Potentiality of suitable regions for different irrigation systems implementation by using analytic hierarchy process (Case study: Izeh plain, Iran)

Lamya Neissi[1], Mohammad Albaji[1], Saeed Boroomand Nasab[1]

[1.] Irrigation and Drainage Dept. Faculty of Water Sciences Eng.Shahid Chamran Univ, Ahvaz Iran. Postal Code: 61357-8-3151. Tell: +98 611 3135589, Fax: +98 611 3365670
E-mail: boroomandsaeed@yahoo.com

Abstract: Potentiality of suitable regions for irrigation systems for this study area is a multicriteria decision-making problem. A model for potentiality of optimized irrigation systems for suitable regions was developed by considering socio-economic and the physical criteria. GIS can play an important role in the identification of the suitable regions for the locating of the irrigation systems in more facile manner. In this paper a methodology is proposed to identify the suitable regions in the state for the locating the irrigation systems by using Analytical Hierarchy Process (AHP) and Geographic Information Systems (GIS) to boost rural economies and promote the efficiency of the irrigation systems. The result of this study was shown as GIS map. All kind of common irrigation systems were considered in this case study. Respectively, Hand move sprinkler irrigation system, Surface irrigation system and Localized Irrigation System were found to have the highest percent of locating area among other irrigation systems.

[Lamya Neissi, Mohammad Albaji, Saeed Boroomand Nasab. **Potentiality of suitable regions for different irrigation systems implementation by using analytic hierarchy process (Case study: Izeh plain, Iran).** *World Rural Observ* 2016;8(4):19-27]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 3. doi:10.7537/marswro080416.03.

Keywords: Irrigation systems, analytic hierarchy process, multi criteria decision making, socio - economic criteria, physical criteria.

1. Introduction

Making a decision to improve irrigation efficiency and use more properly land and water resources is usually followed by selection of the best irrigation system to be applied in field conditions. This selection is influenced by different factors such as production and irrigation system expenses, water availability and quality, soil characteristics, climate conditions, labor skills, and cultural acceptability of the irrigation methods (Montazar and Behbahani, 2007). Some factors are quantitative and some are qualitative. Formulating the evaluation criterions is a problem itself, because they should reflect more or less conflict farmer's interests such as reducing total cost of agricultural production, increasing net return, reducing prices of agricultural products, improving soil quality, optimizing water allocation, improving usage of human resources and machines etc. In other words, it is necessary to include relevant stages. The major issue is how to relate several factors and determine dominance of one factor over another by checking certain dominant/weak structures (Z.Srdjevic and B.Srdjevic,2010).

Many studies have been conducted on conditions and the factors involved in irrigation system design. Studies of impacts and limitations of physical parameters relating to irrigation system performance include Keller et al. (1976), Heerman and Kohl(1983), Walker and Skogerboe(1987), Keller and Bliesner(1990), Walker and Bosman(1990), Willardson(1992), and Tarjuelo(1992). Hansen et al (1979), Gole and Rao (1980), Keller and Bliesner (1990), and Kumar et al. (1992) studied various socio_ economic and environmental factors and their impacts on the selection of an irrigation system. Keller and Bliesner (1990) introduced the different factors involved in selecting various types of modern irrigation systems employed in developing countries. They recognized five stages in selecting an irrigation system: (1) identification of impacts and objectives of irrigation system development; (2) definition of the local conditions; (3) preliminary surveys aimed at selecting a set of compatible and appropriate irrigation systems; (4) detailed design and economic analysis of the systems designed in the previous stage; (5) comparison of the systems under evaluation in terms of their capability of achieving the objectives of the development project. (Bunruamkaew and Murayam, 2011) showed that the method has steps to determine the relative importance of weights on each criteria, before determining the final score. (Chen et al., 2010a; Akinci et al., 2013) reveled, AHP is one of the promising methods used for the agricultural land suitability analysis based on individual criterions through quantitative analysis. Pair wise comparison method is used to estimate the overall weight of individual criteria or element.

The objective of this work is to evaluate and develop a comprehensive model of locating suitable regions of irrigation systems according to different criteria and parameters including socio -economic and physical factors affecting system efficiency with the aim of improving resource exploitation for agriculture in the Izeh Plain.

2. Material and Methods

Study region: The present study was conducted over an area of approximately 11081 ha in the Izeh plain Khuzestan province, south west Iran during 2015-2016(Fig.1). The study area is located northeast of the city of Ahvaz capital of Khuzestan province, 49° 45′to 49° 59′E and 31° 46′to 31° 57′N. The average annual temperature, precipitation and evaporation for 1977 to 2009 were 24° C, 656mm and 1685 mm, respectively, after several experiments the soil texture considered to be Loam texture(Khuzestan Water and Power Authority,2010).

irrigation systems such as Surface Irrigation System, Low Pressure Surface Irrigation System, and pressurized irrigation systems such as Solid Set Irrigation System, Solid Set- Portable Riser Irrigation System (Semi Portable), Hand Move Sprinkler Irrigation System, Center Pivot Irrigation System, Wheel Move Sprinkler Irrigation System, Gun Sprinkler Irrigation System, Linear Irrigation System, Localized Irrigation System were evaluated for selection of the best irrigation method for Izeh plain.

The physical criteria have four sub-criteria and they have numerous options. In nomenclature symbols of options of sub-criteria has been mentioned.

Criteria selection: Two main criteria were selected to rank and determine suitable regions for pressurized irrigation systems, which are (1) socio-economic criteria, (2) physical criteria. These criteria, the derived sub-criteria and the rationale behind selecting them are detailed hereafter.

Analytic hierarchy process: Analytic Hierarchy Process (AHP) is one of Multi Criteria decision making method that was originally developed by Prof. Thomas L. Saaty. In short, it is a method to derive ratio scales from paired comparisons. The input can be obtained from actual measurement such as price, weight etc., or from subjective opinion such as satisfaction feelings and preference. AHP allow some small inconsistency in judgment because human is not always consistent. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value. The AHP was used for optimization. It was introduced by Saaty (1992) and is one of the most suitable methods of multivariate discrete analysis and is used as an analytical tool in various branches of technology.

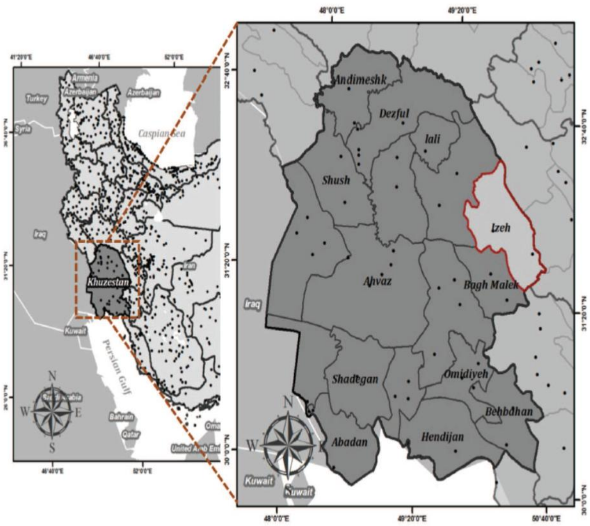


Fig1 Location map of the study area.

The method is capable of systematically introducing different qualitative and quantitative factors in the decision - making model. To develop the required model using AHP, the following three steps were taken:

(a) Defining a site - specific hierarchy structure;
(b) Calculating weights; and,
(c) Computing inconsistency ratios (Montazar and Behbahani, 2007).
(d) Extract the geographic layers corresponding to each sub-criterion by using GIS.

The meaning of the analytic hierarchy process is to decomposition a complex problem into a hierarchy with objective (goal) at the top of the hierarchy, criterions and sub- criterions at levels and sub- levels of the hierarchy, and decision alternatives at the bottom level of the hierarchy. Based on questionnaire survey or your own paired comparison, we make several comparison matrices.

The normalized principal Eigen vector is also called priority vector**.** Since it is normalized, the sum of all elements in priority vector is 1. The priority vector shows normalized weights among the criterion that we compare. Fig.2 shows the route followed for locating suitable regions of the irrigation systems in the first stage. Level 1 in the Figure shows the objective, i.e., locating an irrigation system in a region of the study area. Level 2 shows the criteria of the problem or the parameters involved in the selection of an irrigation system. The different options or scenarios, i.e. the sub - criteria, are shown in level 3. For weighting the criteria and sub - criteria, Pair - wise comparison was used. The options at each level are compared pair - wise with the corresponding options at one level up to compute their normalize weights.

Nomenclature

W bm	biological materials		
W aw	Available water in the farm	P pd	plant pest
W cl	chloride concentration	P pk	plant type
W ws	wind speed	C cd	crop density
AW	Available water in the soil	I ir	infiltration rate
R as	relative acceptability of an irrigation system	W sm	suspended materials
T sr	technical support requirements	W na	sodium concentration
S ec	system costs	C re	climate of the region
L ls	labor skills	L hd	height difference
W	normalized weight	L so	land slope

Results of the comparison (for each factors pair) were described in term of integer values from 1 (equal value) to 9 (extreme different) where higher number means the chosen factor is considered more important in greater degree than other factor being compared with (Table1).

AHP additionally calculates inconsistency index as a ratio of the decision maker's inconsistency and randomly generated index. This index is important to assure the decision maker that his judgments were consistent and that final decision is made well. Inconsistency index less than 0.10 is assumed acceptable. Although higher value of inconsistency index requires re-evaluation of pair - wise comparisons, decisions obtained in certain cases could also be taken as 'the best alternative' [karlsson 1998].

Model evaluation: There are several methods for calculating the eigenvector. Multiplying together the entries in each row of the matrix and then taking the nth root of that product gives a very good approximation to the correct answer. The nth roots are summed and that sum is used to normalize the eigenvector elements to add to 1.00.

The next stage is to calculate λmax so as to lead to the Consistency Index and the Consistency Ratio. If any of the estimates for λmax turns out to be less than n, there has been an error in the calculation, which is a useful sanity check.

Prof. Saaty proved that for consistent reciprocal matrix, the largest Eigen value is equal to the number of comparisons, or λmax= n. Then he gave a measure of consistency, called Consistency Index as deviation or degree of consistency using the following formula (1)

$$\text{CI}=\frac{\lambda\,\text{max}-n}{n-1} \qquad (1)$$

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 (Geoff Coyle, 2004). For this purpose, Saaty defined the consistency ratio (CR) as

$$\text{CR}=\frac{\text{CI}}{\text{IR}} \qquad (2)$$

If λmax = n and CI = 0 the two different matrices of judgments and weights are equal. Saaty argues that a CR > 0.1 indicates that the judgments are at the limit of consistency though CRs> 0.1 (but not too much more) have to be accepted sometimes. In this instance, we are on safe ground (Geoff Coyle, 2004).

Values of I.R illustrated in Table 2.

Table 1. The fundamental Saaty 's scale for the comparative judgments.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much more important	Experience and judgment very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

Table 2. 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

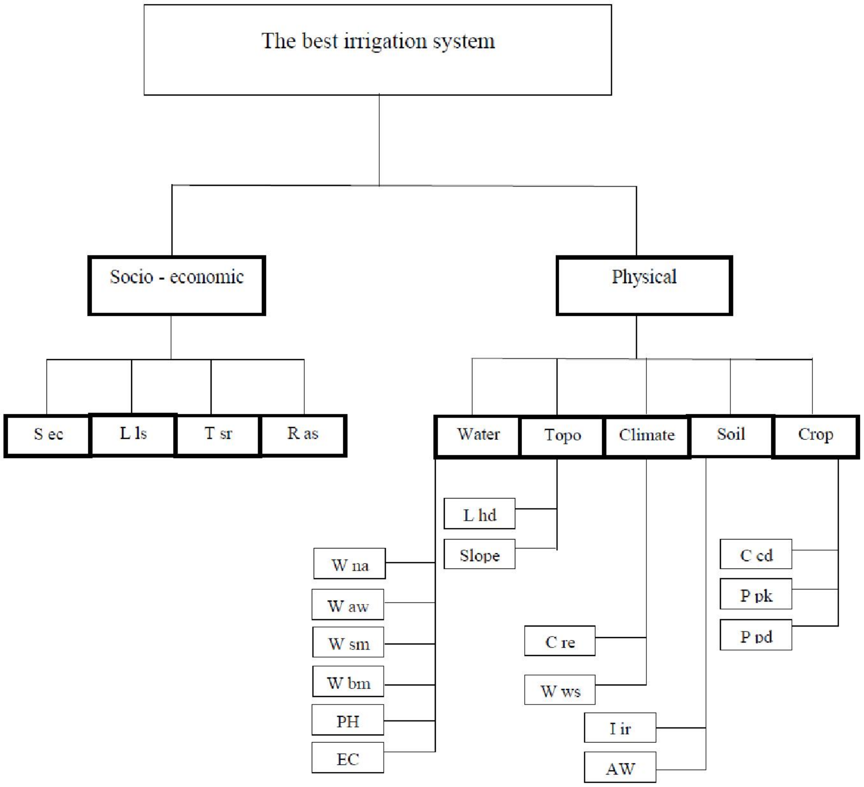


Fig2. AHP structure for selecting optimized irrigation system

Sub-criteria and layering by GIS: Spatial analysis to identify suitable regions for pressurized irrigation systems starts with representing each selected physical 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

The AHP method is used to solve the problem: location of ten irrigation systems and select the most suitable region for these systems. For illustration purpose, two criteria, 9 sub - criteria and 15 options are assumed as mentioned in the previous part (Fig.2).

The AHP methodology says that prioritizing and weighting the criterions should be done firstly. According to fundamental Saaty 's scale for the comparative judgments(Table1) and by performing pair - wise comparisons of criteria with respect to the object, here the comparison and calculation of criteria in 1st, 2nd and 3rd levels in general for Localize irrigation system as an example (Table 3 to 10). The weights of each criterion were computed by using the geometric mean to obtain the weight values. After that the weights should be aggregated and each weight divides on aggregated weights in order to normalize the weights. The normalized weights determine the priority of criteria. The sum of all normalized weights in each Table is equal to unity.

Table3 illustrates comparison matrix of main criteria. Localize irrigation system is more expensive than other irrigation systems and quality of water for this system is more important. Therefore, Physical criterion is almost more important than socio-economic criterion.

Localize irrigation system need technical support, labor high skilled, relative acceptability of the system in the study region and financial support. According to economic situation and high costs of operation, exploitation and maintenance; cost sub-criterion is more important and has the priority comparing to other socio-economic sub-criteria (Table4).

Water criterion has the priority comparing with other physical criteria. Water quality has high influence on localize irrigation system, it can clog the drippers or can damage them (Table5).

Unlike sprinkler pressurized irrigation systems, wind speed has no effect on localize irrigation system, therefore it has less importance than the climate of the region. Climate option include of temperature and sun light duration; these parameter can affect the localize irrigation system by evaporating dripped water to the surface (Table6).

This irrigation system is almost independent of topography. Pair-wise comparing in the matrix of topography, land slope and height differences have the same importance (Table7).

Localize irrigation system is better to be used in high infiltration rate but infiltration rate is low in the study area and available water in the soil is high. Therefore, infiltration rate is almost more important comparing to the available water in the soil and has the priority in pair-wise comparing matrix of the soil (Table8).

Common crops that cultivated in this region are Wheat, barley and canola crops. Localize irrigation system is used for horticultural crops but the crops that have been mentioned before are agricultural crops. Therefore density of crop and crop type has the same importance in the pair-wise comparing matrix of crop. Localize irrigation system deliver the water beneath the crop unlike other pressurize irrigation systems that deliver the water overhead of the crops. Thus, drip fertigation can help reduce the crop pest and this option also has the same importance comparing with other alternatives of comparing matrix of crop (Table9).

Most large drip irrigation systems employ some type of filter to prevent clogging of the small emitter flow path by small waterborne particles. New technologies are now being offered that minimize clogging. Considering conditions of water used for irrigation in the study region, suspended materials (W sm) and biological materials (W bm) were seen in the water according to laboratory experiments. Filters were employed in the farm and the water is available in the farm by pumping it from wells, but filters need to be changed after a while so possibility of clogging in the drippers still exists, therefore, these two alternatives have higher weight than available water. The amount of Sodium concentration (W na) and chloride concentration (W cl) were low and have less importance than other criteria except available water. Localized irrigation systems designed for no leaching fraction. High electrical conductivity (EC) and salts applied with the irrigation water may build up in the root zone but EC of the study region is almost low.

Table 3. Comparison matrix of criteria in 1st level

effective factors	Socio - economic	Physical	**Local Weight**
Socio - economic	1	0.33	0.250
Physical	3	1	0.750
			CR: 0

Table 4. comparison of sub- criteria of socio - economic in 2nd level

socio-economic	Tsr	Lls	cost	Ras	**Local Weight**
Tsr	1	1	0.2	1	0.125
Lls	1	1	0.2	1	0.125
cost	5	5	1	5	0.625
Ras	1	1	0.2	1	0.125
Global Weight	0.031	0.031	0.156	0.031	CR: 0

Table 5. Comparison matrix of sub-criteria of physical in 2nd level

Physical	Topography	Climate	Water	Soil	Crop	**Local Weight**
Topography	1	1	0.14	1	1	0.091
Climate	1	1	0.14	1	1	0.091
Water	7	7	1	7	7	0.636
Soil	1	1	0.14	1	1	0.091
Crop	1	1	0.14	1	1	0.091
Global Weight	0.068	0.068	0.477	0.068	0.068	CR: 0

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

Climate	C re	W ws	**Local Weight**
C re	1	3	0.750
W ws	0.33	1	0.250
Global Weight	0.051	0.017	CR: 0

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

Topography	L hd	Slope	**Local Weight**
L hd	1	1	0.500
Slope	1	1	0.500
Global Weight	0.034	0.034	CR: 0

Table 8. Comparison matrix of sub_criteria of soil in 3rd level

Soil	I ir	EW	**Local Weight**
I ir	1	0.33	0.250
EW	3	1	0.750
Global Weight	0.017	0.051	CR: 0

Table 9. Comparison matrix of sub-criteria of crop in 3rd level

Crop	C cd	P pk	P pd	**Local Weight**
C cd	1	1	1	0.333
P pk	1	1	1	0.333
P pd	1	1	1	0.333
Global Weight	0.023	0.023	0.023	CR: 0

Table 10. comparison matrix of sub-criteria of water in 3rd level

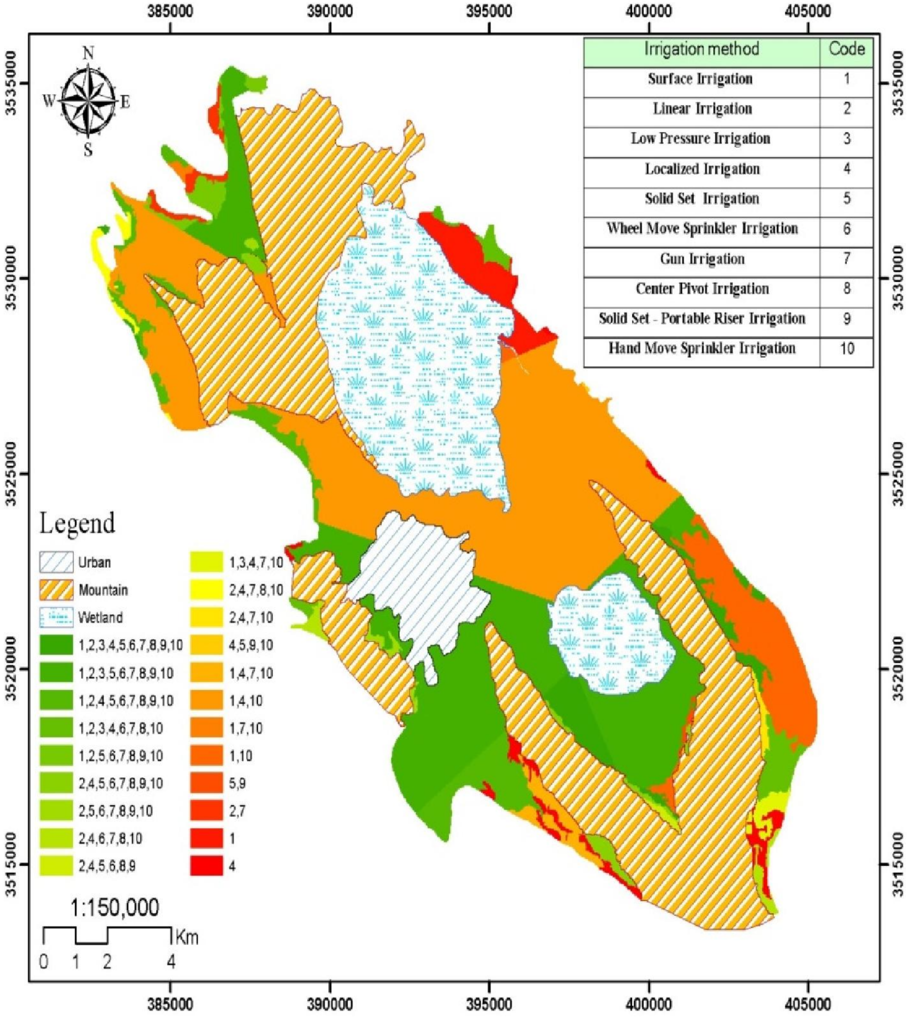
Water	Wna	Waw	Wsm	Wbm	EC	pH	**Local Weight**
Wna	1.00	3.00	0.20	0.20	0.20	0.20	0.052
Waw	0.33	1.00	0.14	0.14	0.14	0.14	0.029
Wsm	5.00	7.00	1.00	1.00	1.00	1.00	0.230
Wbm	5.00	7.00	1.00	1.00	1.00	1.00	0.230
EC	5.00	7.00	1.00	1.00	1.00	1.00	0.230
pH	5.00	7.00	1.00	1.00	1.00	1.00	0.230
Global Weight	0.025	0.014	0.110	0.110	0.110	0.110	CR: 0.01

Table11. The results of comparisons & final weights of AHP evaluation for irrigation systems

			Irrigation system									
criterion	sub-criterion		Localized	Linear	Gun	Wheel Move	Center Pivot	Hand Move	Solid Set	Semi Portable	Surface	Low pressure
socio-economic	Tsr		0.031	0.063	0.033	0.042	0.063	0.021	0.018	0.042	0.026	0.028
	Lls		0.031	0.021	0.033	0.042	0.021	0.063	0.016	0.042	0.036	0.039
	cost		0.156	0.063	0.033	0.042	0.063	0.021	0.094	0.042	0.040	0.043
	Ras		0.031	0.021	0.067	0.042	0.021	0.063	0.038	0.042	0.023	0.025
physical	Topography	L ad	0.038	0.100	0.098	0.100	0.100	0.063	0.149	0.149	0.187	0.081
		Slope	0.038	0.100	0.146	0.100	0.100	0.136	0.050	0.050	0.281	0.243
	climate	C re	0.056	0.050	0.079	0.050	0.050	0.050	0.050	0.050	0.136	0.101
		W ws	0.019	0.149	0.079	0.149	0.149	0.150	0.149	0.149	0.045	0.034
	water	Wna	0.022	0.019	0.018	0.019	0.019	0.019	0.019	0.019	0.008	0.019
		Wcl	0.022	0.019	0.018	0.019	0.019	0.019	0.019	0.019	0.008	0.019
		Waw	0.012	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.019	0.019
		Wsm	0.098	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.011	0.019
		Wbm	0.098	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.011	0.019
		EC	0.098	0.019	0.018	0.019	0.019	0.019	0.019	0.019	0.009	0.019
		pH	0.098	0.019	0.018	0.019	0.019	0.019	0.019	0.019	0.009	0.019
	soil	I ir	0.019	0.100	0.104	0.100	0.100	0.100	0.100	0.100	0.013	0.034
		AW	0.056	0.100	0.104	0.100	0.100	0.100	0.100	0.100	0.063	0.101
	crop	C cd	0.025	0.035	0.034	0.035	0.035	0.035	0.035	0.035	0.019	0.034
		P pk	0.025	0.022	0.021	0.022	0.022	0.022	0.022	0.022	0.019	0.034
		P pd	0.025	0.083	0.081	0.083	0.083	0.083	0.083	0.083	0.038	0.068

Table 12. final results of locating area of GIS map for irrigation systems

irrigation system	percentage	area (ha)
Hand Move Sprinkler	55.3	9760.6
surface	55.2	9740.3
Localized	37.2	6564.1
Gun	29.5	5202.6
Linear	28.7	5063.1
Center Pivot	27.7	4889.6
Wheel Move Sprinkler	27.5	4847.0
Semi Portable	26.4	4651.7
Solid Set	25.5	4490.7
Low Pressure	20.6	3633.8



Irrigation method	Code
Surface Irrigation	1
Linear Irrigation	2
Low Pressure Irrigation	3
Localized Irrigation	4
Solid Set Irrigation	5
Wheel Move Sprinkler Irrigation	6
Gun Irrigation	7
Center Pivot Irrigation	8
Solid Set - Portable Riser Irrigation	9
Hand Move Sprinkler Irrigation	10

Fig3.Final result for located irrigation systems within GIS map in the Izeh plain

Alkaline water (refers to PH) could make sediments in the drippers. Comparing these two criteria with other criteria of water, they have more importance than suspended and biological materials but the same weight (Table 10).

This procedure of calculating final weights and matrix of each criteria and sub-criteria was repeated for other irrigation systems. The final weights of irrigation systems showed in Table11.

The results of computations for this region are presented in Table12 and Fig. 3. The overall decision consistency index was 0.02 which is in the acceptable range.

Table 12 shows that Hand Move Sprinkler irrigation system covers 55.3 percent of the area of the locating map (Fig.3) which can be choose as best irrigation system for this region. Surface irrigation system and Localized irrigation system have the next priority. For farmers of the study region it is easier to deal with Surface irrigation system than the pressurized irrigation systems.

4. Discussions

The analytic hierarchy process (AHP) appears to be an efficient decision-making tool for irrigation system selection particularly since the AHP process allows for the measurement of decision consistency. This is particularly significant where it is necessary to quantify and independently confirm decisions made (Montazar and Behbahani, 2007).

Major advantage of AHP is to formalize and renders systematic what is largely a subjective decision process and as a result facilitates 'accurate' judgments, that weights of criteria are also provided to decision maker, and that sensitivity analysis is easy to conduct by using computer (Narasimhan 1983).

In this study, Localized Irrigation System, Low pressure irrigation system and Surface irrigation systems found to be the best systems for this region, respectively. The comparisons expose that the results from the proposed model are in good agreements with results from the field investigations. An additional benefit of the model is that the decision-maker can perform a more exhaustive conceptual comparison of the different decision components. Causing that an extensive set of factors involved in selecting an irrigation system has been included in the proposed model, it can be claimed to be a comprehensive and practical model that can be used in selecting the irrigation methods for various agricultural sites, thereby improving soil and water resources exploitation and productivity.

Acknowledgements:

The author should gratefully acknowledge the Shahid Chamran University for their financial support and assistance during the study and field visits (Grant No. 93/3/02/27171).

Corresponding Author:

Dr. Boroomand Nasab
Department of Irrigation and Drainage
Shahid Chamran University
Ahvaz. Iran.
Telephone: 00989168019804
E-mail: boroomandsaeed@yahoo.com

References

1. Akıncı, H.O., Zalp, A.Y., Turgut, B. Agricultural land use suitability analysis using GIS and AHP technique. Comput. Electron. Agric. 2013. 97, 71–82.
2. Bunruamkaew, K., Murayam, Y. Site suitability evaluation for ecotourism using GIS & AHP: a case study of Surat Thani Province, Thailand. Procedia.2011. 21, 269–278.
3. Coyle, G. The analytical hierarchy process (AHP). Practical Strategy. Open Access Material. AHP. 2004.
4. Chen, Y., Yu, J., Khan, S. Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation. Environ. Model. Softw. 2010. 25 (12), 1582–1591.
5. Gole, A. C., Rao, B.N. Evaluation of sprinkler irrigation system and comparison with surface system. Haryana Agriculture University. Journal of research, 1980. 10(3), 349-351.
6. Hansen, V.E., Israelsen, O.W., Stringham, G.E. Irrigation principles and practices. John Wiley & Sons Inc., New York, NY. 1979.
7. Heerman, D.F., Kohl, R.A. Fluid dynamics of sprinkler systems. In: Design and Operation of farm irrigation systems (Jensen M E, ed). The American Society of Agricultural Engineers. 1983.
8. Karlsson, J.A. Systematic approach for prioritizing software requirements. Ph.D. dissertation, No. 526. Linkoping, Sverige. 1998.
9. Keller, J., Bliesner, D.C. Sprinkler and Trickle Irrigation, 652 pp Van Nostrand Reinhold Publishing, New York. 1990.
10. Keller, J., Mc Culloch, A.W., Sherman, R.M., Mueller R.C., Jakson, G.R. Ames Irrigation Handbook. W.R. Company, Woodlank, California. 1976.
11. Khuzestan Water and Power Authority (KWPA) Meteorology Report of Izeh Plain, Iran (in Persian). http://www.kwpa.com. 2010.
12. Kumar, D., Heatwole, C.D., Ross, B.B., Taylor, D.B. Cost models for preliminary economic evaluation of sprinkler irrigation systems.

Journal of Irrigation and Drainage Engineering. 1992. 118(3), 757-775.

13. Montazar, A., Behbahani, S.M. Development of an optimized irrigation system selection model using analytical hierarchy process. Biosystems Engineering. 2007. 98, 155-165.
14. Narasimhan, R. An analytical approach to supplier selection. Purchasing and Materials Management. 1983. 19-1:27-32.
15. Saaty, T.L. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 1977. 15, 234–281.
16. Saaty, T. L. Decision Making for Leaders. RWS Publication, Pittsburgh, USA. 1992.
17. Srdjevic, B., Obradovic, D. Reliability and risk in agricultural irrigation. Third International Workshop on Mathematical and Control Applications in Agriculture and Horticulture, 1997. pp 97-102, Hannover, Germany.
18. Srdjevic, Z., Srdjevic, B. Valuation off Irrigation Methods by Equal and Weighted Importance Models and the Analytic Hierarchy Process. Faculty of Agriculture, University of Novi Sad, Serbia and Montenegro. 2010.
19. Tarjuelo, J. Working condition of sprinkler to optimize application of water. Journal of Irrigation and Drainage Engineering. 1992. 118(6), 895-913.
20. Walker, W.R., Bosman, J.D. Real time simulation of furrow infiltration. Journal of Irrigation and Drainage Engineering, 1990. 116(3), 229-318 Second congress on Soil and Water National Problems.
21. Walker, W.R., Skogerboe, G.V. Surface Irrigation: Theory and Practice. Prentice-Hall, Inc., Englewood Cliffs, NJ. 1987.
22. Willardson, L.S. Attainable irrigation efficiencies. Journal of Irrigation and Drainage Engineering. 1992. 118(7), 239-246.

10/25/2016