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Comparison of Different Irrigation Methods Based on the Parametric Evaluation Approach

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Abstract: The main objective of this research is to compare two different irrigation methods according to parametric evaluation system in the Field Plants Central Research Institute-Ikizce Research Farm's soils located in southern Ankara. Soil properties of the study area including texture, depth, EC, drainage, carbonate content and slope were derived from a detailed soil map scaled 1/5000. After analyzing and evaluating soil properties using geographic information system techniques, gravity and drop irrigation suitability maps were generated. Results showed that 13.1% of the study area was highly suitable for surface and gravity irrigation methods, whereas 51.2% of the study area was highly suitable for drop irrigation method. On the other hand, it was found that some land mapping units coded 3, 16, 18 and 19 are not suitable for both irrigation systems. As a result, drop type was suggested the best irrigation system for more than half of the study area soils due to soil and topographic conditions. This study indicates that the geographic information system (GIS) technique has an important role to determine suitability of the study area soils for both gravity and drop irrigation systems.

Key Words: Irrigation, Parametric Evaluation, Soil Characteristics, Geographic Information System (GIS)

Farklı Sulama Yöntemlerinin Parametrik Değerlendirme Yaklaşımına Göre Karşılaştırılması

Özet: Bu çalışmada, Ankara'nın güney kesminde yer alan Tarla Bitkileri Merkez Araştırma Enstitüsü İkizce Araştırma Çiftliği topraklarının parametrik yaklaşım sistemine göre damla ve yüzey sulama metotlarına uygunluğunun karşılaştırılması amaçlanmıştır. İlk olarak, 1/5000 ölçekli detaylı toprak haritasından yaralanarak çalışma alanı topraklarının bünye, derinlik, kireç, elektriksel iletkenlik, drenaj ve eğim özellikleri belirlenmiş ve coğrafi bilgi sistemi yardımıyla çalışma alanının yüzey ve damla sulama yöntemlerinin uygunluk haritaları oluşturulmuştur. Araştırma sonuçlarına göre, çalışma alanının %13.1'i yüzey sulama metodu için çok uygun iken, bu oran damla sulamada %51.2 olarak bulunmuştur. Ayrıca 3, 16, 18 ve 19 nolu haritalama üniteleri ise her iki sulama sistemine uygun bulunamamıştır. Sonuç olarak toprak ve topografik koşullardan dolayı, damla sulama yarıdan fazla çalışma alanı toprakları için en uygun sulama şekli olduğu önerilmektedir. Bu çalışma alanı topraklarının yüzey ve damla sulama yöntemlerine uygunluklarının belirlenmesinde Coğrafi Bilgi Sistemi (CBS) tekniği kullanılmasının önemli bir rolü olduğunu da göstermiştir.

Anahtar Sözcükler: Sulama, Parametrik Değerlendirme, Toprak Özellikleri, Cografi Bilgi Sistemi (CBS)

Introduction

Food security and stability in the world depends very much on how we manage natural resources. Due to depletion of groundwater reserves and an increase in population, irrigated area per capita is declining, and irrigated lands now produce 40% of the food supply (Hargreaves and Mekley, 1998). Consequently, the available water resources may not be able to meet various demands of mankind. Irrigation of additional lands is, however, a strategic necessity for the food security on the world.

The suitability of a given piece of land is its natural ability to support a specific purpose. According to the FAO methodology (1976), this is strongly related to the "land qualities" such as erosion resistance, water availability, and flood hazard that are not measurable. These qualities are affected by the "land characteristics", such as slope angle and length, rainfall and soil texture which are measurable or estimable. In addition, it is also advantageous to use these later values to study the suitability. Thus, the land characteristics parameters were

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used to workout land suitability for irrigation. In addition, Hired et al. (1996) and Bond (2002) developed classification systems for assessing site suitability for effluent irrigation and suitability of land for irrigation water (Griffiths, 1975). Both systems include topographic criteria as well as soil attributes that are taken into consideration when assessing the overall land suitability for irrigation.

Rees and Laffan (2004) investigated land suitability for spray irrigation in stage 1 and 2 at the southwood processing complex, southern Tasmania. In this study, topographic attributes such as slope, land form, surface rock, frequent waterlogging, and soil attributes such as hydraulic conductivity, depth, texture, structure, massive hardpan, stone content and drainage were considered important parameters to assess land suitability for spray irrigation.

Choosing a suitable irrigation method is essential for good irrigation farming to achieve an efficient water use and to reduce land and water degradation as well as for better nutrient and pesticide control in crop production. However, irrigation practice has the potential to make a major impact on the land and water quality in the case of intensive water use. The intensive use of water, in particular, alters the distribution of water throughout the environment, and influences the transportation of pollutants (such as nutrients and pesticides), compaction, erosion, salinization, and waterlogging etc.

Under irrigation, soil and water compatibility is very important. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil. Determining the suitability of land for irrigation requires a thorough evaluation of soil properties, topography and quality of water to be used for irrigation (Seelig and Franzen, 1996). A basic understanding of soil/water/plant interactions will help irrigators efficiently manage their crops, soils, irrigation systems and water supplies.

An optimum yield can be obtained with available water by applying best irrigation management practices. Furthermore, a good management and timely application of water may result in prevention of land degradation. The main objective of this research was to compare two different irrigation methods by taking into consideration land and soil properties.

Materials and Methods

Field description

The study was conducted in the Field Plants Central Research Institute-Ikizce Research Farm's soils. The study area selected is located 45 km along the Ankara-Haymana highway, and coordinates 4383259m N-470201m E, 4383259m N-470400m E, 4383426m N-470400m E, 4383426m N-470201m E. The total study area covers approximately 534.4 ha, and the mean sea level altitude is 1055 m. Average annual temperature and precipitation (for the period of 1978-2003) are 11.8 ^{o}C and 410.5 mm, respectively (DMI, 2003). The study area consists of various topographic features (flat, hilly, rolling etc.). Particularly, flat and rolling physiographic units are common in the study area. Five different soil series (Çayırlı, Meteroloji, Nizamiye, Gölet and Ikizce) were widespread in the area which was classified by Dengiz and Yüksel (1998). The study area has been commonly used as irrigated agriculture while woodland and rangelands cover very small part of the area that was located on the south part of the area.

To determine soil characteristics, a detailed soil map (Figure 1) prepared by Dengiz and Yüksel (1998) was used, and all the data were analysed using TNT Mips 6.4 GIS software.

Data analysis

The digital soil map base preparation is the first step towards the presentation of a GIS module for the irrigation water management. Soil map was digitized and database was prepared. A total of 19 different polygons or land mapping units (LMU) was determined in the base map. Soil characteristics were also given for each LMU. These values were used to generate a land suitability for gravity irrigation map and land suitability for drop irrigation map using GIS.

To evaluate the land suitability for different irrigation methods, the parametric evaluation system described by Sys et al. (1991) was applied, using the soil characteristics. These characteristics are rated and used to calculate the capability index for irrigation (Ci) according to the formula 1:

$$Ci = A* B/100* C/100 * D/100 * E/100 * F/100 \quad [1]$$

where Ci = Capability index for irrigation;

A = soil texture rating, B = soil depth rating, C = $CaCO_3$ status, D = electro-conductivity rating, E = drainage rating, F = slope rating.

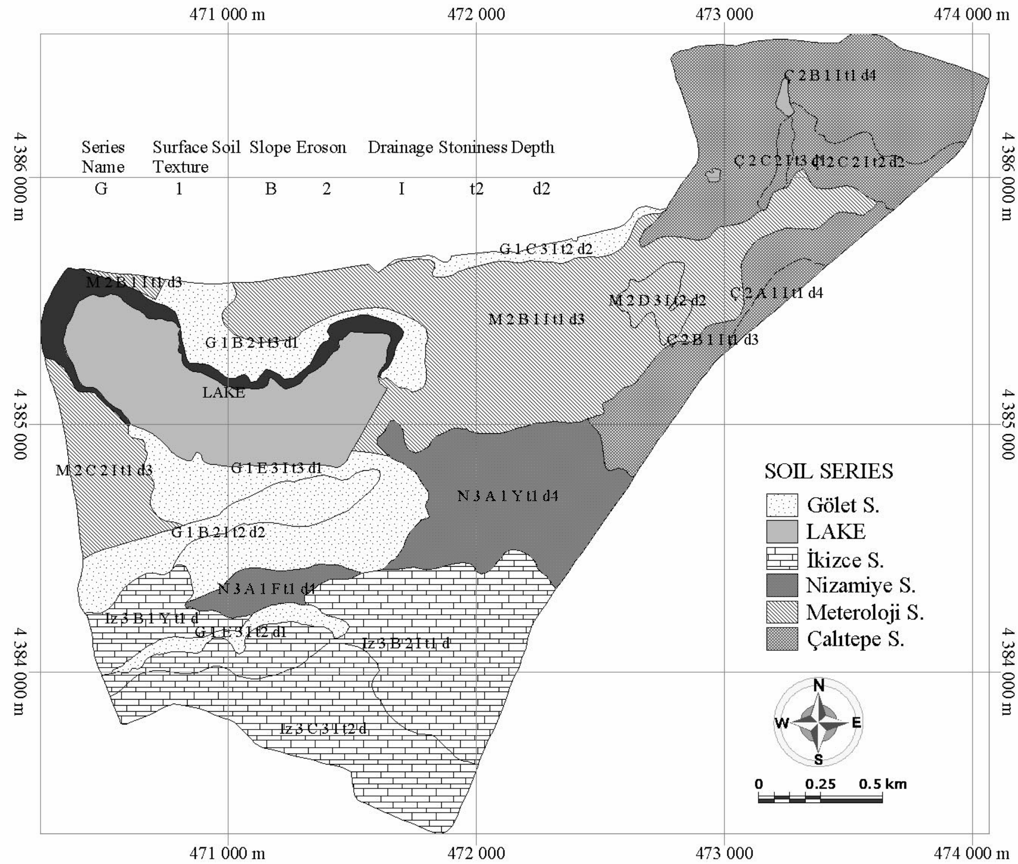

Figure 1. Soil map of the study area.

Suitability classes are defined by considering the value of the capability indices and presented in Table 1. Each of the land and soil characteristics with associated attribute data are digitally encoded in a GIS database to eventually generate six thematic layers. The diagnostic factors of each thematic layer were assigned values of factor rating identified in Tables 2-7. The parametric model is defined using the value of factor rating as formula [1]. 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 2.

Results and Discussion

Non-agricultural lands, swamp, roads, barren lands and water surface, cover 62.7 ha in the study area. According to the methodology, it should be highlighted that 19 LMUs were calculated by taking into consideration their soil characteristics ratio and codes (Table 8). The results of the processing of the parametric evaluation system for gravity and drop irrigation are given in Table 9, and their maps were generated by using GIS technique (Figures 3 and 4).

For the surface or gravity irrigation, 64.6% of the study area was classified as highly and moderately suitable (S1 and S2) that are mostly located in Çayırlı, İkizce and Meteoroloji series. Besides, 20.9% was classified as currently and permanently not suitable (N1 and N2) that are generally common on Gölet and Nizamiye series. Only 14.6% of the study area is found slightly suitable (S3).

The limiting factor to this kind of land use is mainly the soil drainage status and high slope that is mostly sandy, while surface irrigation requires heavier soils. Soil texture was also an important soil characteristic determining irrigation methods. In contrast to these soil handicaps, Tesfai (2002), who studied a land suitability

Table 1. Suitability classes for the irrigation capability indices (Ci) classes.

Capability index	Definition	Symbol
> 80	Highly suitable	S1
60-80	Moderately suitable	S2
45-59	Marginally suitable	S3
30-44	Currently not suitable	N1
< 29	Permanently not suitable	N2

Table 2. Textural class rating.

Textural class	Rating for gravity irrigation					Rating for drop irrigation				
	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
Clay Loam (CL)	100	90	80	80	50	100	90	80	80	50
Silty Loam (SiL)	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
Silty (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 3. Soil depth rating.

Soil depth (cm)	Rating for gravity irrigation	Rating for drop irrigation
< 20	30	30
20-50	60	70
50-80	80	90
80-100	90	100
> 100	100	100

Table 4. $CaCO_3$ status rating.

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

Table 5. Elecrto-conductivity rating.

EC (dS m^{-1})	Rating for gravity irrigation		Rating for drop irrigation	
	C, SiC, S, SC textures	Other textures	C, SiC, 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	35	75	35
> 30	60	20	65	20

C: Clay, SiC: Silty clay, S: Sand, SC: Sandy clay

Table 6. Drainage classes rating.

Drainage classes	Rating for gravity irrigation		Rating for drop irrigation	
	C, SiC, SC textures	Other textures	C, SiC, SC textures	Other textures
Well drained	100	100	100	100
Moderately drained	80	90	100	100
Imperfectly drained	70	80	80	90
Poorly drained	60	65	70	80
Very poorly drained	40	65	50	65
Drainage status not known	70	80	70	80

C: Clay, SiC: Silty clay, SC: Sandy clay

Table 7. Slope rating.

Slope Classes (%)	Rating for gravity irrigation		Rating for drop 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	95	90	100
8-16	70	85	80	90
16-30	50	70	60	70
> 30	30	50	40	50

system for surface irrigation schemes in the Sheeb area of Eritrea, determined salinity hazard as a main limiting soil factor. According to his results, the suitable land for surface irrigation in the Sheeb area is distributed as follows: 16% is highly to moderately suitable, 24% is moderately suitable and 17% is marginally suitable. About 40% of the study area was found to be currently unsuitable for surface irrigation.

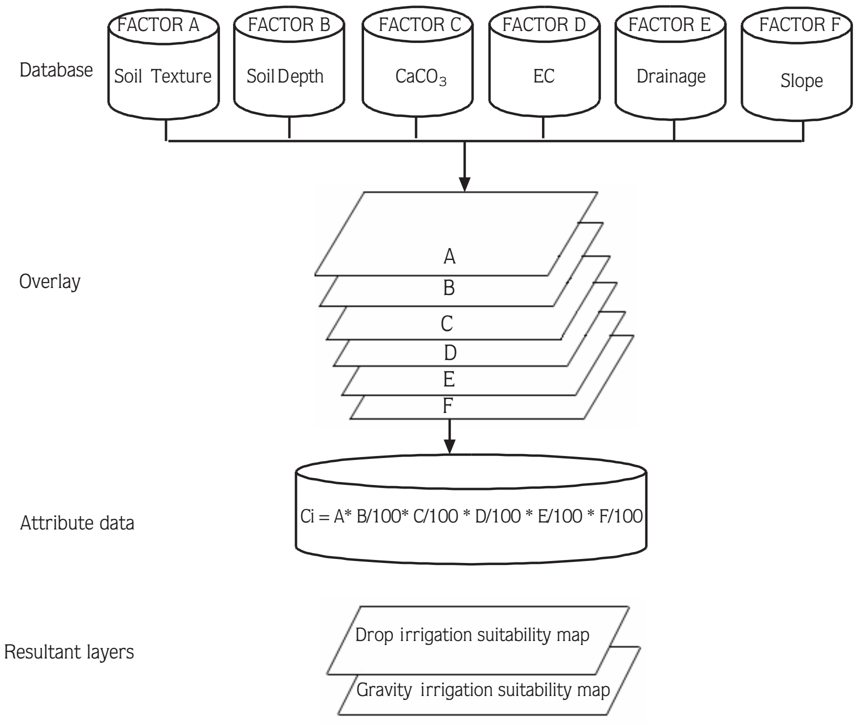

Figure 2. Schematic chart of GIS application for two different irrigation suitability maps.

Table 8. Ci values of gravity and drop irrigation for each LMU.

Codes of LMUs	Soil Series Name	LMUs of Soil Series	Ratio of LMUs for Gravity Irrigation	Ratio of LMUs for Drop Irrigation
1		Ç2.B1id4	90	95
2		Ç2.C2it2d2	48	60
3	Çayırlı	Ç2.C2t3id1	12	13
4		Ç2.A1it1d4	100	95
5		Ç2.B1it1d3	72	86
6		M2.D3it2d2	24	32
7	Meteoroloji	M2.B1it1d3	72	86
8		M2.C2it1d3	64	77
9		M2.B1it1d3	72	86
10	Nizamiye	N3.A1yd4	51	57
11		N3.A1fd4	34	40
12		İz3.B2it1d4	77	81
13	İkizce	İz3.C3t2d3	61	73
14		İz3.B1yt1d4	46	57
15		G1.C3t2d2	38	54
16		G1.E3t2d1	6	8
17	Gölet	G1.B2t2d2	43	61
18		G1.E3t3d1	6	8
19		G1.B2t3d1	22	27

Table 9. Distribution of gravity and drop irrigation suitability.

Suitability	Gravity Irrigation			Drop Irrigation		
	Land Units	Area (ha)	Ratio (%)	Land Units	Area (ha)	Ratio (%)
S1	1 ,4	61.8	13.1	12, 1, 4, 5, 7, 9	241.6	51.2
S2	5, 7, 8, 9, 12, 13	242.8	51.5	8, 13, 2, 17	92.8	19.7
S3	2, 10, 14	68.7	14.6	2, 10, 14, 15	62.8	13.3
N1	11, 15, 17	31.4	6.7	6, 11	12.9	2.7
N2	3, 6, 16, 18, 19	67.0	14.2	3, 16, 18, 19	61.6	13.1
Total		471.7	100		471.7	100

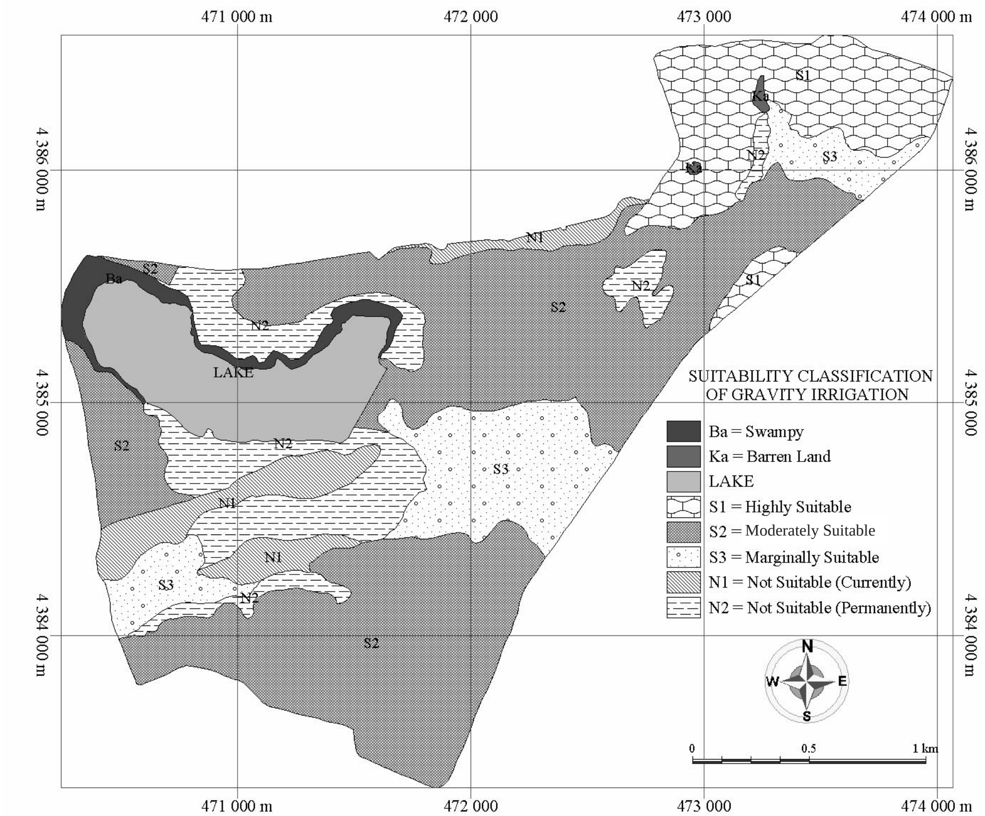

Figure 3. Gravity irrigation suitability map.

For drop and localized irrigation, a good proportion (51.2%) of the area is highly suitable (S1) and 19.7% is classified as suitable (S2). Only a few lands were found to be almost suitable (N1, 2.7%) and unsuitable (N2, 13.1%) where soils are formed on high slopes. These soils were found on Gölet and Nizamiye soil series, and soil texture, and depth of soils were major limited factors for both irrigation methods.

Using the same methodology, IAO (Istituto Agronomic per l'Oltermerare, 1997) also found that while 5.83% of the Ben Slimane located in the central western region of Morocco was non-suitable for drop irrigation due to

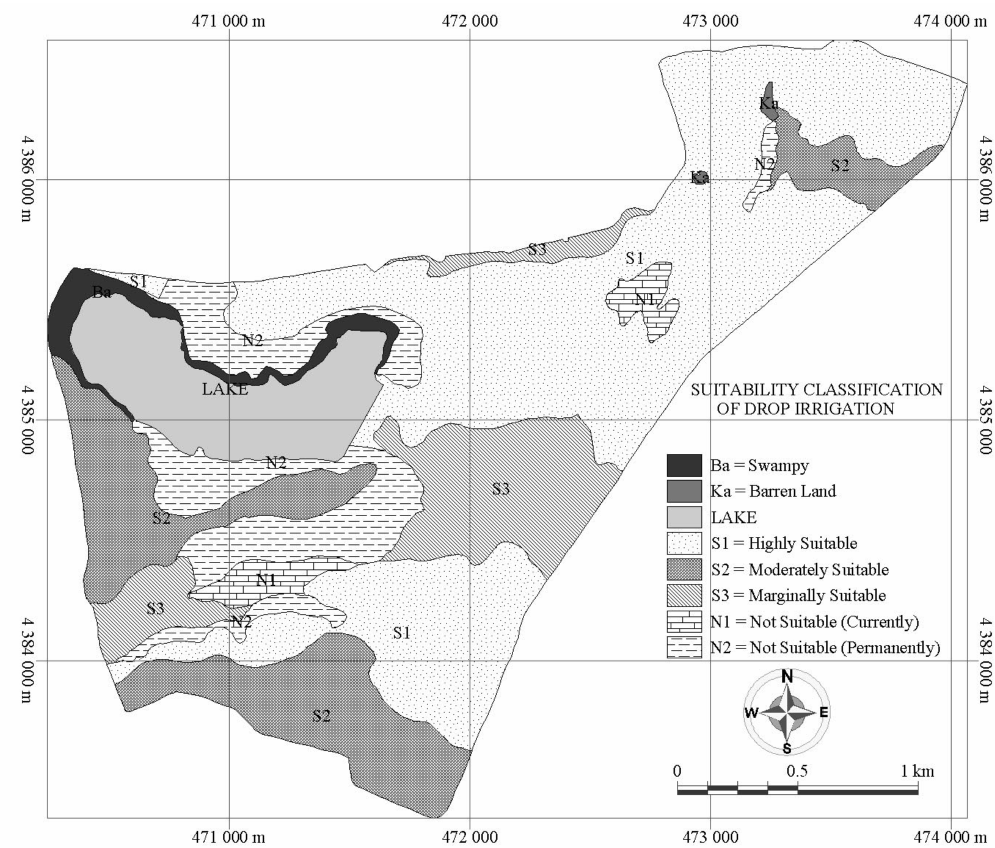

Figure 4. Drop irrigation suitability map.

shallow soil depth, poor drainage and bad texture, most of the study area (57.66%) was classified as unsuitable for surface irrigation owing to high slope and sandy texture.

The comparison of the two types of irrigation revealed that it would be of more benefit to irrigate by drop irrigation. Another way to view this concept, some LMUs are more suitable for drop irrigation than gravity or surface irrigation. Suitability of the land units from gravity (surface) to drop type of irrigation was presented in Table 10. Only the 3, 16, 18 and 19 land units are unsuitable for both irrigation methods, but they are already not used for agriculture. Moreover, because of the insufficiency of surface water, and the aridity and semi-aridity of the climate, only the drop irrigation is recommended for a sustainable use of this natural resource.

Water, in the form of precipitation or irrigation, is one of the most critical inputs in crop production. Natural rainfall can be unpredictable. Water must be supplied in sufficient quantity, and desired quality, when the crop needs it. In addition, beyond good soil management techniques, irrigation is the best management technique available to meet crop's water requirements when natural rainfall is inadequate (Hargreaves and Mekley, 1998).

In this study, an attempt has been made to analyze and compare two irrigation systems by taking into account various soil and land characteristics. The results obtained showed that drop irrigation method is more suitable than surface or gravity irrigation method for most of soils tested. In addition, because of the insufficiency of water in arid and semi-arid climate area, this method can be also recommended for a sustainable water use.

Table 10. Improvement of suitability classes of the land units from gravity (surface) to drop type of irrigation.

Improvement of suitability classes from gravity to drop irrigation	Land units
From S2 to S1	5, 7, 9, 12
From S3 to S2	2
From N1 to S2	17
From N1 to S3	15
From N2 to N1	6

It is necessary to use modern methods of surveying and analysis tools. GIS with its capability of data collection and analysis is now considered an efficient and effective tool for irrigation water management. The capability of GIS to analyze the information across space and time would help in managing such dynamic systems as irrigation systems. The study shows the efficacy of this tool to analyze the information on irrigation system in various domains in an integrated manner to understand the system. It is also very easy to update data involved in GIS database with more accuracy and reliability.

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