Research Journal of Environmental and Earth Sciences 4(3): 230-236, 2012
ISSN: 2041-0492

Submitted: October 07, 2011 Accepted: November 16, 2011 Published: March 01, 2012

Comparison of Surface and Drip Irrigation Methods Based on the Parametric Evaluation Approach in Terms of FAO Framework in Hendijan Plain

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Abstract: This study was conducted aiming to evaluate and compare the land suitability for surface and drip irrigation systems in *Hendijan* plain with a surface area of 23500 ha in *Khuzestan* province, southwest *Iran*. In order to perform the land suitability evaluation, the topographic and physiochemical characteristics of soil were utilized. Parametric approach in terms of FAO framework were used in order to determine the suitability classes of each soil series for mentioned irrigation systems. The results showed that Capability Index (CI) for drip irrigation was 65.73 (moderately suitable) while it was 56.38 (marginally suitable) for surface irrigation. On the other hand, it was found that the soil series 13 with a percentage of 1.40 (330.21 ha), the soil series 1 and 11 with a percentage of 17.35 (4075.19 ha) and the soil series 2, 3 and 12 with a percentage of 29.66 (6967.21 ha) had moderately (S2), marginally (S3) and permanently non suitable (N2) class for both surface and drip irrigation systems, respectively. As a result, drip irrigation was suggested as the best irrigation system for more than half of the study area soils due to soil and topographic conditions. Also based on achieved results, the main limiting factor for both surface and drip irrigation systems in this region was the high quantities of soil salinity and alkalinity.

Key words: Drip irrigation, FAO framework, land suitability, parametric approach, surface irrigation

INTRODUCTION

Food security and stability in the world depends very much on how we manage natural resources. Due to depletion of groundwater reserves and an increase in population, the irrigated area per capita is declining, and the irrigated lands now produce 40% of the food supply (Hargreaves and Mekley, 1998). A fuller use of land and water resources by the development of irrigation facilities could lead to sustainable increases in food production in many parts of the world (Menker, 2001). The land suitability evaluation is an appropriate alternative in order to obtain a sustainable production and water resources management. According to FAO (1983) land evaluation is “the process of assessment of land performance when used for specified purposes”. In other words, Land Evaluation is the estimation of the possible behavior of the land when used for a particular purpose; this use can be the current one or a potential one. In this sense, Land evaluation can be regarded as a tool to take decisions about the land. Land evaluation using a scientific approach, Is substantial to assess the land potential and limitations in a region (Rossiter, 1996). Different methodologies have been developed for land evaluation. Some of these systems were developed before the FAO Framework for Land Evaluation (1978), such as the USBR Land Suitability for Irrigation (U.S. Department of the Interior, 1951), or the USDA Land Capability (Klingebiel and Montgomery, 1966), Following the publication of the FAO guidelines for Land Evaluation (FAO, 1976, 1983), many countries started to apply this system or developed their own, according to the theory and methodology of the FAO framework. This system is based on matching between land qualities/characteristics and crop requirements which expresses suitability in descriptive terms: highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable with (N1) or without (N2) possibilities for land improvement (FAO, 1976). Many of suitability evaluation procedures in use are adaptations to the local conditions of the Framework for Land Evaluation FAO (1976), and focus on the severity of land limitations related to crops and land use. One kind of land suitability evaluation is the land classification for different irrigation methods. There are several approaches to evaluate the land suitability for irrigation methods. The first system for land evaluation for irrigation has been elaborated by the United States Bureau of Reclamation (USBR, 1951). Some of these procedures are adapted for regional conditions such as the evaluation system for irrigation developed by FAO in Iran (Mahler, 1979). Parametric evaluation system is one other kinds of land evaluation approaches for irrigated agriculture, the aim of this evaluation system is to provide a method that permits evaluation for irrigational purposes,

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and that is based on the standard granulo-metrical and physiochemical characteristics of a soil profile (Sys and Verheye, 1974). Determining the suitability of land for irrigation requires a thorough evaluation of soil properties, topography and quality of water to be used for irrigation (Seelig and Franzen, 1996). The factors influencing the soil suitability for irrigation can therefore be subdivided in the following four groups:

- Physical properties such as texture, structure and soil depth, also $Caco_3$ status and Gypsum status could be considered here, as these parameters determine the soil-water relationship in the solum
- Chemical properties such as soluble salts and exchangeable Na that interfere in the salinity/alkalinity status
- Drainage properties
- Environmental factors such as slope (Sys *et al*., 1991).

Liu *et al.* (2006) using parametric approach that is recommended by Sys *et al*. (1991) evaluating the land suitability for surface and drip irrigation systems in Danling County, Sichuan province, China. The results showed that land suitability classes for drip irrigation were everywhere higher than surface irrigation due to the minor environmental impact that it caused.

Dengiz (2006) using parametric approach conducted a research on Comparison of surface and drip irrigation systems in the Field Plants Central Research Institute-Ikizce Research Farm's soils located in southern Ankara, Turkey. The obtained results showed that, drip irrigation was suggested as the best irrigation system for more than half of the study area soils due to soil and topographic conditions.

Albaji *et al.* (2010) compared different irrigation systems based on parametric approach in Dosalegh plain, Iran. The results indicated that the drip and sprinkler irrigations methods were more effective and more efficient than those of surface irrigation for improved land productivity.

The main objectives of this research were to evaluate and to compare the land suitability evaluation for surface and drip irrigation methods based on the parametric evaluation system in terms of FAO framework and determining the land limitation factors for each irrigation method in Hendijan plain, Khuzestan Province, southwest Iran.

MATERIALS AND METHODS

This study was conducted in Hendijan plan in Khuzestan province, southwest Iran, in 2011. The study region with a surface area of 23500 ha is located in latitude of 30º29″ to 30º43″ northern and in longitude of 49º33″ to 49º49″ eastern. Average annual temperature and precipitation (for the period of 1965-2004) are 27.4ºC and 253 mm, respectively. The studied area is a topographically smooth area and it has a slope of 0-2% and the basic materials forming the soil are the alluvial materials of the river (KWPA, 2007). The main water resource which is utilized by the formers of this area is Zohre River which is located in the western margin of the investigated area.

METHODOLOGY

The land evaluation was determined based on topography and soil characteristics of the region. The semi-detailed soil survey report of Hendijan plain (KWPA, 2007) was used to determine the soil characteristics. The groups of soils that had similar properties and were located in the same physiographic unit were categorized as a soil series and were classified to form a soil family as described by Soil Survey Staff (2006). Thirteen soil series were selected for the evaluation of land suitability for surface and drip irrigation. To obtain the average soil texture, salinity and alkalinity, Gypsum and $CaCO_3$ for the upper 150 cm of soil surface, the profile was subdivided into 6 equal sections 25 cm apart. Weighting factors of 2, 1.5, 1, 0.75 0.50 and 0.25 were used for each section, respectively (Sys *et al*., 1991).

The parametric approach (Sys *et al.*, 1991) in terms of FAO framework (FAO, 1976) were used in order to determine the suitability classes of each soil series for mentioned irrigation systems. In parametric approach, the land is evaluated according to numerical indexes. In this classification system, firstly a degree, whose rate is from 0 to 100, is given to any land characteristic through comparing them with the tables of soil requirements. The specified degrees are used in order to measur the land index that is a multiplicative index that combines ratings assigned to soil map units and other physical conditions that affect the land use (Olson, 1981).

Seven parameters including slope, drainage properties, electrical conductivity of soil solution, calcium carbonates status, Gypsum status, soil texture and soil depth (Sys *et al*., 1991) were also considered and rated through comparing their values with the tables of soil requirements for surface and drip irrigation that were provided for conditions present in Iran (Mahler, 1979; ISWESC, 2008), thus, the capability index for irrigation (Ci) was developed as shown in the equation below (Sys *et al.*, 1991):

$$Ci = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100} \times \frac{G}{100}$$

where, A, B, C, D, E, F and G are ratings of soil texture, soil depth, calcium carbonate content, Gypsum, electrical conductivity, drainage and slope, respectively.

In Table 1 the ranges of capability index and the corresponding suitability classes are shown.

Table 1: Capability indices for the different capability classes (Sys *et al.*, 1991)

Capability index	Class	Definition
>80	I	Excellent
60-80	II	Suitable
45-60	III	Slightly suitable
30-45	IV	Almost unsuitable
<30	V	Unsuitable

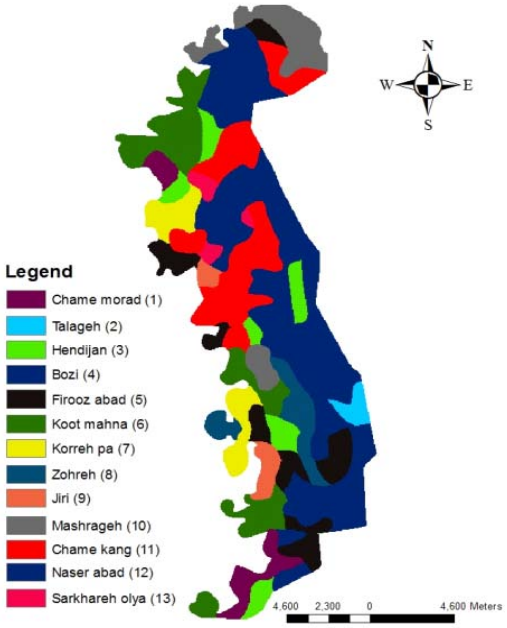

Fig. 1: Soil map of the studied area

To provide the land suitability maps for different irrigation methods, the 1:25000 map of the soil of this area (Fig. 1), which was prepared by Khuzestan Water and Power Authority (KWPA, 2007), was used as the basic map. In order to carry out this, the considered map was firstly vectored and subsequently georefrenced through the ArcGIS 9.2 software (ESRI, 2009). To set up an information bank, the results obtained through the parametric method for evaluation of different irrigation and all the data for soil characteristics were incorporated to the digital map of the soil series in the ArcGIS 9.2 software and ultimately, land suitability maps for surface and drip irrigation systems were extracted from the contributed bank.

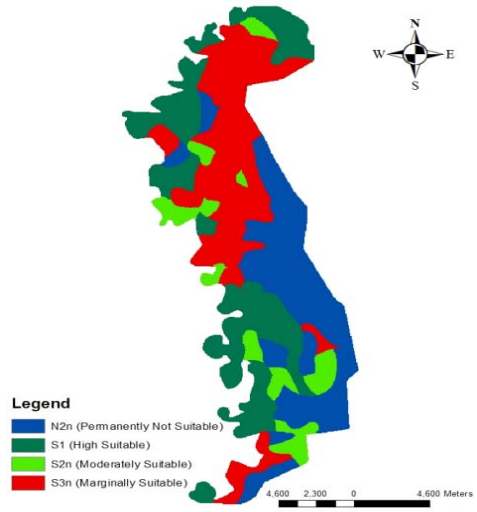

Fig. 2: Land suitability classification map for surface irrigation

RESULTS AND DISCUSSION

Table 2 indicates the results obtained from the laboratory analysis of the water derived from the Zohreh River. Based on achieved results, its water has a high salinity and a low alkalinity following the Willcox (1958) diagram and it settles at class C4-S1 which is considered unsuitable water for agricultural purposes but this is observed during the dry seasons, whereas, with the beginning of precipitation, the river water improves not just quantitatively but also qualitatively.

As shown in Table 3 and 4, the obtained results for surface irrigation suggest that the soil series 6, 7, 8, 9, 10 and 13 with a percentage of 31.29 (7351.03 ha) out of the total surface area of the studied region include a moderate suitability (S2), the soil series 1, 5 and 11 with a percentage of 25.92 (6089.70 ha) had a marginal suitability (S3), the soil series 4 with a percentage of 13.10 (3078.90 ha) is currently not suitable (N1) and the soil series 2, 3 and 12 with a percentage of 29.66 (6968.78 ha) were reported as permanently non suitable (N2). The results also show that the main limiting factor to this kind of land use is the high quantities of salinity and alkalinity.

The analysis of the land suitability classification map for surface irrigation (Fig. 2), indicates that the parcel

Table 2: results of laboratory analysis of Zohreh river water

				Oluble cations (meq/L)			
Variable	T.D.S (mg/L)	Ecw(µmohs/cm)	pHS	Ca^{++}	Mg^{++}	Na^{+}	K
Value	1515	2546	7.97	6.2	5.4	13.6	0.25
Variable	S.S.P (%)	T.H (mg/L)	S.A.R	Soluble anions (meq/L)			
				Co_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{-}
Value	53.4	574	5.65	0.0	2.4	21.0	2.2

Table 3: Capability indexes (Ci) and suitability classes of surface and drip irrigation for each soil series

	Surface irrigation		Drip irrigation	
Soil series	Ci	Suitability classes	Ci	Suitability classes
1	48.60	S3n*	59.95	S3n
2	0.98	N2n	1.08	N2n
3	12.39	N2n	12.58	N2n
4	39.65	N1n	58.31	S3n
5	58.77	S3n	67.10	S2n
6	77.07	S2n	89.19	S1
7	72.99	S2n	86.98	S1
8	70.92	S2n	82.21	S1
9	79.51	S2n	90.50	S1
10	79.35	S2n	83.89	S1
11	45.71	S3n	59.63	S3n
12	1.00	N2n	1.00	N2n
13	73.24	S2n	79.96	S2n

*: Litiming factor for surface and drip irrigations; n: salinity and alkalinity

which, is moderately suitable (S2), is located adjacent to Zohreh river and at the center of the investigated area as the quantities of salinity and alkalinity through this portion include lower quantities than the rest of the area. Other factors such as drainage, depth, soil texture, slope, calcium carbonate and gypsum content had no influence on the suitability of the area.

The moderately suitable (S2) lands were found in the largest part of this plain comparing with other suitability classes. The marginally suitable (S3) area that is located in some part of the studied area had higher quantities of salinity and alkalinity comparing with the moderately suitable (S2) area while the influence of the other factors on land evaluation were found approximately similar for both moderately and marginally suitable areas. The map also indicated that only some part of this plain was evaluated as currently non suitable (N1) land. These zones had higher quantities of salinity and alkalinity comparing with the both moderately (S2) and marginally suitable (S3) areas and they were found in the smallest part of this plain. The permanently non-suitable (N2) zones that are located in some part of this study area were due to very severe salinity and alkalinity. This region is the second largest part of this plain.

Since Choosing a suitable irrigation method is essential for good irrigation farming to achieve an efficient water use and to reduce land and water degradation as well as for land water management and sustainable development in crop production, using the same methodology (parametric approach), the land suitability evaluation for drip irrigation was conducted.

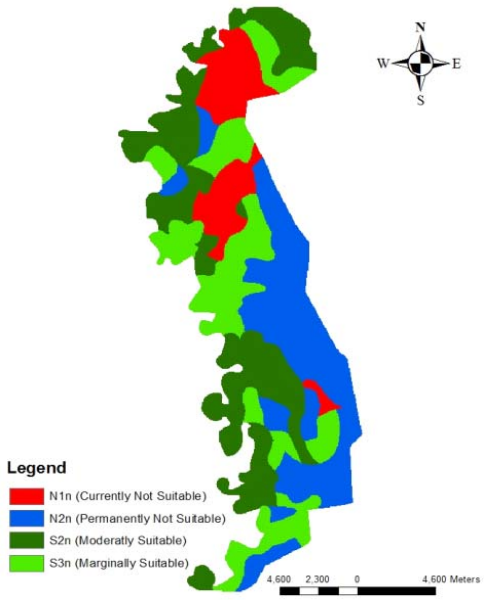

Fig. 3: Land suitability classification map for drip irrigation

The obtained results for drip irrigation (Table 3 and 4) suggest that soil series 6, 7, 8, 9, and 10 with a percentage of 29.89 (7021.50 ha) out of the total surface area of the studied region include a high suitability (S1), the soil series 5 and 13 with a percentage of 9.98 (2345.30 ha) had a moderate suitability (S2), the soil series 1, 4 and 11 with a percentage of 30.46 (7154.72 ha) include a marginal suitability (S3) and the soil series 2, 3 and 12 with a percentage of 29.66 (6967.35 ha) were permanently not suitable (N2). The major limiting factors for this irrigation system were soil salinity and alkalinity.

Figure 3 indicated the land suitability classification map for drip irrigation. The zones with the high suitability (S1) are located in the western and northern margins and also in center of the investigated area. These portions had the second largest area in this plain and all of parameters that are used in land evaluation for irrigation even soil salinity and alkalinity had no influence on suitability class

Table 4: Distribution of surface and drip irrigation suitability

Suitability	Surface irrigation			Drip irrigation		
	Soil series	Area (ha)	Ratio (%)	Soil series	Area (ha)	Ratio (%)
S1	-	-		6, 7, 8, 9, 10	7021.50	29.89
S2n	6, 7, 8, 9, 10, 1	7351.03	31.29	5, 13	2345.30	9.98
S3n	1, 5, 11	6089.70	25.92	1, 4, 11	7154.72	30.46
N1n	4	3078.90	13.10	-	-	-
N2n	2,3, 12	6968.78	29.66	2, 3, 12	6967.35	29.66

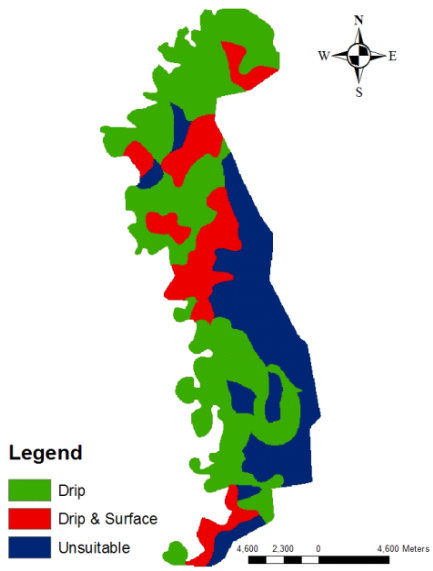

Fig. 4: Land suitability classification map for different irrigation systems

Table 5: The most suitable soil series for surface and drip irrigation systems by notation to suitability class for different irrigation system

Soil series	The aximum capability index (Ci)	Suitability classes	The most suitable irrigation system
1	59.95	S3	Drip and Surface
2	1.08	N2	Permanently non suitable
3	12.58	N2	Permanently non suitable
4	58.31	S3	Drip
5	67.10	S2	Drip
6	89.19	S1	Drip
7	86.19	S1	Drip
8	82.21	S1	Drip
9	90.50	S1	Drip
10	83.89	S1	Drip
11	59.63	S3	Drip and Surface
12	1.00	N2	Permanently non suitable
13	79.96	S2	Drip and Surface

in this part. The portions that had moderate suitability (S2) are located in some part of this studied area. These portions had the smallest area in this plain and the quantities of soil salinity and alkalinity had higher amounts than the zones with high suitability (S1) in this part. The zones that were found with the marginal suitability (S3) are located in some part of the studied area that had higher quantities of soil salinity and alkalinity comparing with both regions with high (S1) and moderate suitability (S2). Also these portions had the largest area comparing with the other suitability classes. Finally the zones with the permanent non suitability (N2) that are located in some part of the studied region had the highest quantities of salinity and alkalinity comparing with other suitability classes.

As shown in Table 5 soil series 6, 7, 8, 9 and 10 with a percentage of 29.89 (7021.50 ha) out of the total surface area of the studied region, the soil series 5 with a percentage of 8.57 (2014.22 ha) and the soil series 4 with a percentage of 13.11 (3079.47 ha) that are respectively settled in high (S1), moderate (S2) and marginal (S3) classes are only suitable for drip irrigation. In these soil series, applying drip irrigation instead of surface irrigation, could improve the water resource management.

The soil series 1 and 11 with a percentage of 17.35 (4075.19 ha) and a class of marginally suitable (S3) are suitable for both surface and drip irrigation systems. The soil series 13 with a percentage of 1.40 (330.21 ha) and a suitability class of moderate (S2) is suitable for both mentioned irrigation systems. Finally, the soil series 2, 3 and 12 with a percentage of 29.66 (6967.21 ha) are permanently non suitable (N2) for both surface and drip irrigation systems. Figure 4 shows the most suitable area for surface and drip irrigation systems in Hendijan plain. As seen from this map, the largest part of this region that is located in some part of the studied area is only suitable for drip irrigation while the portion with similar suitability for both drip and surface irrigation systems that is located in some part of the studied area includes a small part of this plain and the zones with permanently non suitable (N2) class for both mentioned irrigation systems include the second largest part of the investigated area.

The above discussions show that the land suitability class for drip irrigation is higher than surface irrigation as the mean Capability Index (CI) for drip irrigation was 65.73 (moderately suitable) while for surface irrigation it was 56.38 (marginally suitable). Dengiz (2006), Liu *et al.* (2006), Barberis and Minelli (2005) and Albaji *et al.* (2010) compared the suitability evaluation for the application of different irrigation systems, the conclusion of these investigations showed that the application of drip irrigation was more effective and efficient than the other irrigation methods and it improved the land suitability for irrigation purposes. In addition, because of the insufficiency of water in arid and semi-arid climate area, this method can be also recommended for a sustainable water use (Dengiz, 2006).Also based on achieved results as shown in Table 3, the main limiting factor for Drip and Surface irrigation systems in this region were the high quantities of soil salinity and alkalinity while the other factors such as soil texture, slope, drainage, depth and content of soil calcium carbonate and gypsum had no influence on determining the suitability classes. In contrast to this soil handicap Tesfai (2002) and Landi *et al.* (2008) studied the land suitability for irrigation based on parametric method. Their results showed that the soil alkalinity and salinity is one of the main limiting factors for surface and drip irrigation, respectively.

CONCLUSION

Sustainability of ecosystem productivity and biodiversity requires the quantification of quality and quantity of natural resources and their suitability for a range of land use in the planning process of future rural, urban and industrial activities (kilic *et al.*, 2005).

In this study, an attempt has been made to analyze and to compare two irrigation systems by taking the various soils and land characteristics into account. The results of land suitability evaluation for different irrigation approaches in Hendijan plain suggest that the soil series of the investigated region include the highest class of suitability for drip irrigation. Moreover, because of the insufficiency of surface water, and the aridity and semi-aridity of the climate, only the drip irrigation is recommended for a sustainable use of this natural resource. Also, typically because of applying the less amounts of water, it is necessary and more beneficial to use drip irrigation instead of surface irrigation method to improve the water use efficiency and to resolve water shortage problems through the Hendijan plain. Since the soil alkalinity and salinity are the major limiting factors for different irrigation systems, it is recommended to set up the drainage systems in order to improve the salinity limitations and also to enhance the land production capability of the area. On the other hand, the water of Zohreh River includes high values of salinity and alkalinity in the dry seasons and it does not contain a suitable quality for irrigation. Therefore, it is advisable to confine the plantation and irrigation to the seasons including precipitation, during which the quality of river water improves. Producing the crops whose soil requirements have a higher suitability with the present conditions of the area (specially the salinity resistant crops) can increase the land productivity.

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