International Journal of Farming and Allied Sciences
Available online at www.ijfas.com
©2013 IJFAS Journal-2013-2-23/1095-1102
ISSN 2322-4134 ©2013 IJFAS

Evaluation and Landslide hazard zonation using LIM model with GIS techniques (case study: Saein watershed. Ardabil)

Elham Nezhadali[1*], Abazar Esmaili ouri[2] and Ebrahim Pazira[1]

1. Department of Agricultural Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
2. Department of Agricultural Engineering, Faculty of Agricultural Science, University of Mohaghegh Ardabili, Ardabil, Iran

Corresponding author: Elham Nezhadali

ABSTRACT: The main goal of studing landslide would be finding ways of reduceing the damage couse abou which necessitates using zonation. This study was done to identify effective factors in landslide and also to identify the regions which have the potential hazard in saeen and it was Landslide Index Method (LIM). In this study using different sources at studies topographic maps, satellite images and knowledge of GIS the following factors were considered to have the main in fluence: geoloyy, slope degree, distance of fault, plasticity of soil, landuse, precipitation, distans from road, stream, slope aspect, hight and degree of annual extraction temperature and then distribution ma of landslide using field reaserch and satellite images was made**.** In LIM eleven effective factors in landslide were evaluated and after obtaining the weight each factors map and the column of final weight of each unit and ultimately algebric sum of eleven factor layers the final weight of the map and zonation of risk and landslide..were..done**.** It was concluded that geologicale factor in model is the first priority and but other factors example slope plasticity, soil height and other factors in model have fined weights and different priorities and the LIM model has more correspondence compert to the condition of distribution in landslide.

Keywords**:** Landslide, Zonation , Evaluation , Hazard , Landslide Index Method (LIM) , Saeen

INTRODUCTION

Scientific and comprehensive study of landslide phenomenon in the world is one of the most important issues due to financial and human damage inflicted on human communities and the environment. The study objectives include achieving optimal safety and economical results in construction projects, such as route selection, highways construction and main and sub-main highland roads, forest and natural pastures development projects in the study group and attention to the stability of area natural slopes (Nasrabadi et al., 2003).

Landslides have an effective role in the destruction of communication roads, degradation of pastures and residential areas and causing erosion and sedimentation in watersheds. Numerous domestic and foreign studies have been already conducted regarding zoning of landslides danger, which include the use of the bivariate and multi-variate statistical methods, (Sarroli, 2001; Mianji, 1999), or a combination of above statistical methods with Mora and Varson methods, Nielsen method, modified Nielsen method (Ejlali, 2003), the weight of variables, the informational value of area density and Nielsen method (Fattahi and Ardakani, 2001), multi-variate regression and informational value, discriminant analysis and weighted least squares (Shirani et al., 2003).

Based on initial estimates, 500 million dollars of financial damage is annually imposed on Iran due to landslides, while irreversible loss of natural resources has not been taken into account (Nasiri, 2005, P. 1). About 35 percent of the landslides in databases have been stimulated and exacerbated due to human manipulation and indiscriminate activities such as wrong road construction, destruction of vegetation and their conversion into low-yielding dry-lands and loading through creation of habitats (Nasiri, 2005).

(Zare ,2011) with examining factors affecting the occurrence of landslide and its hazard zonation in Vaz basin with regard to geological factors, road, slope, drainage, lands use, precipitation, slope direction, height and fault, zoned the basin using hierarchical analysis method, and the results showed that the geology has had the most influence in the area. (Mohammadi , 2010), in a study in Haraz basin, in the north of Iran, performed the zoning of landslide using the methods, including confidence factor, informational value and hierarchical analysis process in GIS environment, and the results showed that models of confidence factor, AHP and informational value provide the most accuracy in preparing risk maps of the landslides, respectively. (Noiee, 2011) used LIM model for zoning the landslide danger in Givi Chai watershed basin, and the results showed among the obtained information layers, the levels of precipitation, elevation, low vegetation, soils with high permeability, east-facing hillsides, geology and land use, slope and finally the linear elements are respectively the factors affecting the occurrence of landslides.

(Uttar et al., 2011) studied the landslide susceptibility zonation using GIS and Rs in Kan-Betoa region, India and examined the factors, including geology, land use, land cover, drainage, slope, plant species and the soil types in the studies area; their results showed with management of land slope and use, planning for the lands would be possible. (Aiello ,2005) mentioned the factors of lithology, height and slope of the area Sadou in Japan as the main causes of landslides occurrence, and using AHP model and logistic regression, he examined the sensitivity in the area. The results revealed more accuracy of AHP method in classification of landslide susceptibility in the region.

Zoning in the study area was performed using the model of landslide index method with an acceptable accuracy in the area. The development of Geographic Information System (GIS) has made the use of mentioned method in areas with high expansion and is used as a solution for data management and designing.

The purpose of this study was to review and evaluate the factors affecting landslide occurrence and the impact of each of the factors as well as determining that which influence has been more, and also, the LIM model evaluation in the studied area and identification of areas with high risks.

Location and characteristics of the study area

Sain area range with an area of 198 square kilometers is located in the western part of Ardabil province, which is one of the main upstream areas of Balghali Chai. The studied region is of mountainous areas that the steep slopes, lithology and the difference in height evidenced such a situation. The region soil has a xeric moisture regime. This moisture regime is in the Mediterranean climate. It has cold and humid winters and hot and dry summers. In this moisture regime, there is surplus reserve water causing leaching that can reduce the soil shear strength and provides conditions for landslides. The area soil has Mesic temperature regime. The average rainfall is 331 mm, and geologically, the studied area is composed of igneous and pyroclastic rocks.

MATERIALS AND METHODS

Landslide Susceptibility Mapping

For landslides mapping, initially, the satellite images should be examined carefully, which needs high surface resolution; but, the most important task of mapping the landslides distribution is related to field visits, so that all marked areas on the satellite images were visited by field observation and questionnaire completion and areas not related to landslides were excluded. Approximately 5.56% of the area surface was engulfed by landslides (Fig 1).

Preparation of informational layers

Due to different performance of geological units to tectonic processes in the region and other conditions, this factor plays an important role in developing the sensitivity map to landslides. Geological map of the area was used for providing the lithological mapping. Formations in the region in terms of sensitivity to landslides are classified in four potential classes, including Mr pumice stones units with too much potential, Mpr-Pr trachyte- andesite and limestone rocks with high potential, Qal-Qt1-Qv-Mtr-Qta alluvial terraces with average potential and Mrpe-Qt-Qb1 perlite and alluvial lava with low potential (Fig 2).

To provide topographic factors mapping (slope, slope direction, elevation), Digital Elevation Model with a grid size of 20 m was used, and topographic maps were used for preparation of digital elevation model.

Satellite images and topographic maps were used in preparation of land use mapping that the gardens have the highest landslide percentage in the zone, which provides the conditions due to be located on the moderate slopes. Mapping of linear elements (roads, streams, faults), four buffer zones were considered for distancing the linear elements, and the slides percentage in each of the buffers varies with respect to linear elements. The landslides association with space from the fault is upside down.

The soil plasticity percentage remarkably influences the stability of hillsides by changes in Atterberg moisture content in the area, and to have soil plasticity, the moisture of samples collected from the area was determined by Casey Grande method.

Landslide Index Method (LIM)

In LIM model, for zoning these movements (landslides), a large number of qualitative and quantitative variables based on their detection and weighted values can be considered. In this model, the qualitative variables can be made quantitative, and changing the variable, i.e., taking the natural logarithm, the weight of different variables may be included in the calculations, which is one of the advantages of this model compared to other zoning models. For example, the weighted values for a specific lithology unit in the lithology map or a specific unit of slope map is defined as the natural logarithm of ratio between landslide density in that unit and landslide density in the entire drainage basin that the weighted values usually range between positive and negative numbers, which respectively indicate higher and lower stress of studied variables (Van Woston, 1995, p.82).

This model is based on the natural logarithm (Ln) of landslide density ratio of each unit of functional layers to the entire basin landslide density that the result of this ration is achievement to the weight of each functional layers unit. The LIM model is based on the following equation:

$$Lnw_1 = Ln\left[\frac{Densclas}{Densmap}\right] = Ln\left[\frac{Npix(si)/\,Npix(N_i)}{\sum Np_i x(s_i)/\sum Np_i x(N_i)}\right]$$

In this method, initially by obtaining the frequency of sliding pixels of unit of factor layers and the frequency of whole pixels per unit, the landslide density per unit (Densclas) is calculated and after the calculation of frequency of slipped pixels in the entire basin and the whole basin frequency, the landslide density in the entire basin (Densmap) is obtained, and finally, the natural logarithm of the ratio between landslide density per unit of each functional layer and sliding density in the entire basin are calculated; then, the final weight of each layer functional units, with positive and negative range in a separate column is resulted (Tables 1 to 11). The column of units final weight in the table resulted from matching the landslides distribution map and functional layers is connected to the functional layers data table, and by use of the information in this column, the weighted layers of factors affecting landslides are made. The final map is obtained from their sum. Sum of 11 weighted factor layers results in the final weighted map (Map fw) based on the following equation:

$$mapf_w = slop_w + geo_w + landuse_w + ...n_w$$

Then, the final weight map was divided into five classes, including very low potential, low potential, moderate potential, high potential and very high potential due to the range of weight changes of pixels and based on changes in histogram curve, and the zonation map of landslide occurrence hazard was prepared for the basin (Fig 3).

Results and review of landslide susceptibility maps

To become aware of the results accuracy, the landslide susceptibility map produced by using LIM method was matched with landslide distribution map, and the results showed that the regions with very high susceptibility encompass 75.74% of regions with landslide risk, and there is about 15.18% of regions with high sensitivity in the area; also, low and very low potentials have low sensitivity of landslides in the region.

RESULTS AND DISCUSSION

In this research, a comprehensive study was conducted to identify the risk of landslide and prepare landslide susceptibility mapping in the area, and results obtained by LIM model showed that the volcanic rocks (Rhyolite, Rhyodacite, trachyte and basalt) have the highest potential for landslides, which is due to their clay marl texture and having seams and gaps or bulk state resulting from tectonic movements or due to contraction. The relationship between landslide and the distance from the fault is reverse. The lower the distance to the fault, the more would be the likelihood of landslide occurrence due to comminution of rocks by the fault. The slope layers more than 22.20% have landslides. In very high slopes, the soil does not accumulate to the extent that the soil slips, and in the low slopes, the resisting forces such as friction of soil are higher than driving forces such as gravity. Thus, the highest rate of landslides occurs in moderate slopes. Most of the landslides have occurred in the vicinity of gardens, miscellaneous lands and rural areas. The results can be justified as such that the gardens and countryside due to their improper construction, located at critical slopes and formations susceptible to landslides, have the conditions for landslide events.

Eastern slopes have the most landslides rates. It can be stated that eastern directions provide the conditions for the occurrence of landslides by locating in the moderate slopes as well as having relatively high humidity. The average elevations have the maximum landslide occurrence. Such a result shows that precipitations occurred in the area have been mostly as rainfall, which provide the conditions for landslides. However, with increasing height, the precipitations are mostly as snow and the frost phenomenon occur in the region. In conditions of reduced moisture in the formations, the process of soil formation slows down. At lower altitudes, huma intervention exacerbates the sliding conditions. Around the roads and waterways, the landslides rate is relatively high. The roads and regional roads change the region slope balance and stability, and due to traffic in pathways, there is a high pressure on the lower formations of the roads. River erosion in the region also makes the equilibrium of river slope unstable. According to the study of parameters and landslides distribution maps, it can be concluded that the LIM model has an acceptable accuracy for hazard zonation of landslides in the Sain area.

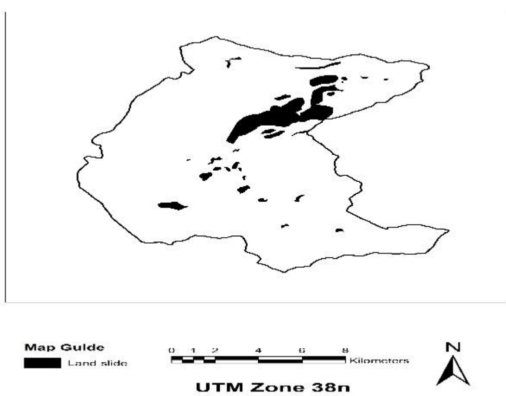

Figure 1. Landslide distribution mapping

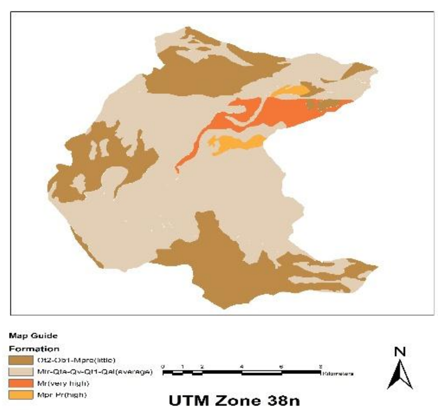

Figure 2. Landslide stones sensitivity map

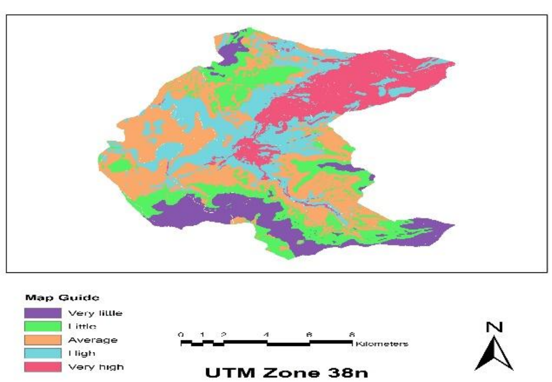

Figure 3. Zonation map of landslide using LIM mode

Table 1. Geological Units

Row	Geological Units	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	Mr	489485	28337	0.0578	26693	1834	0.077	0.162
2	$Mpr - pr$	489485	28337	0.0578	7812	3657.5	0.468	2.091
3	$Mtr - plat - Qta$ $Qac - Qt_1 - Q_n$	489485	28337	0.0578	296102	1923.25	0.0704	0.197
4	$Qt_2 - Qb_1 - mrpe$	489485	28337	0.0578	160423	1923.25	0.011	-1.65

Table 2. Elevation Unist

Row	Height Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	1595.60-1904.82	489485	28337	0.0578	76210.08	18525	0.243	1.436
2	1904.82-2166.80	489485	28337	0.0578	127911.57	8961	0.07	0.191
3	2166.80-2695.05	489485	28337	0.0578	285358.29	855	0.0029	-2.992

Table 3. Slop Units

Row	Slope Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	0-5.6	489485	28337	0.0578	200849.40	3940	0.0196	-1.081
2	5.6-12.13	489485	28337	0.0578	153830.45	10054	0.0653	0.122
3	12.13-20.22	489485	28337	0.0578	93026.86	8500	0.0913	0.457
4	20.22-45.43	489485	28337	0.0578	41292.96	5846	0.1415	0.895
5	45.43-79.67	489485	28337	0.0578	480.26	6	0.0126	-1.539

Table 4. Slope direction Units

Row	Slope direction Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	F	489485	28337	0/0578	81471/04	5167	0/0634	0/092
2	N	489485	28337	0/0578	162150/22	10248	0/0632	0/089
3	E	489485	28337	0/0578	82749/83	5440	0/065	0/117
4	S	489485	28337	0/0578	81044/14	2472	0/0305	-0/639
5	W	489485	28337	0/0578	82064/70	5011	0/061	0/0538

Table 5. Land use Units

Row	Land use Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	Grassland	489485	28337	0/0578	320025	20228	0/063	0/086
2	Agriculture	489485	28337	0/0578	150960	4392	0/029	-0/689
3	Miscellaneous lands	489485	28337	0/0578	3455	697	0/201	1/246
4	Gardens	489485	28337	0/0578	13983	2959	0/211	1/294

Table 6. Road Units

Row	Distance from the Road(M)	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	0-50	489485	28337	0/0578	45591	2761	0/0605	0/0456
2	50-100	489485	28337	0/0578	41264	2751	0/0666	0/1417
3	100-150	489485	28337	0/0578	37370	2559	0/0684	0/1683
4	150-200	489485	28337	0/0578	33447	2359	0/0705	0/1986

Table 7. Stream Units

Row	Distance from the Stream(M)	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	0-50	489485	28337	0/0578	65346	3537	0/0514	-0/066
2	50-100	489485	28337	0/0578	61608	3550	0/0576	-0/0034
3	100-150	489485	28337	0/0578	57408	3348	0/0583	0/00861
4	150-200	489485	28337	0/0578	52449	2990	0/0570	-0/0139

Table 8. Fault Units

Row	Distance from the Fault(M)	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	0-50	489485	28337	0/0578	16701	2417	0/144	0/912
2	50-100	489485	28337	0/0578	16461	2206	0/134	0/840
3	100-150	489485	28337	0/0578	16183	2034	0/125	0/771
4	150-200	489485	28337	0/0578	15716	1937	0/116	0/696

Table 9. soil plasticity Units

Row	Soil plasticity Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	10/85-14/61	489485	28337	0/0578	56841	8095	0/142	0/898
2	14/61-17/93	489485	28337	0/0578	216692	7085	0/032	-0/591
3	17/93-21/10	489485	28337	0/0578	100679	5956	0/059	0/020
4	21/10-23/97	489485	28337	0/0578	73567	5309	0/072	0/2196
5	23/97-29/72	489485	28337	0/0578	41563	1890	0/045	-0/250

Table 10. Precipitation Units

Row	Precipitation Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	344/913	489485	28337	0/0578	49521	8831	0/1783	1/126
2	365/121	489485	28337	0/0578	167332	15806	0/0944	0/490
3	385/329	489485	28337	0/0578	200228	3613	0/0180	-1/166
4	405/537	489485	28337	0/0578	62444	96	0/0015	-3/651
5	425/745	489485	28337	0/0578	9966	0	0	0

Table 11.Temperature Units

Row	Temperature Classes	Area Whole Frequency	Land slide Frequency	Land slide Density	Whole Frequency	Land slide Frequency per Unit	Land slide Density per Unit	Unit Final Weight
1	3/507	489485	28337	0/0578	9966	0	0	0
2	4/673	489485	28337	0/0578	62444	96	0/0015	-3/651
3	5/838	489485	28337	0/0578	200228	3613	0/018	-1/166
4	7/003	489485	28337	0/0578	167332	15806	0/094	0/486
5	8/169	489485	28337	0/0578	49521	8831	0/178	1/124

REFERENCES

Alimohammadi S, Shtaei SH, Parsaei L. 2009. Evaluating performance models for landslide hazard zonation Seid Kalateye Ramian Watershed.Journal of Soil and Water Conservation Research , Vol .

Ashis K, Ravi P. 2005. An approach for GIs – based statistical landslide susceptibility zonation – with a case study in the Himalayas.

Aykut A. 2012). A comparison of landslide susceptibility maps produced by logistic regression, multi- criteria decision, and likelihood ratio methods:a case study at izmir, Turkey.Landslide, volume9, Number 1, pages 93-106.

Behnaifar A, Ghanbarzadeh H, Mansouri M. 2009. Landslide hazard zonation and instibility range to AHP methods and Probability.(Case study :Abriz Watershed,northe slopes Binalood.)Islamic Azad University of Ahar.

Chugh K, Timothy D. 2005. Permanent seismic deformation analysis of a landslides.

Esmaili A , Ahmadi H. 2002. Mass movement hazard zonation in the Germi Watershed and offering a regional model .M.Sc. Thesis ,University of Natural Resources ,Tehran University.

Lee s , Ryu JH , Won Js , park HJ. 2004. Determination and application of the weights for landslide susceptaibility mapping using an artificial neural network . engineering geology , 71: 289-302.

Mosafaei J, Oingh M.2009 .Comparison of empirical models for landslide hazard zonation (Alamut stream Watershed). Journal of Water and Soil Conservation , No4 .

Noei B ,Madadi A ,Esmaili A. 2009. Landslide hazard zonation with using LIM model (Case Study : Givi Watershed , Ardabil). Geomorphology.

Nagarajan R, A muklerjee, A Roy and MV klier. 1998. Temporal remote sensing data and GIs application in landslide hazard zonation of part of wetern ghat , India . Int. J. remote sensing , vol 19 , No . 4, 573-585.

Pradhan B. 2011. Soil erosion assessment and its correlation with Landslide events using remote sensing datd and GIS:a case study at Penang Island ,Malaysia .

Rostaei SH. 2000 . Research on the dynamics of the Earth causes landslide occurrence using morphometric methods in Ahrchay Watershed.PhD thesis, University of Tabriz.
Shariatjafari M. 1996 . Landslide (foundations and principles of natural slope stability) , structural Publications.
Sidle R.1995. A distributed slope stability model for steep forested basins , water resource research , vol . 31 , No 8.
Varnes DJ . 1984. Landslide hazard zonation . a review of principle and practice , unexco , paries , G3 pp.
Yalcin A. 2008. GIs- based landslide susceptibility mapping using analytical hierarchy process and bivariated statistics in ardesen (turkey) : camparisons of result and confirmations , catena, 7Z, 1-12.