

Wells water quality evaluation in southern part of Tohama plains, Saudi Arabia



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Introduction

- The groundwater is the main water resource in arid countries such as Saudi Arabia. However, the water resources in Saudi Arabia are limited, non-renewable and vary from region to region.
- According to estimates, about 90% of water demand in agriculture sector is currently being met from non-renewable groundwater sources.
- Large percentage of the population (rural and desert areas) depends on groundwater from their private wells as the main source of drinking water.
- Evaluation of groundwater quality is importance to establish a database for planning water resources strategies in future.
- Irrigated agriculture is dependent on adequate water supply of usable quality. Quality is defined by certain physical, chemical and biological characteristics.
- In irrigation water evaluation, emphases are placed on the chemical and physical characteristics of the water and rarely are any other factors considered important.
- In Saudi Arabia, studies about the water quality are few. However, some researchers have evaluated water qualities in some other regions of Saudi Arabia such Faruq et al. (1996), Abdel-Aal et al. (1997), Falatah et al. (1999), and Al-Harbi et al. (2006).
- The main objective of this paper is to evaluate water quality of wells in the southern part of Tohama plains, Saudi Arabia to determine its possible use in the field of irrigated agriculture.

Materials and Methods

- **Location:** The studied area (Fig. 1) is located at the southern part of Tohama plain (Jazan Region) and lies between latitude $16^{\circ} 24' 24.2''$ N and $17^{\circ} 48' 29.9''$ N and longitude $42^{\circ} 0' 4.2''$ E and $43^{\circ} 10' 58.4''$ E .
- **Water samples collection:** About 262 groundwater samples were collected from different wells in the study area for chemical analysis. The water samples were collected in plastic bottles and stored in ice box to avoid any chemical reaction before analysis.
- **Water analysis:** Chemical composition was determined according the standard methods (Richards, 1954). Electrical conductivity (EC_{iw}) was measured by conductivity-meter and pH was measured by pH- meter. Different ions such as calcium (Ca^{+2}) and magnesium (Mg^{+2}) were determined by titration with EDTA method, sodium (Na^{+}) and potassium (K^{+}) were determined by flame photometer, chloride (Cl^{-}) by titration with silver nitrate, sulfate ($SO_4^{=}$) by turbidity method, nitrate (NO_3^{-}) by colorimetric method, carbonate and bicarbonate by titration with HCl.
- **Water quality indices:** The criteria used to evaluate the quality of water for use in agriculture (Ayers and Westcot, 1994) are: salinity of irrigation water (EC_{iw}), sodium adsorption ratio (SAR), adjusted sodium ratio ($Adj.RNa$), soluble sodium percentage (SSP), residual sodium carbonate (RSC), effective salinity (ES), potential salinity (PS), and the toxic effects of specific ions such as Na , Cl , SO_4 and B on plant growth and yield.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

$$adj\ SAR = SAR [1 + (8.4 - pH_c)]$$

$$pH_c = (pk_2 - pk_c) + p(Ca + Mg) + p(Alk)$$

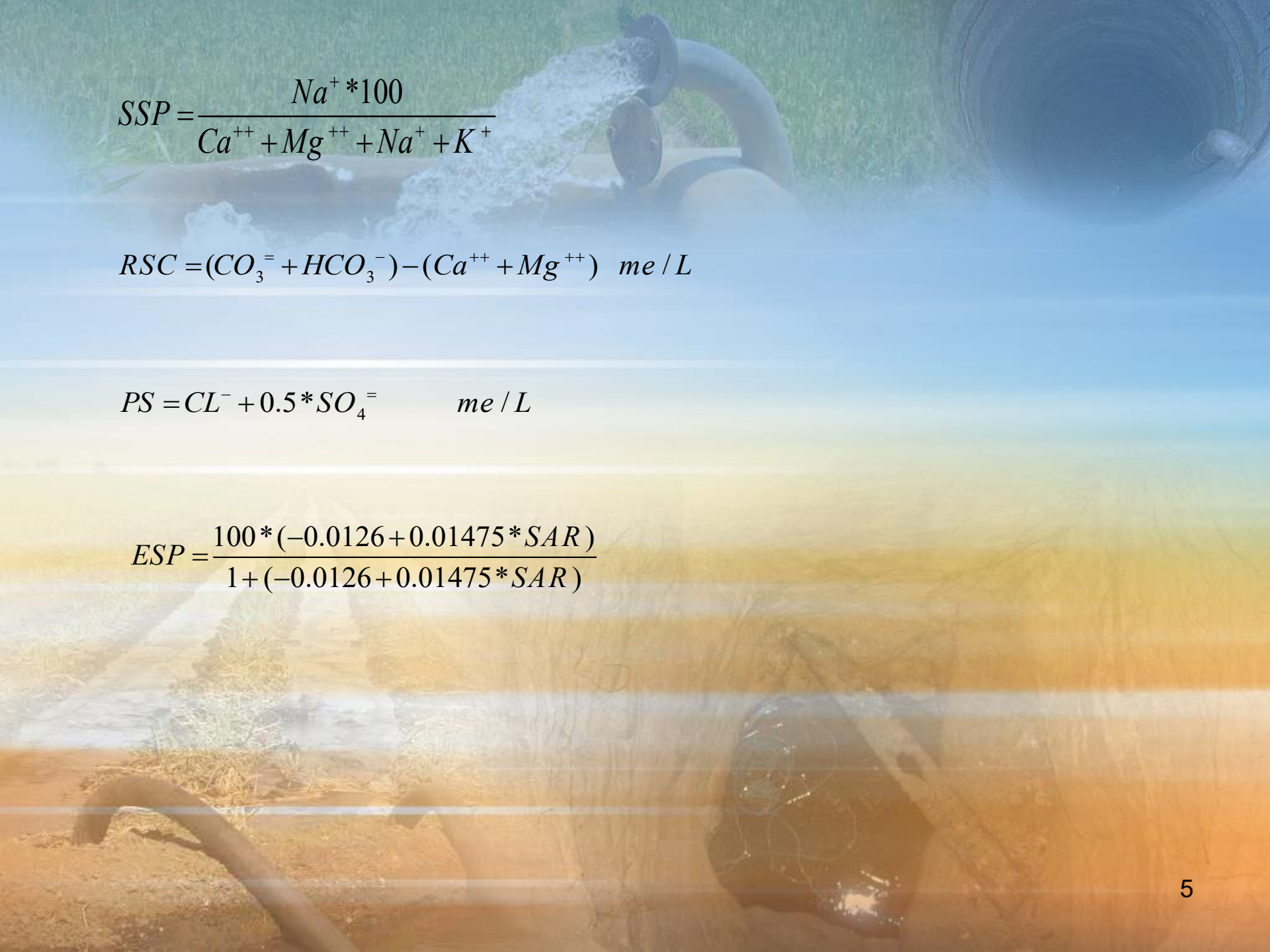
$$(pk_2 - pk_c) = 2.107 * (Ca + Mg + Na)^{0.038}$$

$$p(Ca + Mg) = 3.298 - 0.34 * \ln(Ca + Mg)$$

$$pAlk = 2.998 - 0.43 * \ln(CO_3 + HCO_3)$$

$$Adj.R_{Na} = \frac{Na}{\sqrt{\frac{Ca_x + Mg}{2}}}$$

$$Ca_x = 2.09 * EC^{0.100398} * \left(\frac{HCO_3}{Ca} \right)^{-0.66721}$$


$$SSP = \frac{Na^{+} * 100}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}}$$

$$RSC = (CO_3^{-} + HCO_3^{-}) - (Ca^{++} + Mg^{++}) \text{ me / L}$$

$$PS = CL^{-} + 0.5 * SO_4^{-} \text{ me / L}$$

$$ESP = \frac{100 * (-0.0126 + 0.01475 * SAR)}{1 + (-0.0126 + 0.01475 * SAR)}$$

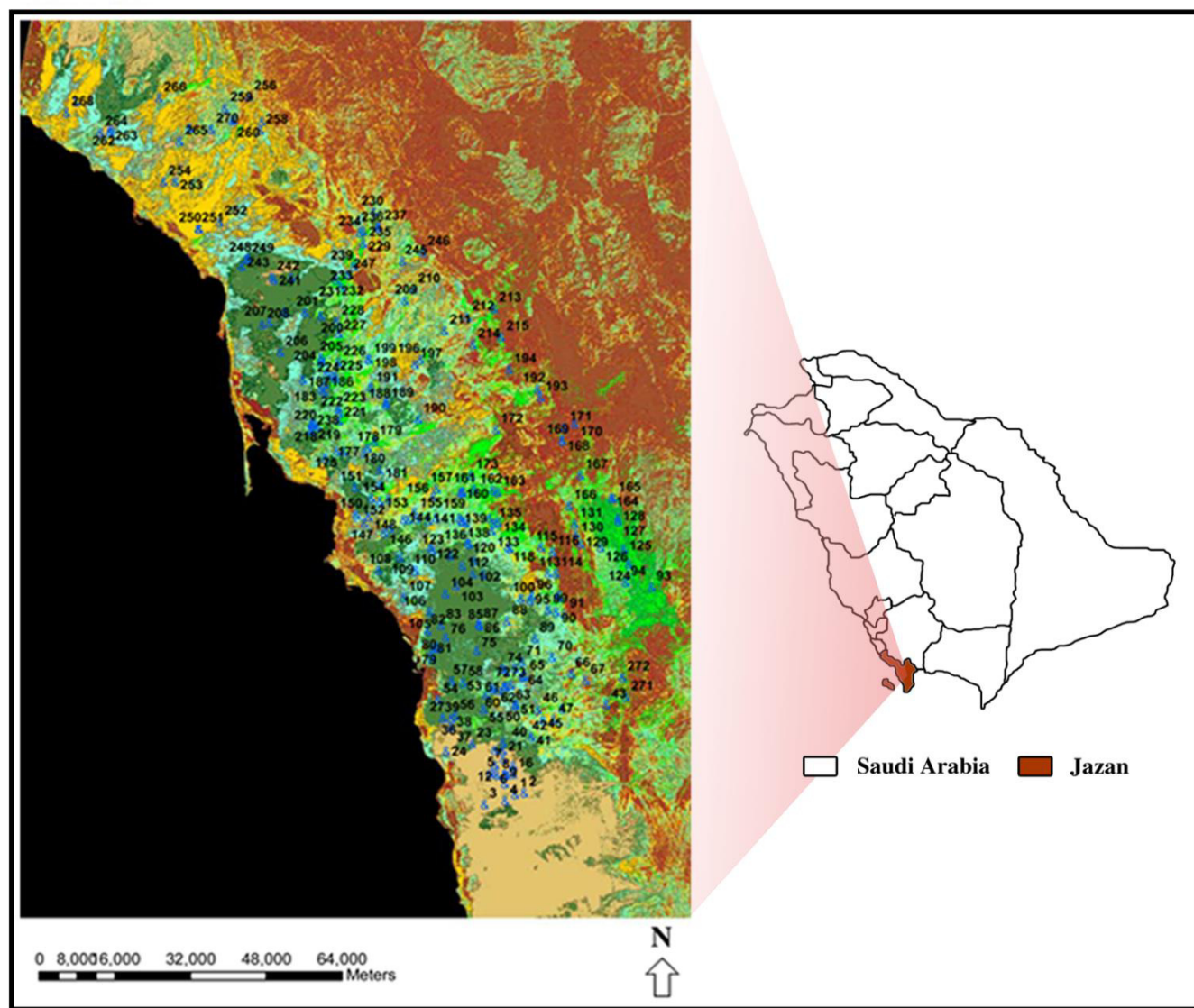


Figure 1. Map of Saudi Arabia and the study area with position of water samples, southern part of Tohama plain (Jazan Region).

Results and discussion

- **Chemical composition:**

The ranges of chemical composition parameters are presented in Table (1). The salinity of well waters ranged between 0.20 and 13.73 dSm⁻¹. On the basis of water classification according to Ayers and Westcot (1994), 6.87% of the wells have no restriction on use (<0.7 dSm⁻¹), 59.16% have slight to moderate restriction on use (0.7 – 3.0 dSm⁻¹) and 33.97% have severe restriction on use (>3.0 dSm⁻¹) with respect to irrigation water quality criteria. In general, the salinity of wells water in the study areas (Fig. 2) increased towards the west (Red sea direction). This trend may be due the direction of groundwater flow and the sea water intrusion. Table (2) shows the area and percentage of EC_{iw} class. The wells that have high salinity level can be used with high salt tolerant crops. With respect to cations, sodium (Na) was the most abundant cation (50.23%) followed by calcium (Ca) (29.46%), and magnesium (Mg) (18.33%). Concerning anions, chloride (Cl) was the most abundant anion (57.19%) followed by sulfate, SO₄ (28.56 %) then carbonate (CO₃) and bicarbonate, HCO₃ (12.84%). The NO₃ concentration ranged between 0.0 and 113.23 mgL⁻¹ in all well waters and in some locations it is higher than the recommended level for drinking (45 mgL⁻¹) as recommended by WHO (1984). These specific locations were mainly fertilized irrigated farms.

Table 1. Chemical composition of groundwater samples collected from southern Tohama plain region.

Well No.	pH	EC_w dSm ⁻¹	Soluble Cations(meqL ⁻¹)				Soluble Anions(meqL ⁻¹)				B mgL ⁻¹	NO_3 mgL ⁻¹
			Ca^{++}	Mg^{++}	Na^+	K^+	$CO_3^{=}$	HCO_3^-	CL^-	$SO_4^{=}$		
MIN	6.3	0.2	0.3	0.1	0.1	0.0	0.0	0.1	0.3	0.2	0.0	0.0
MAX	8.7	13.7	52.9	54.3	69.5	4.3	1.5	8.5	105.5	45.7	4.4	113.2
AVER.	7.6	2.8	8.2	5.1	14.0	0.2	0.1	3.6	16.0	8.0	0.9	5.0
STDEV	0.3	2.1	6.9	5.6	12.6	0.5	0.2	1.4	17.2	6.9	0.9	14.8
VAR	0.1	4.6	48.0	31.8	157.8	0.2	0.1	2.1	296.3	48.2	0.8	218.9
VC(%)	4.0	76.5	84.2	110.1	89.5	207.1	297.4	40.3	107.8	87.0	93.1	298.3

Table 2. Area and percentage of EC_{iw} classes.

EC_{iw} (dS m ⁻¹)	Area	
	(Km ²)	(% of total)
<0.25	2.66	0.03
0.25- 0.75	405.60	4.92
0.75- 1.50	1716.70	20.84
1.50- 3.00	3448.19	41.86
3.00- 5.00	1642.80	19.95
5.00-10.00	898.41	10.91
>10	122.09	1.48
Total	8236.44	100.00

Water quality indicators:

The water quality parameters were calculated and presented in Table (3). The results indicate that the ranges of water quality parameters were 0.07 – 53.35 for *SAR*, 0.09- 62.87 for *Adj. SAR*, 0.05 – 45.42 for *Adj. R_{Na}*, 1.16-96.19 % for *SSP*, -103.31- -2.68 meqL⁻¹ for *RSC* and 0.00 to 43.64% for *ESP*. All these indices expressed the effect of sodium ion in irrigation water. The ranges of *PS* and *ES* were 0.55 to 117.33 and 0.25 to 108.39 meqL⁻¹, respectively. Boron was ranged between 0.0 and 4.31 mgL⁻¹ and *NO₃* from 0.0 to 113.23 mgL⁻¹.

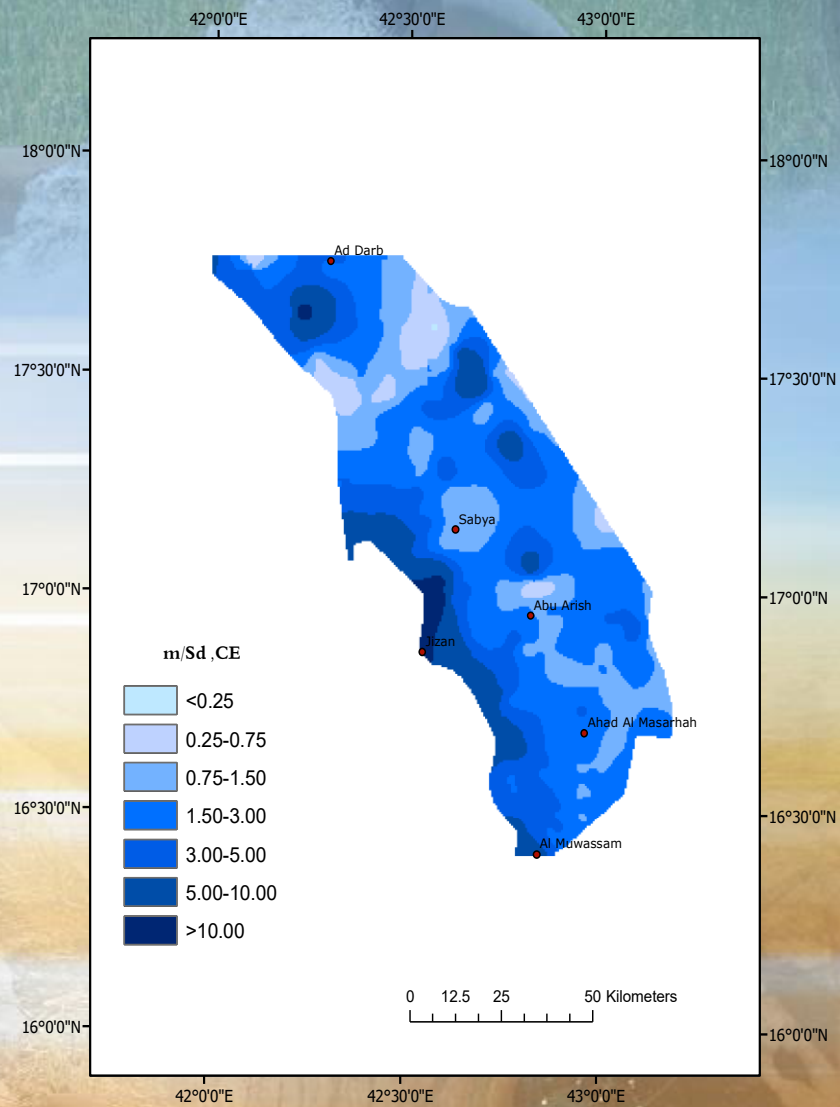


Figure 2. Map of ECi_w classes using ArcGIS 9.0

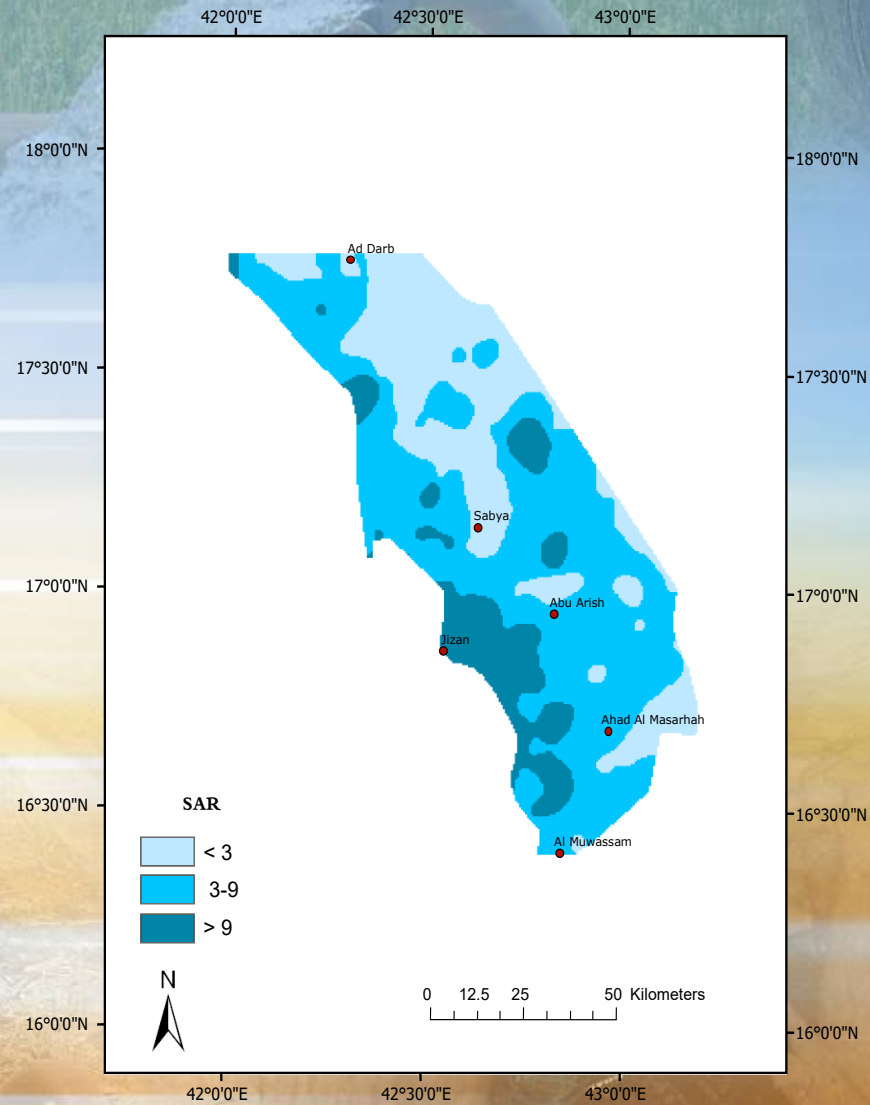
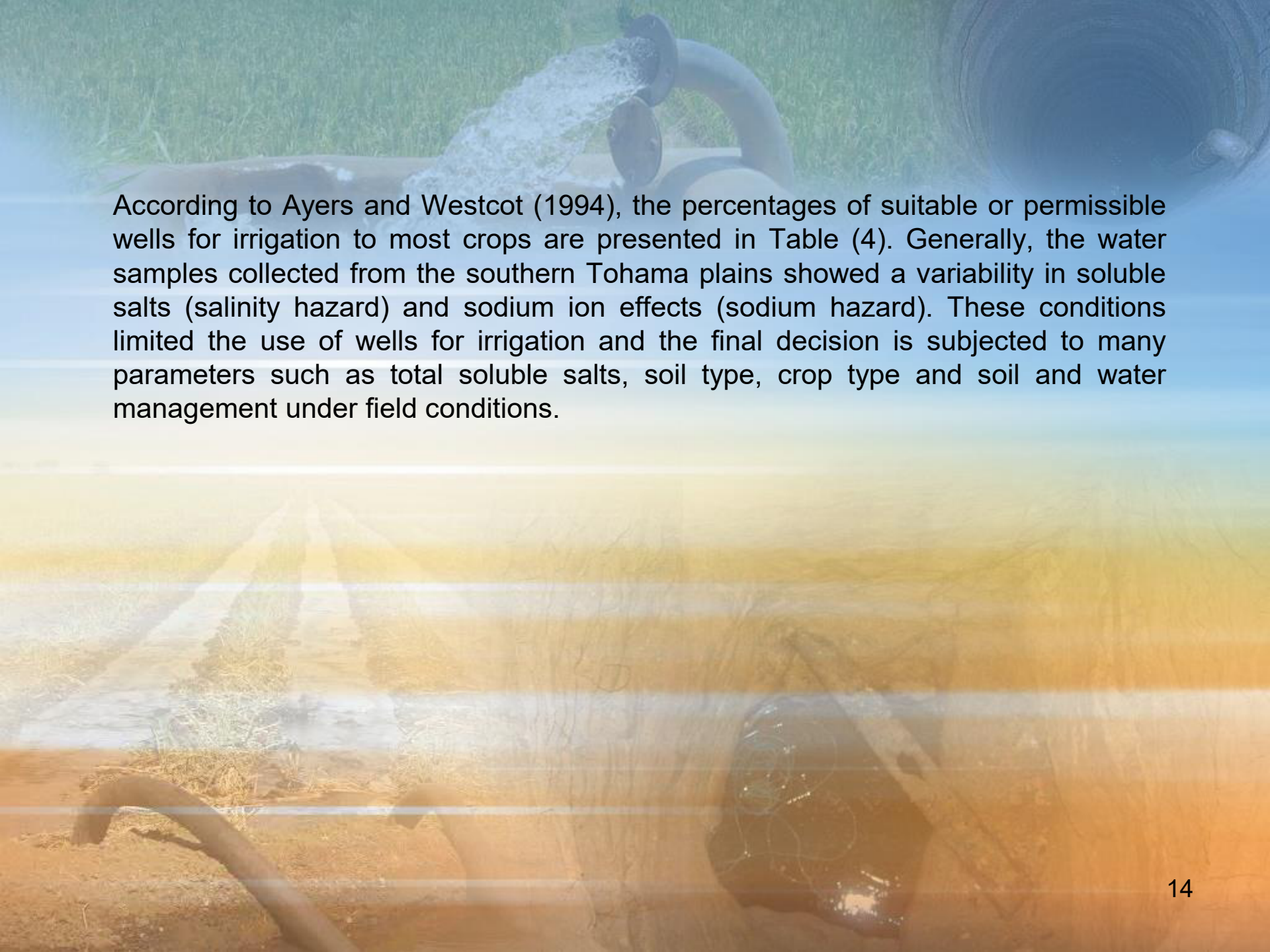


Figure 3. Map of SAR classes using ArcGIS 9.0

Table 3: Water quality indices of groundwater samples collected from southern Tohama plain region.

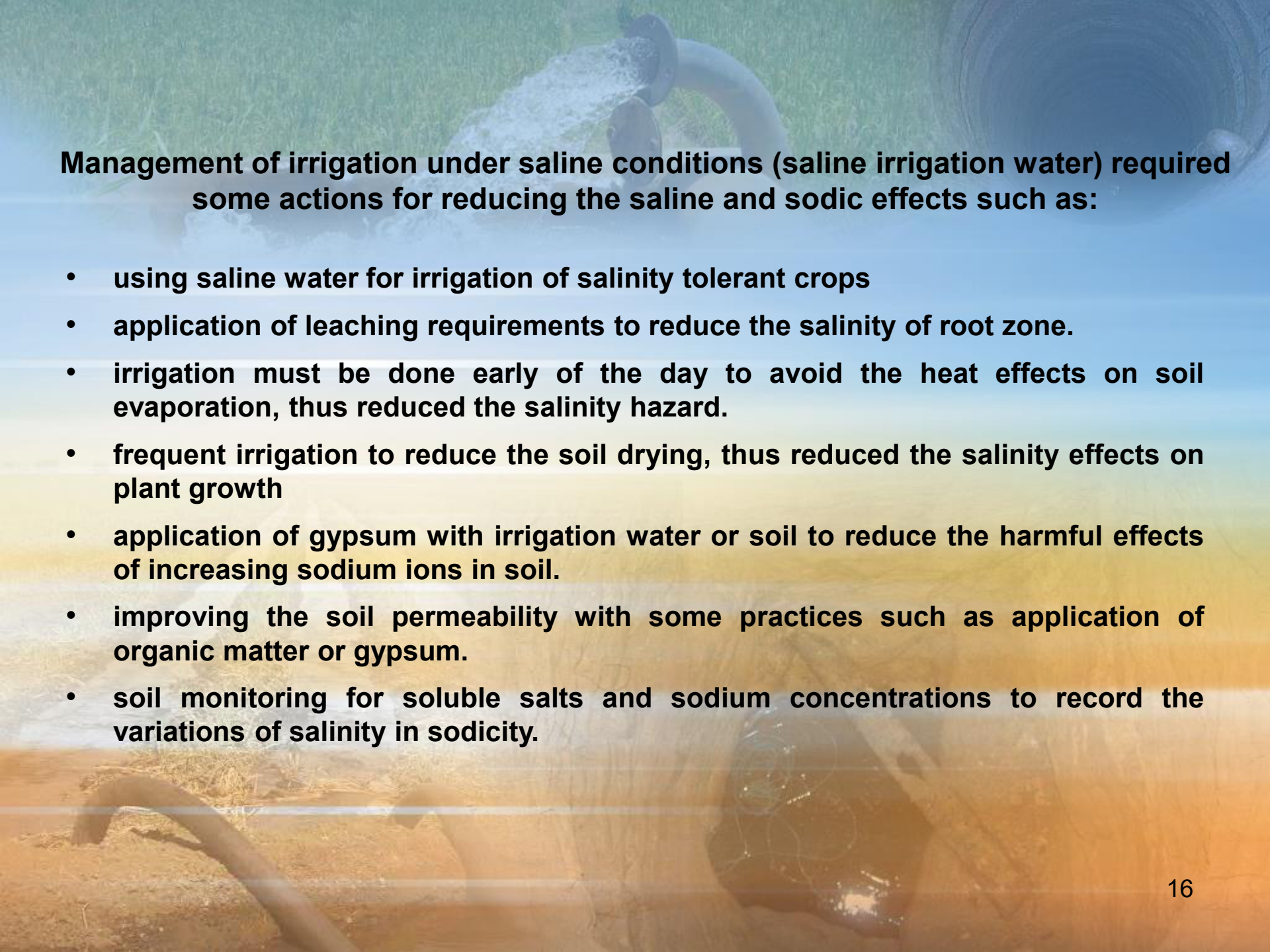
Well No.	<i>pH</i>	<i>EC_{iw}</i> dSm ⁻¹	<i>SAR</i>	<i>Adj.SAR</i>	<i>Adj.R_{Na}</i>	<i>SSP</i> %	<i>RSC</i> meqL ⁻¹	<i>ES</i> meqL ⁻¹	<i>PS</i> meqL ⁻¹	<i>ESP</i> %	<i>B</i> mgL ⁻¹	<i>NO₃</i> mgL ⁻¹
<i>MIN</i>	6.3	0.2	0.1	0.1	0.1	1.2	-103.3	0.3	0.6	0.0	0.0	0.0
<i>MAX</i>	8.7	13.7	53.4	62.9	45.4	96.2	2.7	108.4	117.3	43.6	4.3	113.2
<i>AVER.</i>	7.6	2.8	5.7	11.4	6.6	48.1	-9.7	16.3	20.0	6.3	0.9	5.0
<i>STDEV</i>	0.3	2.1	5.0	8.9	5.4	16.8	12.0	17.5	18.9	5.3	0.9	14.8
<i>VAR</i>	0.1	4.6	25.4	79.3	28.8	282.7	142.9	307.7	358.3	28.5	0.7	218.7
<i>VC(%)</i>	4.0	76.5	89.0	77.9	81.0	35.0	123.6	107.8	94.8	85.1	93.1	298.3



According to Ayers and Westcot (1994), the percentages of suitable or permissible wells for irrigation to most crops are presented in Table (4). Generally, the water samples collected from the southern Tohama plains showed a variability in soluble salts (salinity hazard) and sodium ion effects (sodium hazard). These conditions limited the use of wells for irrigation and the final decision is subjected to many parameters such as total soluble salts, soil type, crop type and soil and water management under field conditions.

Table 4: Quality of well water collected from southern Tohama plains, Saudi Arabia for irrigation of most crops according to Ayers and Westcot (1994).

Water quality indices	% of suitable or permissible wells	% of unsuitable wells	Permissible values
EC_{iw}	66.03	33.97	$<3 \text{ dSm}^{-1}$
SAR	86.26	13.74	<9
$Adj. SAR$	49.62	50.38	<9
$Adj. R_{Na}$	78.24	21.76	<9
RSC	99.62	00.36	$<2.5 \text{ meqL}^{-1}$
PS	14.89	85.11	$<5 \text{ meqL}^{-1}$
ESP	93.89	6.11	$<15 \%$
B	86.26	13.74	$<2 \text{ mgL}^{-1}$
NO_3	96.56	03.44	$<45 \text{ mgL}^{-1}$



Management of irrigation under saline conditions (saline irrigation water) required some actions for reducing the saline and sodic effects such as:

- **using saline water for irrigation of salinity tolerant crops**
- **application of leaching requirements to reduce the salinity of root zone.**
- **irrigation must be done early of the day to avoid the heat effects on soil evaporation, thus reduced the salinity hazard.**
- **frequent irrigation to reduce the soil drying, thus reduced the salinity effects on plant growth**
- **application of gypsum with irrigation water or soil to reduce the harmful effects of increasing sodium ions in soil.**
- **improving the soil permeability with some practices such as application of organic matter or gypsum.**
- **soil monitoring for soluble salts and sodium concentrations to record the variations of salinity in sodicity.**

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**Great Thanks
for your kind attention**

