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Full Length Research Paper

Investigation of different irrigation systems based on the parametric evaluation approach in Boneh Basht plain - Iran

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The main objective of this research is to compare different irrigation methods based on parametric evaluation system in an area of 4688 ha in the Boneh Basht plain located in the Khuzestan Province, in the Southwest of Iran. The results showed that for 760 ha (16.21%) of the study area sprinkle irrigation method was highly recommended; however there was not any highly suitable lands for both drip and surface irrigation methods; moreover, for all irrigation systems the unsuitable lands did not exist in this zone. The results demonstrated that by applying sprinkle irrigation instead of drip and surface irrigation methods, the arability of 3104 ha (66.21%) in the Boneh Basht plain will improve. In addition by applying drip irrigation instead of sprinkle and surface irrigation methods, the land suitability of 1584 ha (33.79%) of this plain will improve. The comparison of the three different types of irrigation techniques revealed that the sprinkle and drip irrigations methods were more effective and efficient than the surface irrigation methods for improving land productivity. It is of note however that the main limiting factors in using different irrigation methods in this area are soil texture, $CaCo_3$ and slope.

Key words: Surface irrigation, sprinkle irrigation, drip irrigation, land suitability evaluation, parametric method, soil series.

INTRODUCTION

Food security and stability in the world greatly depends on the management of natural resources. Due to the depletion of water resources and an increase in population, the extent of irrigated area per capita is declining and irrigated lands now produce 40% of the food supply (Hargreaves and Mekley, 1998). Consequently, available water resources will not be able to meet various demands in the near future and this will inevitably result into the seeking of newer lands for irrigation in order to achieve sustainable global food security. Land suitability, by definition, is the natural capability of a given land to support a defined use. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for a defined use.

According to FAO methodology (1976), land suitability is strongly related to "land qualities" including erosion resistance, water availability, and flood hazards which are in themselves immeasurable qualities. Since these quailties are derived from "land characteristics", such as slope angle and length, rainfall and soil texture which are measurable or estimable, it is advantageous to use the latter indicators in the land suitability studies, and then use the land parameters for determining the land suitability for irrigation purposes. Sys et al. (1991) suggested a parametric evaluation system for irrigation methods which was primarily based upon physical and chemical soil properties. In their proposed system, the factors affecting soil suitability for irrigation purposes can be subdivided into four groups:

a. Physical properties determining the soil-water relationship in the soil such as permeability and available water content.
b. Chemical properties interfering with the salinity/ alkalinity status such as soluble salts and exchangeable Na.
c. Drainage properties.

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d. Environmental factors such as slope.

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, while no highly suitable areas were found in the studied area. The largest part of the agricultural areas was classified as marginally suitable, the most limiting factors being physical parameters such as slope, soil calcium carbonate, sandy soil texture and soil depth.

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 systems. The area not suitable for surface irrigation was 29.22% of total surface and 9% with the drip irrigation while the suitable area was 19 versus 70%. Moreover, high suitability was extended on a surface of 3.29% in the former case and it became 38.96% in the latter. The main limiting factors were physical limitations such as the slope and sandy soil texture.

Bienvenue et al. (2003) evaluated the land suitability for surface (gravity) and drip (localized) irrigation in the Thies, Senegal, by using the parametric evaluation systems. Regarding surface irrigation, there was no area classified as highly suitable (S_1). Only 20.24% of the study area proved suitable (S_2, 7.73%) or slightly suitable (S_3, 12. 51%). Most of the study area (57.66%) was classified as unsuitable (N_2). The limiting factor to this kind of land use was mainly the soil drainage status and texture that was mostly sandy while surface irrigation generally requires heavier soils. For drip (localized) irrigation, a good portion (45.25%) of the area was suitable (S_2) while 25.03% was classified as highly suitable (S_1) and only a small portion was relatively suitable (N_1, 5 .83 %) or unsuitable (N_2, 5.83%). In the latter cases, the handicap was largely due to the shallow soil depth and incomepatible texture as a result of a large amount of coarse gravel and/or poor drainage.

Mbodj et al. (2004) performed a land suitability evaluation for two types of irrigation that is, surface irrigation and drip irrigation, in the Tunisian Oued Rmel Catchment using the suggested parametric evaluation. According to the results, the drip irrigation suitability gave more irrigable areas compared to the surface irrigation practice due to the topographic (slope), soil (depth and texture) and drainage limitations encountered with in the surface irrigation suitability evaluation.

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 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%). The most limiting factors were physical parameters including slope and soil depth. Dengize (2006) also compared different irrigation methods including surface and drip irrigation in the pilot fields of central research institute, Ikizce 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. The most important limiting factors for surface irrigation in study area were soil salinity, drainage and soil texture, respectively whereas, the major limiting factors for drip or localized irrigation were soil salinity and drainage.

Liu et al. (2006) evaluated the land suitability for surface and drip irrigation in the Danling County, Sichuan province, China, using a Sys's parametric evaluation system. For surface irrigation the most suitable areas (S_1) represented about (24%) of Danling County, (33%) was moderately suitable (S_2), (%9) was classified as marginally suitable (S_3), (7%) of the area was founded currently not suitable (N_1) and (25%) was very unsuitable for surface irrigation due to their high slope gradient. Drip irrigation was everywhere more suitable than surface irrigation due to the minor environmental impact that it caused. Areas highly suitable for this practice covered 38% of Danling County; about 10% was marginally suitable (the steep dip slope and the structural rolling rises of the Jurassic period). The steeper zones of the study area (23%) were either approximately or totally unsuitable for such a practice.

Albaji et al. (2007) carried out a land suitability evaluation for surface and drip Irrigation in the Shavoor plain, in Iran. The results showed that 41% of the area was suitable for surface irrigation; 50% of the area was highly recommend for drip irrigation and the rest of the area was not considered suitable for either irrigation method due to soil salinity and drainage problem.

Albaji et al. (2008a) 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. Ultimately, the application of a drip irrigation system was suggested as the best method to be applied to the study area. The main limiting factors in using surface irrigation methods in this area were sandy soil texture and slope, moreover, for drip irrigation methods; the main limiting factor was soil calcium carbonate.

Albaji et al. (2008b) investigated different irrigation methods based upon a parametric evaluation system in an area of 29300 ha in the Abbas plain located in the Elam Province, in the West of Iran. The results demonstrated that by applying sprinkle irrigation instead of surface and drip irrigation methods, the arability of 21250 ha (72.53%) in the Abbas plain will improve. In addition by applying drip irrigation instead of surface and sprinkle irrigation methods, the land suitability of 6275 ha (21.42%) of this plain will improve. The comparison of the

Table 1. 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

different types of irrigation techniques revealed that the sprinkle and drip irrigations methods were more effective and efficient than the surface irrigation methods for improving land productivity. It is of note however that the main limiting factor in using either surface or/ and sprinkle irrigation methods in this area is soil texture and the main limiting factor in using drip irrigation methods were soil calcium carbonate content and soil texture.

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

MATERIALS AND METHODS

The present study was conducted in an area about 4688 ha in the Bones Basht plain, in the Khuzestan Province, located in the South-west of Iran during 2007-2008. The study area is located 15 km south of the city of Behbahan, 3370750 to 3382625 N and 423750′ to 437000′ E. The average annual temperature and precipitation for the period of 1965 - 2004 were 24.4°C and 346.7 mm, respectively. Also, the annual evaporation of the area is 1950 mm (KWPA, 2005). The Khir Abad 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 one distinct physiographic features, that is Plateaux. Also, five different soil series were found in the area. The semi-detailed soil survey report of the Boneh Basht plain (KWPA, 2003) was used in order to determine the soil characteristics. The land evaluation was determined based upon topography and soil characteristics of the region. The topographic characteristics included 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 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.

Based upon the profile description and laboratory analysis, the groups of soils that had similar properties and were located in a same physiographic unit, were categorized as soil series and were taxonomied to form a soil family as per the keys to soil taxonomy (2000). Ultimately, five soil series were selected for the surface, sprinkle 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 6 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, sprinkle 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.

Six parameters including slope, drainage properties, electrical conductivity of soil solution, calcium carbonates status, soil texture and soil depth were also considered and rates were assigned to each as per the related tables, thus, the capability index for irrigation (Ci) was developed as shown in the equation below:

$$Ci = A \times B/100 \times C/100 \times D/100 \times E/100 \times F/100 \quad (1)$$

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

In order to develop land suitability maps for different irrigation methods (Figures 1 - 4), a semi-detailed soil map (Figure 5) prepared by Albaji (KWPA, 2003) 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 5 different land mapping units (LMU) were determined in the base map. Soil characteristics were also given for each LMU. These values were used to generate the land suitability maps for surface, sprinkle and drip irrigation systems using geographic information systems.

RESULTS

Over much of the Boneh Basht 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 sprinkle and drip irrigation on large area farms in the Boneh Basht plain.

Five soil series or land units and fifteen series phases were derived from the semi-detailed soil study of the area. The land units are shown in Figure 5 as the basis for further land evaluation practice. The soils of the area are of Inceptisols and Entisols orders. Also, the soil moisture regimes are Ustic and Xeric while the soil temperature regime is Hyperthermic (KWPA, 2003).

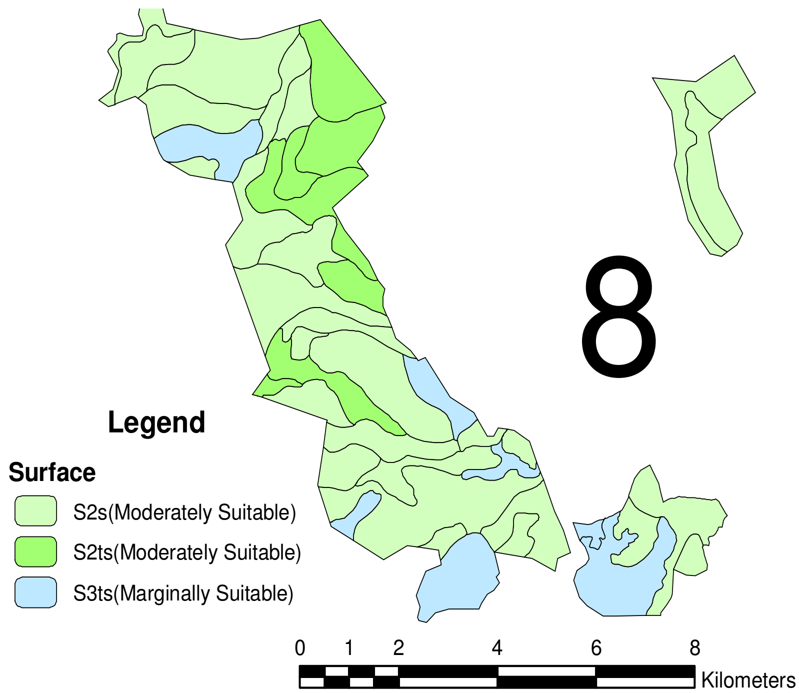

Figure 1. Land suitability map for surface irrigation.

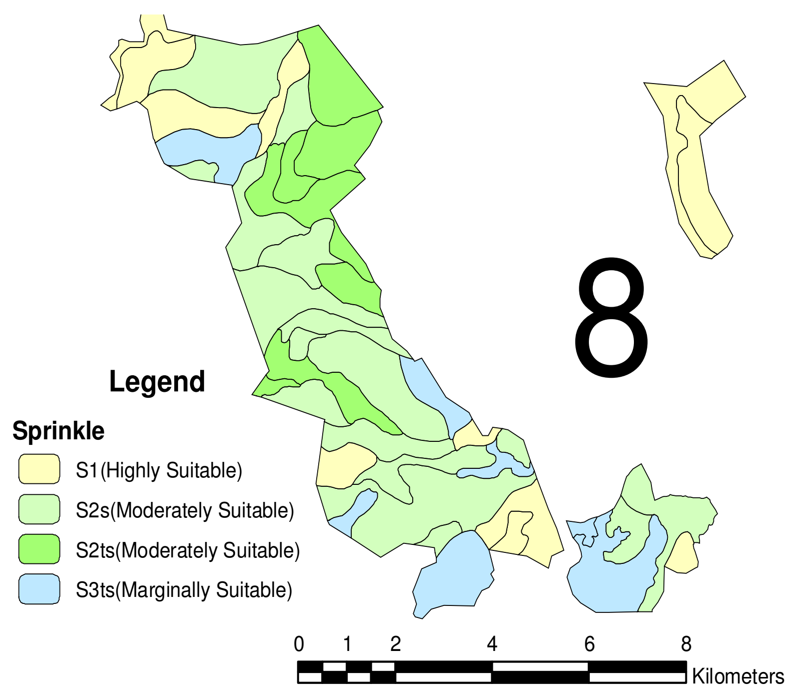

Figure 2. Land suitability map for sprinkle irrigation.

As shown in Tables 2 and 3 for surface irrigation, there was not found highly suitable lands (S_1) in this area. The soil series coded 1, 2 and 3 (3103.9 ha - 66.21 %) were classified as moderately suitable (S_2), and soil series coded 4 and 5 (1584.1 ha - 33.79%) were found to be marginally suitable (S_3). Further, there was not found not-suitable lands (N_1 and N_2) for any surface irrigation exercises.

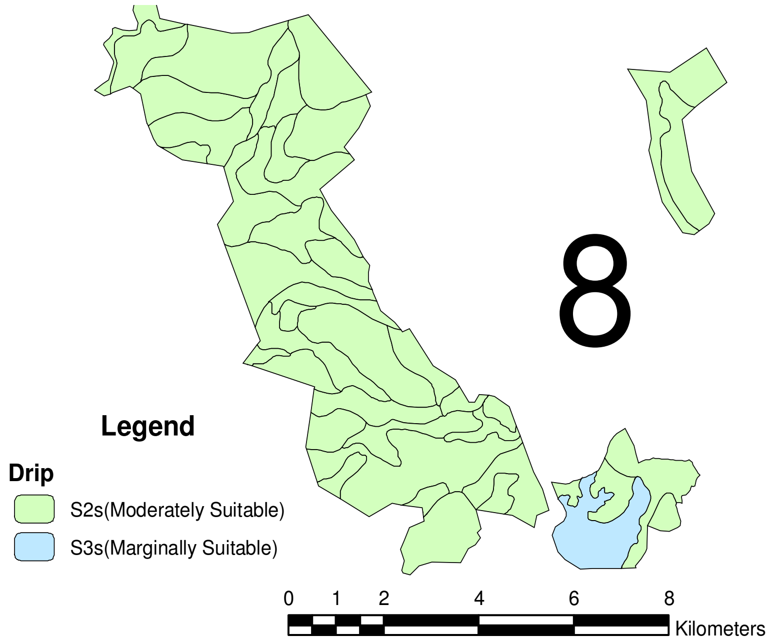

Figure 3. Land suitability map for drip irrigation.

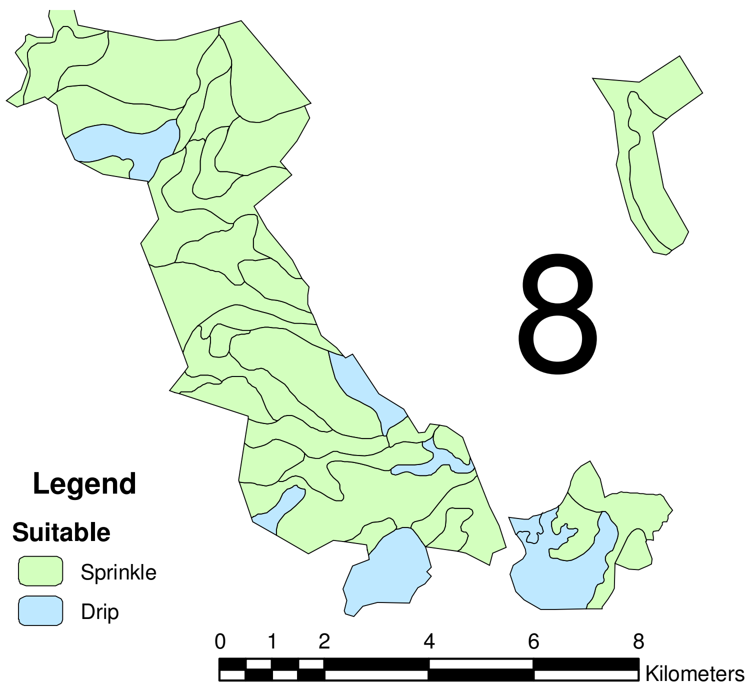

Figure 4. The most suitable map for different irrigation systems.

The analysis of the suitability irrigation maps for surface irrigation (Figure 1), indicate that the major portion of the cultivated area in this plain (located in the north and center) is deemed as being moderately suitable land due to gently slope and light soil texture of the area. The marginally suitable area is located in the south of this zone due to medium slope and gravely soil texture. There was no highly suitable, currently non-suitable and permanently non-suitable land in this plain. For almost the total study area elements such as soil depth, salinity, drainage, and $CaCO_3$ were not considered as limiting factors.

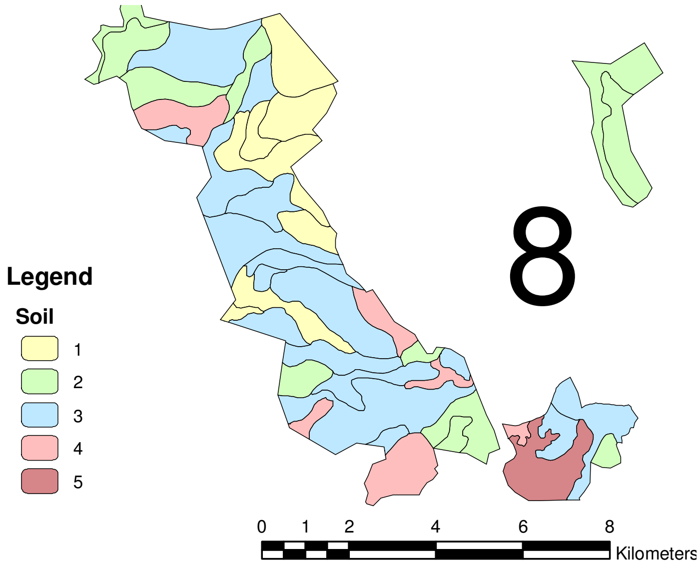

Figure 5. Soil map of the study area.

Table 2. Ci values and suitability classes of surface ,sprinkle and drip irrigation for each Land Units.

Codes of Land Units	Surface Irrigation		Sprinkle Irrigation		Drip Irrigation	
	Ci	Suitability classes	Ci	suitability classes	Ci	suitability classes
1	64.80	$S_{2\ TS}$*	68.85	$S_{2\ TS}$ **	64.80	$S_{2\ S}$ ***
2	78.97	$S_{2\ S}$	81.00	S_1	72.00	$S_{2\ S}$
3	74.92	$S_{2\ S}$	78.97	$S_{2\ S}$	72.00	$S_{2\ S}$
4	46.80	$S_{3\ TS}$	57.37	$S_{3\ TS}$	61.20	$S_{2\ S}$
5	56.00	$S_{3\ TS}$	57.50	$S_{3\ TS}$	59.85	$S_{3\ S}$

* &** Limiting factors for surface and sprinkle irrigations: $_{T:}$ (Slope) s :(Soil texture).
*** Limiting factors for drip irrigation: s :(Calcium carbonate and soil texture).

Table 3. Distribution of surface, sprinkle and drip irrigation suitability

suitability	Surface Irrigation			Sprinkle Irrigation			Drip Irrigation		
	Land unit	Area (ha)	Ratio (%)	Land unit	Area (ha)	Ratio (%)	Land unit	Area (ha)	Ratio (%)
S_1	-	-	-	2	759.9	16.21	-	-	-
S_2	1 , 2 , 3	3103.9	66.21	1 , 3	2344	50	1 , 2 , 3 , 4	3341.4	71.28
S_3	4 , 5	1584.1	33.79	4 , 5	1584.1	33.79	5	1346.6	28.72
N_1	-	-	-	-	-	-	-	-	-
N_2	-	-	-	-	-	-	-	-	-
Total		4688	100		4688	100		4688	100

In order to verify the possible effects of different management practices, the land suitability for sprinkle and drip irrigation was evaluated (Tables 2 and 3).

For sprinkle irrigation, only soil series coded 2 (759.9 ha - 16.21%) were highly suitable (S_1) while soil series coded 1 and 3 (2344 ha - 50%) were classified as moderately suitable (S_2) and soil series coded 4 and 5 (1584.1 ha - 33.79%) were found to be marginally suitable (S_3). Also, there was not found not-suitable lands ($N_1$and N_2) for sprinkle irrigation.

Regarding sprinkle irrigation, (Figure 2) the highly suitable area can be observed just in the some part of the cultivated zone in this plain (located in the north and south) due to deep soil, good drainage, texture, salinity

Table 4. The most suitable land units for surface, sprinkle and drip irrigation systems by notation to capability index (Ci) for different irrigation systems.

Codes of land units	The maximum capability index for irrigation(Ci)	Suitability classes	The most suitable irrigation systems	Limiting factors
1	68.85	$S_{2\ TS}$	Sprinkle	Slope and soil texture
2	81.00	S_1	Sprinkle	No exist
3	78.97	S_2 s	Sprinkle	Soil texture
4	61.20	$S_{2\ S}$	Drip	Calcium carbonate and soil texture
5	59.85	$S_{3\ S}$	Drip	Calcium carbonate and soil texture

and proper slope of the area. As seen from the map, the largest portion of the cultivated area in this plain was evaluated as moderately suitable for sprinkle irrigation because of the gently slope and light soil texture. The marginally suitable lands are located in the south and northwest of the plain and their light-suitability of the land is due to the moderate slope and gravely soil texture. The currently non-suitable lands and permanently not-suitable lands did not exist in this plain. For almost the entire study area soil depth, salinity, drainage, and $CaCO_3$ were never taken as limiting factors.

For drip irrigation, there was not found highly suitable lands (S1), while soil series coded 1, 2, 3 and 4 (3341.4 ha - 71.28%) were classified as moderately suitable (S2). Further, only soil series coded 5 (1346.6 ha, 28.72%) were found to be slightly suitable (S3) for drip irrigation. Moreover, there was not found not-suitable lands (N1and N2) for any drip irrigation exercises.

Regarding drip irrigation (Figure 3), the major portion of the cultivated area in this plain (located in nearly all of the plain) is deemed as being moderately suitable land due to medium CaCO3 content and light soil texture of the zone. The marginally suitable area located in the south of this zone was due to its medium $CaCO_3$ content and gravely soil texture. There was no highly suitable, currently non-suitable and permanently non-suitable land in this plain. For almost the total study area elements such as soil depth, slope, salinity and drainage were not considered as limiting factors.

DISCUSSION

The mean capability index (Ci) for surface irrigation was 67.68 (moderately suitable) while for sprinkle irrigation it was 71.57 (moderately suitable). Moreover, for drip irrigation it was 67.22 (moderately suitable) for the comparison of the capability indices for surface, sprinkle and drip irrigation. Tables 2 and 4 indicated that in soil series coded 4 and 5, applying drip irrigation systems was the most suitable option as compared to sprinkle and surface irrigation systems. In soil series coded 1, 2 and 3, applying sprinkle irrigation systems was more suitable than drip and surface irrigation systems. Figure 4 shows the most suitable map for surface, sprinkle and drip irrigation systems in the Boneh Basht 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 sprinkle irrigation systems and some parts of this area was suitable for drip irrigation systems; however, there was not found lands as being suitable for surface irrigation systems.

The results of Tables 2 and 4 indicated that by applying sprinkle irrigation instead of drip and surface irrigation methods, the land suitability of 3103.9 ha (66.21%) of the Boneh Basht plain's land could be improved substantially. However by applying drip irrigation instead of sprinkle and surface irrigation methods, the suitability of 1584.1 ha (33.79%) of this plain's land could be improved. The application of surface irrigation instead of sprinkle and drip irrigation methods would not provide land suitability improvement in this zone. The comparison of the different types of irrigation revealed that sprinkle irrigation was more effective and efficient than 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 Boneh Basht plain were sprinkle irrigation, drip irrigation and surface irrigation respectively. Moreover, the main limiting factors in using surface and sprinkle irrigation methods in this area were soil texture and slope, and the main limiting factors in using drip irrigation methods were the soil's calcium carbonate content and texture.

Conclusion

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 sprinkle and drip irrigation systems are more suitable than surface irrigation method for all of the study area. The major limiting factor for both sprinkle and surface irrigation methods were soil texture and slope. However for drip irrigation method, soil calcium carbonate content and soil texture 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 in as such that the application of sprinkle and drip irrigation techniques could provide 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. The shift from surface irrigation to high-tech irrigation technologies, e.g. sprinkle and drip irrigation systems, therefore, offers significant water-saving potentials. On the other hand, since sprinkle 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 sprinkle 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 sprinkle and drip irrigation methods are more suitable than surface or gravity irrigation method for all 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, sprinkle 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 (sprinkle and drip) in the study area are proposed.

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