Review

Analysis of the effect of landslides on the microenvironment in Iran: A case study of Lityan Basin

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The Latian basin is situated at the north east of Iran, and has a social and economical importance for this city and its people. This territory, due to its natural conditions, has suffered from natural disasters including earthquakes, floods and land mass movements, even in recent centuries. The combination of these natural factors as the basic cause, unintelligent human intervention as an intensifying enforcer, has resulted in “landslides” in many parts of the Lityan basin. In this paper, after introducing the Lityan territory with its geographical and natural natural factors in developing the landslides, the impact of unintelligent human intervention as a reinforcing element, disturbance of the environmental balance and the impact of these landslides on the environment. This paper describes one of the geotechnical hazard assessments, landslide, in the area. A hazard zonation map for the Latian basin is established by using historical data.

Key words: Landslide, land destruction, land utilization, landuse changes, hazard zonation, Lityan basin.

INTRODUCTION

Landslide is a global problem and is the most common type of land surface forming phenomenon. This occurred at all geological ages. Landslide is exerting excessive and extensive damage to natural forests, roads, cities, towns, villages and important installations every year. With regard to the abundance of land sliding incidents at some parts of Iran, which had forest coverage before, the investigations done by a number of foreign researchers in this field, to a considerable extent, reflect gloomy prospects in near future, at the destroyed and transformed lands by previously occurred landslides, within the area that is researched in this paper pertaining to the Lityan basin. Landslide is a global problem and is the most common type of land surface forming phenomenon. This occurred at all geological ages. Landslide is exerting excessive and extensive damage to natural forests, roads, cities, towns, villages and important installations every year (Asadian and Arzjani, 2010). Some geologists have suggested that in very rapidly moving rock avalanches, air trapped under the rock mass creates an air cushion that reduces friction. This could explain why some landslides reach speeds of several hundred km$^2$ per hour. If the rock mass suddenly enters a lake or bay, it can create a huge wave that destroys lives and property far beyond the area of the original landslide. (Plummer and Mcgeary, 1991). In the resent, climate change makes the challenge more complicated. First, the impacts of a changing climate are already being felt, with more droughts, more floods,…..and governments, drawing resource away from development. Second, continuing climate change, at current rates, will pose increasingly severe challenges to development. (World Bank, 2010). Landslides cause extensive damage to property, and occasionally result in the loss of life. Specifically, the landslides occurred in Iran. It is therefore necessary to assess and manage areas that are susceptible to landslides in order to mitigate any damage associated with them. Among the many causes, landslides triggered by earthquake-induced are the most common throughout Iran. Landslides may occur as a consequence of a number of determining and triggering factors. In order to assess susceptibility from landslide it is therefore necessary to identify and analyze the factors leading to landslide. The following parameters were used: slope, aspect, curvature, proximity to drainage, lithology, proximity to
major structures, land cover, geomorphologic/Terrain Units (Ghanefar and Tabar, 2005).

Therefore, the main objective of the present study is to consider more comprehensively the landslide hazard of Lityan basin. The correlation between landslide occurrence and geological formation, slope angle, and slope height are investigated. A landslide hazard zonation map is also proposed based on spatial distribution of historical data. The potential use of GIS technology in incorporating geological, geomorphologic, and climatic data is illustrated using Lityan area.

Natural features of the Lityan Basin

Lityan territory is situated at the northeastern of Iran and the southwest of the Caspian Sea. It has a surface area of 69800 km$^2$, and is located between 35° 45′ to 36° 3′ north latitude and 51° 28′ to 51° 52′ in geographical eastern longitude (Figure 1). The eastern Alborz range is located between this territory and Iran inland, as a gigantic barrier. Lityan territory is composed of the following regions: The lowlands, and the mountainous region.

Landslides of the Lityan Basin

Thousands of landslides are triggered by earthquakes in mountainous or hilly area. Such areas are slide prone under the best of conditions, and even a small earthquake will triggered many slope failures (Pipkin and Term, 2000). The combination of serious natural incidents such as abundant rain falls; earthquakes; and unintelligent human interference such as destruction of woodland areas, occupation of unstable foothills, construction of improper roads and inefficient exploitation of mines has increased the occurrence of landslides in the Lityan Basin (Figure 2). Varnes et al. (1984) has categorized the land sliding factors into two groups:

a) The substantial conditions, including geological, geomorphologic, climatic and those due to vegetation coverage.

b) The altering factors favoring instability are loading, earthquakes, slope or altitude change, water level fluctuation, erosion, gradual sedimentation, seasonal fluctuation of subterranean waters. The factor which is more effective towards mass movement is the change in the foothill slope. Figure 3 shows the photograph of a typical landslide affected area in the Lityan region (Figure 4).

Some researches in water drainage basin in Tajan and Sari (East Caspian Sea region) have indicated that the minimum occurrence of landslide belongs to the region of intense forest usage. Its landslide index is put at each 100 km$^2$, is 5.5 landslides. The maximum occurrence is at orchard and farming usage with its index, at each 100 km$^2$, is 118 landslides.

GEOLOGY

The skeleton of the Lityan Basin was formed at the Cambrian, to the present period. At Pleistocene, tectonic and climatic changes as well as erosion had the most effective impact on the external shape alteration (Geological Map, 1990) of the Lityan Basin (Figure 6). Most part of the Lityan territory is covered by present age sedimentation with river, delta and coastal deposits and samples of older stones. The major Msha-Fasham Fault that has an east–southeast and west–northwest direction at the Lityan basin and many other minor faults have great importance in the tectonic processes and seismic coefficients of the Lityan basin.

Based on geological maps recognized units include: red sandstone formations that the Lityan structures have been constructed on it. (Rezaeei, 2008). Youngest alluvial at study area are alluvial fans and old and young alluvial terrace, undivided quaternary alluvial deposits. Tuff units and Limestone and clay marls due to water infiltration and weathering have good potential for landslide (Vahdati, 2001).

THE CLIMATE

Like other regions of Iran, the Lityan territory is exposed to continental masses and currents. External factors influencing the weather in the Lityan region include the Siberian anticyclone, polar masses and the Mediterranean cyclones in the cold season and, southwestern Asian cores in the hot season (Asadian and Arzjani, 2010) (Figure 5). The rainfall of the southern regions of Caspian Sea is of unstable type and climatologically stations indicate that the rainiest months of the year are from October to December and the least rainy months are from March to June. Average annual precipitation, about 370 mm and the cold steppe climate profile is seen in the region. It should be mentioned, the precipitation rate in the years after 1380 is much more (Figure 7).

WATER RESOURCES

The most significant water resources of the Lityan basin are rain and snow falls. The probability of snowfall at all months of the year is quite high. At hydrological side, the rate of rain is higher in all rivers. One of the most important and most permanent rivers in Iran’s internal basin is Jajrud river.

The Subterranean waters: The mountainous part of the region, from its geological structure and vegetation coverage characteristics, has no significant appropriate conditions towards forming subterranean water aquifers. But the rivers’ cylinder shape-throws and the sedimentary plains possess more suitable conditions towards forming
water aquifers.
In general, in some areas which have been studied, the control of fountains as well as the waterway trenching towards the main rivers, can be one way for reducing the aggravation of landslides (Morgan, 1988).

LOADING ON THE FOOTHILLS

Sedimentation process and concentration of water that have resulted from precipitation at suitable foothills would cause a mass increase, weight and stress on the foothills and would enhance the intensification of water penetration, at clay stones and soils. This would result in the decrease of the resistance. Loading caused by unintelligent human actions can aggravate this process. By erection of heavy buildings in recent years and increasing the load on the foothills of this region by other means such as transportation, the equilibrium of the foothills is disturbed (Figure 8).

Native architecture, in recent years at Lityan basin, has undergone extensive changes some of which can be termed as unintelligent human intervention that can add to the feasibility of landslides due to erosion. The occupancy of unstable foothills as a result of increased population, especially the rural population, and the utilization of the cement blocks, iron beams and heavy raw materials of building in general, has increased the foothills loading. This aggravates sliding and other mass movements. Vulnerability of old houses in case of land slide has decreased and its repair is easier than heavy buildings with new style (Figure 8), (Riazi, 1995). In Lityan basin, design and construction of roads has been made without considering the hydrological, geological and topographical interrelation and without attention to its pros and cons. This is again unintelligent human interaction. This results in sloping of the foothills and thus increasing the latter's instability. Construction of improper roads at some sliding foothills can result in deformation of the foothills and creation of horizontal cleavages on the moving foothill surface. The abundant precipitations in some years have been an important cause, or first cause for landslides, the instability of forest lands and the large numbers of landslides even at cultivated lands. Figure 9 clearly indicate that destruction of forests and other unintelligent human interventions are the severe aggravating factors for the phenomena of landslides.

Though the natural causes for landslides have an increase or decrease that are rather small and almost beyond the human control, what is most worrisome is that the increase in the unintelligent human interventions is not natural but clearly a societal, governmental and even an international problem (Alfors et al., 1973).

Using geographic information system (GIS) in geotechnical hazard zonation

Data handling for assessment of geotechnical hazards is often difficult, time consuming and costly (Dhakal et al.,
Figure 2. Landslide of the Latyan basin.

Figure 3. Photograph of a typical landslide affected area in Lityan.

Geographic information system has overcome the many working difficulties associated with data handling (Carrara, 1983). The relative contributions of the landslide causing factors are assessed on the assumption that the landslide hazards will be more likely to occur under conditions similar to those of previous landslides hazards. Hazard maps can be produced from the results of the analyses. One of the most important features of this study is making use of GIS in most stages of the work, including data analyses.
Landslide hazard zonation

Landslide is defined as "the perceptible downward sliding or falling of a relatively dry mass of earth, rock or a mixture of two" (Sharp, 1938). In this study, using existing data, interpretation of aerial photos and field working, were located on topography maps. For preparation of landslide hazard map (scale: 1/250,000) the following procedures was used:

1) Factor maps like geology, topography, land use, landslide inventory, earthquake hazard, rainfall, roads and rivers maps were digitized;
2) The intermediate maps like slope map, slope aspect map and engineering geology map were prepared from base maps;
3) Every factor map is crossed by the landslide inventory map and the total area of polygons having landslide is distinguished;
4) To evaluate the rate of landslide distribution with regard to each factor, surface percentage index (SPI) was used. This can be defined as:
SPI = \left( \frac{\text{Surface area affected by landslide for a defined factor group}}{\text{Total area of that factor group}} \right) \times 100 \ldots (1)

Using this formula, the SPI can be investigated and calculated for each individual factor and the susceptibility of the factor can be defined. The main factors influencing instability and other SPIs are indicated in Table 1.

5) In order to evaluate the potential for slope failure, the
weight of each contributory factor was considered with reference to its surface distribution (SPI).
6) From dispersivity of standard deviation of SP numbers, factor maps were weighted; (Table 2).
7) The factor maps overlaying on each other by GIS and 50,000 polygons are built;
8) A value of hazard potential index (HPI) for each of the defined factors was calculated based on the Equation (2).

Table 1. Hazard Potential Index (HPI) values and their Surface Percentages Index (SPI).

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<th>Rate of weighting</th>
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<th>No. of affected unit</th>
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<td>B</td>
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<td>280</td>
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<td>Low</td>
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<td>80</td>
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Figure 8. Altitude based land use of the landslides in the Lityan region.

Figure 9. Landslide in the sloppy area.
Table 2. Distribution of landslide in relation to its factor [SPI: Surface Percentage Index: W=Weight=Rate,G:Group].

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<th>Factor</th>
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<th>Affected area (Km²)</th>
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Where: \( HPI = \frac{\sum_{i=1}^{p} (R_i + W_i)}{\sum_{i=1}^{p} W_i} \)  

(2)
Figure 10. Landslide hazard zonation of Lityan Basin.

that represents the weight of the particular factor.
9) Based on HPI range, three hazard groups are defined (low, medium, and high);
10) Based on HPI and defined ranges, landslide hazard zonation map of the province were provided by GIS. The landslide hazard map is shown in Figure 10.

CONCLUSIONS AND SUGGESTIONS

A framework for analyzing landslide hazard analysis is proposed for Latyan Basin based on landslide records through the use of GIS technology. This should be a useful tool for developing a basic understanding of the distribution of instability. Such a map will also be valuable when planning future development schemes. A good correlation has been shown between the landslide hazard zonation map produced for the Latyan Basin and the actual occurrence of landslides in this region. From the surface distribution of landslides represented by the surface percentage index (SPI) it has been shown that the lithology is the most important factor affecting landslides in the area, where the less resistance rock units such as the acidic volcanic rocks of Late Eocene age and the marlstones, sandstones and conglomerate of Neogene age are very susceptible to landslides. Such incorporation of landslide dynamics analysis with GIS should result in a more reliable landslide hazard map for city planning and its potential misuse can be minimized.

The framework of landslide hazard analysis and the potential use of GIS discussed here should provide a yardstick for further landslide hazard analysis of Latyan Basin. In addition, landslide-dynamics-based numerical simulations should be included in the hazard analysis so that subjective, and potentially bias, expert opinion can be avoided. Such incorporation of landslide dynamics analysis with GIS should result in a more reliable landslide hazard map for city planning and its potential misuse can be minimized.

Certainly, part of the soil at an extensive level as well as part in the agricultural crops and economic damages to the farmers, are not a pleasant matter. There is a need to search for a process, in which, while exploiting nature, it shall also consider the preservation of equilibrium of nature as well as reliable and development.

For attainment of this objective, the following points shall be considered (Sabeti, 1978):

1) Avoiding the cultivation on sharp sloppy lands exposed to sliding and to prevent any disturbance in the natural
coverage of such foothills.
2) Reinforcement of sloppy heel, which is weakened by erection of the roads and loading, and those which are emptied by under-washing by rivers, by providing barrier walls and piling
3) Studying the geological and soil situation as well as hydrological conditions and impact of the forest trees, at soil stability, prior to transformation of lands to gardens. This can lead to intelligent human intervention, in place of unintelligent human intervention. (Asadian, 2010).

REFERENCES