Evaluation of Agricultural Land Resources for Irrigation in the Ramhormoz Plain by using GIS

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Summary

The main objective of this research is to compare different irrigation methods based upon a parametric evaluation system in an area of 45,000 ha in the Ramhormoz plain located in the Khuzestan Province, in the southwest of Iran. The soil properties of the study area such as texture, depth, electrical conductivity, drainage, calcium carbonate content and slope were derived from a semi-detailed soil study carried out on the Ramhormoz plain on a scale of 1:20,000. Once the soil properties were analyzed and evaluated, suitability maps were generated for surface, sprinkler and drip irrigation methods using Remote Sensing (RS) Techniques and Geographic Information System (GIS). The results demonstrated that by applying sprinkler irrigation instead of surface and drip irrigation methods, the arability of 39,625 ha (87.98%) in the Ramhormoz Plain will improve. In addition by applying drip Irrigation instead of surface and sprinkler irrigation methods, the land suitability of 2925 ha (6.57%) of this Plain will improve. The comparison of the different types of irrigation techniques revealed that the sprinkler and drip irrigations methods were more effective and efficient than the surface irrigation methods for improving land productivity. However, the main limiting factor in using surface irrigation methods in this area were salinity, drainage and carbonate content and the main limiting factor in using sprinkler and drip irrigation methods in this area were salinity and carbonate content.

Key words

surface irrigation, sprinkler irrigation, drip irrigation, land suitability evaluation, parametric method, soil series

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Introduction

Iran's rural economy is mainly depending on agricultural sector but there is shortage of rainfall especially in the southern part of the country. In Ramhormoz plain, irrigation is considered as necessary to support the agricultural base as it plays a very important role in improving the livelihood of farmers. The effective and sustainable utilization of the limited water resource is very crucial in arid and semi-arid areas like Ramhormoz. In 1990 the Khuzestan Water and Power Authority initiated an ambitious plan to construct an "Irrigation & Drainage Network" within ten years with a capacity of irrigating 25,000 ha in the moisture stressed and drought prone areas (Khuzestan Water and Power Authority, 2011). To this end, the commission mandated to increase crop production through construction of irrigation infrastructure in Ramhormoz plain. By the end of 2005 irrigation infrastructure with a nominal capacity of irrigating 25,000 ha of land was completed. But the completed Irrigation Network is operating much below its capacity due to a shortage of water. Only about 15,000 ha of land were actually being irrigated in 2009. According to FAO methodology (1976) land suitability is strongly related to "land qualities" including erosion resistance, water availability and flood hazards that are derived from slope angle and length, rainfall and soil texture. Sys et al. (1991) suggested a parametric evaluation system for irrigation methods that was primarily based on physical and chemical soil properties.

Briza et al. (2001) applied a parametric system (Sys et al., 1991) to evaluate land suitability for both surface and drip irrigation in the Ben Slimane province, Morocco. The largest part of the agricultural areas was classified as marginally suitable.

Bazzani and Incerti (2002) also provided a land suitability evaluation for surface and drip irrigation systems in the province of Larche, Morocco, by using parametric evaluation systems. The results showed a large difference between applying the two irrigation methods.

Bienvenue et al. (2003) evaluated the land suitability for surface (gravity) and drip (localized) irrigation in Senegal using Sys's parametric evaluation systems. Regarding the surface irrigation, there was no area classified as highly suitable (S1). For drip (localized) irrigation, a good portion (25.03%) of the area was classified as highly suitable (S1).

Mbodj et al. (2004) performed a land suitability evaluation for two types of irrigation i. e, surface irrigation and drip irrigation, in the Tunisian Oued Rmel Catchment using the suggested parametric evaluation. They found that the drip irrigation suitability gave more irrigable areas compared to the surface irrigation practice

Istituto Agronomico per l'Oltremare (IAO) (2005) provided land suitability classification for both surface and drip irrigation methods in Shouyang County, Shanxi Province, China, where the study was carried out by a modified parametric system. The results indicated that due to the unusual morphology, the area suitability for the surface irrigation (34%) is smaller than the surface used for the drip irrigation (62%).

Dengiz (2006) also compared different irrigation methods including surface and drip irrigation in the pilot fields of Central Research Institute, Lkizce Research Farm located in southern Ankara. He concluded that the drip irrigation method increased the land suitability by 38% compared to the surface irrigation method.

Liu et al. (2007) evaluated the land suitability for surface and drip irrigation in the Danling County, Sichuan Province, China, using a Sys's parametric evaluation system. Drip irrigation was everywhere more suitable than surface irrigation due to the minor environmental impact that it caused.

Albaji et al. (2009a) compared the suitability of land for surface and drip irrigation methods according to a parametric evaluation system in the plains west of the city of Shush, in the southwest Iran. The results indicated that a larger amount of the land (30,100 ha—71.8%) can be classified as more suitable for drip irrigation than surface irrigation.

The main objective of this research is to evaluate and compare land suitability for surface, sprinkler and drip irrigation methods based on the parametric evaluation systems for the Ramhormoz Plain, in the Khuzestan Province, Iran.

Materials and methods

The present study was conducted in an area about 45,000 hectares in the Ramhormoz Plain, in the Khuzestan Province, located in the Southwest of Iran during 2010-2011. The study area is located 90 km West of the city of Ahwaz, 31° 05´ to 31° 22´ N and 49° 25´ to 49° 43´ E. The Average annual temperature and precipitation for the period of 1987–2011 were 26.1 °C and 315.9 mm, respectively. (Table.1) (Khuzestan Water and Power Authority, 2011).The Marun River supplies the bulk of the water demands of the region. The application of irrigated agriculture 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.

The area is composed of three distinct physiographic features i.e. Plateaux, Piedmont Alluvial Plain and River Alluvial Plain, of which the Piedmont Alluvial Plains physiographic unit is the dominating features. Also, eleven different soil series were found in the area (Table 2). The semi-detailed soil survey report of the Ramhormoz plain (Khuzestan Water and Power Authority, 2010) was used in order to determine the soil characteristics. Table 3 shows some of physico – chemical characteristics for reference profiles of different soil series in the plain. The land evaluation was determined based upon topography and soil characteristics of the region (Albaji et al., 2009b). The topographic characteristics included slope and soil properties such as soil texture, depth, salinity, drainage and calcium carbonate content were taken into account (Behzad et al., 2009). Soil properties such as cation exchange capacity (CEC), percentage of basic saturation (PBC), organic mater (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.

According to the particular semi-detailed studies of the region, samples were taken from each soil series profiles and laboratory analysis were carried out based upon the conventional methods

Table 1. Mean air temperature, relative humidity and total monthly rainfall and evaporation (1987–2011) at Ramhormoz

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Temperature(°C)	12.7	14.7	18.7	25.2	31.8	36.1	38.2	37.8	34	28.6	20.6	14.9	26.1
Relative humidity (%)	70.8	58.4	51.2	37.6	22	17.6	19.5	21.5	21.5	29.1	45.3	67	38.4
													Total
Rainfall (mm)	99.1	55.7	36.8	19.2	2.2	0	0	0	0	6.1	22.2	74.5	315.9

Table 2. Soil series of the study area

Series No	Characteristics description	Area	
		ha	Ratio (%)
1	Soil texture "Medium: L"[1], severe salinity and alkalinity limitation, depth 155 cm, level to very gently sloping: 0 to 2% well drained.	2475	5.51
2	Soil texture "Medium : SIL", slight salinity and alkalinity limitation, depth 140 cm, level to very gently sloping: 0 to 2%, well drained	1925	4.29
3	Soil texture "Medium: SIL", without salinity and alkalinity limitation, depth 140 cm, level to very gently sloping: 0 to 2%, well drained.	1350	2.99
4	Soil texture "Heavy: SICL", moderate salinity and alkalinity limitation, depth 130 cm, level to very gently sloping: 0 to 2%, well drained.	375	0.84
5	Soil texture "Very Heavy: SIC", slight salinity and alkalinity limitation, depth 130 cm, level to very gently sloping: 0 to 2%, well drained.	6800	15.12
6	Soil texture "Very Heavy : SIC", slight salinity and alkalinity limitation, Depth 150 cm, level to very gently sloping: 0 to 2%, moderately drained	3700	8.23
7	Soil texture "Medium: L", severe salinity and alkalinity limitation, depth 150 cm, level to very gently sloping: 0 to 2%, poorly drained.	2925	6.57
8	Soil texture "Very Heavy: SIC", moderate salinity and alkalinity limitation, depth 130 cm, level to very gently sloping: 0 to 2%, poorly drained.	9800	21.75
9	Soil texture "Medium: L", very severe salinity and alkalinity limitation, depth 135 cm, level to very gently sloping: 0 to 2%, moderately drained.	3400	7.55
10	Soil texture "Medium: L", very severe salinity and alkalinity limitation, depth 150 cm, level to very gently sloping: 0 to 2%, moderately drained.	7775	17.19
11	Soil texture "Medium: SL", moderate salinity and alkalinity limitation, depth 140 cm, level to very gently sloping: 0 to 2%, well drained.	2025	4.51
Mis land	Marsh, river wash and urban	2450	5.45
Total		45000	100

[1] Texture symbols: L - Loam; SL - Sandy Loam: SIL - Silty Loam; SICL - Silty Clay Loam; SIC - Silty Clay.

Table 3. Some of physico–chemical characteristics for reference profiles of different soil series

Soil series No	Soil series name	Depth (cm)	Soil texture	ECe ($ds.m^{-1}$)	pH	OM (%)	CEC (meq/100 g)	$CaCO_3$ (%)
1	Morad Bigi	155	L	25.86	8.10	0.25	12.31	43
2	Shifeh	140	SIL	6.56	7.90	0.20	12.24	51
3	Aala	140	SIL	2.97	8.30	0.29	10.56	50
4	Ramous	130	SICL	13.67	8.50	0.15	11.42	24
5	Ramhormoz	130	SIC	7.08	8.10	0.47	12.73	55
6	Sarcheshmeh	150	SIC	6.42	8.00	0.79	14.29	48
7	Koopal	150	L	26.74	8.20	0.39	13.31	9
8	Babel	130	SIC	12.85	8.30	0.27	12.64	49
9	Gavmisheh	135	L	38.67	8.50	0.34	11.41	28
10	Jonushi	150	L	42.12	8.60	0.55	12.71	32
11	Marbacheh	140	SL	11.38	8.20	0.42	12.93	58

of the Iranian Soil and Water Research Institute (Mahjoobi et al., 2010), and the following properties were measured by due methods: Electrical Conductivity (EC) in dS/m was calculated at 25 °C on soil water (1:5) extract; the water soluble cations were calculated using the spectrophotometer method, the Electrical Conductivity correspond to the salinity, the soil texture was determined using the Gravimetric method (pipette). The proportional distribution of coarse sand (2.0-0.2 mm), medium sand (0.2-0.1 mm), fine sand (0.1-0.05 mm), coarse silt (0.05-0.02 mm), fine silt (0.02-0.002 mm), and clay (<0.002 mm) was calculated and the soil texture was successively classified using the USDA Soil Textural Classification System. Lime ($CaCO_3$) in % was expressed as calcium carbonate equivalent using gas volumetric method (Page et al., 1992).

The groups of soils that had similar properties and were located in a same physiographic unit were categorized as soil series and soil family as per the Soil Survey Staff (2008). Ultimately, eleven soil series were selected for the surface, sprinkler and drip irrigation land suitability.

In order to obtain the average soil texture, salinity and $CaCO_3$ for the upper 150 cm of soil surface, the profile was subdivided into six equal sections and weighting factors of 2, 1.5, 1, 0.75, 0.50 and 0.25 were used for each section, respectively (Sys et al., 1991).

For the evaluation of land suitability for surface, sprinkler and drip irrigation, the 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 through comparing them with the tables of soil requirements. The specified degrees are used in order to measure 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).

The chemical and physical soil proprieties are determined in the soil laboratory of Khuzestan Water and Power Authority using different kind of analysis processing. Parameters taken into account for evaluation of suitability for irrigation were the following:

— Soil texture: rated taking in account the permeability and available water content, and calculated, as weighted average, for the upper 100 cm.
— Soil depth: rated with regard to the thickness and the characteristic of the soil layers (horizons).
— Calcium carbonate content: influencing the relationship between soil and water, and the availability of nutrient supply for plant (150 cm of soil profile). It is rated with regard to the $CaCO_3$ content effect on soil profile.
— Salinity: rated on the base of the electrical conductivity of soil solution.
— Drainage, visually estimated during the fieldwork, is indicated with a code that gives it a qualitative characterization.
— Slope, in %, was measured using clinometers.

These parameters (including 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 4-9) [Sys et al. (1991) for surface and drip irrigation & Albaji (2010a) for sprinkler irrigation], thus, the capability index for irrigation (Ci) was developed as shown in the equation below:

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

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

In Table 10 (Sys et al,. 1991) the ranges of capability index and the corresponding suitability classes are shown.

In order to develop land suitability maps for different irrigation methods, a semi-detailed soil map (Fig.1) prepared by Albaji was used, and all the data for soil characteristics were analyzed and incorporated in the map using ArcGIS 9.2 software.

The digital soil map base preparation was the first step towards the presentation of a GIS module for land suitability maps

Table 4. Rating of textural classes for irrigation

Soil series No	Soil series name	Depth (cm)	Soil texture	ECe (ds.m^{-1})	pH	OM (%)	CEC (meq/100 g)	$CaCO_3$ (%)
1	Morad Bigi	155	L	25.86	8.10	0.25	12.31	43
2	Shifeh	140	SIL	6.56	7.90	0.20	12.24	51
3	Aala	140	SIL	2.97	8.30	0.29	10.56	50
4	Ramous	130	SICL	13.67	8.50	0.15	11.42	24
5	Ramhormoz	130	SIC	7.08	8.10	0.47	12.73	55
6	Sarcheshmeh	150	SIC	6.42	8.00	0.79	14.29	48
7	Koopal	150	L	26.74	8.20	0.39	13.31	9
8	Babel	130	SIC	12.85	8.30	0.27	12.64	49
9	Gavmisheh	135	L	38.67	8.50	0.34	11.41	28
10	Jonushi	150	L	42.12	8.60	0.55	12.71	32
11	Marbacheh	140	SL	11.38	8.20	0.42	12.93	58

Table 5. Rating of soil depth for irrigation

Soil depth (cm)	Rating for surface irrigation	Rating for sprinkler irrigation	Rating for drip irrigation
< 20	25	30	35
20-50	60	65	70
50-80	80	85	90
80-100	90	95	100
> 100	100	100	100

Table 6. Rating of $CaCO_3$ for irrigation

$CaCO_3$ (%)	Rating for surface irrigation	Rating for sprinkler irrigation	Rating for drip irrigation
<0.3	90	90	90
0.3 -10	95	95	95
10-25	100	100	95
25-50	90	90	80
>50	80	80	70

Table 7. Rating of salinity for irrigation

EC (ds m $^{-1}$)	Rating for surface irrigation		Rating for sprinkler irrigation		Rating for drip irrigation	
	C, SiC, SiCL, S, SC textures	Other textures	C, SiC, SiCL, S, SC textures	Other textures	C, SiC, SiCL, S, SC textures	Other textures
< 4	100	100	100	100	100	100
4-8	90	95	95	95	95	95
8-16	80	50	85	50	85	50
16-30	70	30	75	35	75	35
> 30	60	20	65	25	65	25

C - Clay; SiC - Silty Clay; SiCL - Silty Clay Loam; S - Sand; SC - Sandy Clay

Table 8. Rating of drainage classes for irrigation

Drainage Classes	Rating for surface irrigation		Rating for sprinkler irrigation		Rating for drip irrigation	
	C, SiC, SiCL, S, SC textures	Other textures	C, SiC, SiCL, S, SC textures	Other textures	C, SiC, SiCL, S, SC textures	Other textures
Well drained	100	100	100	100	100	100
Moderately drained	80	90	90	95	100	100
Imperfectly drained	70	80	75	85	80	90
Poorly drained	60	65	65	70	70	80
Very poorly drained	40	65	45	65	50	65
Drainage status not known	70	80	70	80	70	80

C - Clay; SiC - Silty Clay; SiCL - Silty Clay Loam; S - Sand; SC - Sandy Clay

Table 9. Rating of slope for irrigation

Slope classes (%)	Rating for surface irrigation		Rating for sprinkler irrigation		Rating for drip irrigation	
	Non-terraced	Terraced	Non-terraced	Terraced	Non-terraced	Terraced
0-1	100	100	100	100	100	100
1-3	95	95	100	100	100	100
3-5	90	95	95	100	100	100
5-8	80	90	85	95	90	100
8-16	70	80	75	85	80	90
16-30	50	65	55	70	60	75
> 30	30	45	35	50	40	55

Table 10. Suitability classes for the irrigation capability indices (Ci) classes

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

for different irrigation systems. The soil map was then digitized and a database prepared. A total of eleven different polygons or soil series were determined in the base map. Soil characteristics were also given for each soil series. These values were used to generate the land suitability maps for surface, sprinkler and drip irrigation systems using Geographic Information Systems.

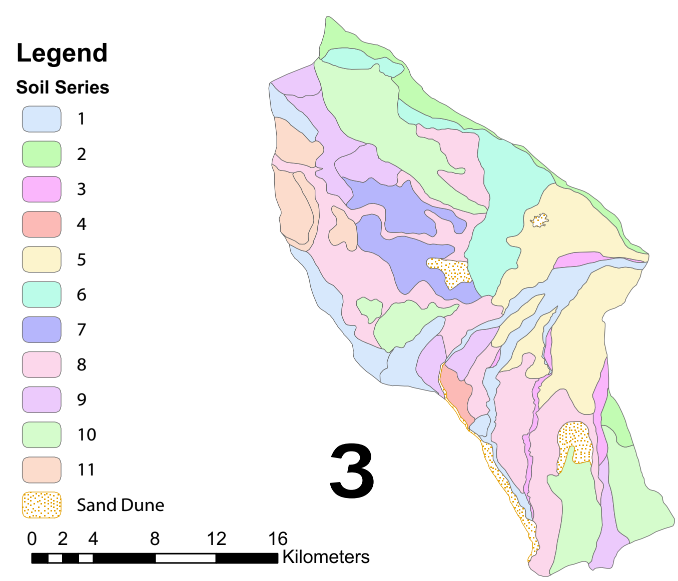

Figure 1. Soil map of the study area

Results and discussion

In Ramhormoz plain, farmers are becoming increasingly aware of irrigation as a tool for optimizing production. When all other management practices are carried out efficiently, irrigation can help the farmers to achieve the top yields and quality demanded for self food security and even to the market. In the study area irrigation is practiced from many water sources: surface water like Marun River, water harvesting and digging wells from the ground water. During the field work, a good observation in Ramhormoz Plain was done. There is soil and water conservation practice on the hill sides that enhances the increment of water table level at the foot slope field, encouraging farmers to dig a well for irrigation practice. Over most of the Ramhormoz Plain, the use of surface irrigation systems has been applied specifically for field crops to meet the water demand of both summer and winter crops. The major irrigated broad-acre crops grown in this area are wheat, barley, and maize, in addition to fruits, melons, watermelons and vegetables such as tomatoes and cucumbers. There are very few instances of sprinkler and drip irrigation on large area farms in the Ramhormoz Plain.

Eleven soil series and sixty two series phases were derived from the semi-detailed soil study of the area. The soil series are shown in Fig. 1 as the basis for further land evaluation practice. The soils of the area are of Entisols, Aridisols, Inceptisols and Mollisols orders. Also, the soil moisture regime is aridic and Torric while the soil temperature regime is hyperthermic (Khuzestan Water and Power Authority, 2010).

As shown in Tables 11 and 12 for surface irrigation, the only soil series coded 3 (1350 ha – 2.99%) were highly suitable (S_1); soil series coded 2 and 4 (2300 ha – 5.13%) were classified as moderately suitable (S_2), soil series coded 5 and 6 (10,500 ha – 23.35%) were found to be marginally suitable (S_3), only soil series coded 8 (9800 ha – 21.75%) were classified as currently not-suitable (N_1) and soil series coded 1, 7, 9, 10 and 11 (18,600 ha – 41.33%) were classified as permanently not-suitable (N_2) for any surface irrigation practices.

The analysis of the suitability irrigation maps for surface irrigation (Fig. 2) indicate that the smallest portion of the cultivated area in this plain (located in the center and east) is deemed as being highly suitable land due to deep soil, good drainage, texture, salinity and proper slope of the area. The moderately suitable area can be observed only in the east of the plain due to moderate limitations of calcium carbonate and salinity. Other factors such as drainage, depth and slope have no influence on the suitability of the area whatsoever. The map also indicates that some part of the cultivated area in this plain was evaluated as marginally suitable because of the high limitations of calcium carbonate, drainage and salinity. The current non-suitable land can be observed in the center and west of the plain because of severe limitations of drainage and salinity. The major portion of the cultivated area in this plain (located in the south, north and center) is deemed as being permanently non-suitable land due to very severe limitations of drainage and salinity. For almost the total study area elements such as soil depth, soil texture and slope were not considered as limiting factors.

Table 11. Ci values and suitability classes of surface, sprinkler and drip irrigation for each soil series

Codes of soil series	Surface irrigation		Sprinkler irrigation		Drip irrigation	
	Ci	Suitability classes	Ci	Suitability classes	Ci	Suitability classes
1	27.64	N_2 sn [1]	28.35	N_2 sn [2]	25.2	N_2 sn [3]
2	74.1	S_{2s}	76	S_{2s}	66.5	S_{2s}
3	87.75	S_1	90	S_1	80	S_1
4	78	S_2 n	85	S_1	80.75	S_1
5	59.67	S_3 sn	64.6	S_{2s}	56.52	S_{3s}
6	53.70	S_3 snw	65.40	S_{2sw}	64.6	S_{2s}
7	18.96	N_2 snw	20.94	N_2 snw	23.94	N_2 snw
8	35.80	N_1 snw	42.26	N_1 snw	40.46	N_1 snw
9	14.21	N_2 snw	15.39	N_2 sn	14.4	N_2 sn
10	14.21	N_2 snw	15.39	N_2 sn	14.4	N_2 sn
11	29.25	N_2 sn	36	N_1 sn	33.25	N_1 sn

[1] Limiting factors for surface irrigation: n: (salinity & alkalinity), w: (drainage) and s: (calcium carbonate)
[2] Limiting factors for sprinkler irrigation: n: (salinity & alkalinity) and s: (calcium carbonate)
[3] Limiting factors for drip irrigation: n: (salinity & alkalinity) and s: (calcium carbonate)

Table 12. Distribution of surface, sprinkler and drip irrigation suitability

Suitability	Surface irrigation			Sprinkler irrigation			Drip irrigation		
	Soil series	Area (ha)	Ratio (%)	Soil series	Area (ha)	Ratio (%)	Soil series	Area (ha)	Ratio (%)
S_1	3	1350	2.99	3, 4	1725	3.83	3, 4	1725	3.83
S_2	2, 4	2300	5.13	2, 5, 6	12,425	27.64	2, 6	5625	12.52
S_3	5, 6	10,500	23.35	-	-	-	5	6800	15.12
N_1	8	9800	21.75	8, 11	11,825	26.26	8, 11	11,825	26.26
N_2	1, 7, 9, 10, 11	18,600	41.33	1, 7, 9, 10	16,575	36.82	1, 7, 9 , 10	16,575	36.82
Mis land[1]		2450	5.45		2450	5.45		2450	5.45
Total		45,000	100		45,000	100		45,000	100

[1]Miscellaneous land: (hill, sand dune and river bed)

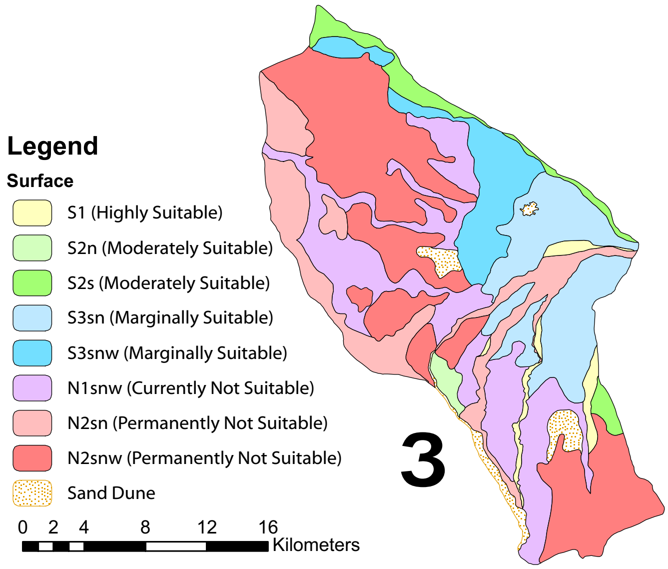

Figure 2. Land suitability map for surface irrigation

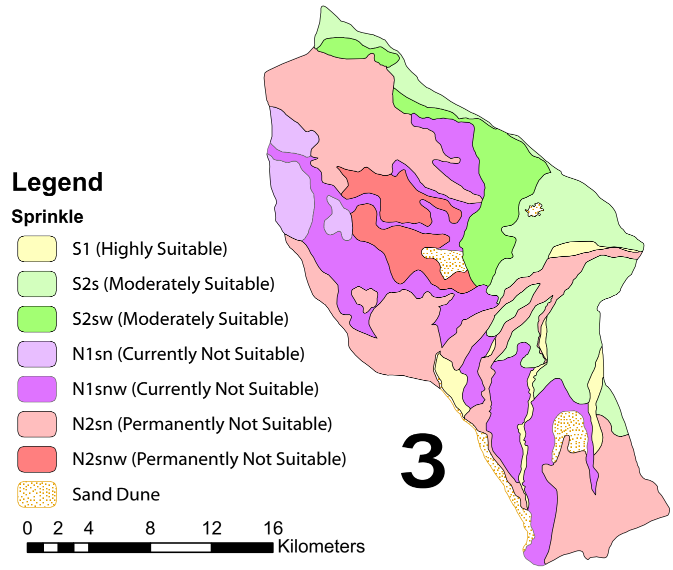

Figure 3. Land suitability map for sprinkler irrigation

In order to verify the possible effects of different management practices, the land suitability for sprinkler and drip irrigation was evaluated (Tables 11 and 12).

For sprinkler irrigation, soil series coded 3 and 4 (1725 ha, 3.83%) were highly suitable (S_1) while soil series coded 2, 5 and 6 (12,425 ha, 27.64%) were classified as moderately suitable (S_2). Soil series coded 8 and 11 (11,825 ha, 26.26%) were classified as currently non-suitable (N_1) and soil series coded 1, 7, 9 and 10 (16,575 ha, 36.82%) were classified as permanently not-suitable (N_2) for sprinkler irrigation.

Regarding sprinkler irrigation (Fig. 3), the highly suitable area can be observed in the the smallest portion of the cultivated area in this plain (located in the center and east) and it is deemed as being highly suitable land due to deep soil, good drainage, texture, salinity and proper slope of the area. As seen from the map, some part of the cultivated area in this plain was evaluated as moderately suitable for sprinkler irrigation because of the moderate limitations of calcium carbonate. Other factors such as depth, salinity and slope never influence the suitability of the area. The marginally suitable lands did not exist in this plain. The current non-suitable lands are located in the center and south of the plain and their non-suitability of the land is due to severe limitations of drainage and salinity. The permanently not-suitable lands covered the largest part of the plain (located in the south, north and west) and their non-suitability of the land is because of very severe limitations of drainage and salinity. For almost the entire study area slope, soil depth and soil texture were never taken as limiting factors.

For drip irrigation, soil series coded 3 and 4 (1725 ha, 3.83%) were highly suitable (S_1) while soil series coded 2 and 6 (5625 ha, 12.52%) were classified as moderately suitable (S_2). Further, only soil series coded 5 (6800 ha, 15.12%) were found to be slightly suitable (S_3). Soil series coded 8 and 11 (11,825 ha, 26.26%) were classified as currently non-suitable (N_1) and soil series coded 1, 7, 9 and 10 (16,575 ha, 36.82%) were classified as permanently not-suitable (N_2) for drip irrigation.

Regarding drip irrigation (Fig. 4), the highly suitable lands covered the smallest part of the plain. The slope, soil texture, soil depth, calcium carbonate, salinity and drainage were in good conditions. The moderately suitable area can be observed only in the east of the plain due to moderate limitations of calcium carbonate. Other factors such as drainage, depth and slope have no influence on the suitability of the area whatsoever. The marginally suitable lands were found only in the east of the area. The limiting factor for this soil series was the high content of calcium carbonate. The current non-suitable lands are located in the center and south of the plain and their non-suitability of the land is due to severe limitations of calcium carbonate, drainage and salinity. The permanently not-suitable lands could be observed over a large portion of the plain (west, north and south parts) due to the very severe limitations of calcium carbonate, drainage and salinity. For the entire study area, slope, soil depth and soil texture were never considered as limiting factors.

The comparison of the capability indexes for surface, sprinkler and drip irrigation (Tables 11 and 13) indicated that in soil series coded 7 applying drip irrigation systems was the most suitable option as compared to surface and sprinkler irrigation systems. In soil series coded 1, 2, 3, 4, 5, 6, 8, 9, 10 and 11 application of sprinkler irrigation systems was more suitable then surface and drip irrigation systems. Fig. 5 shows the most suitable map for surface, sprinkler and drip irrigation systems in the Ramhormoz plain as per the capability index (Ci) for different irrigation systems. As seen from this map, the largest part of this plain was suitable for sprinkler irrigation systems and some parts of this area were suitable for drip irrigation systems.

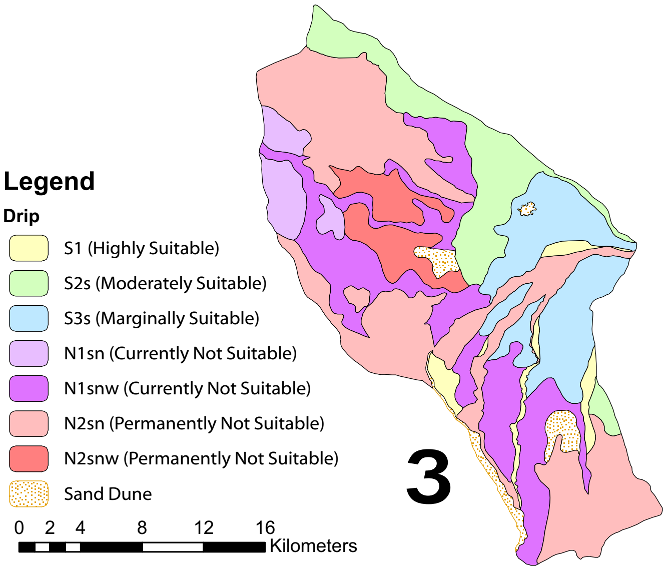

Figure 4. Land suitability map for drip irrigation

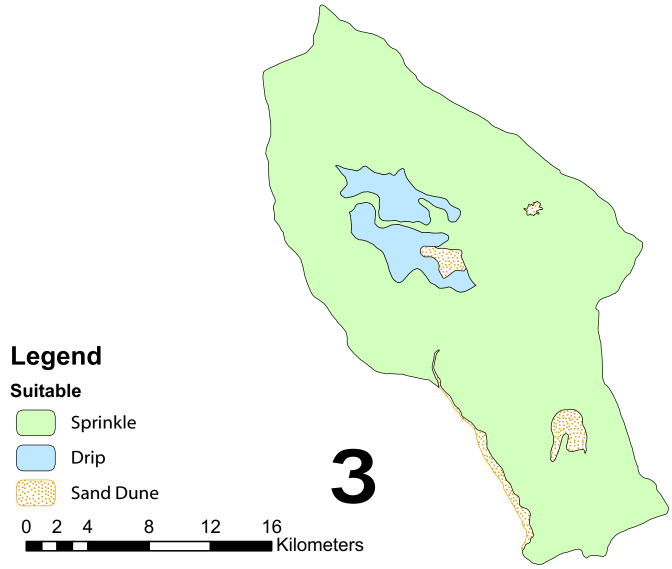

Figure 5. The most suitable map for different irrigation systems

Table 13. The most suitable soil series for surface, sprinkler and drip irrigation systems by notation to capability index (Ci) for different irrigation systems

Codes of soil series	The maximum capability index for irrigation (Ci)	Suitability classes	The most suitable irrigation systems	Limiting factors
1	28.35	N_2 sn	Sprinkler	$CaCO_3$ and salinity & alkalinity
2	76	S_2 s	Sprinkler	$CaCO_3$
3	90	S_1	Sprinkler	None
4	85	S_1	Sprinkler	None
5	64.6	S_2 s	Sprinkler	$CaCO_3$
6	65.40	S_2 sw	Sprinkler	$CaCO_3$ and drainage
7	23.94	N_2 snw	Drip	$CaCO_3$, salinity & alkalinity and drainage
8	42.26	N_1 snw	Sprinkler	$CaCO_3$, salinity & alkalinity and drainage
9	15.39	N_2 sn	Sprinkler	$CaCO_3$ and salinity & alkalinity
10	15.39	N_2 sn	Sprinkler	$CaCO_3$ and salinity & alkalinity
11	36	N_1 sn	Sprinkler	$CaCO_3$ and salinity & alkalinity

The comparison between different irrigation systems (surface and pressurized systems) shows a big difference in the suitability of the different irrigation methods. Pressurized irrigation systems (sprinkler and drip irrigation systems) can be a good irrigation method, if properly managed (good planning, use of filters, etc) (Bavi et al., 2009; Naseri et al., 2009; Albaji et al., 2010b; Albaji et al., 2010c; Albaji and Hemadi, 2011; Jovzi et al., 2012).

The results of Tables 11 and 13 indicated that by applying sprinkler irrigation instead of surface and drip irrigation methods, the land suitability of 39,625 ha (87.98%) of the Ramhormoz Plain's land could be improved substantially. However by applying drip irrigation instead of surface and sprinkler irrigation methods, the suitability of 2925 ha (6.57%) of this Plain's land could be improved. The comparison of the different types of irrigation revealed that sprinkler irrigation was more effective and efficient then the drip and surface irrigation methods and improved land suitability for irrigation purposes. The second best option was the application of drip irrigation, which was considered as being more practical than the surface irrigation method. To sum up, the most suitable irrigation systems for the Ramhormoz Plain were sprinkler irrigation, drip irrigation and surface irrigation respectively. Moreover, the main limiting factor in using surface irrigation methods in this area were salinity, drainage and carbonate content and the main limiting factor in using sprinkler and drip irrigation methods in this area were salinity and carbonate content

Conclusions

Several parameters were used for the analysis of the field data in order to compare the suitability of different irrigation systems. The analyzed parameters included soil and land characteristics. The results obtained showed that sprinkler and drip irrigation systems are more suitable than surface irrigation method for most of the study area. The major limiting factor for both sprinkler and drip irrigation methods were salinity and carbonate content. However for surface irrigation method salinity, drainage and carbonate content were restricting factors. The results of the comparison between the maps indicated that the introduction of a different irrigation management policy would provide an optimal solution; the application of sprinkler and drip irrigation techniques could be beneficial and advantageous. This is the current strategy adopted by large companies cultivating in the area and it will provide to be economically viable for farmers in the long run.

Such a change in irrigation management practices would imply the availability of larger initial capitals to farmers (different credit conditions, for example) as well as a different storage and market organization. On the other hand, because of the insufficiency of water in arid and semi arid climate, the optimization of water use efficiency is necessary to produce more crops per drop and to help resolve water shortage problems in the local agricultural sector. Therefore, the shift from surface irrigation to high-tech irrigation technologies, e.g. sprinkler and drip irrigation systems offers significant water-saving potentials. On the other hand, since sprinkler and drip irrigation systems typically apply lesser amounts of water (as compared with surface irrigations methods) on a frequent basis to maintain soil water near field capacity, it would be more beneficial to use sprinkler and drip irrigations methods in this plain.

In this study, an attempt has been made to analyze and compare three irrigation systems by taking into account various soil and land characteristics. The results obtained showed that sprinkler and drip irrigation methods are more suitable than surface or gravity irrigation method for most of the soils tested. Moreover, because of the insufficiency of surface and ground water resources, and the aridity and semi-aridity of the climate in this area, sprinkler and drip irrigation methods are highly recommended for a sustainable use of this natural resource; hence, the changing of current irrigation methods from gravity (surface) to pressurized (sprinkler and drip) in the study area are proposed.

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