphic attribute, for instance degree of slope, aspect, removal of lateral and underlying support the movement are extremely rapid in the rock material which occur in the form of fall with a run out distance up to 200 meter. The landslides location map of *Naroun* area depict in Figure 8.

The recent noticeable rocks fall in the area recorded on 16.April.2013 during most powerful earthquake with 7.8 magnitude struck Near Saravan City , 120km East of *Naroun* area, which its reverberation were also felt in India. Such earthquakes in the area effect on shear strength and therefore increase the occurrence of slide and fall in the area. According to the distance of fault to the susceptible zone it is acceptable that the Lineaments in the area have no direct effect on landslide but they also are one the parameter which increases the occurrence of landslides in the area.

Slope

The slope map of the study area was derived from the contours and Digital elevation model. The Slope varies from 1 to 85 degrees. Higher degree of slope along with other geomorphic parameters indicates a direct relation to shear strength and cause of landslides. Table 3 and Figure 12 prepared to estimate final ranking of slope which accused for landslide in the area.

Aspect

As explain earlier it is another geomorphic factor which influencing the occurrence of landslide. The output of aspects is similar to differ from other case studies base on elevation and slope of the area. The aspect map and the ranking values of *Naroun* area are shown in Figure 13 and table 4.

Table3. Criteria for ranking base on slope

Number	Slope	Rank	Share%
1	0°-16°	2	
2	16°-30°	3	
3	30°-46°	6	35
4	46°-61°	6	
5	61°-90°	6	

Table4. Criteria for ranking base on aspect

Number	Aspect	Rank	Share%
1	North	4	
2	Northeast	4	
3	East	4	
4	Southeast	6	5
5	South	6	
6	Southwest	6	
7	West	4	
8	Northwest	4	

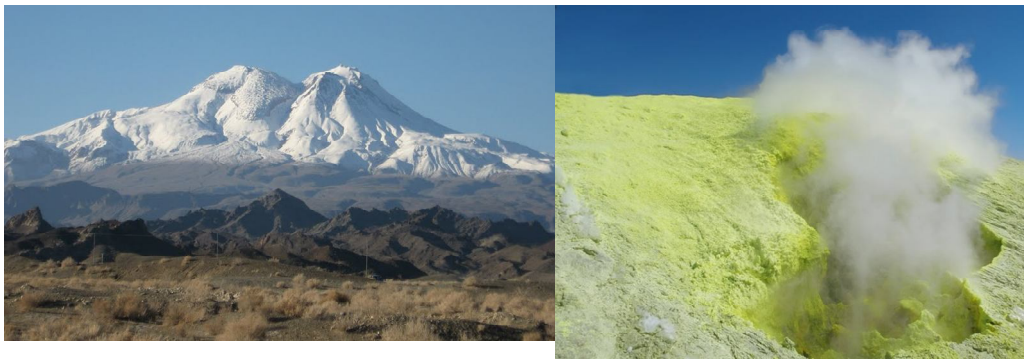

Fig. 2. Taftan Volcano (Left photo) along with its covered sulfur Fumaroles summit

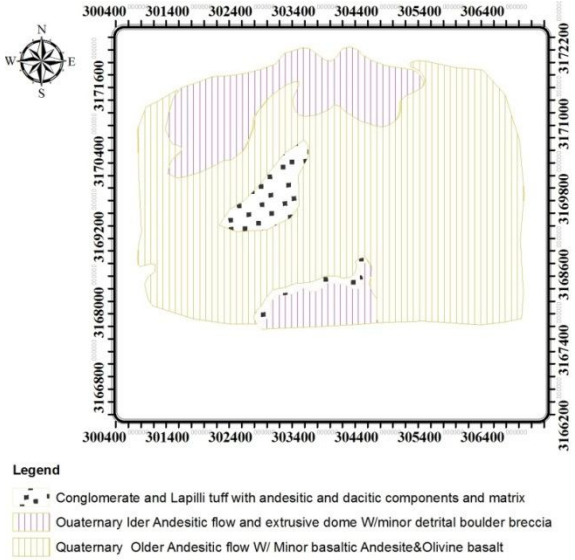

Fig 3. lithological distribution map of *Naroun* area on scale 1:55000

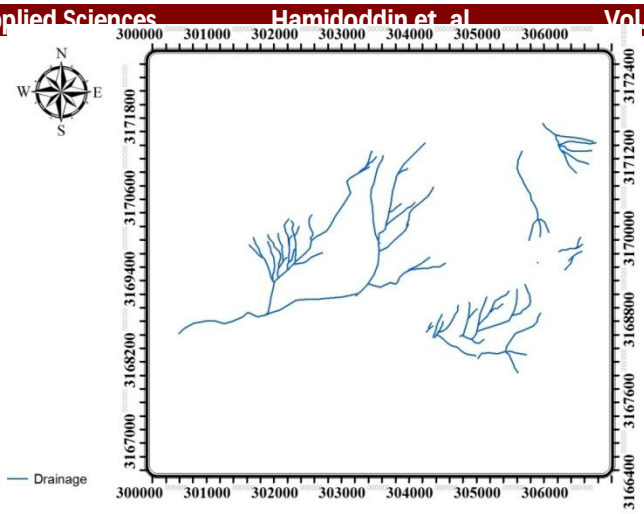

Fig. 4 Drainage network distribution map in *Naroun* area, scale on 1:55000

Fig 5 Sardarya Lake

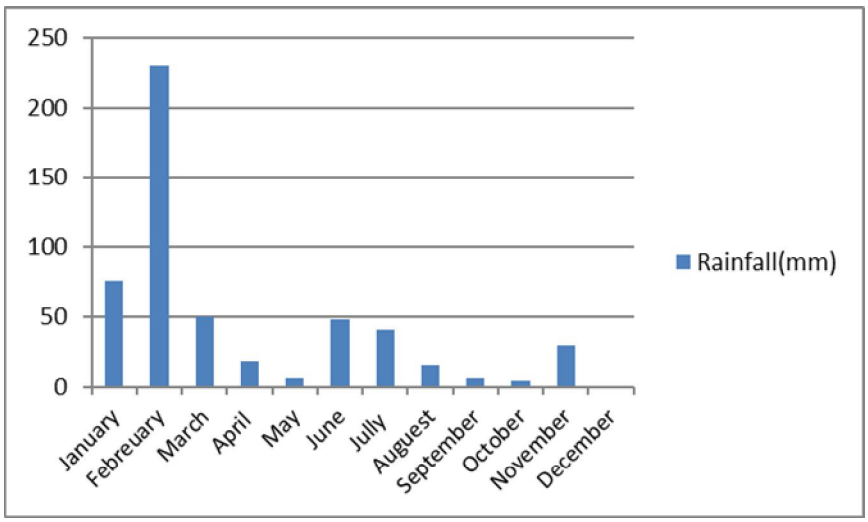

Fig 6. Monthly variation of precipitation in *Naroun*

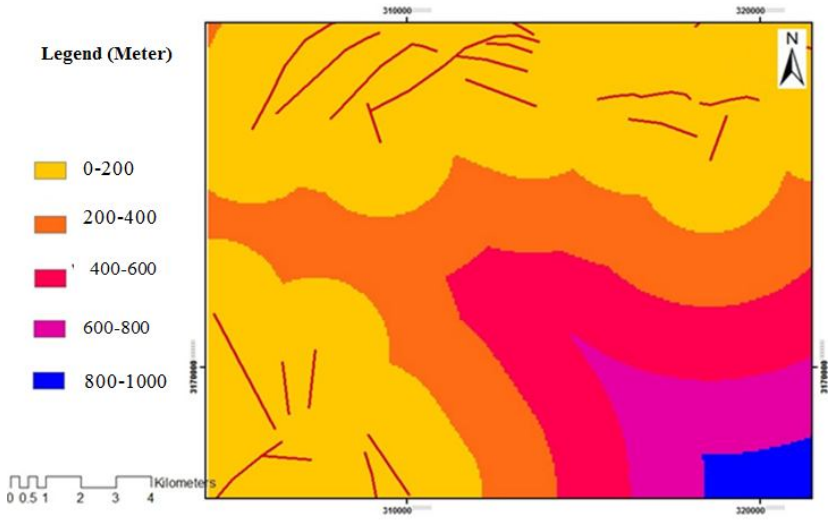

Fig.7 shows the distance of major available lineaments to the *Naroun* area

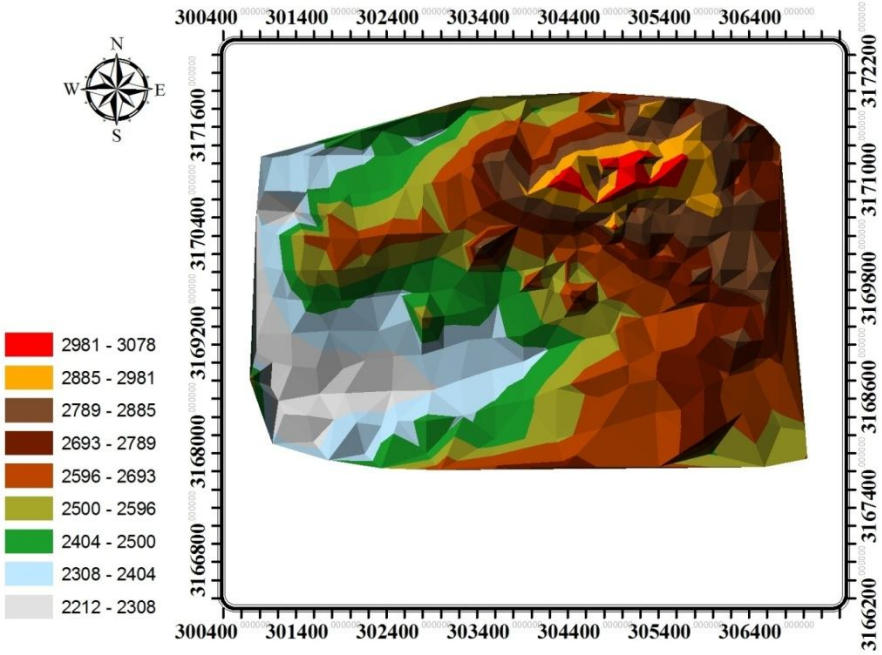

Fig.8. Digital Elevation Model of Naroun area on scale 1:55000

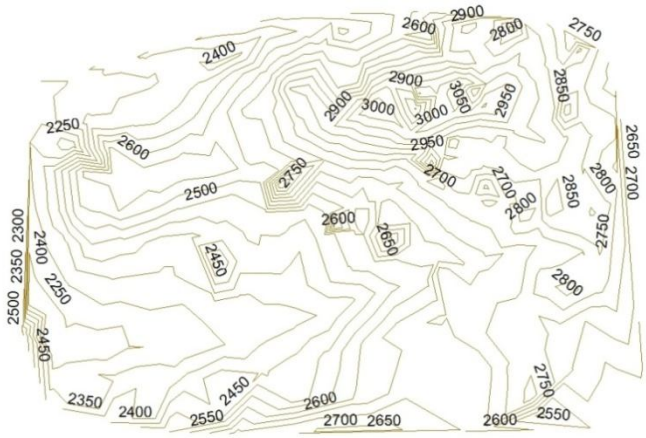

Fig.9 Topography Map of *Naroun* area on scale 1:55000

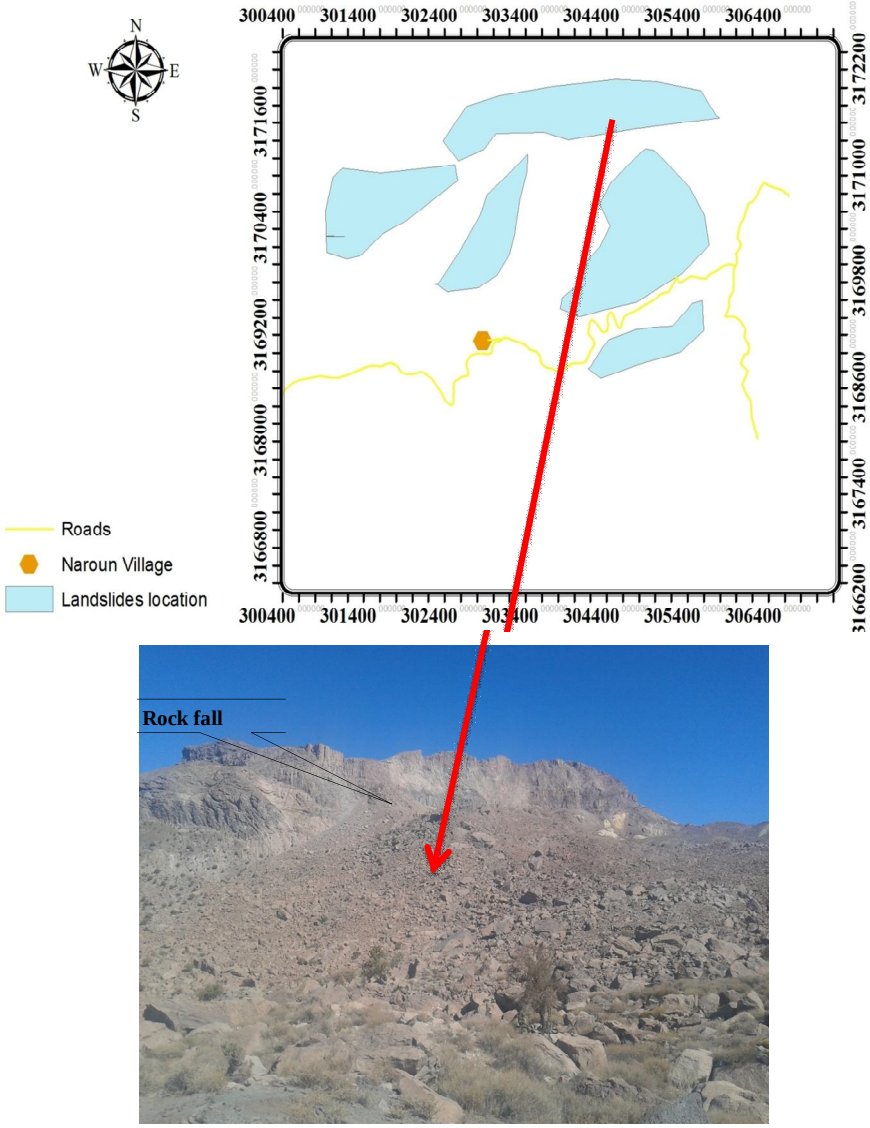

Fig.10. The Landslide location Map of *Naroun*

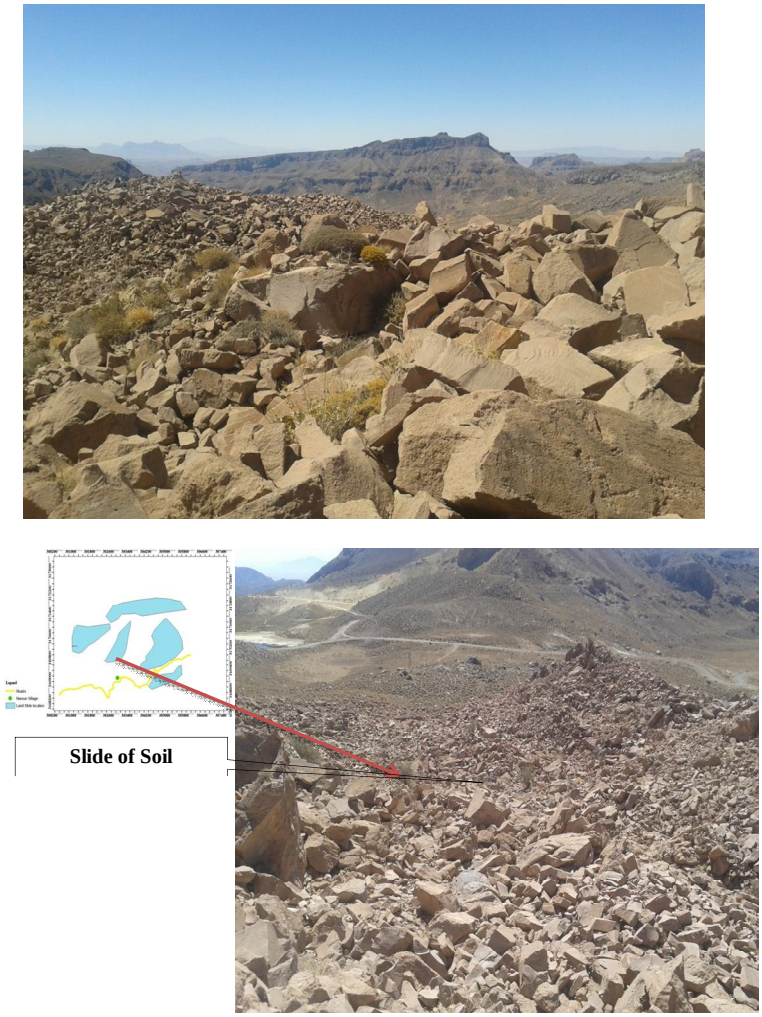

Fig.11. Shows landslide occurrence in the *Naroun* area

Occurrence of rock fall after Saravan Earthquake

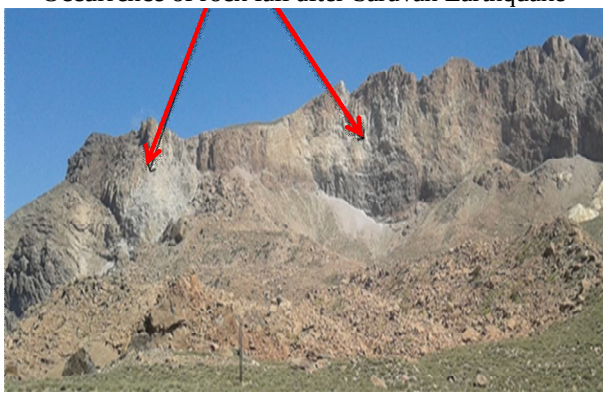

Fig.12. Show the recent rock movement in the area after Saravan earthquake

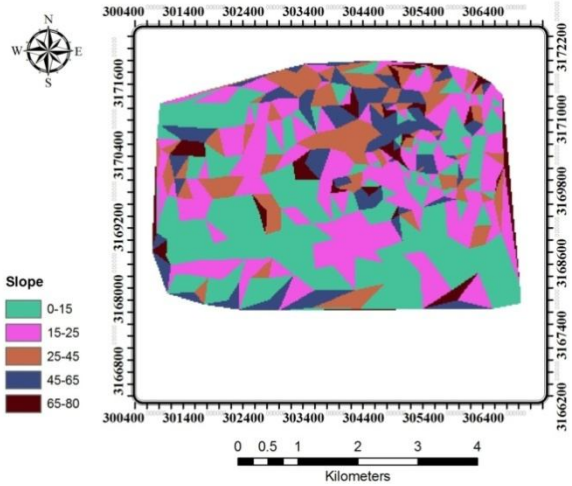

Fig.13. Slopes in *Naroun* Area

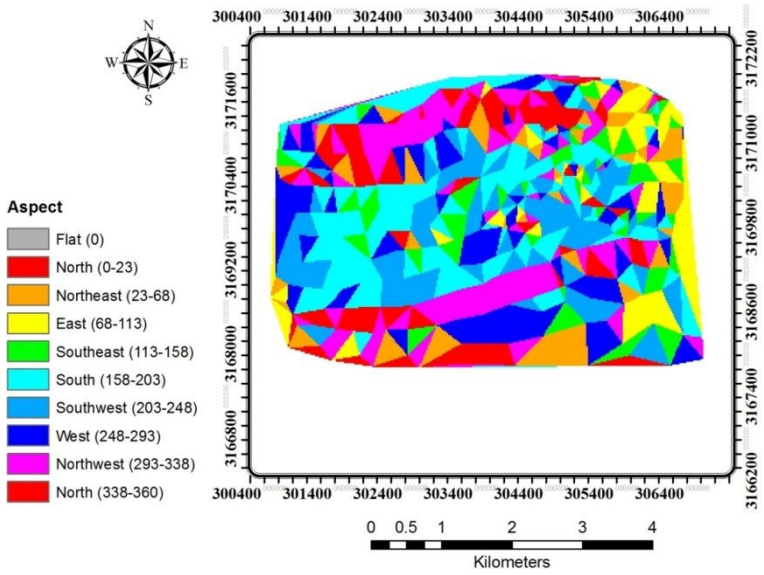

Fig.14. Aspect in *Naroun* area

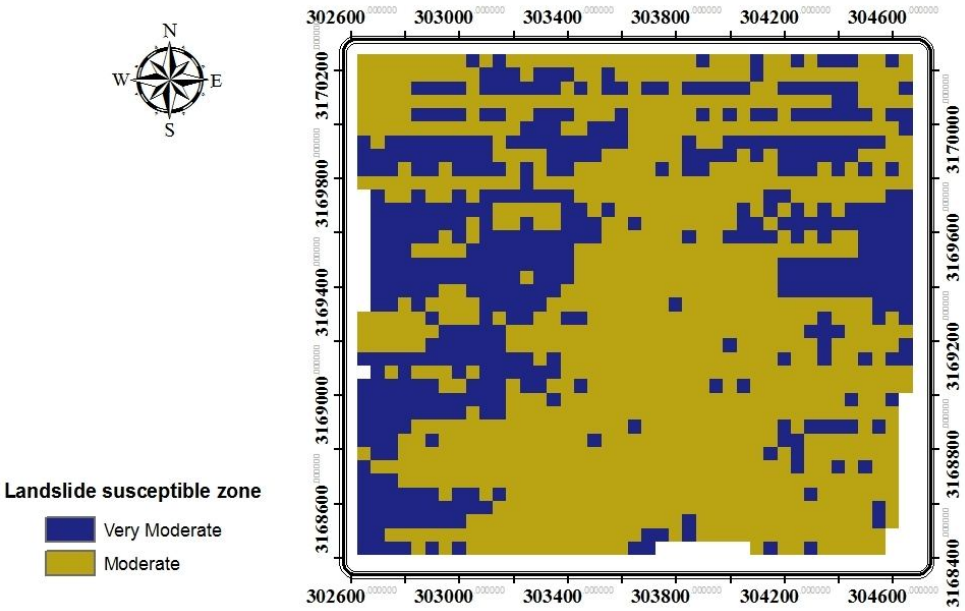

Fig. 15. Indicate the Landslide susceptible zone in the *Naroun* area

Conclusion

Comprehensive analysis of landslide revealed that precipitation, climate, lithology, slope, aspect, elevation, soil and earthquake events along with anthropogenic activities contribute to landslide occurrence in study area. However, such parameters have different level of contribution to landslide base on their density on each section of area .According to the satellite image analysis 430 landslides were inventoried which more than 300 of these landslides are belong to single movement group. The length of recent occurred landslide is about 2600 m and 1400 m in width which occupied an area of 364 square meter and a volume of 45million cube meter. The thickness of displaced materials in the form of slide is 200 meter. Rockfalls slides, flow and debris flow are more common type of landslide in the study area.

Prolongation of joints igdue to shear stress along slides plan, degree of slope, amount of precipitation, lithology characterization are more common factors which accelerate the occurrence of landslide. Most of landslide happened on slope gradient ranging from 10° to 25° as well as due to presence of unconsolidated hydrous tuff layer beneath Andesite layer and manmade activities for road construction. Under Cruden and Varnes (1996) landslide classification susceptible zones divided into two par I and II. Those Landslides indicate only a single effect parameter in a very small or almost in-situ area without any noticeable displacement are belong to part I therefore, in such part of landslides the shear strength is more or less equal to material strength and there is a very uncommon relation between effecting factors and landslides. This harmless part of landslides experience dormant state, confined distribution and single style. Part II live through an active state, advancing distribution and complex style.

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