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Araştırma Makalesi/*Research Article (Original Paper)*

Comparing the Suitability of Two Methods (Surface and Drip) of Irrigation Based on a Parametric Evaluation System

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Abstract: The main purpose of this study was to compare two methods of surface and drip irrigations based on parametric evaluation system. This study was performed on a surface area of 3000 ha in Rimakan region in Behbahan city located in Khuzestan province of Iran. Properties of lands (slope, drainage, soil texture, and topography) and physical and chemical properties of soil (lime, salinity, alkalinity, calcium, and carbonate) were the basis for the parametric evaluation. Lands evaluation was performed after analysis using geographical information system (GIS). Results showed that 10% of the studied lands were appropriate for surface irrigation and 22.45% of the lands were appropriate for drip irrigation and the rest of the lands were inappropriate for both irrigation methods. Drip irrigation method in comparison with the surface irrigation can increase production capacity of lands, but it must be noticed that the main limiting parameters in determining irrigation method in one region are soil texture, salinity, alkalinity, drainage, calcium carbonate, topography, and ground slope. This study also showed that GIS is a beneficial tool for the evaluation of lands suitability for different irrigation methods.

Keywords: Drip irrigation, Evaluation of lands, Geographical information system (GIS), Surface irrigation, Parametric

Parametrik Değerlendirme Sistemine Göre Yüzey ve Damla Sulama Yöntemlerinin Ölçümsel Kıyaslaması

Özet: Bu çalışmanın ana hedefi, yüzey ve basınçlı damla sulama yöntemlerinin parametrik değerlendirme sistemine göre kıyaslamasıdır. Bu çalışma, Huzistan ilinin Behbehan ilçesinde ve Remikan bölgesinde 3000 hektarlık bir alanda yapılmıştır. Arazi özellikleri (eğim, drenaj, tekstür ve topoğrafya) ve toprağın fiziksel ve kimyasal özellikleri (kireç, tuzluluk, alkalilik, kalsiyum ve karbonat) parametrik değerlendirmenin esasları olarak alınmış ve Coğrafi Bilgi Sistemi'nin (CBS) kullanımı ile analizden sonra arazi değerlendirilmesi yapılmıştır. Elde edilen sonuçlara göre incelenen arazinin yüzde 10'luk kısmı yüzey sulamaya uygun, arazinin %22.4'lük kısmı damla sulamaya uygun olduğu ve arazinin geri kalanının her iki sulama yönteminin kullanımı için uygun olmadığı görülmüştür. Bu sonuçlara göre damla sulama, yüzey sulamaya nazaran arazi için uygun yüzey alanını arttırmasına neden olmasına rağmen, her bölgede sulama yönteminin temel sınırlayıcı faktörleri olarak, toprağın dokusu, tuzluluk ve alkalilik, drenaj, kalsiyum karbonat, topografi ve arazi eğimine dikkat etmek, sulama yönteminin seçiminde önem taşımaktadır. Bu çalışma; sınırlayıcı faktörlerin kambinasiyonu ve optimum sistem seçiminin yönetiminde, CBS'nin faydalı bir araç olduğunu göstermiştir.

Anahtar kelimeler: Basınçlı sulama, Arazi değerlendirme, Coğrafik Bilgi sistemi (CBS), Yüzey sulama, Parametrik

Introduction

The limitations of soil and water sources and increase in the growth of population moved countries toward increasing the production of agricultural products per unit area and optimized the productivity of this source (Bazzani et al. 2002; Albaji et al. 2015). According to population growth and rise in the standard level of life, demands for food have increased (Bienvenue et al. 2003; Albaji et al. 2010). Therefore, the knowledge and information about all the effective parameters in food production are essential (Bond 2002). Since water and soil are the most important factors, knowing lands potentials and limitations and providing the required water are the most essential factors for more production. In many regions, due to more limitation of water sources, the need to use new and high efficiency irrigation systems for the irrigation of agricultural products is required in order to benefit the advantages of these systems, such as uniform distribution of water and possibility of irrigation of lands with irregular topographies as well as saving water (DMI 2003; IOA 1997). Due to the high efficiency of drip irrigation method, it is possible to increase the areas under irrigation by a constant amount of water (comparing drip and surface irrigation methods) using these irrigation methods and even produce more products consuming less water than the usual surface irrigation (Griffiths 1975; Albaji et al. 2014). Drip irrigation has some advantages; these advantages include the following.

- It prevents effectively surface runoff and soil erosion in steep lands or lands having severe topography.
- It is possible to correctly irrigate lands and soils with different textures and properties.
- Lands with limited soil depth which cannot be leveled can be irrigated without leveling process.
- In shallow soils or for crops having low root depth and also in initial irrigations in which irrigation must be done up to shallow depths and in a short time, surface irrigation method does not result in an appropriate efficiency while drip irrigation has high efficiency.

Lands suitability based on FAO's method (1976) is extremely dependent on ground quality which includes parameters, such as soil erodibility, usable water, flood dangers, and topography, each of which has its own measurable qualities. Indeed, land qualities are measurable, calculable or estimable parameters which are practical results of the presence of ground properties. Some of these properties which are used for land suitability studies for irrigation purposes are angle and slope length, soil texture, and salinity (Tesfai 2002; Albaji et al. 2009; Knox et al. 2012). Sys et al. (1991) proposed parametric evaluation system for irrigation methods which is based on physical and chemical properties of soil. Measurable factors of lands suitability for irrigation are divided in to four categories: soil physical properties, such as textures, structure, depth, which is related to water present in the soil; soil chemical properties, such as soluble salts, gypsum, calcium carbonate, and exchangeable sodium; drainage properties; and environmental factors, such as slope.

Dengiz (1998), used parametric evaluation to compare two surface and drip irrigation methods in a research field in the south of Ankara. He used geographical information system (GIS) for the data analysis and plotting of related maps. He showed by analyzing soil physical properties, the topography, salinity and alkalinity, and drainage, that 13.1% of the studied lands were appropriate for surface irrigation and 51.2% of the lands were appropriate for drip irrigation and drip irrigation is more appropriate than surface irrigation for more than half of the studied lands. Use of GIS in parametric evaluation for irrigation methods is very important and in addition to saving the time needed for data analysis, it is possible to update data easily.

Naseri et al. (2009) investigated soil quality for different irrigation methods in Lali plain and considered 6 factors: soil texture, soil depth, lime, soil salinity, drainage, and slope. The results showed that 1732 ha (48.5%) of studied lands were appropriate for three irrigation methods of surface, drip, and sprinkler, while 384 ha (10.8%) of the studied lands were not appropriate for surface irrigation and were appropriate for sprinkler and drip irrigations. The purpose of this study was evaluate lands suitability for two surface and drip irrigation methods in Rimakan region of Behbahan city.

Materials and Methods

The present study was performed on a surface area of 3000 ha in Rimakan region in Khuzestan province of Iran. The studied region is located in 10 km Eastern North of Behbahan having UTM coordinates of 422000 to 435500 eastern longitude and 3393000 to 3402000 northern latitude. Average annual rainfall, temperature, and humidity are 331.3 mm, 24°C, and 47%, respectively (statistical period: 1994 to 2003). Thermal regime of the studied region is hyperthermic and its humidity regime is located in Ustic class. Its climate condition is dry and length of dry periods is 230 days. The required water for agricultural uses is provided by Maroon River. The topographic characteristics including slope and soil properties, such as soil texture, depth, salinity, drainage, and calcium carbonate content were taken into account. Soil properties, such as cation exchange capacity (CEC), percentage of basic saturation (PBC), organic matter (OM), and pH were considered in terms of soil fertility. Sys et al. (1991) suggested that soil characteristics, such as OM and PBS do not require any evaluation in arid regions, whereas clay CEC rate usually exceeds the plant requirement without further limitation; thus, fertility properties can be excluded from land evaluation if it is done for the purpose of irrigation. For laboratory analysis, particle size distribution was determined using hydrometer method 9. Soil pH was measured in 1:2.5 soil/liquid ratio in 0.1 N KCl. Soil organic carbon (SOC) was estimated by combustion at 8400°C. CEC was determined by percolating 2.5 g of soil with 100 ml of IM ammonium chloride for about 4 h. Before percolating soil samples, samples were soaked with extraction solution overnight. For the evaluation of lands suitability for surface and drip irrigation, parametric evaluation system was used (Sys et al. 1991). This method is based on morphology, physical, and chemical properties of soil. In parametric method, 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 by comparing them with the tables of soil requirements. The specified degrees were used in order to measure the land index, that is, a multiplicative index that combines ratings assigned to soil map units and the other physical conditions that affect the land use. In order to evaluate lands suitability for different irrigation methods, parametric evaluation proposed by Sys et al. (1991) was used. In this method, soil properties are graded and capability index for irrigation is calculated by using soil properties grades and the following equation:

$$Ci = (\text{Grade values of soil texture}) \times (\text{Soil depth}/100) \times (\text{Lime}/100) \times (\text{Drainage}/100) \times (\text{Electrical conductivity}/100) \times (\text{Slope}/100)$$

Irrigation capability index (Ci) was calculated for each unit of lands and the lands suitability was determined on the map by different colors and labels. These labels include: S1 (completely appropriate), S2 (partly appropriate), S3 (approximately appropriate), N1 (inappropriate in present condition), and N2 (permanently inappropriate). The parametric model is defined by using the value of factor rating as formula. These six layers were then spatially overlaid to produce resultant layers. Schematic chart of the spatial overlay showing the land and soil characteristics are illustrated in Figure 1. These factors (including soil texture, soil depth, calcium carbonates status, electrical conductivity of soil solution, drainage properties, and slope) were also considered and values were assigned to each as per the related tables (Tables 1 to 6). In Table 7 shows the ranges of capability index and the corresponding suitability classes.

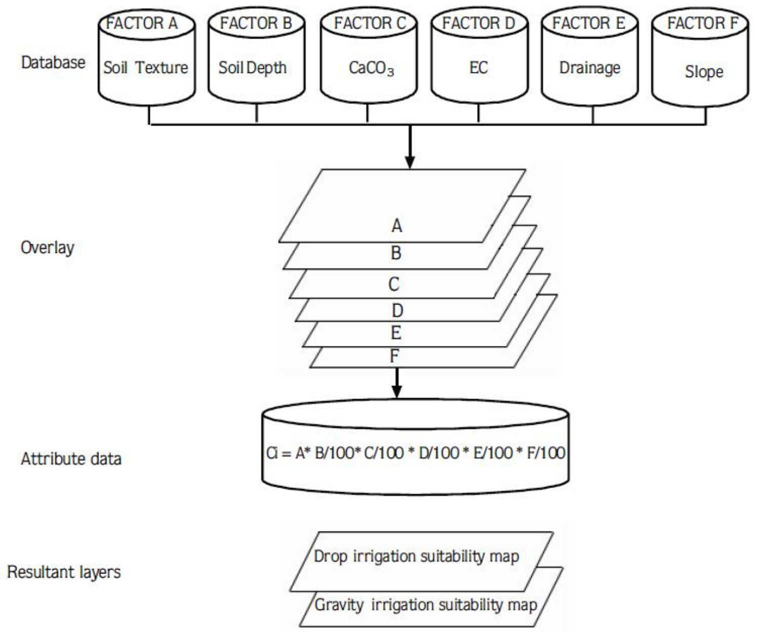

Figure 1. Schematic chart of GIS application for two different irrigation suitability maps.

Table 1.Rating of Soil Depth for Irrigation

Soil depth (cm)	Rating for surface irrigation	Rating for drip irrigation
<20	25	35
20–50	60	70
50–80	80	90
80–100	90	100
>100	100	100

Table 2. Rating of $CaCo_3$ for Irrigation

$CaCo_3$ (%)	Rating for surface irrigation	Rating for drip irrigation
<0.3	90	90
0.3–10	95	95
10–25	100	95
25–50	90	80
>50	80	70

Table 3. Rating of salinity for irrigation.

	Rating for surface irrigation		Rating for drip irrigation	
EC (ds/m)	*C, SiC, SiCL, S, SC Textures	Other Textures	C, SiC, SiCL, S, SC Textures	Other Textures
<4	100	100	100	100
4–8	90	95	95	95
8–16	80	50	85	50
16–30	70	30	75	35
>30	60	20	65	25

* C: Clay SiC: Silty Clay SiCL: Silty Clay Loam S: Sand SC: Sandy Clay

Table 4. Rating of Drainage Classes for Irrigation

	Rating for surface irrigation		Rating for drip irrigation	
Drainage classes	*C, SiC, SiCL, S, SC Textures	Other textures	C, SiC, SiCL, S, SC textures	Other textures
Well drained	100	100	100	100
Imperfectly drained	70	80	80	90
Poorly drained	60	65	70	80
Very poorly drained	40	65	50	65

* C: Clay SiC: Silty Clay SiCL: Silty Clay Loam S: Sand SC: Sandy Clay

Table 5. Rating of slope for irrigation

Slope Classes	Rating for surface irrigation		Rating for drip irrigation	
(%)	Non-terraced	Terraced	Non-terraced	Terraced
0–1	100	100	100	100
1–3	95	95	100	100
3–5	90	95	100	100
5–8	80	90	90	100
8–16	70	80	80	90
16–30	50	65	60	75
>30	30	45	40	55

Table 6. Rating of textural classes for irrigation

Textural class	Rating for surface irrigation					Rating for drip and localized irrigation				
	Fine gravel	Fine gravel			Coarse gravel	Fine gravel	Fine gravel			Coarse gravel
	<15%	15-40%	40-75%	15-40%	40-75%	<15%	15-40%	40-75%	15-40%	40-75%
Clay Loam (CL)	100	90	80	80	50	100	90	80	80	50
Silty Clay Loam (SiCL)	100	90	80	80	50	100	90	80	80	50
Sandy Clay Loam (SCL)	95	85	75	75	45	95	85	75	75	45
Loam (L)	90	80	70	70	45	90	80	70	70	45
Silty Loam (SiL)	90	80	70	70	45	90	80	70	70	45
Silt (Si)	90	80	70	70	45	90	80	70	70	45
Silty Clay (SiC)	85	95	80	80	40	85	95	80	80	40
Clay (C)	85	95	80	80	40	85	95	80	80	40
Sandy Clay (SC)	80	90	75	75	35	95	90	85	80	35
Sandy Loam (SL)	75	65	60	60	35	95	85	80	75	35
Loamy Sand (LS)	55	50	45	45	25	85	75	55	60	35
Sandy (S)	30	25	25	25	25	70	65	50	35	35

Table 7. Suitability classes for the irrigation capability indices (Ci) classes

Capability index	Definition	Symbol
>80	Highly suitable	S_1
60–80	Moderately suitable	S_2
45–59	Marginally suitable	S_3
30–44	Currently not suitable	N_1
<29	Permanently not suitable	N_2

Results and Discussion

Based on semi-detailed soil studies performed by Water and Soil Consulting Engineers of Iran, there are four physiographic units in the studied region: hillside plains, fan like lands with pebbles, upper plateaus, and old riverbed. Six different soil series were used for determination of soil properties from the results of tests on witness profiles. Figure 2 shows the lands units map produced by GIS. Different parameters, such as soil texture, soil depth, lime, electrical conductivity, drainage, and slope were added for each of the units to database table and lands evaluation maps for surface and drip irrigations were produced by overlapping these strata in ARCGIS 9.3 software.

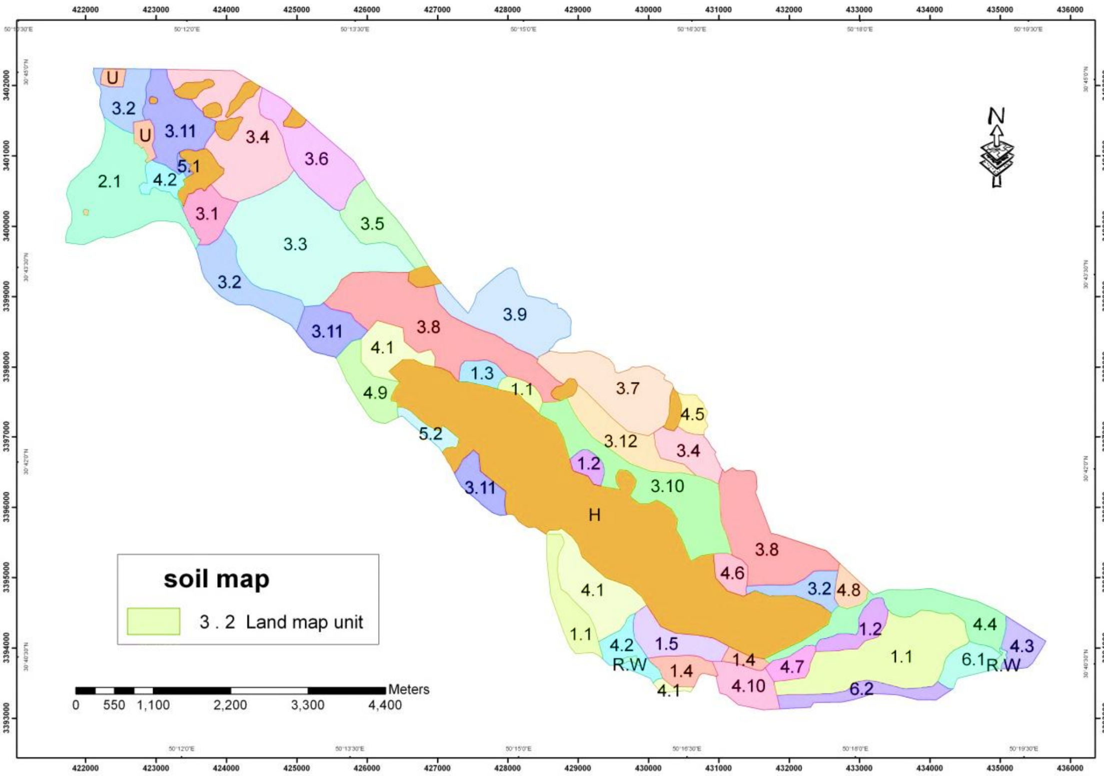

Figure 2. Land units map.

The groups of soils that had similar properties and were located in the same physiographic unit were categorized as soil series and were taxonomized to form a soil family as per the Keys to Soil Taxonomy (2010). In the studied region, 32 units of lands with a surface area equal to 95% of lands were separated and 5% of lands belonging to residential regions and water courses were considered as miscellaneous lands. Lands suitability evaluation for surface irrigation based on parametric system showed that units of 3.2, 3.11, 4.2, 3.1, 4.1, 5.2, 3.10, 4.2, 4.7, 4.4, 4.3, 4.11, 4.10, 5.2, and 4.6 which include surface area of 1206 ha have N1 suitability and units of 3.4, 3.6, 3.5, 3.3, 3.8, 3.9, 3.7, 3.12, 4.5, 3.4, 3.8, 4.9, and 6.2 with surface area of 1394 ha have N2 suitability and units of 2.1, 1.3, 1.1, 1.2, 1.5, 1.4, 6.2, and 6.1 with surface area of 299 ha have S3 suitability and there were no S1 and S2 suitability in the studied region. Also, lands suitability for drip irrigation based on parametric system showed that units of 1.1 and 1.4 with surface area of 278 ha (9.09%) have S2 suitability and units of 1.2, 1.3, 2.1, 3.1, and 4.1 which include surface area of approximately 409 ha (13.36%) have S3 suitability and units of 1.5, 3.4, 3.8, 3.10, 3.11, 3.12, 4.4, 4.8, 4.10, 5.2, 6.1, and 6.2 with surface area of 939 ha (30.72%) have N1 suitability and units of 3.2, 3.3, 3.5, 3.6, 3.7, 3.9, 4.2, 4.3, 4.5, 4.6, 4.7, 5.2, and 5.1 having surface area of 1275 ha (41.63%) have N2 suitability and there are no S1 suitability in the region. Figures 3 and 4 show the maps of lands suitability for surface irrigation and drip irrigation, respectively.

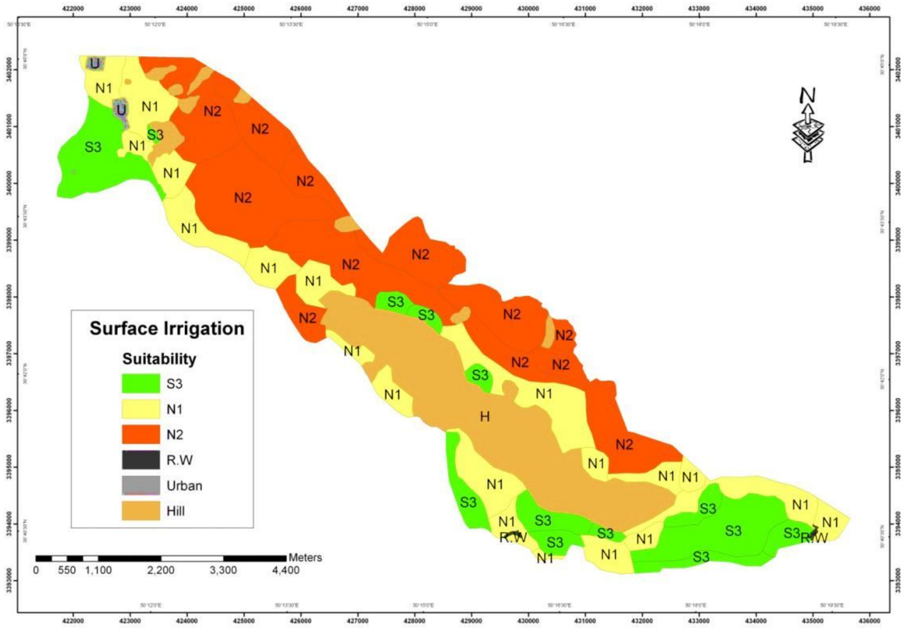

Figure 3. Lands suitability map for surface irrigation.

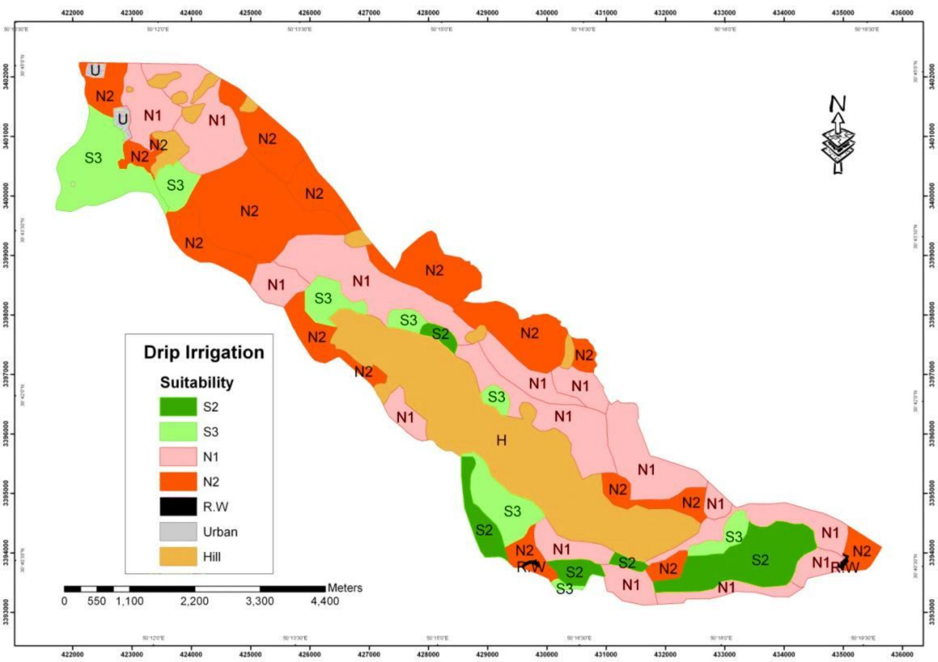

Figure 4. Lands suitability map for drip irrigation.

Figures 3 and 4 show that the best places for surface and drip irrigations based on parametric segmentation are units 1.1, 6.2, and 6.1, and they are located in the southern Rimakan plains. Unit 2.1, the areas placed in the northern plains of Rimakan, is also one of the suitable units for irrigation. Areas of north-east and east plains are appropriate for none of the irrigation methods.

Since in the method of drip irrigation, soil, slope, and the drainage features of land make less limitation, as shown in images 3 and 4, the proportion of land suitable for irrigation is calculated based on parametric classification system, using drip method is more than 2 times the surface method. Moreover, underlying shifts in the areas of s3 quality in surface irrigation to the areas of s2 quality in drip irrigation are also shown. Figures 3 and 4 show the surface and drip methods. Land with irrigation potential of type s1 cannot be seen, because of the limitations of soil depth and slope of the land of the underlying plains. Iran, in term of climatic conditions, is considered to be arid and semi-arid. The change from surface irrigation to drip irrigation can increase cultivation in the Rimakan plains, to double the current level without the need to withdraw more water from groundwater sources.

Considering areas with high slope and too low soil depth, the use of surface water, leads to wash away soil. It seems that restrictions are applied in these areas, because the additive effect of these two parameters is not considered in the tables presented in the parametric approach. Therefore, it can be guessed in terms of the use of surface irrigation that restrictions in areas of high slope increase. This means that in the area around the hill on the plains, the amount of land suitable for irrigation in practice is more than the calculated values based on the parametric system, because if you use a drip system with adjust discharge rates of dripper and hours of system operation, it may reduce interaction of restrictions, land slope, and soil depth. The comparison of two types of irrigation techniques revealed that the drip irrigation method was more effective than surface irrigation for improved land productivity and analysis of the suitability irrigation maps for surface irrigation and drip irrigations shown that, the main limiting factor in using either surface or drip irrigation methods in Rimakan plain were soil depth and slope, and the main limiting factor in using drip irrigation method was the $CaCo_3$ content, soil texture and salinity. Figure 3 indicate that the major portion of the cultivated area in this plain located in the north and south is deemed as being highly suitable land due to deep soil, texture, salinity, good drainage, and proper slope of the area. In drip irrigation the moderately suitable (s_2) area is located to the south and north of this area due to sandy loam soil texture. Other factors such as drainage, salinity, depth, and alkalinity have no influence on the suitability of the area. The surface irrigation map (Figure 3) also indicates that 1206 ha (41.16%) of the Rimakan Plain's land was evaluated as marginally suitable because of the loamy sand soil texture and 44.98% of the Rimakan Plain's land was evaluated as Permanently not suitable, the current nonsuitable land for two methods can be observed in the center of the plain and around the hill because of physical limitations especially gravelly soil depth. The permanently nonsuitable for two methods can be observed in the north-east and east for surface irrigation and east of the plain for drip irrigation for almost the total study area elements such as salinity and $CaCO_3$ were not considered as limiting factors. The results of Figure 3 and Figure 4 indicated that by applying drip irrigation instead of surface irrigation method, the land suitability of 388 ha (13.33%) of the Rimakan Plain's land could be improved substantially. However by applying drip irrigation instead of surface irrigation method, the suitability of 278 ha (9.09%) of this plain's land could be improved to moderately suitable (s_2). The comparison of two types of irrigations revealed that drip irrigation was more effective and efficient than the surface and drip irrigation method improved land suitability for irrigation purposes. To sum up, the most suitable irrigation systems for the Rimakan Plain was drip irrigation. Moreover, the main limiting factor in using surface and drip irrigation methods in this area was soil depth and the main limiting factors in using drip irrigation methods was the soil's texture.

Conclusion

Iran, in term of climatic conditions is considered to be arid and semi-arid. The change from surface irrigation to drip irrigation can increase cultivation in the Rimakan plains (and such areas), to double the current level without the need to withdraw more water from groundwater sources. Considering areas with high slope and too low soil depth, the use of surface water leads to wash away soil. It seems that restrictions are applied in these areas, because the additive effect of these two parameters is not considered in the tables presented in the parametric approach.

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