European Online Journal of Natural and Social Sciences 2015; www.european-science.com
Vol.4, No.1 pp. 39-49
ISSN 1805-3602

Flood Hazard Zonation using Spatial Multi-Criteria Evaluation (SMCE) in GIS (Case Study: Omidieh-Khuzestan)

Mina Arianpour[1] and Ali Akbar Jamali [2*]
[1]Department of GIS & RS, Yazd Science and Research Branch, Islamic Azad University, Yazd, Iran; [2]Department of Watershed MGT, Maybod Branch, Islamic Azad University, Maybod, Iran.
*E-mail: jamaliaa@maybodiau.ac.ir

Received for publication: 12 August 2014.
Accepted for publication: 06 January 2015.

Abstract

This study aims to discover the risk reasons, effective in flooding and the flood-susceptible areas. The researcher uses GIS and SMCE to identify the watershed of Omidieh and Bidboland 1262.25 Km^2 area. So, the researcher first examines the causes affecting flooding. These reasons included: slope, land use, geology, erosion rates, soil texture, average annual rainfall, drainage density and vegetation of the area. Then, after describing data collection, Boolean and Fuzzy rules standardized the reasons in the SMCE model. Analytic hierarchy process (AHP) determined the weight of each case. The next step was to integrate GIS layers by designing a criteria tree which resulted in the composite index map with fuzzy values (from 0 to 1). As a result, areas with values closer to one, equal to 466.025 Km^2, were flooding-susceptible areas. The results show that about 62% of zonation area runs zero-risk while the remaining areas have a higher potential of flooding in a Northeastern – Southeastern strip. This higher risk is because of less time focus, higher slope, and lower permeability of surface ground. Low vegetation, closeness to oil and gas installations and residential areas are other reasons. The potential for more flooding included 13% low risk, 23% moderate risk and 2% high-risk. To control and reduce the risk of flood damage, officials should take special measures.

Keywords: flood hazard zonation, Iran, Omidieh, spatial multi-criteria (SMCE).

Introduction

With developing crisis management in the world and in Iran, being aware of the crisis-developing capacities can play an important role in managing their financial and life risks. Floods bring about much damage in different parts of the country each year. Today, because of the rapid growth of population and spreading residential areas in high-risk regions, the study of floodwaters has become much more important. Floods cause wide socioeconomic losses, mainly because of unplanned urbanization, uncontrolled overpopulation and unauthorized constructions. Thus, controlling flood-susceptible areas are necessary for decision makers to plan and perform managerial duties. Because of their importance, many researchers have explored the issues of flood and flood hazard in recent decades. Nosrati (2000) examined flooding in Gavrud using remote sensing and GIS. He decided the western subareas of Gavrud were more apt to flooding because of less concentration time, high slope and low permeability of surface layers of the earth and less vegetation. Kholqi (2002) conducted a research called "applying MCDM methods in setting priorities to subareas for controlling floods in 49 sub watershed of Ken – a Northwest river in Tehran". He inferred that multi-criteria decision method can be effective in watershed management. This method considers various criteria and multiobjective linear programming. Shemshaki (2011) conducted a research called "mapping flood hazard in Golestan Province". He used slope, land use, vegetation, rainfall, drainage density, geological formations, flooding history and physiographic condition for presentation and zonation of flood hazard in watershed subcatchments of the province. Taheri Mashhadi et al (2011) determined the flood - generator areas, and the priorities of water subareas using the HEC_HMS software. They ranked the sub watersheds of Jajrud for their priorities of flood hazard. Saman Badii Zadeh et al (2012) studied the hydraulic criteria and vulnerability analysis in urban flood hazard zonation using multi-criteria decision making techniques and weighted index AHP, and divided the potential of flooding in Gorgan into five different classes. Parastar and Esfandiari (2013) looked into the reasons affecting flood hazard and crisis management in upstream Yamchi Dam using GIS, slope causes, lithology, and distance from streams and rainfall as affecting reasons in flooding. Amirahmadi A. et al (2013) used the flood hazard zonation ANP model as a multi-criteria decision making techniques in Islamabad-e Gharb. Nouri et al. (2013) ranked actions in environmental research with the approach of flood hazard in coastal towns in West Mazandaran using Multi Criteria Decision Making in GIS ranked flood risk mitigation measures. They inferred the change of land use, transforming vast areas of forest and fields to cities and towns, and the wrong uses of forests were the main reasons for interval decrease and intensity increase in Mazandaran. Also, unsuitable urban development, removal of sand from rivers and high population density in the narrow coastal strip could increase flood hazard and losses in western Mazandaran.

In a study to discover the best landfill sites in city, China Chyna, Columbia, Sharifi and Retsios (2006) integrated GIS with Spatial Multi Criteria Evaluation. They standardized and weighted reasons, including the technical characteristics and socioeconomic causes and determined suitable places. To locate parks in Bergamo, Italy, Antonella et al. (2007) used decision support, AHP, overlaying the layers and the criteria tree. In their study in Manshadi in Yazd, Jamali and Abdolkhani (2009) found out decision-making techniques with environmental causes and constraints (linear and polygon) to decide areas susceptible to landslides because of the target location and data type. Fernandez et al (2010) in a research on urban flood hazard zonation Tokoman province, Argentine used GIS and Multi Criteria Decision to get the final flood hazard map. Marufi et al. (2012), in a research entitled "Assessing flood spreading using map overlap index method and fuzzy and Boolean logic in catchments of Poshtekuh Hamadan" decided that overlap index method is the best method because it has the highest overlap compared with other methods. Soo Jun et al. (2012) in a research called "Fuzzy multi criteria approach to flood hazard vulnerability in South Korea" used multi criteria decision making techniques and methods of Fuzzy and Topssis and total weighted index to quantify flood vulnerable locations.

The purpose of this study was to find out the reasons which were effective in creating the flood and flood hazard zonation map of watersheds of Omidieh and to provide more flexible and more accurate for evaluation by decision makers to evaluate the effective reasons influencing occurring flood in the area.

Materials and methods

Conditions in the study area

Watershed of Omidieh that is the location of conducting this study, has 1262.25Km2 area and it is located between North latitude, 30 ^{to} 30 ′56 ″to 31° 01′ 23 ″and east longitude of 49° 26 ′ 22 ″to 49°, 54 ′22 ″in the East Khuzestan province (Figure 1). The average height of basin from sea level is 159 meters and varies from 20 m to 298 m. The general slope of the area is from east to west, and therefore, runoff flow from east to west. The region has warm winters and dry summers. Average annual rainfall is 250 mm, mean annual temperature is 24.5° C and regional climate is warm and dry with Domarten.

In the studied area two units, three types and 24 geomorphologic facies have been identified and separated. The type of the mountain areas in the north and northeast parts is a thin strip at the edge of the area as a whole (as a northeast - southeast bar) and formations include Mishan (Mmn) and Aghajari (MuPlaj) and the total area of these formations are known as the Fars Group which is about 336.90 Km^2. In addition to the mentioned formations, Bakhtyary formation (Plbk) with an area of about 6.36 Km^2in the southern area has covered a small part. A great part of the Basin is covered by formation of Quaternary geology (Cenozoic). A quaternary unit includes Qf2 which is a plain with an area of 919.04 Km^2, which is apparently a suitable place for the project. Vegetation in the area in the plain region mainly consists of bush, trees and shrubs (Department of Natural Resources and Watershed of Khuzestan province, Master Plan of desertification studies of Omidieh, 2004).

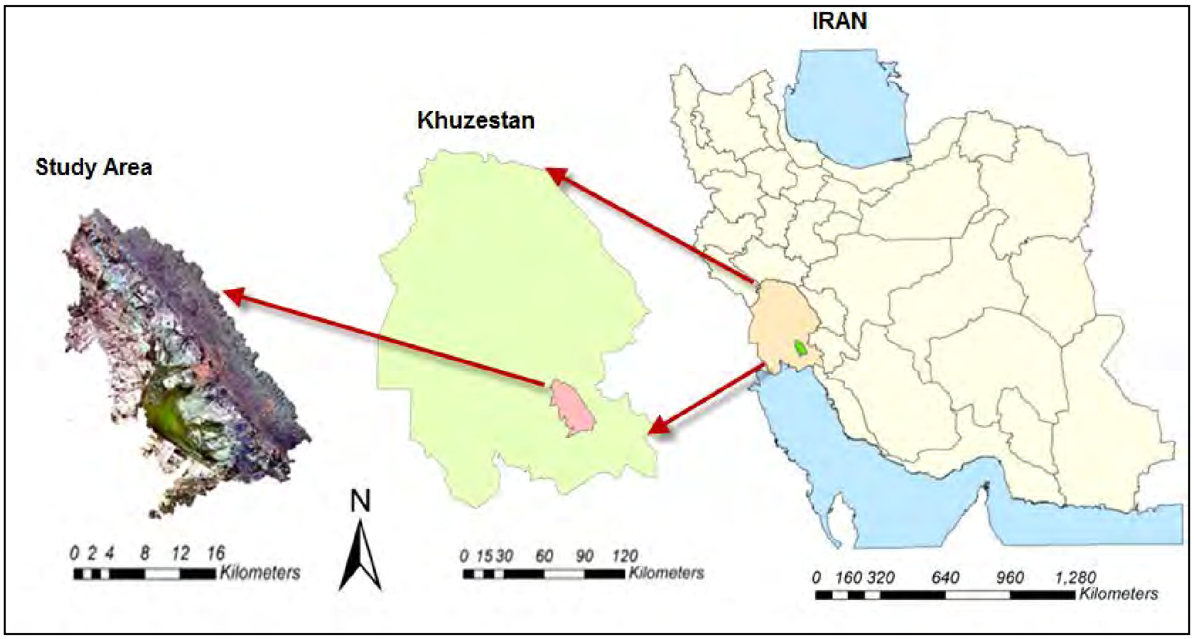

Figure1. Location of study area in Omidieh Iran and Khuzestan province

In this study, using ArcGIS10.1 software from topographic maps of mapping organization of Iran with scale 1:25000 and DGN format for all four corners of the study area, layers of linear features, such as contour lines and streams as well as point features such as towns and villages were extracted. Geological maps with scale 1:100000 and 1:250000 of the geology organization of the country, geological facies maps and geomorphology of the area were prepared; so first these maps were scanned and geo-referenced maps and layers of polygon features and NDVI were created in software ArcGIS10.1, and corrected by the help of satellite images Operational Land Imager (OLI). Google earth satellite imagery was used to check the current land use. First a map of erosion intensity was obtained of the erosion of the EPM model and formula (2), particularly in the estimated amount of erosion; watershed using formula (4, 3) was prepared as well as rainfall map using formula (5), respectively (Figure2 and Table 1). Drainage density map dividing the area into several parts was prepared based on drainage density and their densities were obtained. Drainage density actually represents the characteristics of topography, lithology, soil, vegetation and water movement and is also a determining factor in time. Drainage density as a determinant of water movement time was noticed and the result obtained by dividing the net surface area (formula 1):

Formula (1) $D = \Sigma L / A$

In this equation, L is the length of drainage per kilometer, A watershed area per square kilometer and D density per square kilometer of the stream network. Based on the stream network in the study area, 0.32 square kilometers are calculated.

Formula (2) $Z = y.Xa(\Psi + I^{0.5})$

Z = rate of erosion

Y = coefficient of rock and soil susceptibility to erosion

Xa = coefficient of land use

I = average slope of the watershed

Formula (3) $\mathbf{Wsp = T.H.\pi.Z^{1}.5}$

Wsp = amount of erosion, especially in terms of cubic kilometers per year.

T = the temperature coefficient of the formula (4) is obtained:

Formula (4) $T = \left(\frac{t}{10} + 0.1\right)^{0.5}$

t = Average annual temperature is.

π=pi

H = height of the average rainfall in the area terms mm

Formula (5) Rain map= 197.6+0.66*DEM

DEM = Digital Elevation Model of the study area

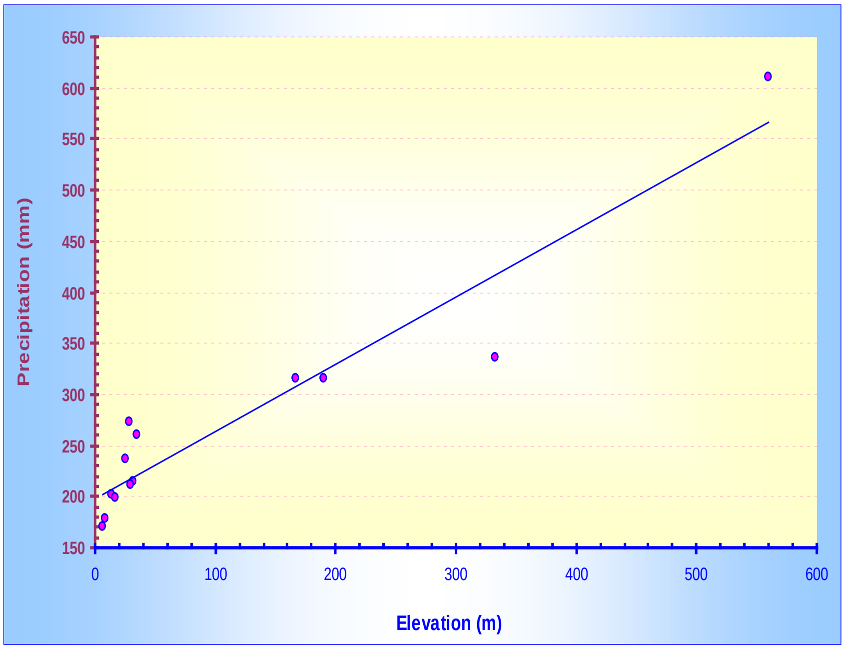

Figure 2: Annual rainfall gradient region (1997-2012)

Tree model of layers integration was designed with SMCE environment by ILWIS 3.3 software, the factors and criteria were selected according to what was mentioned in the Introduction and Background Investigations. Techniques for applying multi-criteria evaluation in GIS spatial data layers used in place and maps in the form of restrictions (in both groups) were selected for incorporation and planning. Criteria and constraints such as spatial gradients were also involved (Figure 3).

Table 1: Distribution of monthly rainfall in the study area

Monthly rainfall **mm**	Percentage of monthly rainfall stations Omidieh	Months
10	4	September
27.5	11	October
55	22	November
40	16	December
33.8	13.5	January
50	20	February
28.7	11.5	March
5	2	April
0.0	0.0	May
0.0	0.0	June
0.0	0.0	July
0.0	0.0	August
250	100	Annual

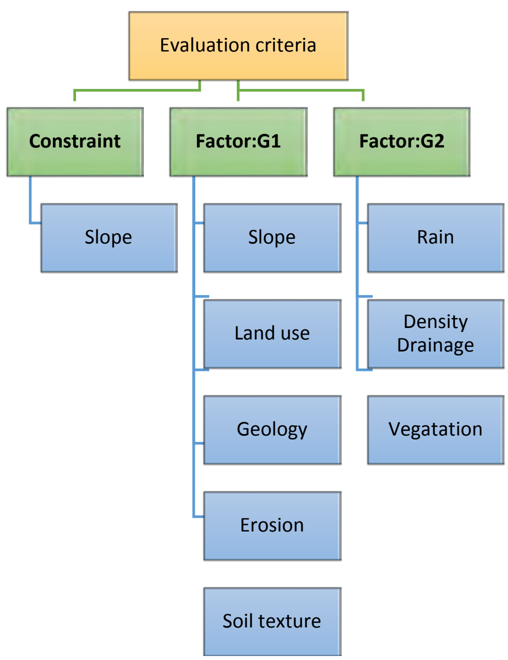

Figure 3: Conceptual model of criteria tree structure for flood potential sites

After gathering information layers, digitizing and raster map all the layers with a georeferencing, the map of factors and constraints were obtained from the raw maps. Slope map of the contour curves and NDVI maps from Landsat imagery Operational Land Imager (OLI) were extracted (Figure 4). Operating constraints such as high slopes are at least equal to that involved in the project in a Boolean (true or false) have been excluded from the program.

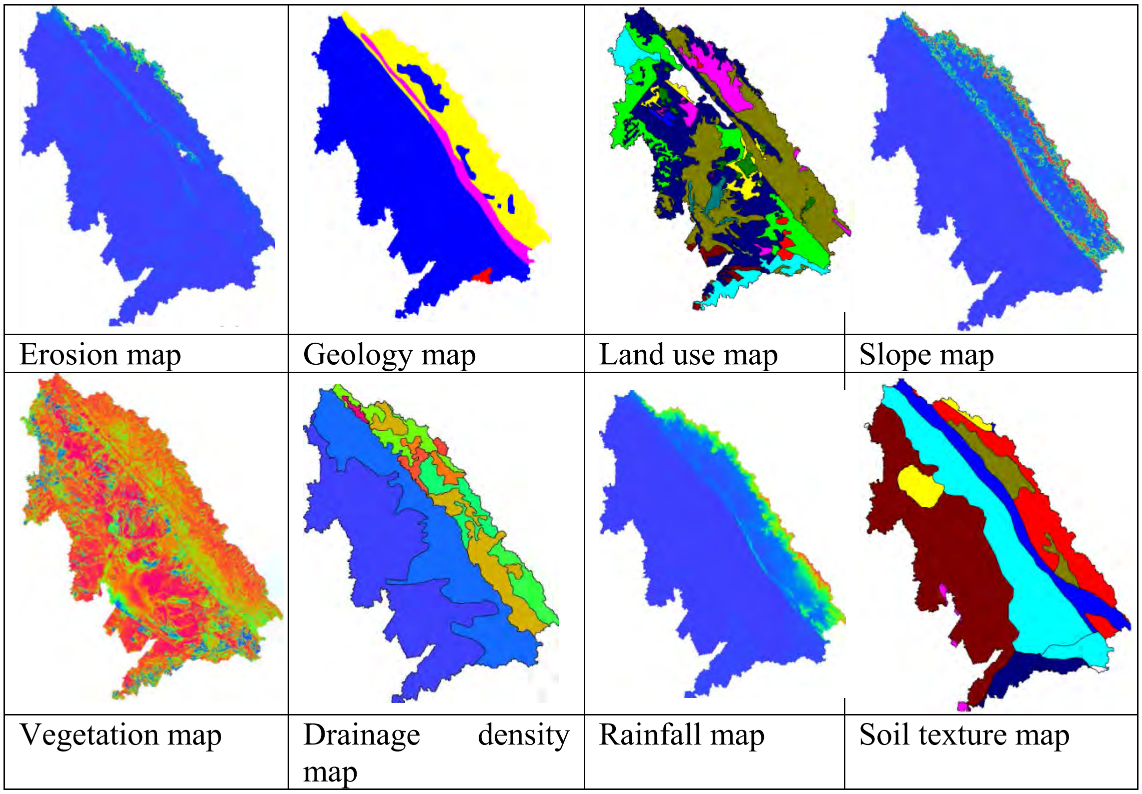

Figure 4: map of the factors and constraints used in the criteria tree model.

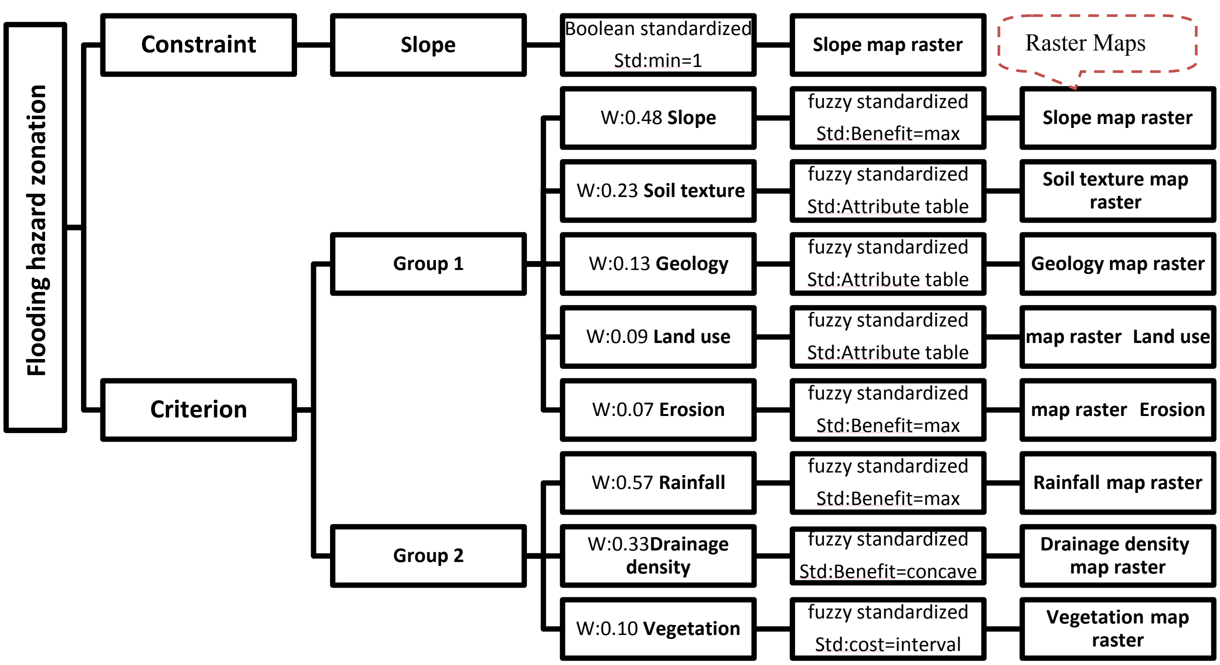

Figure 5. Criteria tree in GIS environment (SMCE in ILWIS 3.31 software). W: Weight by pairwise (AHP), Std: Standardizing methods (Boolean and Fuzzy)

Criteria tree of layers integration was designed with SMCE environment by ILWIS 3.3 software. Then for homogeneity of layers, all layers were converted to 0 or 1 values, in other words, using related rules, Boolean and fuzzy were standardized. To compare the different parameters, it is necessary to standardize values in various ranges and low and high and in the range between 0 and 1. Ways to maximize (standardized by dividing the map values by the largest value in the map) and benefit (Standardizing by dividing map values in a range of values between a specified minimum and maximum value in the map) were used. Also a direct linear function (Benefit) or indirectly (Cost) was used (Figure 5).

The criteria tree used in this analysis in the study area:

On the left, there are the constraints and parameters used. The factors and related weight are according to experts. On the right, there are names of corresponding maps with constraints and factors. This tree has been created with ILWIS software, SMCE model which called multi criteria evaluation techniques in GIS environment (Table2, 3).

Table 2: Standardization map and method used to display slope constraint.

Constraint	Source data (raw)	Derived map	Standardization
Slope	Slope map derived from contour curves of topographic maps	Map of slope by Elimination slopes of less than 1%	Linear function Minimum=1

Table 3. Standardization maps and methods used to display factors

Criterion	Group	Source data (raw)	Derived map	Standardization
Slope	**Group 1**	The slope map prepared by the above method	Slope map with presenting the proper slope for spread	Linear function of cost
Soil texture		Soil map derived from the above method	Soil maps showing flood prone soils	Attribute table
Geology		The geology map prepared by the above method	Geologic map showing flood-prone facies.	Attribute table
Land use		Use the map prepared by the above method	Land use map showing flood-prone land uses	Attribute table
Erosion		Erosion maps obtained from equation 1 and 2	Erosion maps and show places prone to flooding	Linear function of benefit
Rainfall	**Group 2**	Rainfall maps obtained from equation (3)	Rainfall map of the demonstration sites prone to flooding rainfall	Linear function of benefit
Drainage density		Maps of stream density	Drainage density map showing the stream density	Linear function of benefit
Vegetation		NDVI map derived from the above method	Coverage maps showing areas with low risk coverage	Linear function of cost

With the rise in the values of a factor, utility increases that there is a direct or beneficiary relationship or mode of relationship there is a cost. For example, the inverse relation and vegetation or a cost and slope of the direct relationship or benefit in the values are standardized. Weights of factors are also determined by pairwise comparison through the AHP method in software Expert choice and were entered to tree criteria directly. In The analytical hierarchy process, factors are compared pairwise and the relative importance of factors are assessed in determining the suitability of a pixel to a particular type of decision for the decision maker and only two criteria are compared at one time; the relative value of a continuous scale is from 1 to 9.

Care must be taken that incompatibility in weighting has changed from 0 to 0.1 as far as possible. Weights of factors are determined by the analytic hierarchy method (AHP) in subtypes and in two groups of factors with a direct method (Fig.6 and 7). Normal weights of factors (numbers range from 0 to 1), also in the total weight factor group, are calculated and entered integration (Table 4). Constraints due to direct removal are not weighted. For example, the slope over 6 percent is removed (with a value of 0). For example, a slope of less than one percent removal (zero value) is less prone to flooding. Finally, by creating a composite index map (Figure 8) composed of layers overlaying that has values from 0 to 1, the priorities were identified so that each point is closer to 1, the goal has a greater potential for flooding.

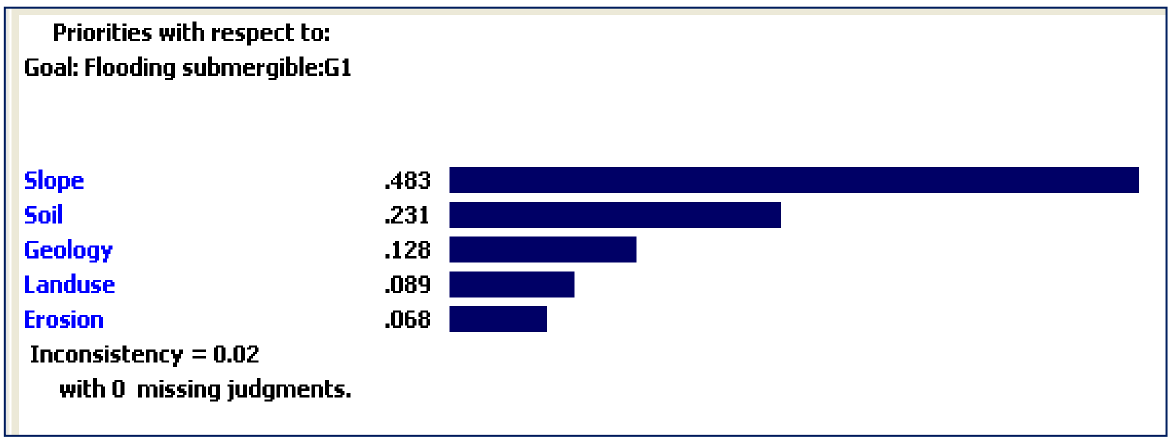

Figure 6. The graphical representation of weighting effective factors (Group 1) in the standard matrix with Expert choice software.

Table 4: Weights used in two groups and factors in groups in the evaluation system

Weight	Group	Weight	Factor
0.50	**Group 1**	0.483	Slope
		0.231	Soil texture
		0.128	Geology
		0.089	Land use
		0.068	Erosion
0.50	**Group 2**	0.570	Rainfall
		0.333	Drainage density
		0.097	Vegetation

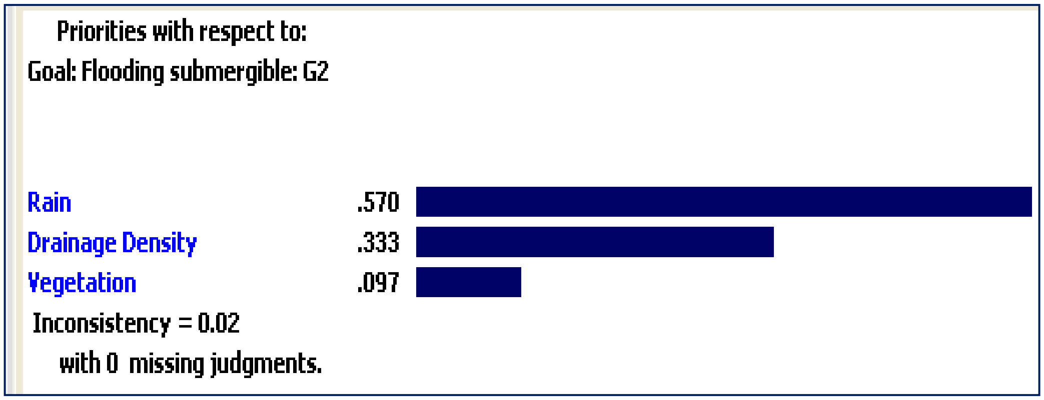

Figure 7. The graphical representation of weighting effective factors (Group 2) in the standard matrix with Expert choice software.

Results

Flood susceptible areas and priority areas were determined in terms of the final map (Figure 8 and Table 5) and the percentage of flood hazard classes (Figure 9). Map areas at risk of flooding probability, valuable information to planners and managers to evaluate the risk of flooding to areas of flood management. Investigate the potential flooding areas on the periphery of the study concluded that the project area (as a northeast - southeast bar) due to less concentration time, high slope, low permeability of the surface layer of earth and less vegetation has a higher flooding potential.

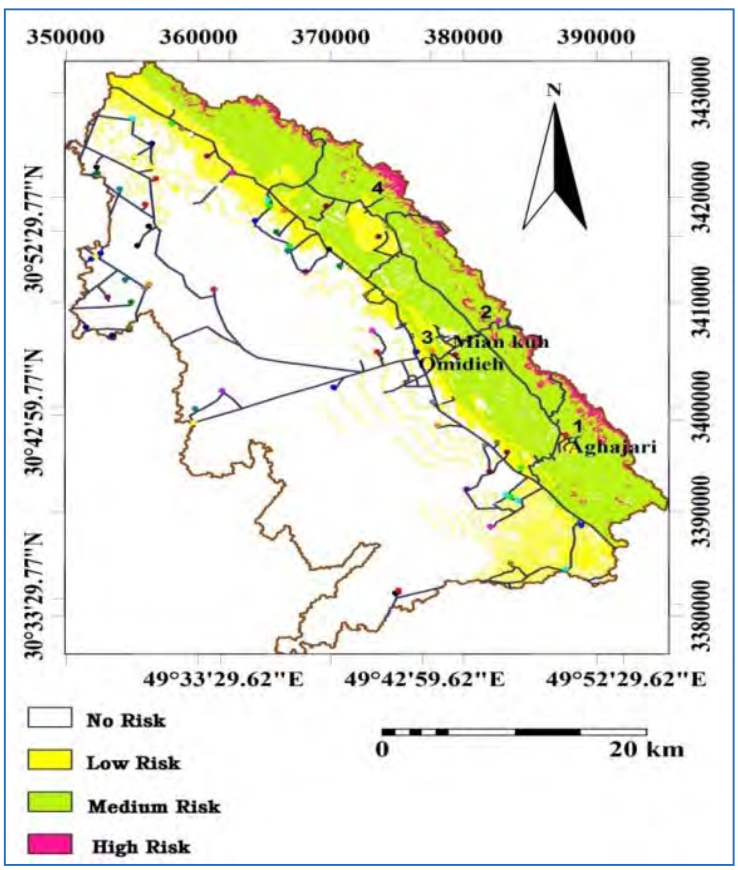

Figure 8. Spatial priority map flood-prone areas in the study area

Table 5. Priority areas where flooding in the study area

Area/km2	Spatial priorities of flood spread
2390.5	First priority
28654.5	Second priority
15557.5	Third priority
46602.5	Total

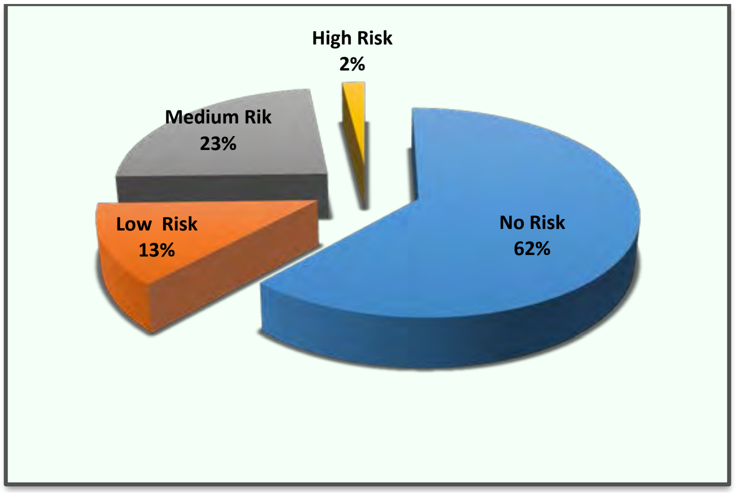

Figure 9: Percentage of risk classes Flooding in the study area

Discussion and conclusions

This study is consistent with the results of previous researches. Because different factors and constraints were removed by multi-criteria analysis techniques no human error was included and the final maps were accurately obtained because the integration of raw data has been avoided. For example, Nosrati et al (2000) investigated the parameters effective in flooding, and concluded that due to less time focusing and high slope and low permeability of surface layer of the earth and less vegetation, the area had great potential of flooding. Also Amir Shemshak and et al (2011) in their study used weighting and factors such as slope map, land use, vegetation, rainfall, drainage density, geological formations, history of floods and physiographic conditions, demonstrated zonation and flood hazard. Saman Badii Zadeh et al (2012) using multi-criteria decision making techniques and AHP weighted, potential flooding index in Gorgan was classified into five different classes. Meanwhile, in four parts based on first and second priorities to proximity to residential places, oil and gas facilities, animal husbandry and poultry farms, factories and workshops, electric transmission lines, pipelines, roads, irrigation and Shahid Rajaie's drainage network, and farm lands and gardens were graded from 1 to 4 so that the regions grade 1 and 2 cases mentioned above, to a greater extent in these areas are subordinate. The model presented in similar regions in Iran.

Acknowledgements

This research was supported by the Iranian National Gas Company, Bid Boland gas refinery and is hereby acknowledged by the aforementioned organization.

References

Amirahmadi, A., Jahanfar A., Parsyany K. (2013). ANP model's ability in flood hazard zonation (case study catchment Islamabad West), Fifth Conference on Water Resources Management in Iran.

Antonella, Z., Sharifi, A.M., Andrea, G.F.(2008). Application of Spatial Multi-Criteria Analysis to Site Selection for A Local Park: A Case study in The Bergamot Province, Italy. Journal of Operational Research, 158, 1-18.

Badii Zadeh, S., Benefit, A., Aramaic, A.(2012). Hydraulic parameters and vulnerability analysis in urban flood hazard zonation using multi-criteria decision making techniques, the third national conference on combating desertification and sustainable development of wetlands Iranian desert.

Fernandez, D.S., Lutz, M.A.(2010).Urban flood hazard zoning in Tucuman Province, Argentina, using GIS and multicriteria decision analysis, Engineering Geology, 111(1–4), 90–98.

Jamali, A.A., Abdolkhani, A.(2009). Preparedness AgainstLandslide Disasters with Mapping of Landslide Potential by GISSMCE (Yazd-Iran), International Journal of Geoinformatics, l5(4), 25-31.

Nosrati, M., Jabbari I.(2000). Zonation flood watershed Qavrud, master's thesis, University of Kermanshah, pp. 110-130.

Nouri, J., Mansouri, N., Kialashaki, A., SadeghiPouya, A.(2012). Research priority environmental measures for flood risk with the approach of in the West Coast cities of Mazandaran, Planning and Environmental Management Third Conference.

Omidieh(2003) Comprehensive Plan of desertification. Consulting Engineers Arian Green Saman, Department of Natural Resources and Watershed Khuzestan.

Parastar, S., Esfandiari F. (2012). Survey of effective factors flooding and disaster management in Yamchi Dam using GIS, First National Conference on Geography, urbanization and Sustainability.

Ramshirdam, A - Axis Dare Abbas,(2003) Phase II small flood control dams. Arvand Sabzab Engineering, Department of Natural Resources and Watershed Khuzestan.

Saaty, T.L., Vargas L.G.(1984). Comparison of Eigenvalue and logarithmic least squares and least squares methods in estimating ratios. Mathematical modelling, 5, 309-324.

Sharifi,M. A. , Retsios, V.(2006). Site selection for waste disposal through Spatial Multiple
Criteria Decision Analysis. Warsaw, Poland.

Shemshak, A., Ghasemi AR., Mohammadi Y.(2011). Flood hazard map of Golestan Province, Thirtieth Meeting of Geological Sciences.

Taheri Mashhadi, H., Zinati Shajae T.(2011). Prioritizing of flooding in the basin hydrologic units Jajrood Third Conference on crisis disaster comprehensive management.

Soo Jun, K., Sung Chung, E., Gyu Kim, Y. (2013). A fuzzy multi-criteria approach to flood risk by considering climate change impacts, Expert Systems with Applications, 40(4), 1003–1013.

Zhaoli, W., Hongliang, M., Chengguang, L., Haijuan,S.(2012). Set Pair Analysis Model Based on GIS to Evaluation for Flood Damage Risk, Procedia Engineering, 28, 196–201.