Evaluation of Suitable Pressurized Irrigation Systems by Using Analytical Hierarchy Process (AHP) and GIS for Izeh plain area of Iran

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Abstract: The present study describes an innovative methodology to evaluate susceptible regions for pressurized irrigation systems by using Analytical Hierarchy Process (AHP) based on Geographic Information System (GIS) where the Izeh plain (Iran) is selected as the considered area. The model is extendable worldwide and is relatively simple. Several influential parameters are identified considering climate (Cre), labor skills (L ls), topography, system costs (S ec) and etc. They are grouped in two main criteria, namely socio- economic criterion and physical criterion. Each criterion is subdivided into several sub-criteria. A matrix of the pair-wise comparison is used to compare these criteria and sub-criteria and to evaluate them according to their relative importance for region susceptibility. By using GIS for these criteria, geographical layers are obtained for the sub-criteria, leading to determine susceptible region and ranking the suitable pressurized irrigation systems for this study area. The results of this study were shown as GIS maps by using AHP. Localize irrigation system, Gun irrigation system and Linear irrigation system were found to be the best selections for this region, respectively.
[Lamya Neissi, Mohammad Albaji, Saeed Boroomand Nasab. **Evaluation of Suitable Pressurized Irrigation Systems by Using Analytical Hierarchy Process (AHP) and GIS for Izeh plain area of Iran.** *World Rural Observ* 2016;8(4):10-18]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 2. doi:10.7537/marswro080416.02.

Keywords: AHP, GIS, Iran, Localize irrigation system.

1. Introduction

Irrigation technology has the potential to dramatically increase water-use efficiency in crop production in arid and semi-arid regions of Iran. However, due to the increased complexity and variation in irrigation technologies, farmers face the difficult task of making a rational decision when adopting new irrigation methods. This decision-making process consists of a series of actions and choices, over time, through which a farmer evaluates a new irrigation method and decides whether to incorporate it into his ongoing practices. Due to the diversity of social, economic and natural factors influencing the adoption of irrigation technologies, making such a decision is not a simple process. Interference by the private sector (the desire of suppliers to sell irrigation equipment and maximize their profit regardless of appropriateness for farmers) and government polices (subsidized prices, low interest loans and extension campaigns) add to the complexity of the decision process. (Karami and Rezai-Moghaddam, 2002). The present study aims to establish an innovative methodology to determine the susceptible region for the pressurized irrigation systems. It integrates AHP method into a GIS model to select the most susceptible regions for pressurized irrigation systems according to final weight of each system gain by weighting and GIS maps. The methodology uses easy-to-get data from Khuzestan official institutions of Water and Power Authority (KWPA) and available satellite images.

Multi-Criteria Decision Making (MCDM) methods can facilitate the process, because they account for parameters that effect irrigation systems. The MCDM methods deal with the process of making decisions in the presence of multiple criteria or objectives. Analytical Hierarchy Process (AHP) is one of the MCDM methods. Saaty (1977) defined AHP as a decision method that decomposes a complex multi-criteria decision problem into a hierarchy.

The AHP methodology has been applied on the numerous issues of irrigation systems and water resources (Montazar and Behbahani, 2007; Okada et al., 2008a, b; Srdjevic and Medeiros, 2008; Montazar and Zadbagher, 2010). Several MCDA techniques have been used in many fields for site selection and land allocation such as ELECTRE, PROMETHEE, AHP, TOPSIS, AIM, etc. (Behzadian et al., 2010; Conté et al., 2008; Gilliams et al., 2005; Reyhani-Khoram et al., 2007; Zhong-Wu et al., 2006). However, only few of them are integrated into GIS (Al- Adamat et al., 2010; Anane et al., 2008; Kallali et al., 2007; Marinoni, 2004), where Analytic Hierarchy Process (AHP) is the most applied (Anane et al., 2007; Tegou et al., 2010). AHP was established by Thomas Lorie Saaty in the 1970s and used to determine the priority for different decision alternatives via pair-wise comparisons with respect to common criteria.

2. Material and Methods

Study region: The study area corresponds to the Izeh plain. It is located at 'Khuzestan' province at the Southwestern part of Iran northeast of the city of Ahvaz capital of Khuzestan province, 49° 45′ to 49° 59′ E and 31° 46′ to 31° 57′N (Figure. 1). It covers 11080.5 km^2 of surface area. The climate is semi-wet with 656 mm and 1685 mm as annual average precipitation and evaporation at Izeh city, respectively. 24 ◦C reported as average temperature. The elevation varies between 0 m and 342 m, general slope varies from 2-5 percent and some sites have 0-2 percent slope that consider as flat area. After several experiments the soil texture considered to be Loam texture. The economic activities are mainly based on agriculture.

The wells supply the bulk of the irrigation water demands of the region. Irrigation has been common in the study area. Currently, the irrigation systems used by farmlands in the region are furrow irrigation, basin irrigation and border irrigation schemes and the water efficiency is pretty low and it's better to use pressurized irrigation systems to prevent water loss. Considering results of wells water samples and according to diagram of Wilcox, this alkaline water refers to C3S1 class (EC 760 Micromohs/cm and SAR 2) (Khuzestan Water and Power Authority, 2010).

Pressurized irrigation systems such as Solid Set Irrigation System, Gun Sprinkler Irrigation System, Linear Irrigation System, Localized Irrigation System were evaluated for selection of the best irrigation method for Izeh plain.

Methodology overview: To locate the best area susceptible for pressurized irrigation systems, an Analytic Hierarchy Process (AHP) combined with a GIS was used. The methodology involved the following major steps:

(1) Select criteria, sub-criteria and alternatives,

(2) develop a decision hierarchy structure and identify priorities (local weights and global weights) for each decision criterion and sub-criterion using a pair-wise comparison matrix,

(3) apply a consistency ratio to check the accuracy of global weights,

(4) Extract the geographic layers corresponding to each sub-criterion by using GIS.

Criteria selection: Two main criteria were selected to determine susceptible regions for pressurized irrigation systems, which are (i) socio-economic criteria, (ii) physical criteria. These criteria, the derived sub-criteria and the rationale behind selecting them are detailed hereafter.

Establish hierarchical structure

The proposed criteria and sub-criteria indicators include:

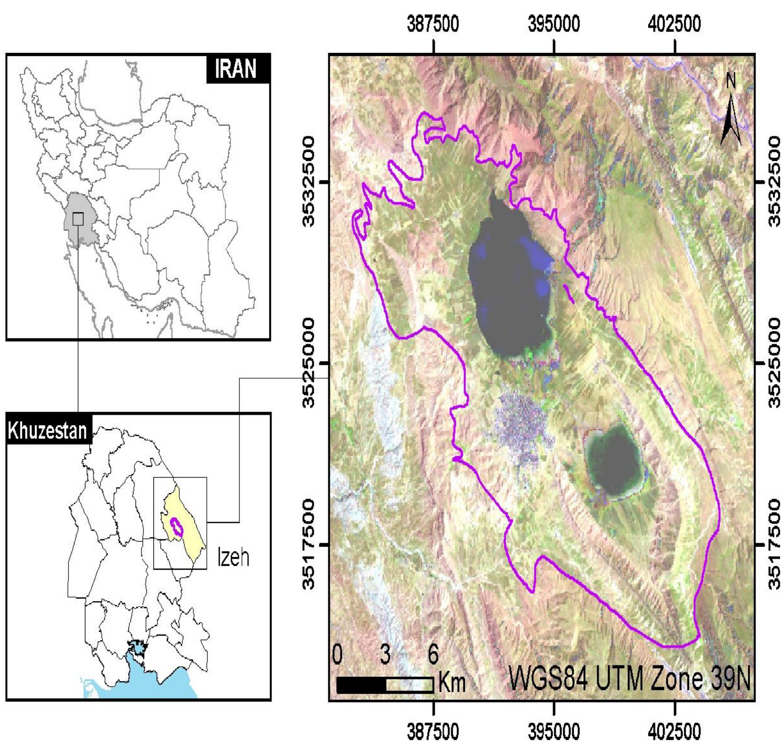

Figure1. Location map of the study area

1. socio-economic: relative acceptability of an irrigation system (Ras), technical support requirements (T sr), system costs (S ec) and labor skills (L ls).

2. Physical: Topography, Water, Climate, Soil, Crop.

Which the Sub-criteria of physical criterion are classified in:

Topography: height difference (L ad), land slope (L so); Water: suspended materials (W sm), sodium concentration (W na), chloride concentration (W cl), biological materials (W bm), availability of water (W aw), EC, pH; Climate: climate of the region (C re), wind speed (W ws); Soil: infiltration rate (I ir), Available water in the soil (AW); Crop: crop density (C cd), crop type (P pk), crop pest (P pd).

Physical criterion: Successful pressurized irrigation system requires a suitable physical medium for an appropriate crop development. The land suitability for irrigation includes soil characteristics and land slopes. Soil texture is determined by the size of soil particles and it affects water storage, infiltration and holding capacity (Asawa, 2008). Soil depth refers to the thickness of the soil materials which provide structural support, nutrients, and water for plants (Scherer et al., 1996). Depth is an important factor that offers a medium to the roots to develop and influences the amount of water available to the crop (Asawa, 2008). According to land slope, it influences runoff and soil drainage and determines the erosion hazard to which the field is exposed (Scherer et al., 1996). Furthermore, farmlands management and irrigation techniques depend on the slope and slope in this study area is almost low.

Socio-economic criterion: Performance assessment methods are often classified into qualitative and quantitative approaches. Some examples of qualitative methods include diagnostic analysis, rapid appraisal, reference methodology, and framework appraisal (Hazell et al., 2001). For evaluating performance of irrigation systems we need to involve Labor skill and technical support in socio-economic criterion. The two mentioned sub-criteria can make clear that the irrigation system can perform good or bad in the study area. Technical support is low and it almost has less global weight in irrigation systems. We need to train and skill the labor for using pressurized irrigation systems.

Data analysis

Analytical hierarchy process and weighting: The hierarchy structure in:

AHP method consists to organize the decision problem in a number of levels. In this case two levels hierarchy structure is developed (Figure. 2).

In order to determine the susceptibility of a given site, a global weight for each sub-criterion is assigned. Weighting expresses the criterion degree of relevance or preference relatively to the others. The process is achieved through the pairwise comparison between the elements for each hierarchical level (Saaty, 1980). Indeed, a pairwise matrix for the main decision criteria is obtained. The pairwise comparison employed a semantic 9-point scale for the assignment of priority values were 1, 3, 5, 7, and 9 correspond respectively to equally, moderately, strongly, very strongly and extremely important criterion when compared with another. 2, 4, 6 and 8 are intermediate values. The assignment of preference values is based upon experts consulting and reviewing technical documents and of international published guidelines. The procedure of calculating local and global weights of each criterion and sub-criterion and alternatives is mentioned hereafter by an example. The final weight for each system is obtained from GIS maps of cited systems in this study.

The AHP methodology says that prioritizing and weighting the criterions should be done firstly. According to fundamental Saaty 's scale for the comparative judgments and by performing pair - wise comparisons of criterions with respect to the object, hereafter the comparison and calculation of criteria in1st, 2nd and 3rd levels in general for Localized irrigation systems as an example (table 1to 8).

The local weights of each criterion were computed by using the geometric mean. After that the local weights should be aggregated and each local weight divides on aggregated local weights in order to normalize the weights. The sum of all normalized weights in each table is equal to unity.

Each matrix consistency is checked out through the calculation of consistency ratio (CR) which is defined as the quotient between the consistency index (CI) and the random index (RI) as follows:

$$\mathrm{CR} = \frac{CI}{RI}$$

The consistency index (CI) is determined using the following quotient:

$$\mathrm{CI}=\frac{\lambda\,\mathrm{max} - n}{n-1}$$

Where λ max the maximum value of eigenvector and n is the criteria number.

The random index (RI) is obtained from a table established by Oak Ridge National Laboratory for matrix with rows going from 1 to 15 (Saaty, 1980). For CR lesser than 0.1, the priorities assigned are considered satisfying, otherwise they are determined not consistent to generate weights and have to be revised and improved. The global weight for each sub criterion is calculated by the multiplication of the local weights of all the hierarchy levels.

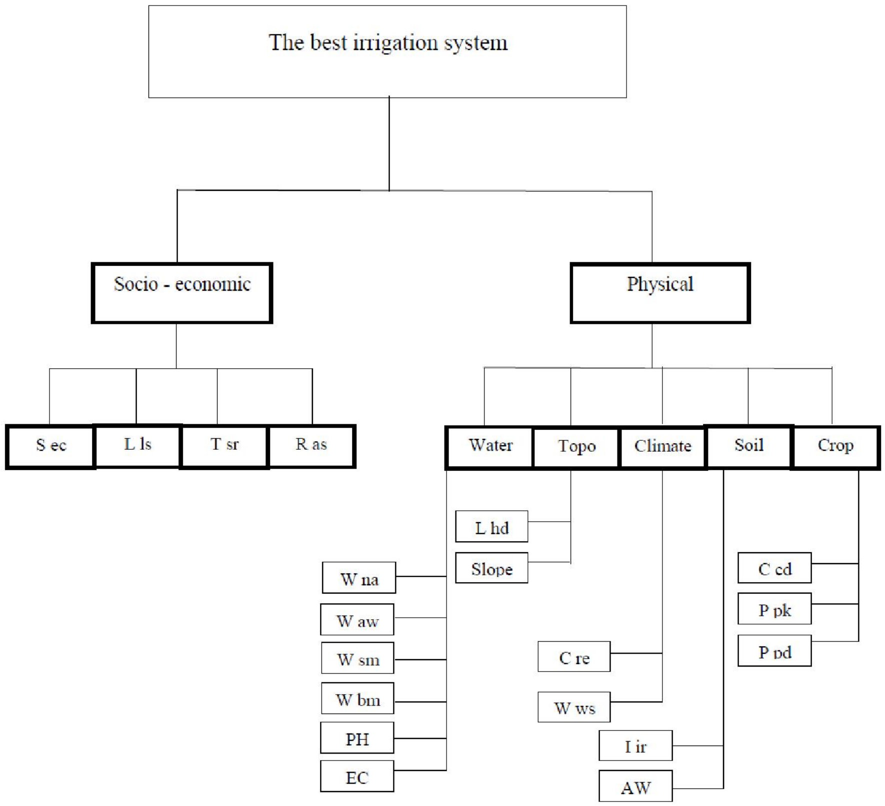

Figure2. AHP structure for selecting optimized irrigation system

Sub-criteria and constraints layering by GIS: Spatial analysis to identify susceptible regions for pressurized irrigation systems starts with representing each selected sub-criterion by a thematic layer in which each point takes a value (0 to 9) which the samples have been gathered in a laboratory or a qualification according to that criterion. In order to layer all the criteria, data are gathered from satellite images and official sources at different available forms (digital and hard copy maps, tables and charts). Then, they are analyzed and treated using GIS and geostatistical tools. Each layer is obtained in raster data model. Spatial data on water characteristics, topography and climate (temperature map) are obtained from “water and power authority’’ of Khuzestan district, which is the Iranian official source of agricultural spatial database. Data are already available in digital format with 1/150,000 scale.

3. Results and Discussion

Table1 illustrates comparison matrix of main criteria for Localize irrigation system as an example. Localize irrigation system is more expensive than other pressurized irrigation systems but quality of water for this system is more important. Therefore, Physical criterion is almost more important than socio-economic criteria.

This procedure of calculating global weights and matrix of each criterion and sub-criterion was repeated for other pressurized irrigation systems.

The final step is to calculate the Consistency Ratio (CR) for this set of judgment using the CI for the corresponding value from large samples of matrices of purely random judgments using the table below, derived from Saaty’s book, in which the upper row is the order of the random matrix, and the lower is the corresponding index of consistency for random judgments (Table9) (Geoff Coyle, 2004).

Table 1. Comparison matrix of criteria in 1st level

effective factors	Socio - economic	Physical	**Global W**
Socio - economic	1	1/3	0.25
Physical	3	1	0.75
			CR: 0

Table 2. comparison of sub- criteria of socio - economic in 2nd level

socio-economic	Tsr	Lls	cost	Ras	**Local W**
Tsr	1	1	1/5	1	0.1250
Lls	1	1	1/5	1	0.1250
cost	5	5	1	5	0.6250
Ras	1	1	1/5	1	0.1250
Global W	0.0313	0.0313	0.1563	0.0313	CR: 0

Table 3. Comparison matrix of sub-criteria of physical in 2nd level

Physical	Topography	Climate	Water	Soil	Crop	**Local W**
Topography	1	1	1/7	1	1	0.091
Climate	1	1	1/7	1	1	0.091
Water	7	7	1	7	7	0.636
Soil	1	1	1/7	1	1	0.091
Crop	1	1	1/7	1	1	0.091
Global W	0.0682	0.0682	0.4773	0.0682	0.0682	CR: 0

Table 4. Comparison matrix of sub-criteria of climate in 3rd level

Climate	C re	W ws	**Local W**
C re	1	3	0.75
W ws	1/3	1	0.25
Global W	0.0511	0.0170	CR: 0

Table 5. Comparison matrix of sub-criteria of topography in 3rd level

Topography	L ad	Slope	**Local W**
L ad	1	1	0.5
Slope	1	1	0.5
Global W	0.0375	0.0375	CR: 0

Table 6. Comparison matrix of sub-criteria of soil in 3rd level

Soil	I ir	AW	**Local W**
I ir	1	3	0.750
AW	1/3	1	0.250
Global W	0.0511	0.0170	CR: 0

Table 7. Comparison matrix of sub-criteria of crop in 3rd level

Crop	C cd	P pk	P pd	**Local W**
C cd	1	1	1	0.3333
P pk	1	1	1	0.3333
P pd	1	1	1	0.3333
Global W	0.0227	0.0227	0.0227	CR: 0

Table 8. comparison matrix of sub-criteria of water in 3rd level

Water	Wna	Wcl	Waw	Wsm	Wbm	EC	PH	**Local W**
Wna	1	1	3	1/5	1/5	1/5	1/5	0.0496
Wcl	1	1	3	1/5	1/5	1/5	1/5	0.0496
Waw	1/3	1/3	1	1/7	1/7	1/7	1/7	0.0259
Wsm	5	5	7	1	1	1	1	0.2187
Wbm	5	5	7	1	1	1	1	0.2187
EC	5	5	7	1	1	1	1	0.2187
PH	5	5	7	1	1	1	1	0.2187
Global W	0.0236	0.0236	0.0123	0.1043	0.1043	0.1043	0.10438	CR: 0.0122

Table 9. R.I Index

R.I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table10. The results of computations & Global Weights of irrigation systems

criteion	sub-criterion		Localized	Linear	Gun	Solid Set
socio-economic	Tsr		0.0313	0.0625	0.0333	0.0179
	Lls		0.0313	0.0208	0.0333	0.0163
	cost		0.1563	0.0625	0.0333	0.0942
	Ras		0.0313	0.0208	0.0667	0.0383
physical	Topography	L ad	0.0375	0.0996	0.0975	0.1494
		Slope	0.0375	0.0996	0.1463	0.0498
	climate	C re	0.0563	0.0498	0.0786	0.0498
		W ws	0.0188	0.1494	0.0786	0.1494
	water	Wna	0.02232	0.0191	0.0175	0.0191
		Wcl	0.02232	0.0191	0.0175	0.0191
		Waw	0.01166	0.0071	0.0066	0.0071
		Wsm	0.09842	0.0071	0.0066	0.0071
		Wbm	0.09842	0.0053	0.0049	0.0053
		EC	0.09842	0.0191	0.0175	0.0191
		PH	0.09842	0.0191	0.0175	0.0191
	soil	I ir	0.0188	0.0996	0.1037	0.0996
		AW	0.0563	0.0996	0.1037	0.0996
	crop	C cd	0.0250	0.0349	0.0341	0.0349
		P pk	0.0250	0.0220	0.0215	0.0220
		P pd	0.0251	0.0831	0.0811	0.0831

3. Results

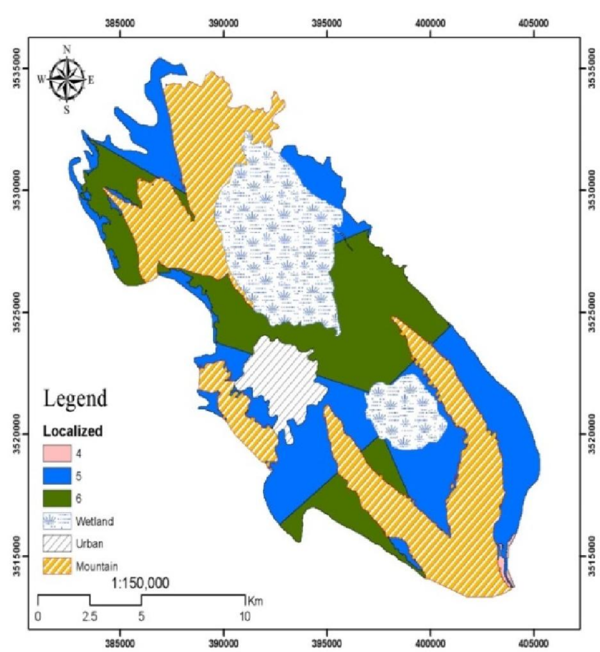

Figure 3. Result map of final value of Localize irrigation system

GIS maps obtained from table10 as results of this Pressurized irrigation systems:

The maps are showing the results of evaluating for pressurized irrigation systems (Figure3 to 6). Wetland, Urban and Mountain were showed in the maps and these parts didn't considered for evaluating the pressurized irrigation systems.

Table 11 was obtained from GIS maps. Table 11 shows that Localize irrigation system has the highest final value and is the best irrigation system for this region.

4. Conclusions

In the present work, a single-objective AHP integrated with a GIS was carried out to identify susceptible regions for pressurized irrigation systems in the Izeh plain. Two main criteria were selected, physical and socio-economic.

Evaluation of susceptible regions for pressurized irrigation systems, using AHP integrated in a GIS, reveals that the best irrigation systems are Localize irrigation system, Gun irrigation systems and Linear irrigation system already were installed and used in the study region.

Considering the effective parameters on the performance of irrigation projects and determining the local weight in pair-wise comparisons, the effectiveness of each aspect and indicator in the irrigation system can be provided. As the proposed methodology can identify the effects of major factors and overcome the problem of uncertainty related to the quality parameters affecting the performance assessment, one can apply the methodology as a comprehensive and decision-making approach with the aim of improving the performance of susceptible regions.

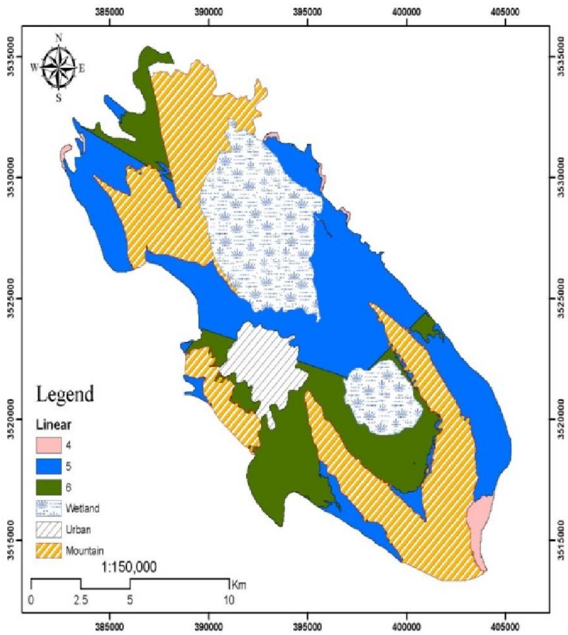

Figure 4. Result map of final physical value of Linear irrigation system

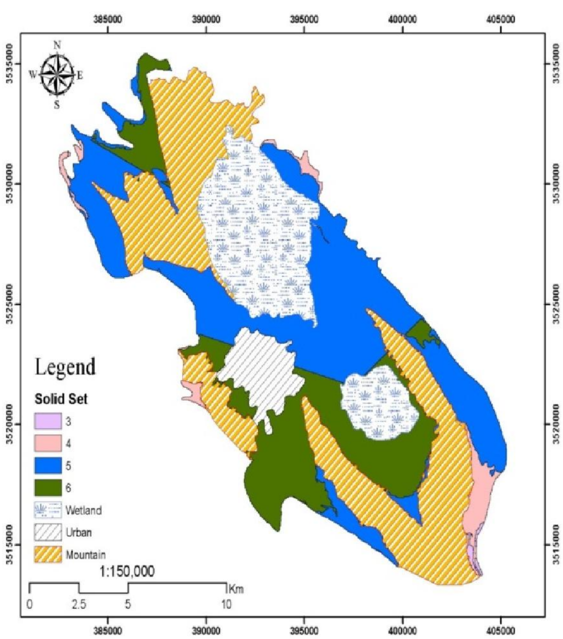

Figure 5. Result map of final value of Solid Set irrigation system

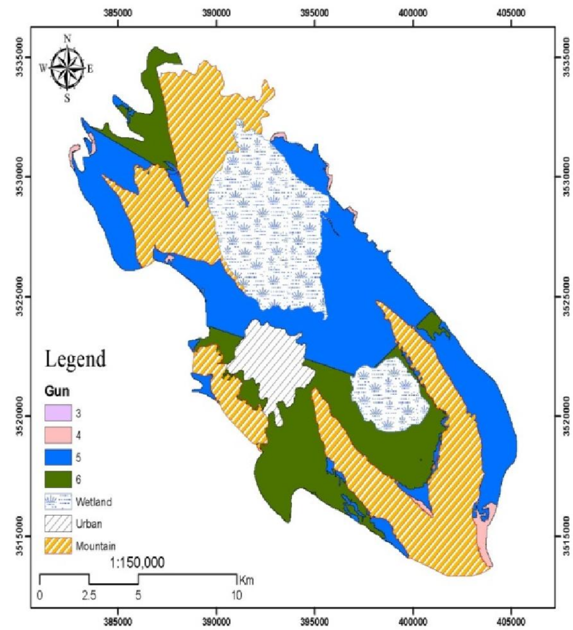

Figure 6. Result map of final value of Gun irrigation system

Table11**.** Final results of pressurized irrigation systems

irrigation method	value	percentage	final value
	4	0.478	
Localized	5	54.263	5.44
	6	45.26	
	4	3.20	
Linear	5	62.10	5.31
	6	34.70	
	3	0.23	
Gun	4	3.30	5.32
	5	60.39	
	6	36.08	
	3	0.47	
Solid Set	4	6.01	5.27
	5	59.07	
	6	34.45	

This work constitutes a helpful technical support for decision makers for a better integrated water management in the Izeh plain.

Acknowledgements

The author should gratefully acknowledge the Shahid Chamran University for their financial support and assistance during the study and field visits.

References

1. Al-Adamat RAN, Foster IDL, Baban SNJ. Groundwater vulnerability and risk mapping for the Basaltic aquifer of the Azraq basin of Jordan using GIS, Remote sensing and DRASTIC. Applied Geography. 2003.23:303–24.
2. Al-Adamat R, Diabat A, Shatnawi G. Combining GIS with multicriteria decision making for sitting water harvesting ponds in Northern Jordan. Journal of Arid Environments;. 2010. 74:1471–7.
3. Anane M, Kallali H, Jellali S, Ouessar M. Soil aquifer treatment areas in Tunisia: Jerba Island. Wastewater reuse–risk assessment, decision-making and environmental security. Book Series: NATO Security through Science Series. The Netherlands: Springerpp. 2007. 65–72.
4. Anane M, Kallali H, Jellali S, Ouessar M., Ranking suitable sites for SAT in Jerba island (Tunisia) using GIS, Remote Sensing and AHP-multicriteria decision analysis. International Journal of Water; 2008.4:121–35.
5. Asawa GL. Irrigation and water resources engineering. New Age International Publisher. 2008.
6. Aslani M, Alesheikh AA. Site selection for small gas stations using GIS. Scientific Research and Essays;. 2011. 6:1361–3171.
7. Behzadian M, Kazemzadeh RB, Albadvi A, Aghdasi M. PROMETHEE: a comprehensive literature review on methodologies and applications. European Journal of Operational Research; 2010. 200:198–215.
8. Conté G, Anane M, Goltara A, Principi I, Kallali H. Multicriteria analysis for water and wastewater management in small rural areas. Sustainable Water Management (Zer0-M); 2008. 2:20–4.
9. Coyle G. THE ANALYTIC HIERARCHY PROCESS (AHP). Practical Strategy. Open Access Material. AHP. 2004.
10. Ding D, Cai L, Wang X, Shao B, Zheng Y. Application of comprehensive evaluation of the airport site selection. Applied Mechanics and Materials; 2011. 97/98: 311–5.
11. Gilliams S, Raymaekers D, Muys B, Van Orshoven J. Comparing multiple criteria decision methods to extend a geographical information system on afforestation. Computers and Electronics in Agriculture; 2005. 49:142–58.
12. Hazell, P., Chakravorty, U., Dixon, J., Celis, R. Monitoring systems for managing natural resources: economics indicators and environmental externalities in a Costa Rican watershed. EPTD Discussion Paper No. 73, International Food Policy Research Institute and the World Bank. 2001.
13. Karami, E., Rezai-Moghaddam, K. The use of sprinkler irrigation system: problems and obstacles. Q. J. Agric. Econ. Dev. 2002. 37, 221–245 (in Farsi with English abstract).
14. Khalili, D. Comparison of multi-criteria decision making procedures in evaluation of irrigation technologies. In: Proceedings of the First Scientific-Applied Meeting on Economics of Water Resources, 1996. p. 72–86 (in Farsi).
15. Khuzestan Water and Power Authority (KWPA). Meteorology Report of Izeh Plain, Iran (in Persian). http://www.kwpa.com. 2010.
16. Marinoni O. Implementation of the analytical hierarchy process with VBA in ArcGIS'. Computers and Geosciences; 2004. 30:637–46.
17. Montazar, A., Behbahani, S.M. Development of an optimized irrigation system selection model using analytical hierarchy process. Biosystems Engineering.2007. 98, 155–165.
18. Montazar, A., Zadbagher, E. An Analytical Hierarchy Model for Assessing Global Water Productivity of Irrigation Networks in Iran. Water Resources Management. 2010. 24, 2817–2832.
19. Nouri N, Poorhashemi SA, Monavari SM, Dabiri F, Hassani AH. Legal criteria and executive standards of solid waste disposal subjected to solid waste management act. International Journal of Environmental Research; 2011. 5:971–80.
20. Okada, H., Styles, S.W., Grismer, M.E. Application of the Analytic Hierarchy Process to irrigation project improvement Part I. Impacts of irrigation project internal processes on crop yields. Agricultural Water Management. 2008a. 95, 199–204.
21. Okada, H., Styles, S.W., Grismer, M.E. Application of the Analytic Hierarchy Process to irrigation project improvement Part II. How professionals evaluate an irrigation project for its improvement. Agricultural Water Management. 2008b. 95, 205–210.
22. Lai, V.S., Wong, B.K., Cheung, W. Group decision making in a multiple criteria environment: a case using the AHP in software selection. Eur. J. Operational Res. 2002. 137, 134 _144.
23. Saaty, T.L. Axiomatic foundation of the analytical hierarchy process. Management Science. 1986. 32 (7), 841–855.
24. Saaty, T.L. A scaling method for priorities in hierarchical structure. Journal of Mathematical Psychology. 1977. 15, 228–234.

25. Scherer TF, Seelig B, Franzen D. Soil, water and plant characteristics important to irrigation,http://www.ag.ndsu.edu/pubs/ageng/irrigate/eb66w.htm [last access 10.05.12]. 1996.
26. Srdjevic, B., Medeiros, Y.D.P. Fuzzy AHP Assessment of water management plans. Water Resources Management. 2008. 22, 877–894.
27. Tegou L, Polatidis H, Haralambopoulos DA. Environmental management framework for wind farm sitting: methodology and case study. Journal of Environmental Management; 2010. 91:730–42.
28. Zhong-Wu L, Guang-Ming Z, Hua Z, Bin Y, Sheng J. The integrated eco-environment assessment of the red soil hilly region based on GIS—a case study in Changsha City, China. Ecological Modelling; 2006. 202:540–6.

10/25/2016