Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 5, p. 119-127, 2014
http://www.innspub.net

RESEARCH PAPER

Locating flood spreading suitable sites for groundwater recharging through multi criteria modeling in GIS (case study: Omidieh-Khuzestan)

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Article published on November 11, 2014

Key words: Spatial Multi-Criteria Evaluation, SMCE, Aquifer, Flood spreading, Omidieh.

Abstract

Use of geographic Information systems (GIS) to determine the suitable potential sites for flood spreading is not possible without using decision making systems. The aim of determining flood spreading suitable sites is enhancing ground-water in arid and semi-arid areas through spatial multi-criteria evaluation (SMCE) in GIS for combating with drought and dryness. Thus the area of Omidieh with 1262.55 Km^2 was selected. In this study, economic factors such as, proximity to the road, the village and streams were considered. The natural limiting factors of slope, land use, geology, NDVI[1] and soil texture were also involved so that in the spatial multi-criteria evaluation the factors ، Boolean and Fuzzy were standardized using related equations. Weight of factors was determined by the ranking method. In the next step, integration layers were performed by designing criteria tree in the ILWIS[2] software environment which was resulted in the composite index map with fuzzy values (0 till 1). Consequently, suitable sites for flood spreading with values closer to1, had an area equivalent to 139.8425 Km^2 and three priorities covered 11.7% of the area. This region has appropriate overlap with the implemented region of the flood spreading scheme; on the other hand, obtained evidence and reasons indicate suitability by selecting the SMCE model for this project.

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[1] Normalized Difference vegetation index

[2] Integrated Land and Water Information Systems

Introduction

Artificial recharge aquifers is extremely important, and what has key role in the success of the mentioned operation is to locate suitable flood spreading sites. The importance of the issue has made many researchers benefit from the new science and technologies in this field and do research; some of them are mentioned here. By weighting variables affecting flooding and table feeding and using Boolean logic models, overlapping indices and fuzzy logic models in GIS environment prioritized areas prone to flooding for controlling the flood spread in the 6 cities of Khorasan Razavi province. Their results showed that the fuzzy model has the best adaptation compared with other models for identifying and locating suitable sites for flood spreading (Dadrasi Sabzwari and Khosrovshahi, 2008). In the Miankooh watershed area of Yazd, the appropriate sites of flood spread through tree modeling and spatial multi-criteria evaluation techniques, Boolean Logic Models, Fuzzy logic models was determined and overlapped Index with vegetation density factors, geomorphology, land use and slope degree along with spatial - economic factors and decision making of suitable areas for flood spreading that are consistent with the implemented sites or flood spreading (Jamali *et al.*, 2010). Determining the suitable area for flood spreading in the Garebayegan watershed of Fasa plain in Shiraz using AHP hierarchy process and criteria of slope, height, land use, geomorphology, geology, portability, alluvium thickness, drainage density and electrical conductivity as a Pairwise comparison and factors' weight and parameters (Faraji Sabokbar *et al.*, 2011). In order to locate suitable areas for flood spreading and artificial recharge of aquifers in the north of Andimeshk, after selecting influential indices in locating these sites such as slope, permeability, thickness of alluvium, portability, and flooding, electrical conductivity, a classification for each of these indicators was prepared and then was integrated these indicators using Boolean logic and weight overlay index (Asgharipour Dasht Bozorg *et al.*, 2011). To determine suitable areas for implementing flood spreading project in the Meikharan area of Kermanshah, economic - social, Hydrogeology, soil, physiography, vegetation and geology factors was investigated by using hierarchical process and geographic information system and stated that the geology factor with normal weight of 0.293 is the most effective one in locating and proposing the final map of suitable sites for flood spreading by integrating layers (Shari *et al.*, 2012). In reviewing performance of GCA FAHP methods to locate flood spreading the Drainage basin Gerebaygan, changed 9 indices of the slope, height, land use, geomorphology, geology, portability, thickness of alluvium, drainage density and electrical conductivity into data layers and classified them (Faraji *et al.*, 2012). In his study ،he has developed a decision making support system for the selection of suitable locations of flood spread in Iran. First determined the effective factors and rated their importance in determining the best place of flood spread using GIS & RS tool and expertise of specialists in AHP method and specified the best place for flood spreading in Chandab Varamin area (Kheirkhah Zarkesh, 2005). In a study to determine the best landfills around China Chyna located in Columbia by integrating Spatial Multi Criteria Evaluation with GIS, standardization and weighting of factors, including the technical, social and economic factors determining the location of appropriate sites (Sharifi, Retsios, 2006). In order to select the location of building park in the province of Bergamo, Italy, decision support system, AHP method was used, and tree branch model and layers integration was created (Antonella *et al.*, 2007). In Gavbandy region, southern Iran, using the factors slope, permeability, underground water depth, quality of alluvial sediments, land use, weighting with Boolean and fuzzy concluded that 12% of the area is the best place and 8% of the area are on average good areas and most of suitable areas are located on alluvial fans (Ghayoumian *et al.*, 2007). In their study of flood spreading sites of the Samal drainage basin in Bushehr, basin slope maps, land capability, surface permeability, and thickness of Quaternary formation, thickness of alluvial in GIS environment was used and based on fuzzy logic models introducing the most appropriate strategy for flood spreading (Alesheikh *et al.*, 2008). By combining stakeholder analysis and SMCE to identify and prioritize landfill sites in alpine mountainous region of Italy, first the relevant criteria, including dust pollution, field of view and availability was specified and then they were integrated and finally the desired map was obtained. The result of that study revealed three priorities that are close together, are located in the most northern point in the area (Davide, 2009). In their study in Manshad area of Yazd, decision making techniques with relevant environmental factors and limitations was investigated (Poly sack and manuscript) to determine areas susceptible to landslides according to the target, status of the location and data type (Jamali, Abdolkhani, 2009). In the district C Vagangay of India, to determine suitable areas for artificial feeding, the research was conducted by benefiting land use maps, geomorphology, vegetation and TM satellite images and SRTM, and nutrition prone areas based on the number of parameters and classification of final maps in three classes were identified (Balachandar *et al.*, 2010). In a research entitled application of the overlay weighting model and the Boolean logic method to optimally locate feeding the ground water in the northwestern region of Egypt, by comparing both methods concluded that the overlay weighting method gives more accurate results (Peter *et al.*, 2011). In a research entitled assessment of flood spreading sites using the overlay index map, fuzzy and Boolean logic method in drainage basin Poshtkooh Hamedan mountain concluded that overlay index method due to the highest level of overlay compared with other methods is the best one. (Marofi *et al.*, 2012). In an investigation entitled RS, GIS in the artificial recharge of ground water in south India stated that deep understanding of the structural details of geological and hydrological conditions of the study area is essential for the success of the applied method (Murugiah *et al.*, 2013).

Regarding the distribution and extent of the area suitable for the construction of flood spreading systems and several major contributing factors in the designing and implementation of relevant plans influencing on the discharge of wells in the region, performance evaluation of flood spreading systems in terms of the applied criteria in the construction of the locating in different areas of the country is essential in order to achieve optimal patterns. Having a variety of factors such as wide alluvial plains and rocky and flood-prone mountains, watershed of Omidieh area is suitable due to various factors like the vast alluvial plains and rocky mountains and flood-prone position to propose and implement flood spreading sites.

The aim of this study is determining flood spreading suitable sites for enhancing ground-water in arid and semi-arid of the areas through spatial multi-criteria evaluation （SMCE） in GIS in order to combating with drought and dryness and flood mitigatigation.

Materials and Methods

I. Study area

Watershed of Omidieh that is the location of conducting this study, is 1262.25Km2 area and it is located between North latitude, 30^{o} 30 '56 "to 31^{o} 01' 23 "and east longitude of 49^{o} 26 ' 22" to 49^{o} 54 '22" in the East Khuzestan province (Fig. 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, the runoff flows 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^{2}in 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 Km², which is apparently a suitable place for the project. Vegetation in the area in the plain region mainly consists of bushes, trees and shrubs (Department of Natural Resources and Watershed of Khuzestan province, Master Plan of desertification studies of Omidieh, 2004).

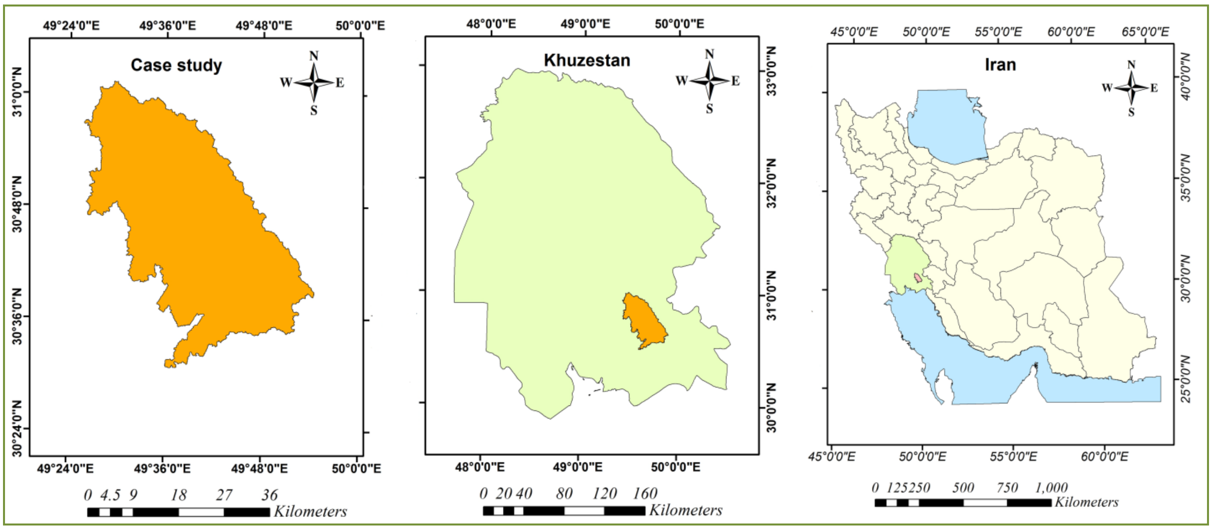


Fig.1. Location of study area in Omidieh Iran and Khuzestan province.

II. Method

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 with the help of satellite images Operational Land Imager (OLI) (Landsat 8). Google earth satellite imagery was used to check the current land use. Designing spatial multi-criteria analysis model as a criteria tree in SMCE ILWIS 3.31 the choice of factors and criteria was done according to what is stated in the introduction and background of the investigation. For applying multi-criteria evaluation of GIS, spatial layers data was used and maps used in the form of constraints, environmental factors and social, economic factors were selected for incorporation and planning. Selection of social, economic factors reduces the cost associated with the implementation of the plan related to people, so that closeness to the road reduces transport cost, equipment and forces; and closeness to village reduces transportation cost of local forces for implementing tasks and thus increases the benefit of plan to cost (Fig. 2).

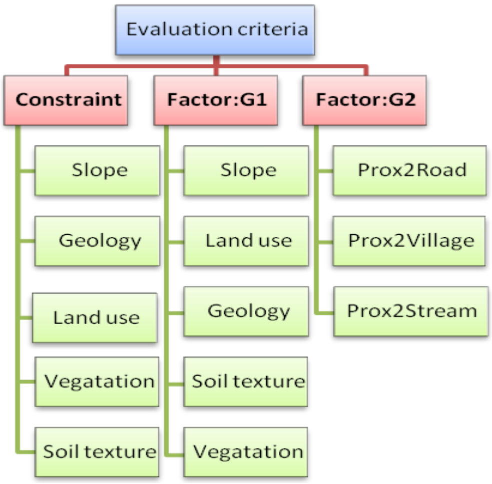
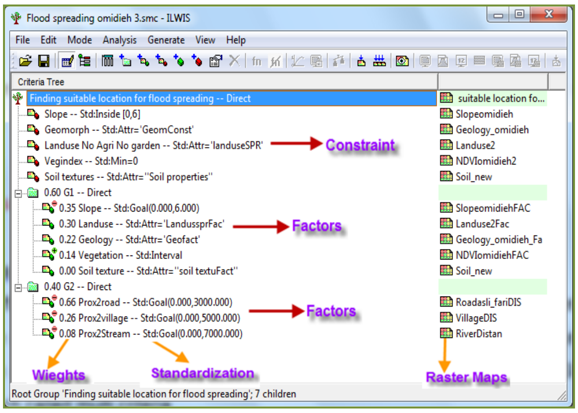


Fig. 2. Criteria tree structure used in the evaluation and selection suitable areas of flood spreading.

After gathering information layers, digitizing and Rastering map all the layers with a georeferencing, factors map and constraints were obtained from the raw maps. The slope was obtained from contour curves, proximity to roads, villages and streams were obtained by creating the distance area around them in software, (Fig. 3) and of constraint factors such as exposed stone facies of geological facies with high-gradient, lands with heavy soil texture, clay and salt, residential areas, irrigated agriculture, and wetlands that are not involved in implementing the plan were excluded from the program in case Boolean (true or false).



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Finding suitable location for flood spreading -- Direct          suitable location fo...
    Slope -- Std:Inside [0,6]                                    Slopeomidieh
    Geomorph -- Std:Attr='GeomConst'                             Geology_omidieh
    Landuse No Agri No garden -- Std:Attr='landuseSPR'           Landuse2
    Vegindex -- Std:Min=0                                        NDVIomidieh2
    Soil textures -- Std:Attr="Soil properties"                  Soil_new
    0.60 G1 -- Direct
        0.35 Slope -- Std:Goal(0.000,6.000)                      SlopeomidiehFAC
        0.30 Landuse -- Std:Attr='LandussprFac'                  Landuse2Fac
        0.22 Geology -- Std:Attr='Geofact'                       Geology_omidieh_Fa
        0.14 Vegetation -- Std:Interval                          NDVIomidiehFAC
        0.00 Soil texture -- Std:Attr="soil textuFact"           Soil_new
    0.40 G2 -- Direct
        0.66 Prox2road -- Std:Goal(0.000,3000.000)               Roadasli_fariDIS
        0.26 Prox2village -- Std:Goal(0.000,5000.000)            VillageDIS
        0.08 Prox2Stream -- Std:Goal(0.000,7000.000)             RiverDistan
Root Group 'Finding suitable location for flood spreading'; 7 children
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Fig. 3. Criteria tree in GIS environment (SMCE in ILWIS 3.31 software).

Tree model of integrated layers was designed with SMCE environment by ILWIS 3.31 software. Then for homogeneity of layers, all layers were converted to 0 , 1 values, in other words, using related relations, were Boolean and fuzzy standardized. To compare the different parameters, it is necessary to standardize values in various ranges, low and high and in the ranges between 0,1 ways to maximize (standardized by dividing the map values by the largest value in the map) and the 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 inverse Function (Cost) was used.

The criteria tree used in this analysis in the study area
On the left, there are the used factors and constraints. 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 is called multi criteria evaluation techniques in GIS environment (Table 2, 3).

Table 1. Standardization maps and methods that are used to display constraints.

constraint	Source data(raw)	Drived map	standardization
slope	Slope map drived from contour curves of topographic maps	Map of slope by eliminating slopes above 6%	linear function Maximum=0
Geology	Facies map obtained from scaning geological maps	Geological map by removing stone zones	Attribute table
Land use	Land use maps obtained from satellite imagery of Google earth	land use map by removing salt land, residential, wetlands, irrigated agriculture, poor pastures, rock	Attribute table
Vegetation	NDVI maps derived from satellite imagery of Operational Land Imager (OLI) (Landsat 8)	Map of vegetation by removing high low coverage areas and without coverage areas	linear function Minimum=0
Soil texture	Soil texture maps obtained from scanning Soil Science Map	Map of soil by removing lands with saline soil ,high alkalinity, heavy and shallow	Attribute table

Table 2. Standardization maps and methods that are used to display factors.

Criterion	Group	Source data(raw)	Drived 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
Land use		The use map prepared by the above method	Use map with presenting uses appropriate for spread	Attribute table
Geology		The geology map prepared by the above method	Geology map with presenting the proper uses for spread	Attribute table
Vegetation		NDVI map derived from the above method	Vegetation map with presenting the proper vegetation for spread	Linear function of benefit
Soil texture		Soil map derived from the above method	Soil map with presenting the proper soil for spread	Attribute table
Road	Group 2	The roads map derived from topographic maps 1:25000	Road map with presenting the proper distance from roads	linear function of cost
Village		Villages map derived from topographic maps 1:25000	Village map with presenting the proper distance from villeges	linear function of cost
Streams		Streams map derived from topographic maps 1:25000	Streams map showing the suitable distance from the streams	linear function of cost

Table 3. The weights used in two groups and factors in groups in the evaluation system.

Weight	group	Weight	Factor
0.60	Group 1	0.437	Slope
		0.260	Landuse
		0.132	Geology
		0.101	Soil texture
		0.070	NDVI
0.40	Group 2	0.669	Road
		0.243	Village
		0.088	Stream

With the rise in the values of a factor, utility increases that there is a direct or beneficiary relationship, or the reverse states and there is cost relation or mode is established, and the related cost. For example, slope takes reverse or cost relation in the standardizing values. Weight of factors was also determined by pairwise comparison through the AHP method in software Expert choice and were entered into criteria tree directly. In The analytical hierarchy process, factors are compared pair wise and the relative importance of factors is 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.

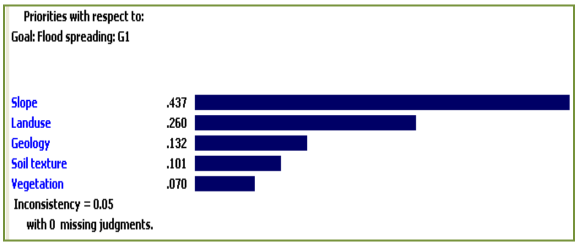
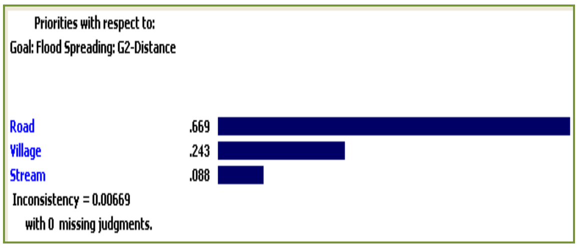


Fig. 4. The graphical representation of weighting effective factors (Group 1) in the standard matrix with Expert choice software.

Care must be taken that incompatibility in weighting has changed from 0 to 0.1 as far as possible. Weight of factors is determined by the analytic hierarchy method (AHP) in subtypes and in two groups of factors with a direct method (Fig 4 and 5). Normal weight of factors (numbers range from 0 to 1), that should also be in the total weight factor group, are calculated and entered integration (Table 3).


Priorities with respect to:
Goal: Flood Spreading: G2-Distance

Road	.669
Village	.243
Stream	.088

Inconsistency = 0.00669
with 0 missing judgments.

Fig. 5. The graphical representation of weighting effective factors (Group 2) in the standard matrix with Expert choice software.

Constraints due to direct removal, are not weighted. For example, the slope over 6 percent are removed (with a value of zero) and less than that is suitable for the flood spreading (Jamali *et al* 2010). Finally, by creating a composite index map (Fig. 6) composed of layer combination that has values from 0 to 1, the priorities were identified so that each point is closer to 1, is more appropriate regarding the goal.

Results

Integration of layers was done in GIS environment resulting in a composite index map and area according priorities (Fig. 6, Table 4) was valued fuzzy. In investigating the factors and constraints, index map and table 4 shows the spatial flood spreading priorities in the area. In fig. 6 local spatial flood spreading priorities in the area is shown. Map of constraint has caused the removal of some parts that in fig. 6 also lacks a specific application and is presented in white. Spatial limits on the slope, removed slopes over 6% (Fig. 6).

Table 4. Priority areas where flood spread in the study area3.

Area/km2	Spatial priorities of flood spread
106.1775	First priority
33.6075	Second priority
0.0575	Third periority
139.8425	total

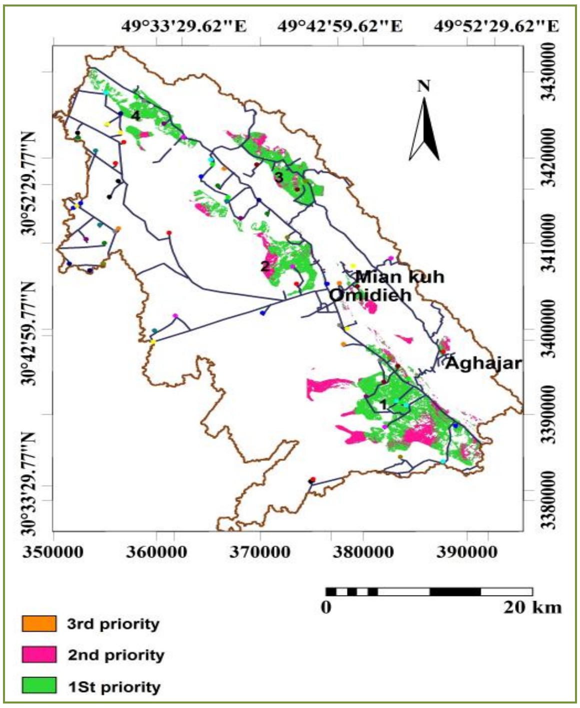


Fig.6. Spatial priority map of flood-prone areas in the study area.

Spatial limits of geomorphologic face removed rock mass areas. Spatial restriction on the land was used by removing the irrigated area that is owned by the rural, residential areas, rock mass, wetlands, marshlands, poor range and salt lands are not involved in prioritizing. Constraints are Boolean standardized and do not have any necessary weighting factors. With the increase of their value, having a positive effect on the choice of spatial priorities, such as slope or vice versa getting away from the road causes fade spatial priority. The composite index map is obtained in the ILWIS software by Multi- criteria (SMCE).

Discussion

Final map of optimal flood spreading (Fig. 6) was determined. Slope as the factor that has the greatest weight in the cost function (-) was entered, meaning that when the slope is greater, it has less value, thus regions with high slope and rock masses were removed, that is consistent with the study by Asghari Poordasht Bozorg *et al.* (2011), Sabokbar *et al.* (2012) on the areas with low slopes are suitable for flood spread and shows the great impact of this factor on flood spread performance. In this study, with multi–criteria analysis techniques, various factors and limitations were used by disposing human error, final maps were obtained precisely since the integration of raw data is avoided. Besides, the first priority in the four areas, based on proximity to the major and minor roads, villages, hand planted forest, rainfed agriculture (fertile lands for agriculture) and range lands were graded from 1 to 4 so that the region with rate 1 was placed in higher priority due to having more advantages.

Flood spread prone areas are mostly in quaternary units in form of alluvial plain (Qf2), and part of Mishan formation. In another study by Hasanpour (2011), Faraji sabokbar *et al.* (2011, 2012), Ghayumyan *et al.*, (2007), Suri *et al.*, (2012) flood spread prone areas were in the quaternary units PLQb, Qscg, Qgsc, Qb, Mn10, the causes of these can be positioned on these units in the margins of the major streams of the basin and, content composed from theses unites from clay, silt, sand, gravel can be referred.

These geology unites at low height, basing with low slope is the result of river sediment deposition. Use of presented pattern in the same area in Iran to find the most suitable sites for flood spreading, leads to the correct use of data and saving time and cost.

Acknowledgments

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

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