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Full Length Research Paper

Application of GIS for determination of groundwater quality suitable in crops influenced by irrigation water in the Damghan region of Iran

Shahram Ashraf[1]*, Hossein Afshari[2] and Abdol Ghaffar Ebadi[3]

[1]Department of Soil Science, Faculty of Agriculture, Armenian State Agrarian University, Armenia.
[2]Department of Agriculture, Damghan Branch, Islamic Azad University, Damghan, Iran.
[3]Department of Biological Sciences, Jouybar Branch, Islamic Azad University, Jouybar, Iran.

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In order to evaluate the quality of groundwater in Damghan plain for irrigation purposes, 199 surveyed wells with GPS data used to produce the map. The features that generally had considered for evaluation of the suitable quality of groundwater for irrigation are salinity, water infiltration rate, and specific ion toxicity. The SAR , ions Ca^{2+},Mg^{2+}, Na^{+}, K^{+}, $CO_3{}^{2-}$, $HCO_3{}^{-}$, $SO_4{}^{2-}$, Cl^{-}, electrical conductivity (EC), total dissolved solids (TDS), pH were analyze as the evaluation indexes. The EC map indicates the presence of about 0.04% of the study area; groundwater lie in good range (none degree of restriction on use) 61.38% slight to moderate and 38.58% severe for irrigation purposes. The suitable zones for EC_W are in the central and northwestern and portion of south of the study area (61.42%). The quality of groundwater for the sodium hazard on infiltration is in 98.9% of study area none degree of restriction on use and in 0.6% slight to moderate and 0.5% severe. The suitable zones for infiltration have no degree of restriction on use in majority of the study area. The maps result of crops yield potential as influenced by irrigation water salinity (EC_W) indicates that crops barley>wheat > Alfalfa respectively have yield potential more against EC_W in study area (99.42,92.3 and 0.23%). The results of thematic maps of $sodium_w$, $cholorid_w$ were overlaid with maps of $sodium_{plant}$, $cholorid_{plant}$ showed that the crops yield potential of barley and wheat. Alfalfa in all the study area is 100%.

Key words: Geomorphological mapping, GIS, Damghan plain, total dissolved solids (TDS), electrical conductivity (EC), water standard, groundwater.

INTRODUCTION

The chemical composition of water is an important factor to be considered before it is used for domestic or irrigation purpose (Suresh et al., 1991). Water quality is something relative characteristics of the use of water for specific uses will affect. Characteristics of water quality through physical, chemical and biological definition is National Committee of Irrigation and Drainage, 2001). In irrigation water evaluation, emphasis is placed on the chemical and physical characteristics of the water and only rarely is any other factors considered important.

Salts in soil or water reduce water availability to the crop to such an extent that yield is affected (Bernstein, 1975).

Relatively high sodium or low calcium content of soil or water reduces the rate at which irrigation water enters soil .Certain ions (sodium, chloride, or boron) from soil or water accumulate in a sensitive crop to concentrations high enough to cause crop damage and reduce yields. Excessive nutrients reduce yield or quality; unsightly deposits on fruit or foliage reduce marketability. All plants do not respond to salinity in a similar manner; some crops can produce acceptable yields at much greater soil salinity than others. In areas where a build-up of soil salinity cannot be controlled at an acceptable concentration for the crop being grown, an alternative crop can be selected that is both more tolerant of the

*Corresponding author. E-mail: shahramashraf72@yahoo.com.

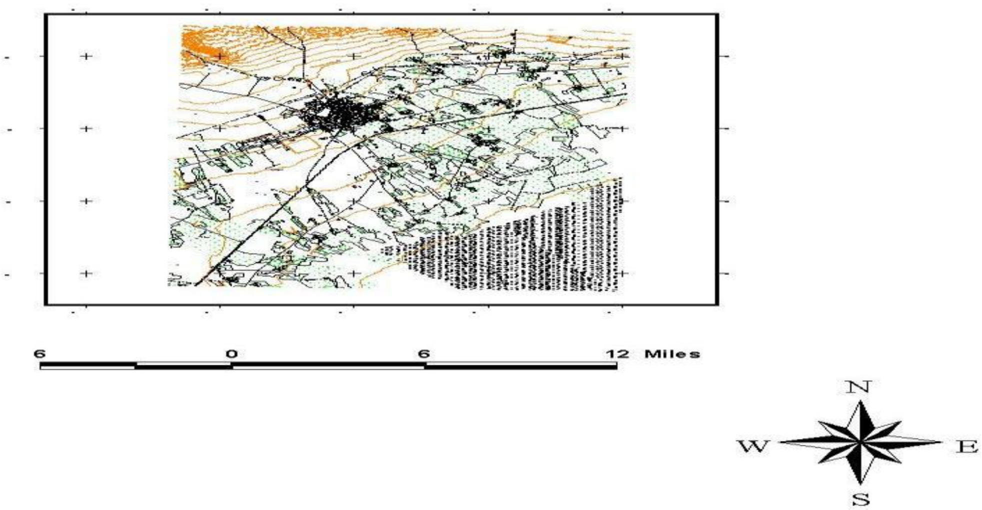

Figure 1. The map of the study area.

expected soil salinity and can produce economical yields. Availability of adequate good quality water is one of the most important inputs in successful crop production. As the anthropogenic activities also influence the role of evaporation, leading to an increase in Na^+ and Cl^- and thus total dissolved solids (TDS), the samples fall in an environment that tends toward a semi-arid/arid climate. Features that generally need to consider for evaluation of the suitable quality of groundwater for irrigation are the electrical conductivity (EC), percent sodium, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC)

It is therefore obvious that the groundwater contribution is a significant component of water balance and should be recognized as providing part of the water needed by the crop for evapotranspiration. The Most important cation and anion in ground water resources are under Ca^{2+}, Mg^{2+}, Na^+, HCO^{3-} and NO^{3-}. There is close relationship between soil and water salinity. The geographic information system (GIS), is potential tool for facilitating the generation and use of thematic information, has been applied and analyzed for identification of groundwater quality suitable zones for domestic and irrigation purposes. Geographic information system (gis) is one of the best and fastest system for this goal (Ganapathy and Ernest, 2004).

MATERIALS AND METHODS

Study area

The study area "Damghan plain" between north latitude 36°, 36° 15' and east longitude 54°, 54° 15' with an area of 673 km^2. Base map is selected from topographic map with 1:50,000-scale .The study region map is shown in Figure 1. It falls in drought-prone region of Semnan, Iran. A river ''Cheshme Ali'' passes through the study area. The Damghan is located in desert margins and low rainfall, plant of crops has encountered with some difficulties, but with all the existing natural barriers, from the past to today, people plant different crops. The serious problems of this area are water shortage. With more empty of table freshwater will be progressive desert saltwater toward Damghan plain. Most of study area soils are new alluvial sediments in period of the Fourth of Geology. Parent material in the the northern and western of plain are sediments mixed with sand and gravel.

Methods

In order to evaluate the quality suitable of groundwater in Damghan plain for crops influenced by irrigation, the samples were collected by GPS from wells water and soil in the study area. The 199 surveyed wells with GPS data were used to produce the map. The concurrent A digital topographic map (1: 5,0000) of the study area obtained from Cartographical Publishing of the Iran army was used as basic information for the GIS database. Features that generally were considered for evaluation of the suitable quality of groundwater for irrigation are salinity, water infiltration rate, and specific ion toxicity (Ayers et al., 1994).

The SAR, major ions Ca^{2+},Mg^{2+}, Na^+, K^+, $CO_3{}^{2-}$, $HCO_3{}^-$, $SO_4{}^{2-}$, Cl^-, EC, TDS, pH were analyze as the evaluation indexes of water (Todd, 1960; Richards, 1954; Eaton, 1950; Lloyd et al., 1985) and SAR, EC for the soil. The samples were analyzed using standard analytical of FAO. The used ranges were selected in accordance to the guidelines set by the Food and Agriculture Organization (Ayers et al., 1985). The GIS software used in this study was Arcview GIS to design maps and microsoft excel was used to transport data to arc view project. Amongst some methods such as, the spline, inverse distance weight (I.D.W.), ordinary kriging, interpolation methods, the I.D.W . produced the best results and was therefore selected to create various groundwater quality maps for various periods for irrigation use. The data of well water were imported intothe GIS microsoft. The different water quality maps are produced using point data spatial analysis of GIS. The results were prepared as maps for insert into the GIS software then they were prepared for integration. All the thematic maps of EC, SAR, sodium, chloride were overlaid With maps of EC_W effective on yield potential and the result were prepared as separate maps (Figure 2).

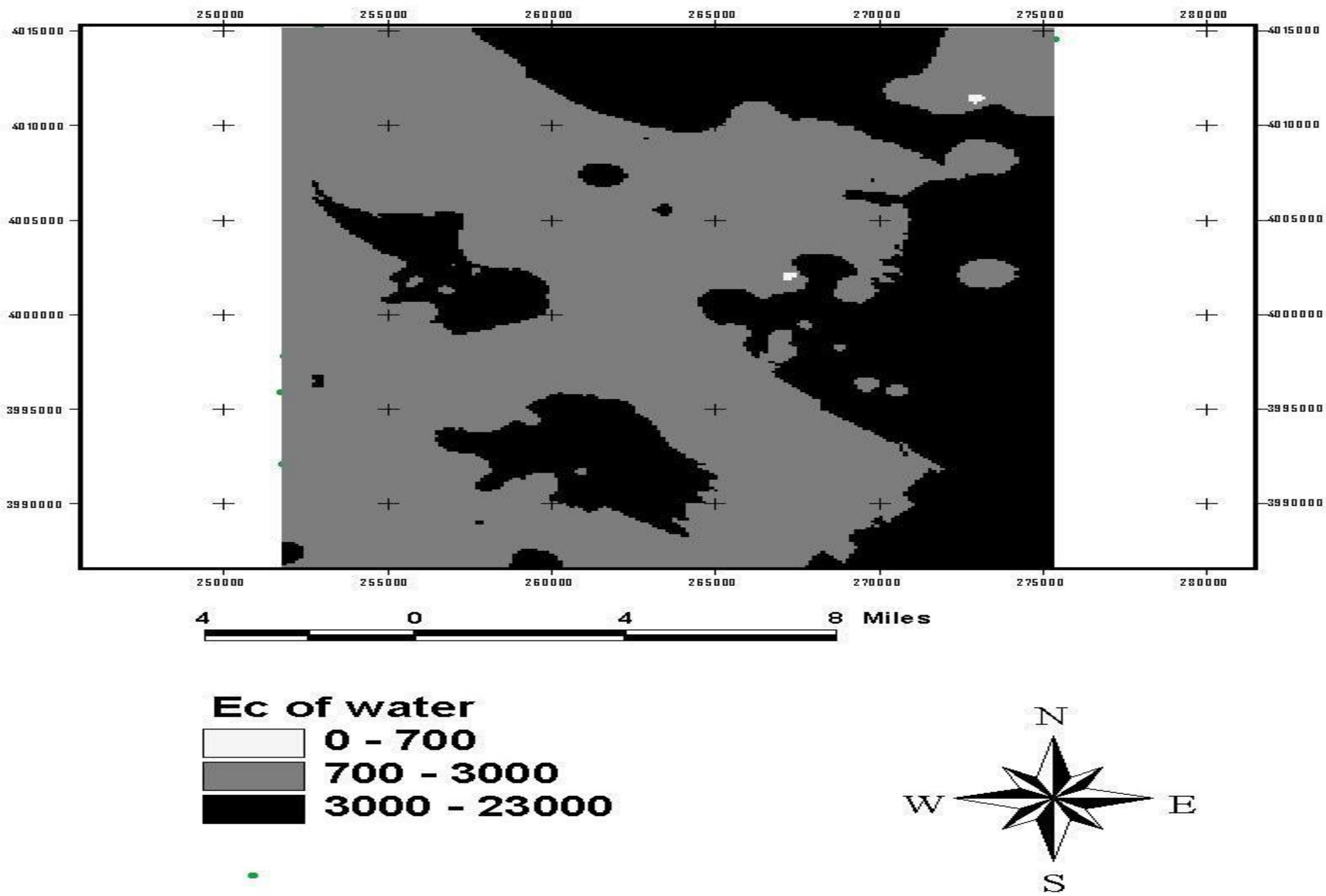

Figure 2. Spatial distribution of EC_W (µs cm^{-1}).

RESULTS

The data obtained by chemical analysis were evaluated in terms of its suitability for irrigation purposes. The analytical results of evaluation indexes are shown in Table 1. Among the cations, the order of abundance (Mg -1 2+ + + + 2+ L) is Ca >Na > Mg > K . The concentration of Ca, to 21.6 and 0.3 to 3 mg L-1 with a mean of 14 , 8.3, 5.1 and 1.2 mg L-1, respectively. Among anions, the order of abundance is Cl->HCO3- >SO42- > CO32- ranged from1.03 to 16.9, 1.1 to 7.4, 2 to 6.7, 0 to 0.1 mg L-1 with a mean of 9.69, 5, 3.3, 0.01 mg L-1, respectively. The results revealed that pH ranged from 6.72 to 8.52. The EC map indicates the presence of higher value that falls in the range between of 300 to over 22100 ds m- 1 in the east to northeastern and south and central area of Damghan plain. The EC map indicates the presence about 0.04% of the study area, groundwater lie in range less than 0.7 ds m-1 and 61.38% between 0.7 to 3 ds m-1 and 38.58% more than 3 ds m-1 for irrigation purposes. The spatial distributions of the total dissolved solids (TDS) values were according to EC map. The map result of crops yield potential as influenced by water salinity in ECw <700 indicates barley ,wheat and Alfalfa have yield potential 100%(in 0.04% study area),100% (in 0.04% study area),100 (in 0.04% study area), respectively (Table 3). The crops yield potential of barley, wheat and Alfalfa in the ECw =700 to 3000, 100 (61.38% study area) and 100% (61.38% study area) and 100%, <100% (in 61.20%, 0.18% study area) respectively. The crops yield potential of barley, wheat and Alfalfa in the ECw >3000 µ cm-1 was 100%,<100 (38.08%, 0.5% study area) and 100,<100% (30.98, 7.69% study area) and < 100% (38.58% study area). The analytical results of EC, SAR, soil and water of the study area is shown in Table 2. The range of minimum, maximum and average of ECsoil and SARsoil are 3, 40, 14.7 dsm-1 and 5, 40 and 6.41. The Results showed that there is a positive correlation between ECw and ECsoil, a positive correlation between SARw and SAR soil. The maps of groundwater quality for Infiltration by ECw and SAR are shown in Figures 3 to 9.

Table 1. Criteria for the classification of thematic maps of groundwater quality for irrigation and their spatial distribution.

Criteria	Degree of restriction on use	Area percentage	Area (Km^2)
Salinity (affects crop water availability)			
ECw		dS m^{-1}	
None	< 0.7	0.04	0.2692
Slight to moderate	0.7 – 3.0	61.38	413.0874
Severe	> 3.0	38.58	259.6434
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)			
SAR = = 0 – 3	ECw = dS m^{-1}		
None	> 0.7	7.13	5.2049
Slight to moderate	0.7 – 0.2	0.0	0.0
Severe	< 0.2	0.0	0.0
SAR = 3 – 6	ECw = dS m^{-1}		
None	> 1.2	84.1	56.5993
Slight to moderate	1.2 – 0.3	0.47	3.1631
Severe	< 0.3	0.48	3.2304
SAR = 6 – 12	ECw = dS m^{-1}		
None	> 1.9	7.67	51.6191
Slight to moderate	1.9 – 0.5	0.132	0.8883
Severe	< 0.5	0.018	1.2114
SAR = 12 – 20	ECw = dS m^{-1}		
None	> 2.9	0.0	0.0
Slight to moderate	2.9 – 1.3	0.0	0.0
Severe	< 1.3	0.0	0.0
SAR = 20 – 40	ECw = dS m^{-1}		
None	> 5.0	0.0	0.0
Slight to moderate	5.0 – 2.9	0.0	0.0
Severe	< 2.9	0.0	0.0
Specific Ion toxicity (affects sensitive crops)) (surface irrigation)			
Sodium (Na+)			
SAR	me l^{-1}		
None	< 3	7.14	48.0522
Slight to moderate	3 – 9	91.69	617.0737
Severe	> 9	1.17	7.8741
Chloride(surface irrigation)			
Cl -	me l^{-1}		
None	< 4	4.29	28.8717
Slight to moderate	4 – 10	48.28	324.9244
Severe	> 10	47.43	319.2039

The quality of groundwater for the sodium hazard on infiltration is in SAR = 0 to 3 and Ec > 0.7, EC = 0.7, -0.2 and <0.2 respectively, 7.13 (none), 0, 0% and in SAR = 3 to 6 and Ec >1.2, Ec = 1.2 to 0.3 and EC<0.3 respectively 84.1, 0.47, 0.48% (severe) and in SAR = 6 to 12 and Ec > 1.9, EC = 1.9-.5, EC< 0.5 respectively 7.67, 0.132, 0.018% (severe) of the study area. The map of groundwater quality for Specific Ion Toxicity (affects sensitive crops) is shown in Figures 10 - 12. The evaluation of suitable zones of groundwater quality for

Table 2. Statistical parameters of EC, SAR in soil and water of the study area.

Criteria	Min	Max	Average	SD	Correlation coefficient
EC_W	300	22100	2876	1959.5	+ 0.379
EC_{soil}	3000	40000	14700	12009	
SAR_W	0.5	16	4.27	2.04	+0.227
SAR_{soil}	5	40	6.41	13.11	

Table 3. Crop tolerance and yield potential of selected crops as influenced by irrigation water salinity (EC_W) or soil salinity (EC_e).

Field crop	Yield potential (%)									
	100		90		75		50		0	
	EC_e	EC_W	EC_e	EC_W	EC_e	EC_W	EC_e	EC_W	EC_e	EC_W
Barley *(Hordeum vulgare)*	8.0	5.3	10	6.7	13	8.7	18	12	28	19
Wheat *(Triticum aestivum)*	6.0	4.0	7.4	4.9	9.5	6.3	13	8.7	20	13
Alfalfa *(Medicago sativa)*	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16	10

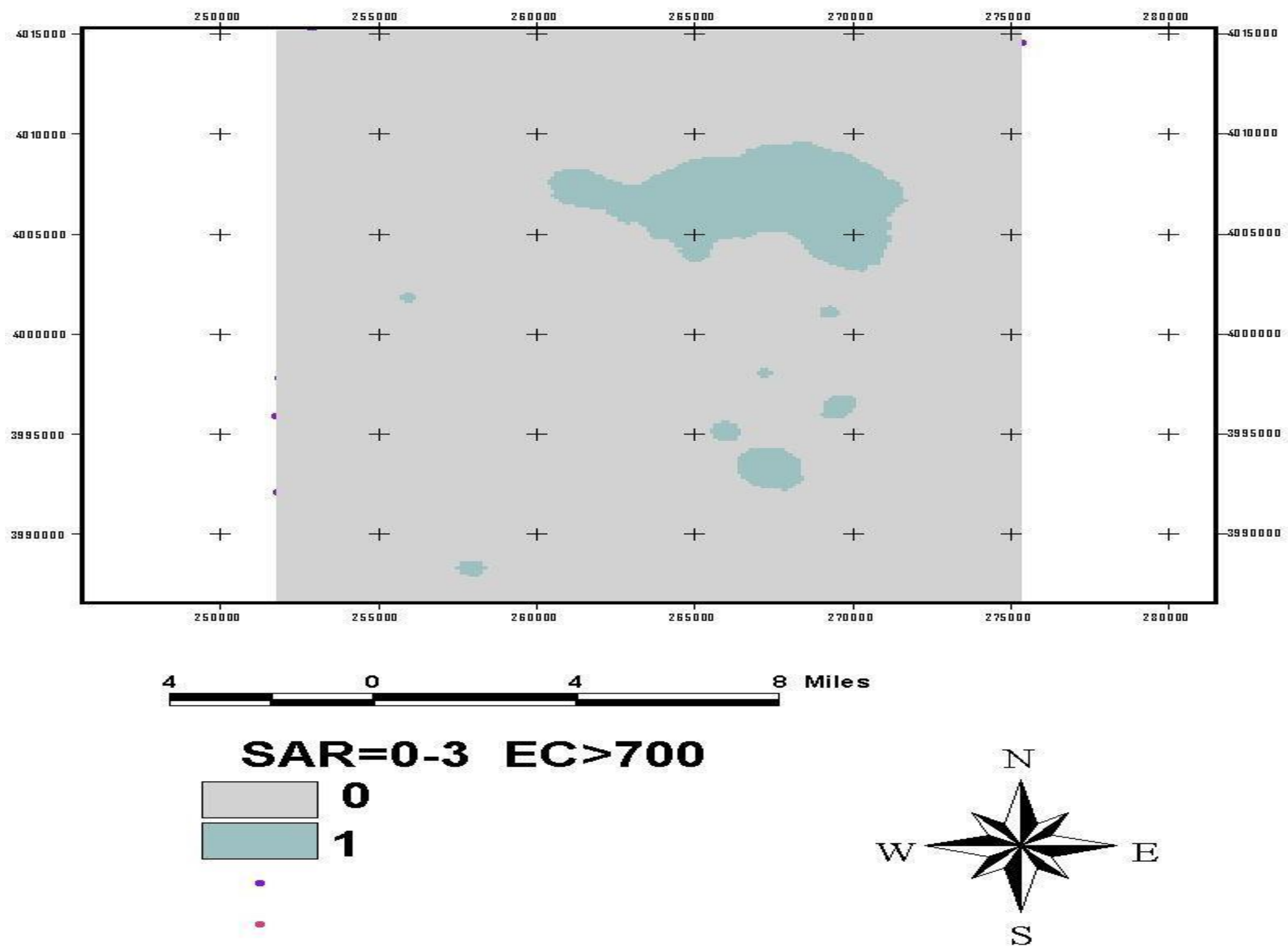

Figure 3. Spatial distribution of SAR_W ,EC_W(µs cm^{-1}). O= not according SAR_W, EC_W, 1=according EC_W, SAR_W.

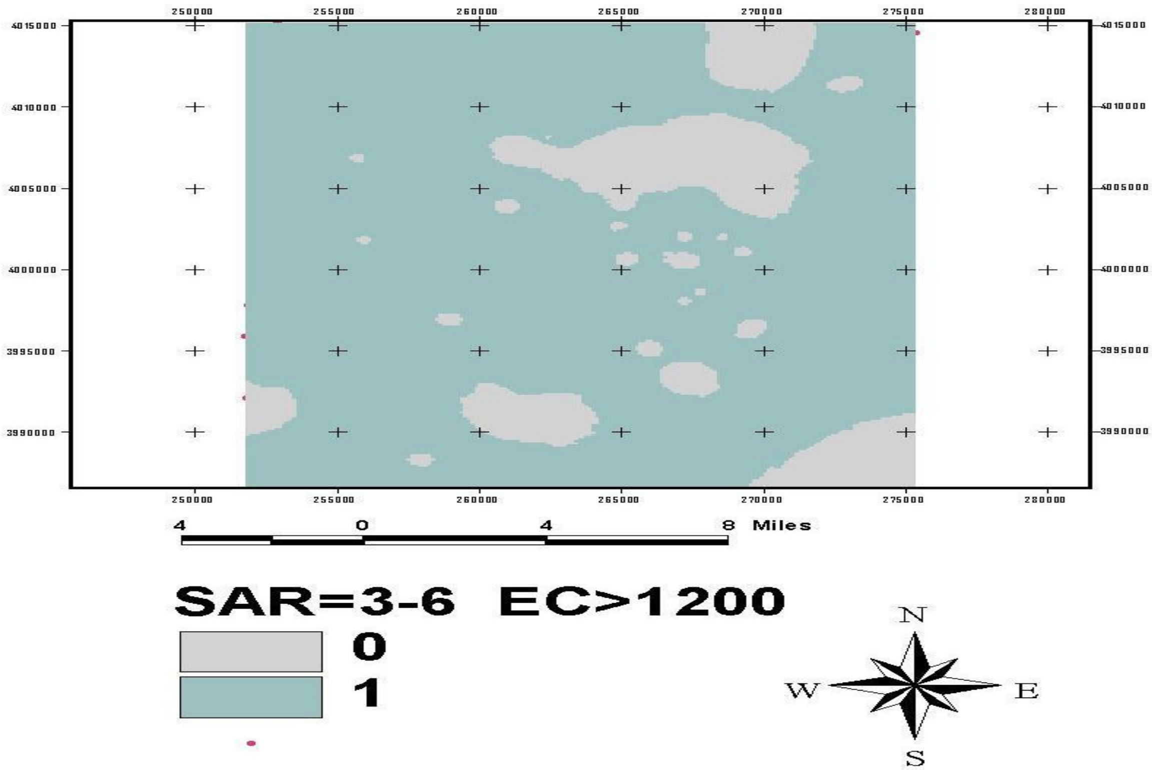

Figure 4. Spatial distribution of SAR_W , EC_W(μs cm^{-1}). O= not according SAR_W, EC_W, 1= according EC_W,SAR_W.

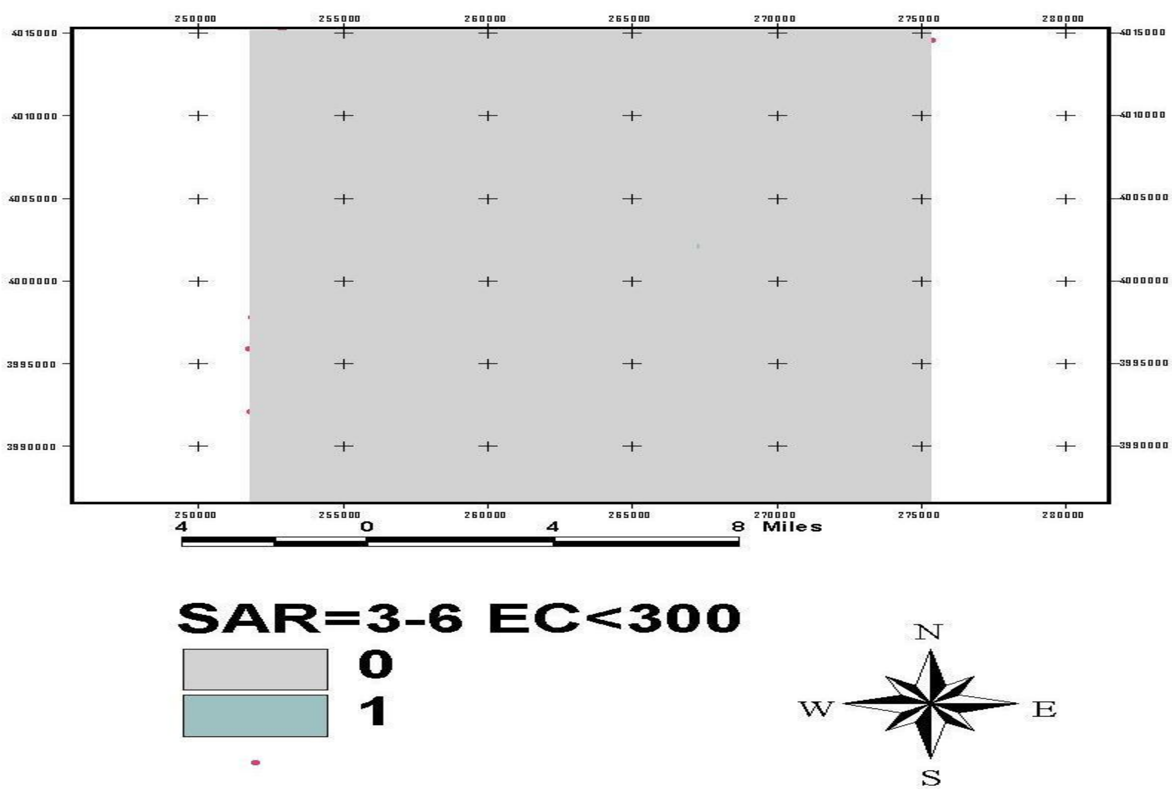

Figure 5. Spatial distribution of SAR_W, EC_W(μs cm^{-1}).

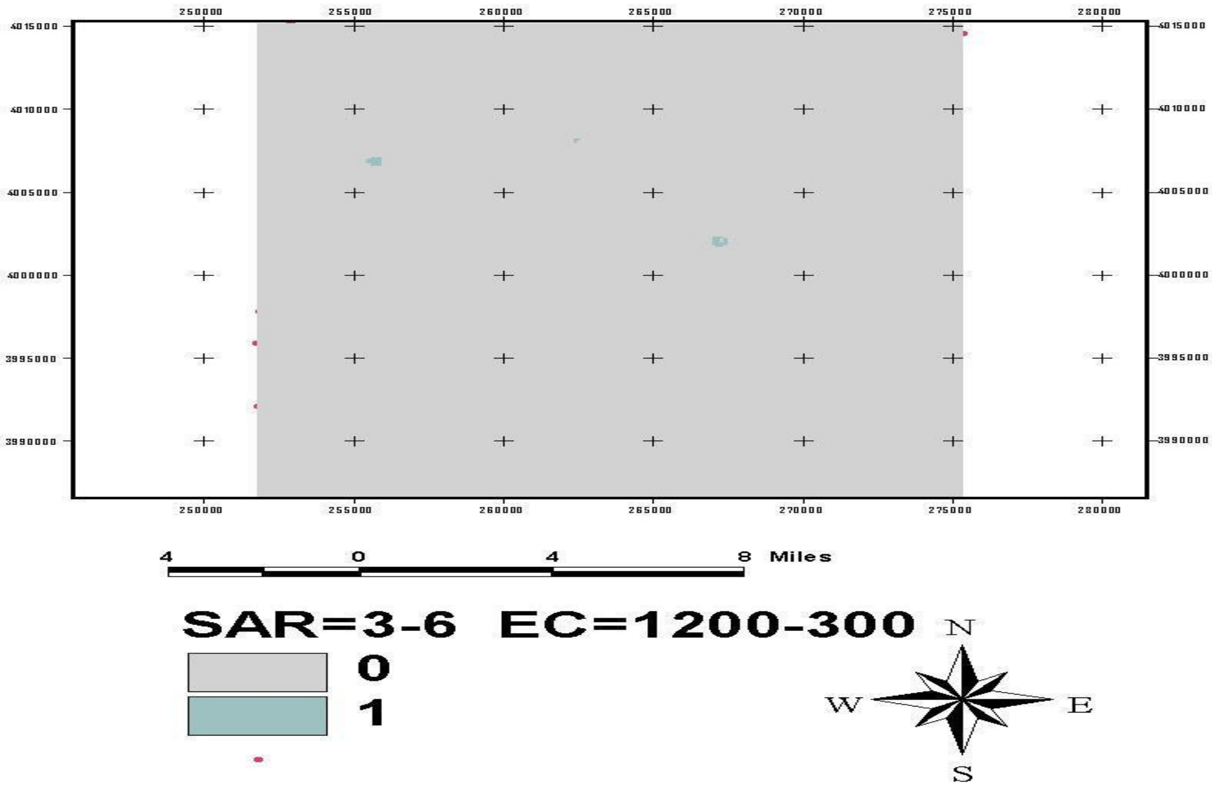

Figure 6. Spatial distribution of SAR_W, EC_W(μs cm^{-1}).

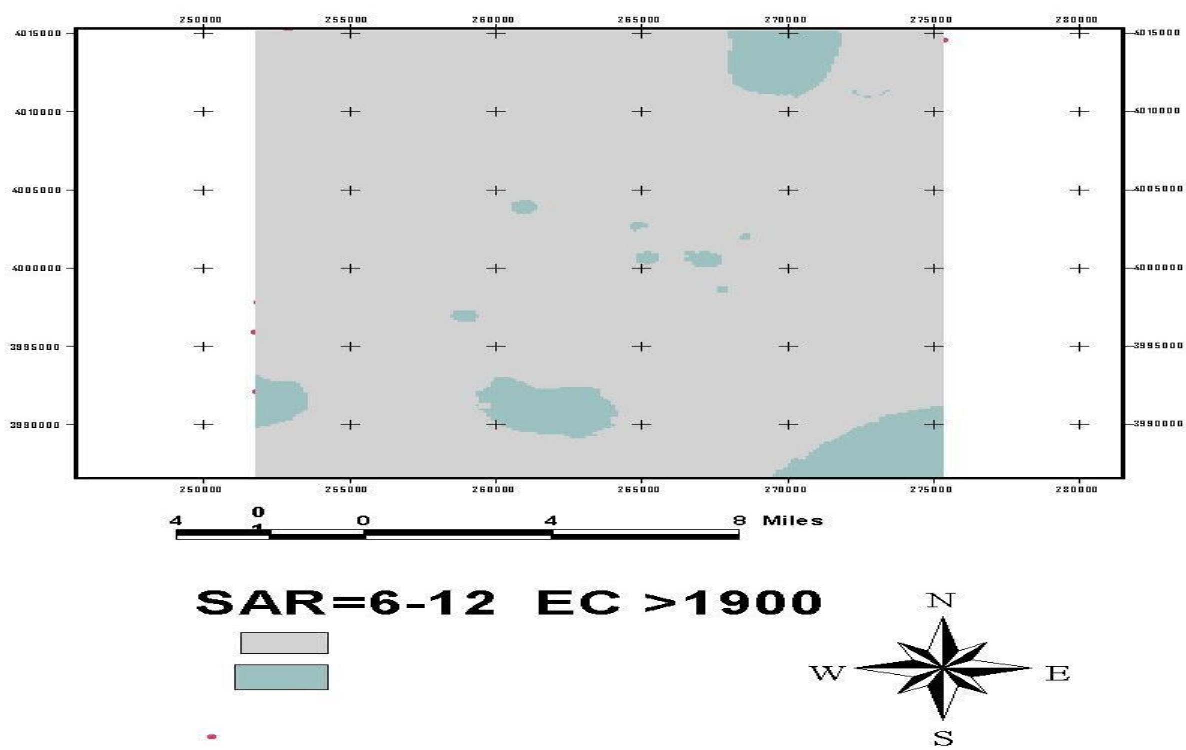

Figure 7. Spatial distribution of SAR_W ,EC_W(μs cm^{-1}).

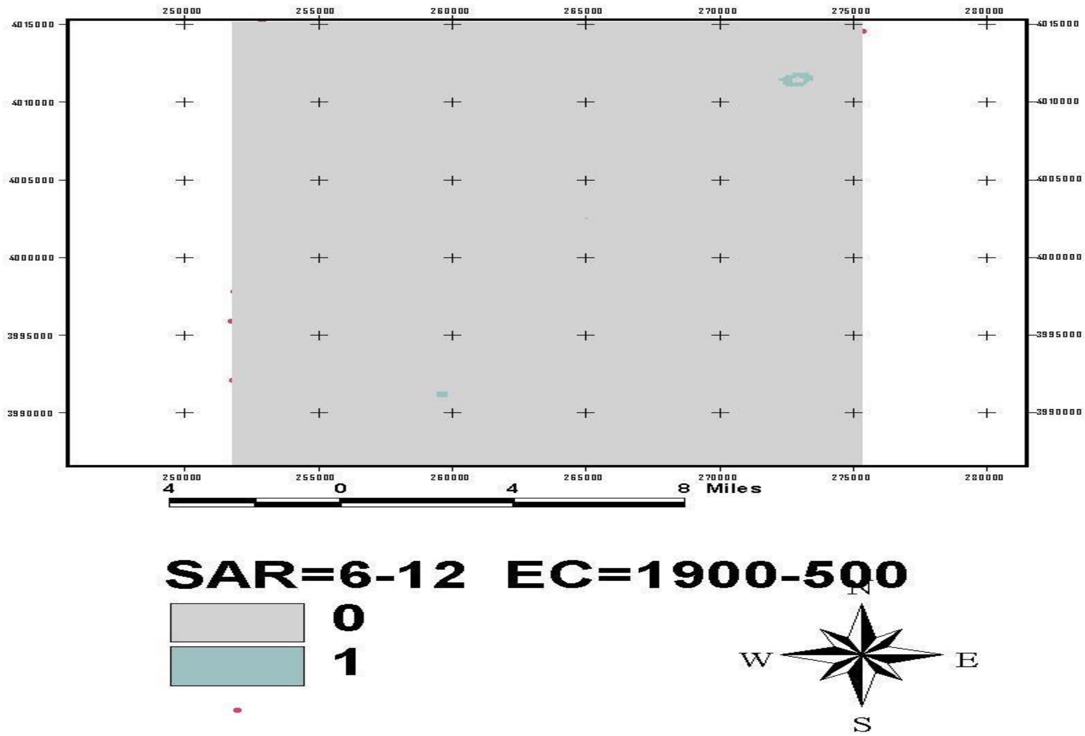

Figure 8. Spatial distribution of SAR_W ,EC_W (µs cm^{-1}).

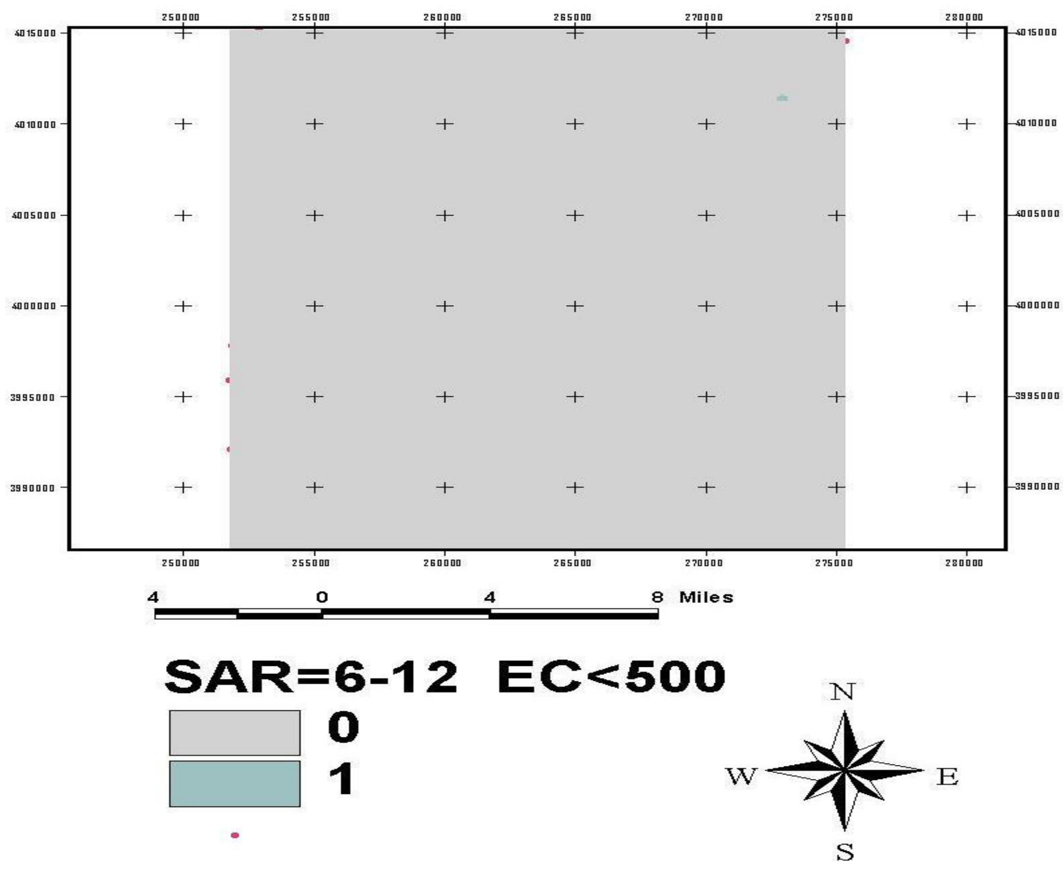

Figure 9. Spatial distribution of SAR_W ,EC_W(µs cm^{-1}).

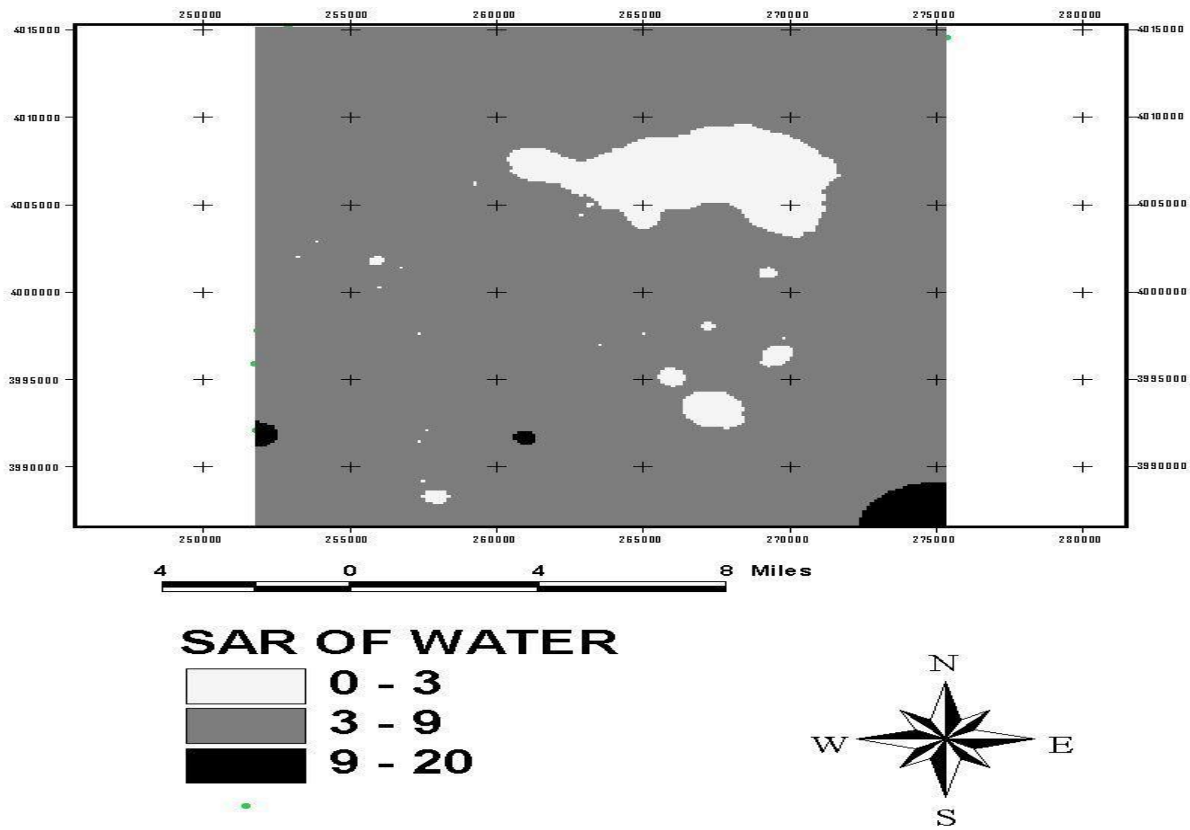

Figure 10. Spatial distribution of SAR_W , EC_W(µs cm^{-1}).

Specific Ion Toxicity According to Ayers (1994) is basd on: Na^+(SAR) and Cl^- .Based on of SAR, 7.14 % of the area are less than 3 meq l^{-1} and 91.69% between 3-9 meq l^{-1} and 5.22% of the are more than 9 meq l^{-1} (Table 4).

The map of groundwater quality for Chloride show 4.29% less than 4 meq l^{-1}, 48.28 between 4-10 meq l^{-1} and 47.43 % more than 10 meql^{-1} (figure 10 and 11).The result of crops yield potential as influenced by water Specific Ion Toxicity (affects sensitive crops) shown in Table 5.

The results of thematic maps of $sodium_W$, $cholorid_W$ were overlaid with maps of $sodium_{plant}$, $cholorid_{plant}$ showed that the crops yield potential of Barley, Wheat. Alfalfa influenced by choloride, sodium in all the study area is 100%.

DISCUSSION

An analysis of the nature and rate of land use change and its associated impact on groundwater quality is essential for a proper understanding of the present environmental problems (Krishna et al., 2001). The present study demonstrated high efficiency for GIS to analyze complex spatial data. A different component and data should be incorporated into GIS applications to determine to physical suitability (Rossiter, 1995). With an adequate database, Geographic Information Systems (GIS) can serve as a powerful analytic and decision-making tool for agriculture development (Hem, 1992; Reid and Wood, 1976).

Furthermore, it can also be used for management and to test consequences of development (Aguilar-Manjarrez and Ross, 1995).The groundwater table maps, which are prepare, based on the spatial data analysis shows that the GIS assisted database system would help to apply groundwater management practices such as; proper groundwater resource management in terms of groundwater quality & quantity. The produced groundwater related database could help as information source to Institutions, researchers, groundwater practitioners, drilling companies and decision makers etc. This study, the evaluation result indicates that parameters of groundwater such as EC_W, SAR_W, chloride, sodium mainly affect on the groundwater quality and crops growth in the study area.

The EC map indicates the presence about 0.04 % of the study area groundwater lie in good range (none degree of Restriction on Use) 61.38 % Slight to Moderate and 38.58% Severe for irrigation purposes. The suitable sensitive crops) is shown in Figures 10 - 12. The evaluation of Suitable zones of groundwater quality for zones for EC_W (Potential Irrigation Problem=none and

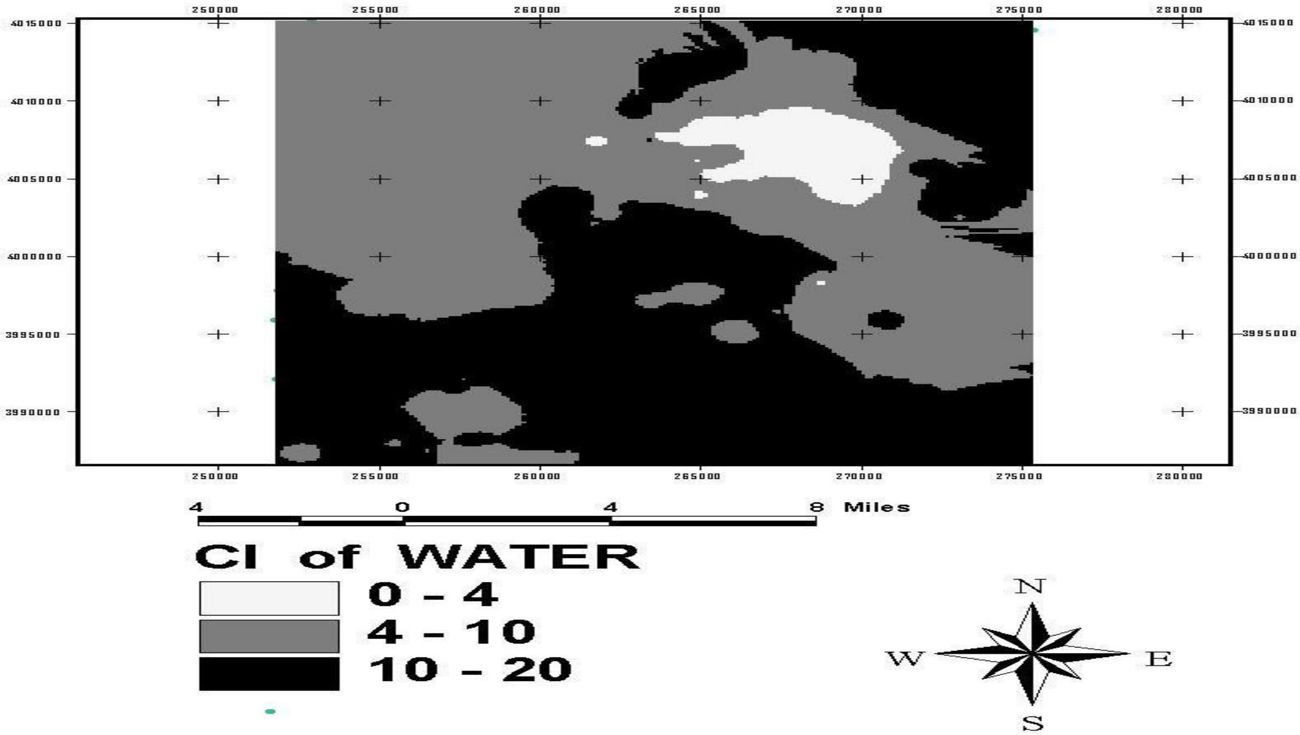

Figure 11. Spatial distribution of SAR_W ,EC_W (µs cm^{-1}).

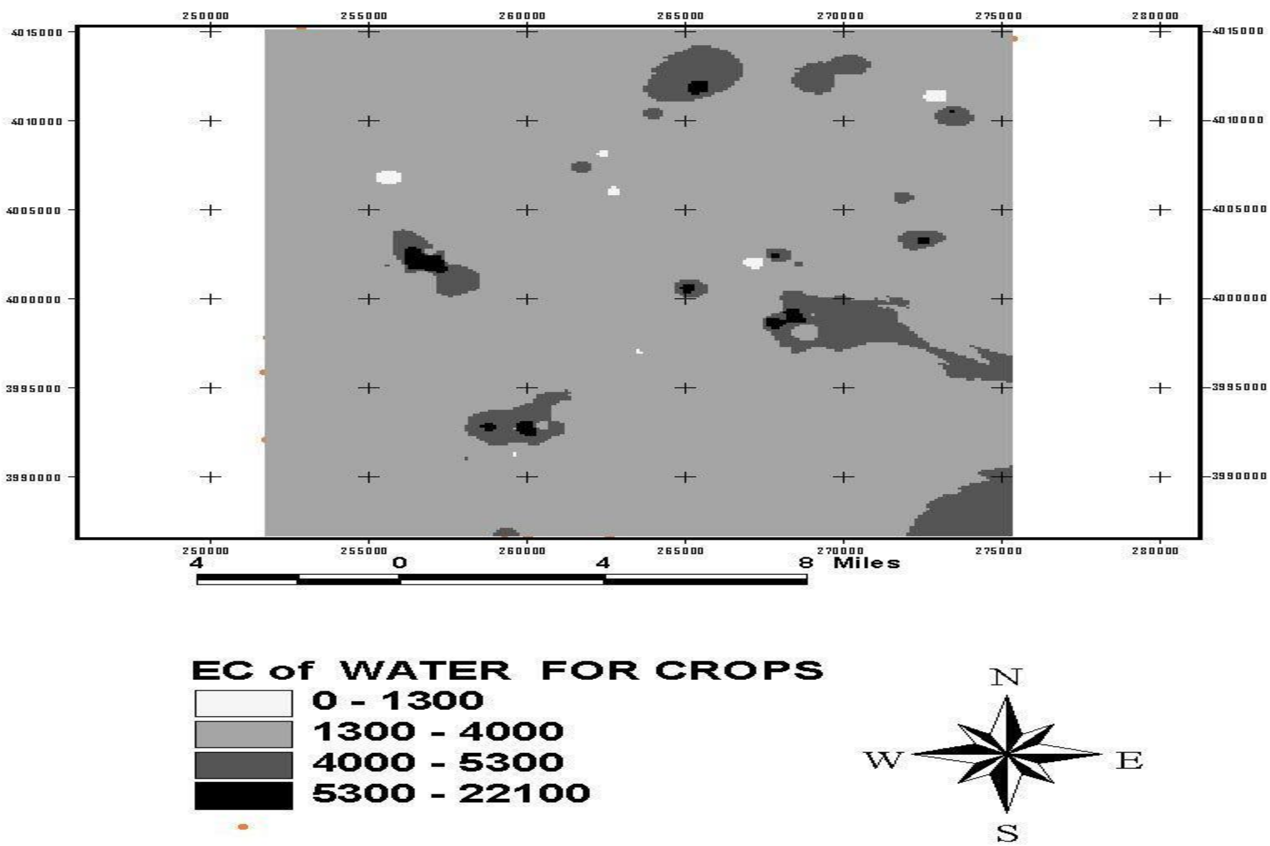

Figure 12. Spatial distribution of EC_W(µs cm^{-1}) for crops.

Table 4. Yield potential of selected crops as influenced by irrigation water salinity (EC_W) or soil salinity (EC_e) and their spatial distribution.

Criteria	Yield potential (%) [Area (%)]			
	EC_W dS/m	Barley	Wheat	Alfalfa
None	< 0.7	100 (0.04)	100 (0.04)	100% (0.04)
Slight to moderate	0.7 – 3.0	100 (61.38)	100 (61.38)	100,<100(0.19, 61.20)
Severe	> 3.0	100 <100((38, 0.58)	100, <100 (30.88, 7.7)	<100 (38.57%)

Salinity (affects crop water availability).

Table 5. Yield potential of selected crops as influenced by irrigation water chloride (Cl_W) and sodium (Na_W) and their spatial distribution.

Criteria	Yield potential=100%		
	Barley [(area (%)]	Wheat [area (%)]	Alfalfa [area)%)]
Chloride	80 meq L^{-1} (100)	60 meq L^{-1} (100)	20 meq L^{-1} (100)
Sodium (ESP)	40-60% (100)	40-60% (100)	40-60% (100)

slightly to moderate) are in the central and northwestern and portion of south of the study area, (61.42%).

The observed high and moderate concentration of EC_W in groundwater in samples is because located near the desert (east and south) and Due to lack of deficiency water and rainfall and the plentiful use of water resources; dug of deep and semi-deep well is increased. With more empty of table freshwater will be progressive desert saltwater toward Damghan plain.

A high salt concentration in water leads to formation of saline soil and a high sodium concentration leads to development of alkaline soil.

However, in the northwest groundwater toward central and south quality is mainly better because the passage of cheshme- Ali river that has a good quality. This river improves quality of soil and wells water. The groundwater quality in these places change because of good permeability of the river water and decreases of salts in water tables.

The quality of groundwater for the sodium hazard on infiltration is in 98.9% of study area include Degree of Restriction on Use= none and in 0.6% Degree of Restriction on Use =Slight to Moderate 0.5% Degree of Restriction on Use =severe. The suitable zones for infiltration have potential of irrigation problem=none in majority of the study area.

The sodium hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of SAR. There is a significant relationship between SAR_W and EC_W values of irrigation water and SAR_{soil} and $EC_{soil\ in}$ the soils of study area (table 5). If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles.

The calculated value of SAR_W in the study area ranges from 0.5 to 16 in groundwater.

In the study area, A high Ca^{2+} concentration in soil and water is high because high $CaCO_3$ (lime) concentration in soil that leads to decreases of water and soil SAR. The map result of crops yield potential as influenced by irrigation water salinity (EC_W) in table 2 indicates that crops barley>wheat > Alfalfa respectively have yield potential more against EC_W in study area(Figure 10).

A high yield potential concentration in barely is because high tolerance (table 2) of barley against salinity of water. The EC_W of study areas have high suitability for crops Barely>Wheat >Alfalfa. The suitable areas for planting crops barely, wheat, alfalfa (yield potential=100%) shown in Table 6.

CONCLUSION

Remote sensing and GIS are effective tools for water quality mapping and land cover mapping essential for monitoring, modeling, and environmental change detection (Skidmore et al., 1997). Application of GIS has been applied and identified the suitable zones of groundwater quality for irrigation purpose. The GIS assisted database system would help to apply groundwater management practices such as; proper groundwater resource management in terms of groundwater quality & quantity, Integrated management of water, land use and the environment; to optimize pumping rates with respect to the capacity of the aquifer system, and to prevent groundwater quality deterioration through proper monitoring & evaluation.

The groundwater quality studies indicate that the groundwater is inclined alkaline and Ca^{2+} and Cl^-, EC are

Table 6. The suitable zone for crops irrigation.

Suitable zone	Area relative percent (Yield potential=100%)	Area (Km^2)
Suitable zone for barley	99.42	669.09
Suitable zone for wheat	92.3	621.17
Suitable zone for alfalfa	0.23	1.54

the parameters mainly affect on the groundwater quality. The suitable quality of groundwater for irrigation of barely, Wheat, Alfalfa respectively is available in 669.09, 621.17, 1.54 km^2 of all the study area (99.42%, 92.3%, 0.23% of the area) (Table 6).

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