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Investigation of Surface, Sprinkler and Drip Irrigation Methods Using GIS

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ABSTRACT

The main objective of this research was to provide a suitable irrigation plan based upon a parametric evaluation system for an area of 1325 ha in the Ghaleh madreseh plain, Iran. The obtained results showed that sprinkler and drip irrigation were highly appropriate methods for 682.3 ha (51.5%) of the study area. Moreover, through applying sprinkler instead of surface and drip irrigation methods, the arability of 1170, 7 ha (88.4%) of Ghaleh madreseh Plain would improve for sprinkler irrigation. Furthermore, the comparison of the different types of irrigation techniques revealed that regarding improving land productivity sprinkler and drip irrigation methods were more effective and efficient than the surface irrigation methods. The parametric evaluation system was employed in evaluating land suitability for surface, sprinkler and drip irrigation. It is of note however, that the main factor limiting the use of all irrigation methods in this area was gravel soil texture.

Keywords: Surface Irrigation, Sprinkler Irrigation, Drip Irrigation, Land Suitability Evaluation, Parametric Method.

INTRODUCTION

Due to the depletion of water resources and the increase in the population, the extent of irrigated area per capita is declining while, at the present, irrigated lands produce 40% of the food supply (Hargreaves and Mekley, 1998). According to FAO methodology (1976) land suitability is strongly related to "land qualities" including erosion resistance, water availability and flood hazards which are more often than not, caused by slope angle and length, rainfall and soil texture. Sys *et al*. (1991) suggested a parametric evaluation system for irrigation methods which was primarily based on physical and chemical soil properties. In their proposed system, the factors affecting land suitability for irrigation purposes were subdivided into four groups: (1) Physical properties determining soil-water relationship in the soil such as permeability and available water content, (2) Chemical properties interfering with the salinity/ alkalinity status such as having soluble salts and exchangeable Na, (3) Drainage properties such as depth of ground water (4), and Environmental factors such as slope.

Briza *et al.* (2001) applied the above parametric system to evaluate land suitability for both surface and drip irrigation in 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, through the use of parametric evaluation system with the results

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indicating a huge difference between applying the two irrigation methods.

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

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

Barberis and Minelli (2005) provided land suitability classification for both surface and drip irrigation methods in Shouyang county, Shanxi province, China where the study was carried out based on a modified parametric system. The results indicated that due to its unusual morphology, the surface of the suitable area for surface irrigation (34%) was less than the surface used for drip irrigation (62%).

Dengize (2006) also compared such different irrigation methods as surface and drip irrigation in the pilot fields of central research institute, lkizce research farm located in southern Ankara. He concluded that, compared to the surface irrigation method, drip irrigation method increased the land suitability by 38%.

Using a Sys's parametric evaluation system, Liu *et al* (2007) evaluated land suitability for surface and drip irrigation in Danling County, Sichuan province, China. Owing to its minor environmental impact, drip irrigation was, in the whole land, more suitable than surface irrigation.

As was said before, the main objective of this research was to evaluate and compare land suitability for surface, sprinkler and drip irrigation methods based on the parametric evaluation system for Ghaleh madreseh Plain, in Khuzestan Province, Iran.

MATERIALS AND METHODS

The present study was conducted in an area of about 1325 hectares in Ghaleh madreseh Plain, in Khuzestan Province, located in the Southwest of Iran during 2011-2012. The study area is located 10 km West of Behbehan city (30° 31´ to 30 ° 33´ N and 50 ° 25´ to 50° 35´ E). The Average annual temperature and precipitation for the period of 1965-2011 were 24.5 C° and 337.6 mm, respectively. Additionally, the annual evaporation of the area is 2,550 mm (Khuzestan Water and Power Authority, 2012). Kheir Abad River supplies the bulk of the water demands of the region. Besides, the application of irrigated agriculture has been common in the study area and currently, the irrigation systems used in the farmlands of the region are furrow, basin and border surface irrigation schemes.

The area is composed of two distinct physiographic features (i.e. River Terraces and Piedmont Plains) of which the former is the dominating feature. Also, four different soil series (1 to 4) were found in the area. The semi-detailed soil survey report of the Ghaleh madreseh plain (Khuzestan Water and Power Authority, 2011) was used in order to determine the soil characteristics. The land evaluation was determined based upon topography and soil characteristics of the region (Albaji *et al*, 2009). 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 put under the category 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.

The soil groups that had similar properties and were located in the same physiographic unit were categorized as soil series and were classified to form a soil family as per the Keys to Soil Taxonomy (2010). Ultimately, four soil series were selected for the land suitability in terms of surface, sprinkler and drip irrigation methods.

In order to obtain the average soil texture, salinity and $CaCO_3$ for the upper 150cm of soil surface, the profile was subdivided into 6 equal sections for which weighting factors of 2, 1.5, 1, 0.75, 0.50 and 0.25 were respectively employed (Sys *et al*, 1991).

The parametric evaluation system, which is based on morphology, physical and chemical properties of soil, was used in evaluating land suitability for surface, sprinkler and drip irrigation (Sys *et al*, 1991).

Six parameters were measured and also considered, including slope, drainage properties, electrical conductivity of soil solution, calcium carbonate status, soil texture and soil depth and values were assigned to each as per the related tables (Sys *et al*, 1991 & Albaji, 2010), hence, the developed capability index for irrigation (Ci) 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, respectively, 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 (Tables 1-6).

Table 7 demonstrates the range of capability and the corresponding suitability classes for different irrigation systems.

Table (1): Rating of Textural Classes for Irrigation.

Tex [a]	Rating for Surface Irrigation					Rating for Sprinkler Irrigation					Rating for Drip Irrigation				
	Fine Gravel (%)			Coarse Gravel (%)		Fine Gravel (%)			Coarse Gravel (%)		Fine Gravel (%)			Coarse Gravel (%)	
	< 15	15-40	40-75	15-40	40-75	< 15	15-40	40-75	15-40	40-75	< 15	15-40	40-75	15-40	40-75
CL[b]	100	90	80	80	50	100	90	80	80	50	100	90	80	80	50
SiL	100	90	80	80	50	100	90	80	80	50	100	90	80	80	50
SCL	95	85	75	75	45	95	85	75	75	45	95	85	75	75	45
L	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
SiL	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
Si	90	80	70	70	45	90	80	70	70	45	90	80	70	70	45
SiC	85	95	80	80	40	85	95	80	80	40	85	95	80	80	40
C	85	95	80	80	40	85	95	80	80	40	85	95	80	80	40
SC	80	90	75	75	35	95	90	80	75	35	95	90	85	80	35
SL	75	65	60	60	35	90	75	70	70	35	95	85	80	75	35
LS	55	50	45	45	25	70	65	50	55	30	85	75	55	60	35
S	30	25	25	25	25	50	45	40	30	30	70	65	50	35	35

a. Tex: Textural Classes.
b. CL: Clay Loam SiL: Silty Loam SCL: Sandy Clay Loam L: Loam SiL: Silty Loam Si: Silty SiC: Silty Clay C: Clay SC: Sandy Clay SL: Sandy Loam LS: Loamy Sand S: Sandy.

Table (2): 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 (3): 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 (4): 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 (5): 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 (6): 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 (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

In order to develop land suitability maps for different irrigation methods, a semi-detailed soil map (Fig.1) prepared by Albaji (2010) 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 for different irrigation systems. The Soil map was then digitized and a database prepared. A total of four different polygons or land mapping units (LMU) were determined in the base map. Soil characteristics were also specified for each LMU. These values were overlaid to generate the land suitability maps for surface, sprinkler and drip irrigation systems using Geographic Information Systems.

RESULTS AND DISCUSSION

Surface irrigation systems have been applied over much of Ghaleh Madreseh Plain specifically for field crops so as 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 such as, melon, watermelon and vegetables like tomato and cucumber. There are very few instances of sprinkler and drip irrigation on high surface area farms in Ghaleh madreseh Plain.

Four soil series and nine phase series or land units were derived from the semi-detailed soil study of the area. The land units are shown in Fig.1 as the basis for further land evaluation practice. The soils of the area are of Inceptisols and Entisols orders. In addition, the soil moisture regime is Ustic while the soil temperature regime is Hyperthermic (Khuzestan Water and Power Authority, 2011).

As shown in Tables 8 and 9 for surface irrigation, land units coded 1.1, 1.2, 1.3, 4.1 and 4.2 (886.9 ha – 67 %) were classified as moderately suitable (S_2), land units coded 1.4, 3.1 and 3.2 (363 ha – 27.3%) were found to be marginally suitable (S_3) and only the land unit coded 2.1 (71.1 ha – 5.4%) was classified as currently not-suitable (N_1) for any surface irrigation practices.

The analysis of the suitability map (Fig. 2) indicated that there were no highly suitable lands in this plain for surface irrigation. The major portion of the cultivated area in this plain (located in the center and the west) is deemed as being moderately suitable due to the light limitations of gravel soil texture and drainage. Moreover the marginally suitable area is located in the northwest and east due to the heavy limitations of gravel, soil texture and drainage. Other factors such as calcium carbonate, slope, depth, salinity and alkalinity had no influence on the suitability of the area for any of the crops. The current non-suitable land can be observed only in the south of the plain because of the physical limitations especially regarding gravel soil texture. There was no permanently non-suitable land in this plain. For almost all the study area, elements such as soil depth, salinity, slope, and calcium carbonate were not considered as limiting factors.

Land suitability for sprinkler and drip irrigation was evaluated, so as to verify the possible effects of different management practices (Tables 8 and 9).

For sprinkler irrigation, land units coded 4.1 and 4.2 (682.3 ha – 51.5%) were highly suitable (S_1) while those coded 1.1, 1.2, 1.3, 1.4, 3.1 and 3.2 (567.6 ha- 42.8%) were classified as moderately suitable (S_2) and only the land unit coded 2.1 (71.1 ha- 5.4%) was classified as currently non-suitable (N_1).

Table (8): The Ci Values and Suitability Classes of Surface, Sprinkler and Drip irrigation for Each Land Units.

Codes of Land Units	Surface Irrigation		Sprinkler Irrigation		Drip Irrigation	
	Ci	Present Suitability Classes	Ci	Present Suitability Classes	Ci	Present Suitability Classes
1.1	63.18	S_2 sw [a]	68.4	$S_{2\,S}$ [b]	64	$S_{2\,S}$ [c]
1.2	71.07	S_2 sw	76.95	S_2 s	72	$S_{2\,S}$
1.3	63.18	S_2 sw	68.4	S_2 s	64	S_2 s
1.4	59.94	S_3 sw	66.69	S_2 s	64	$S_{2\,S}$
2.1	37.44	$N_{1\,S}$	41.6	N_1 s	39.2	$N_{1\,S}$
3.1	59.67	S_3 sw	68.85	S_2 sw	68	S_2 s
3.2	56.61	S_3 sw	67.12	S_2 sw	68	S_2 s
4.1	70.2	S_2 sw	81	S_1	80	S_1
4.2	70.2	S_2 w	81	S_1	80	S_1

a. The Present Limiting Factors for Surface Irrigation: s: (Gravel Soil Texture) and w:(Drainage).

b. The Present Limiting Factors for Sprinkler Irrigation: s: (Gravel Soil Texture).

c. The Present Limiting Factors for Drip Irrigation: s: (Calcium Carbonate & Gravel Soil Texture).

Table (9): Distribution of Surface, Sprinkler and Drip Irrigation Suitability.

Suitability	Surface Irrigation			Sprinkler Irrigation			Drip Irrigation		
	Land unit	Area (ha)	Ratio (%)	Land unit	Area (ha)	Ratio (%)	Land unit	Area (ha)	Ratio (%)
S_1	-	-	-	4.1, 4.2	682.3	51.5	4.1, 4.2	682.3	51.5
S_2	1.1, 1.2, 1.3, 4.1, 4.2	886.9	67	1.1, 1.2, 1.3, 1.4, 3.1, 3.2	567.6	42.8	1.1, 1.2, 1.3, 1.4, 3.1, 3.2	567.6	42.8
S_3	1.4, 3.1, 3.2	363	27.3	-	-	-	-	-	-
N_1	2.1	71.1	5.4	2.1	71.1	5.4	2.1	71.1	5.4
N_2	-	-	-	-	-	-	-	-	-
[a]Mis Land		4	0.3		4	0.3		4	0.3
Total		1325	100		1325	100		1325	100

a. Miscellaneous Land: Urban

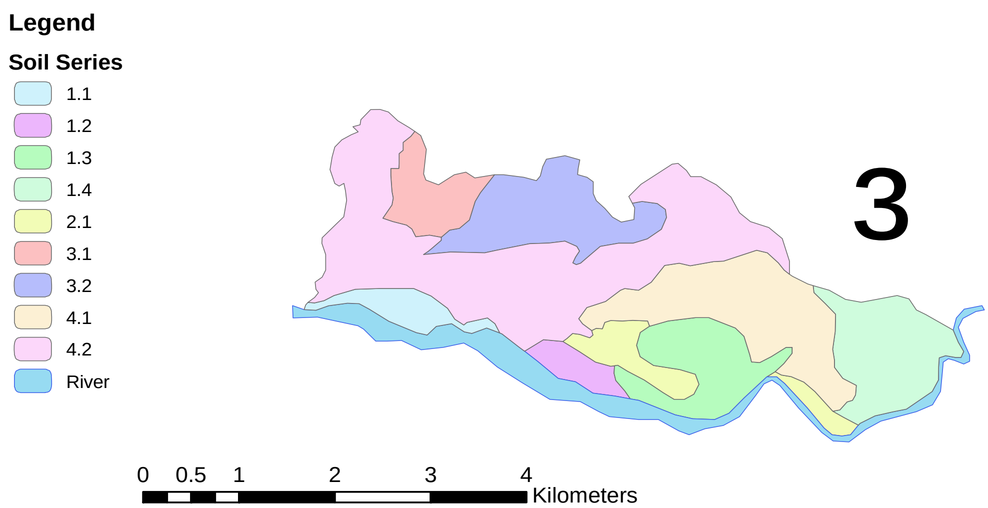

Fig (1): Soil Map of the Study Area.

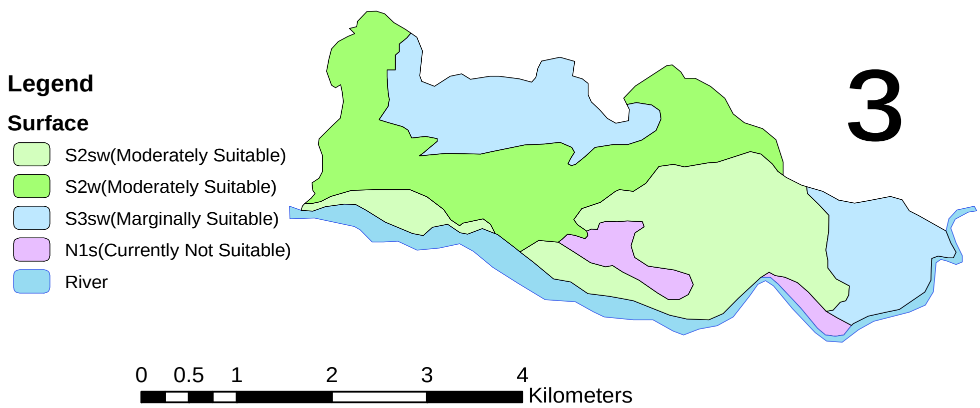

Fig (2): Land Suitability Map for Surface Irrigation.

Regarding sprinkler irrigation, (Fig. 3) a large of the cultivated zone in this plain was highly suitable (located in the center and the west) due to the deep soil, good drainage, texture, salinity and a proper slope. As seen from the map, some parts of the cultivated area in this plain were evaluated as moderately suitable for sprinkler irrigation because of the light limitations of gravel soil texture. Other factors such as drainage, depth, salinity and slope never influence the suitability of the area as far as sprinkler irrigation is concerned. The current non-suitable lands are located only in the south of the plain and their non-suitability is due to the severe limitations of gravel soil texture. Furthermore, there were no marginally suitable lands and permanently not-suitable lands on this plain. For almost the entire study area, slope, soil depth, salinity, drainage, and calcium carbonate were never deemed as limiting factors.

For drip irrigation, land units coded 4.1 and 4.2 (682.3 ha-51.5%) were highly suitable (S_1) while those coded 1.1, 1.2, 1.3, 1.4, 3.1 and 3.2 (567.6 ha- 42.8%) were classified as moderately suitable (S_2) and only the land unit coded 2.1 (71.1 ha- 5.4%) was classified as currently non-suitable (N_1).

Regarding drip irrigation, (Fig. 4) a large part of the cultivated zone in this plain was highly suitable (located in the center and the west) due to the deep soil, good drainage, texture, salinity and a proper slope. As is shown in the map, some parts of the cultivated area in this plain were evaluated as moderately suitable for drip irrigation due to the light limitations of gravel soil texture and calcium carbonate. Concerning drip irrigation, other factors such as drainage, depth, salinity and slope never influence the suitability of the area. The current non-suitable lands are located only in the south of the plain and their non-suitability is due to the severe limitations of gravel soil texture and calcium carbonate. There were no the marginally suitable lands or permanently not-suitable lands on this plain. For almost the entire study area, slope, soil depth, salinity and drainage were never taken as limiting factors.

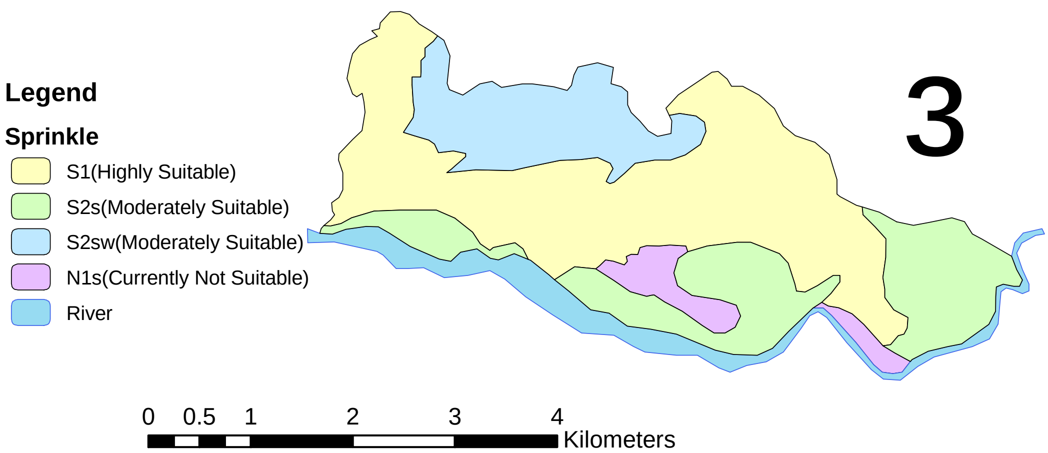

Fig (3): Land Suitability Map for Sprinkler Irrigation.

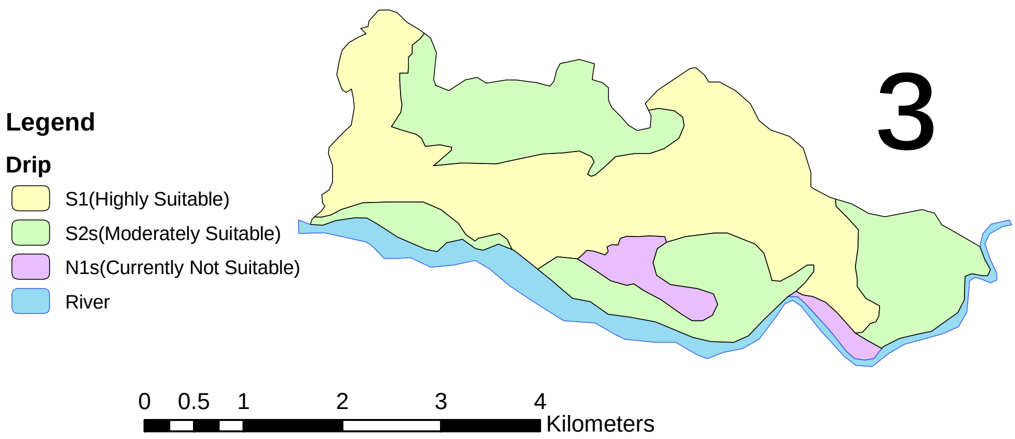

Fig (4): Land Suitability Map for Drip Irrigation

The comparison of the capability indices for surface, sprinkler and drip irrigation (Tables 8 and 10) indicated that in soil series coded 3.2, compared to surface and sprinkler irrigation systems, applying drip irrigation system was the most suitable option. In soil series coded 1.1, 1.2, 1.3, 1.4, 2.1, 3.1, 4.1 and 4.2 applying sprinkler irrigation system was the most suitable with surface and drip irrigation systems coming next. Fig.5 shows the most suitable map for surface, sprinkler and drip irrigation systems in Ghaleh madreseh plain as per the capability index (Ci) for different irrigation systems. Based on the map that a large part of this plain was suitable for sprinkler irrigation system while some parts were suitable for drip irrigation system.

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) (Naseri *et al*, 2009, Moazed *et al*, 2010, Albaji-Hemadi, 2011, Jovzi *et al*, 2012).

According to the results of Tables 8 and 10 by applying sprinkler irrigation instead of surface and drip irrigation methods, the present land suitability of 1170,7 ha (88.4%) of Ghaleh madreseh Plain could be improved substantially. However through the use of drip Irrigation instead of surface and sprinkler irrigation methods, the present suitability of 150, 3 ha (11.3%) of this Plain could be improved (for drip Irrigation). The comparison of the different types of irrigation revealed that sprinkler irrigation was the most effective and efficient with the drip and surface irrigation methods coming afterwards. The second best option was the application of drip irrigation which is considered to be more practical than surface irrigation method. All in all, the most suitable irrigation systems for Ghaleh madreseh Plain' were sprinkler irrigation, drip irrigation and surface irrigation respectively. Moreover, the main limiting factors in using surface irrigation method in this area were gravel soil texture and drainage while as for sprinkler irrigation method the pivotal limiting factor was gravel soil texture and as far as drip irrigation method the gravel soil texture and calcium carbonate were the significant limiting factors.

Table (10): The Most Suitable Land Units for Surface, Sprinkler and Drip Irrigation Systems by Notation to Capability Index (Ci) for Different Irrigation Systems.

Codes of Land Units	The Maximum Present Capability Index for Irrigation(Ci)	Present Suitability Classes	The Most Suitable Irrigation Systems	[a]The Present Limiting Factors
1.1	68.4	$S_{2\,S}$	Sprinkler	Gravel Soil Texture
1.2	76.95	$S_{2\,S}$	Sprinkler	Gravel Soil Texture
1.3	68.4	$S_{2\,S}$	Sprinkler	Gravel Soil Texture
1.4	66.69	$S_{2\,S}$	Sprinkler	Gravel Soil Texture
2.1	41.6	N_1 s	Sprinkler	Gravel Soil Texture
3.1	68.85	S_2 sw	Sprinkler	Gravel Soil Texture and Drainage
3.2	68	S_2 s	Drip	$CaCo_3$& Gravel Soil Texture
4.1	81	S_1	Sprinkler	No Exist
4.2	81	S_1	Sprinkler	No Exist

CONCLUSIONS

In order to compare the suitability of different irrigation systems, several parameters were used for the analysis of the field data. The analyzed parameters included soil and land characteristics. The obtained results showed that sprinkler and drip irrigation systems were more suitable than surface irrigation method for most of the study area. The major limiting factor for both sprinkler and surface irrigation methods was soil texture. However as for drip irrigation method, soil calcium carbonate content and soil texture were the two main restricting factors. Through comparing the maps it became evident that the introduction of a different irrigation management policy would provide an optimal solution in a way that the application of sprinkler and drip irrigation techniques could be proved beneficial and advantageous.

Such a change in irrigation management practices implies 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, since sprinkler and drip irrigation systems typically apply lower amounts of water (as compared with surface irrigation methods) to maintain soil water near field capacity, it would be more beneficial to use sprinkler and drip irrigations methods on this particular plain.

In this study, an attempt was made to analyze and compare three irrigation systems considering various soil and land characteristics. The results obtained showed that sprinkler and drip irrigation methods were 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; therefore, in this particular study area, we propose a change in the current irrigation methods from gravity (surface) to pressurized (sprinkler and drip).

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التحقق من طرق الري السطحي وبالرشاشات وبالتنقيط باستعمال نظام المعلومات الجغرافي (GIS)

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ملخص

إن الهدف الرئيس لهذه الدراسة كان لتقرير نظام ري مناسب بالاعتماد على تقييم نظام ري (لمساحة 1325 هكتار) في سهل مدرسة غاله في إيران. وقد دلت نتائج الدراسة على أن نظامي الري بالرشاشات والتنقيط كانا مناسبين لمساحة الـ 682.3 هكتار (51.5% من منطقة الدراسة) وعلاوة على ذلك فقد كانت النتائج للري بالرشاشات بدل السطحي والتنقيط على مساحة 1170.7 (88.4%) هي الأفضل على سهل مدرسة غاله. وكما اسلفنا سابقاً فإن الري بالرشاشات والتنقيط كان أثر الري بوساطة الرشاشات والتنقيط هما الأكفأ والأكثر إنتاجاً من الري السطحي وكان العامل المقرر في قوام التربة هو مقدار الحصى باستعمال طريقة النظام المقياسي.

الكلمات الدالة: ري سطحي، ري بالرشاشات، ري بالتنقيط، تقييم ملائمة الأرض، طريقة مقياس.

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