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Assessment of groundwater suitability for agricultural utility in veeranam tank drainage basin, Tamilnadu, India.

T.Venkataraman[1*] . N.Manikumari[2]

[1](Department of civil Engineering, Government College of Engineering, Bodinayakkanur,)
[2](Department f civil engineering, FEAT, .Annamalai University)

Abstract ---- The suitability of groundwater quality for agricultural use was assessed in the veeranam tank drainage basin of cuddalore district, TamilNadu.(South India). In order to evaluate the quality of groundwater in the study area, a total of 24 groundwater samples were collected randomly from dug and deep bore wells both in the summer and winter season . The concentration of major ions and other geochemical parameters were analyzed.. The result showed the concentrations of these ions are above the permissible limits for irrigation purposes. The US Salinity diagram highlights that 75 % of the samples fall under high salinity hazard (C3S1) category in both seasons. It indicates that high salinity (C3) and low sodium (S1) are moderately suitable for irrigational purposes. According to Wilcox irrigation water classification 75% of total sample fall under good to permissible category and 21% under permissible to doubtful category.

Keywords: "Groundwater, Irrigation water quality, Salinity, Hydro geochemistry "

INTRODUCTION

Groundwater comprises nearly 95 percent of the worlds readily accessible freshwater and provides the rural, urban, industrial and irrigation water supply needs of 7.5 billion people around the world. Generally, the mineral concentration in the groundwater has high when compare with the surface water. Type of minerals and their concentrations were depend on the environment, movement and source of the groundwater. The type and concentration of minerals of the groundwater decides its suitability for irrigation, industrial, municipal and other uses. Generally, water quality standards have been established for every water use. These water quality standards developed by various agencies, serve as guidelines in determining the suitability of water for various uses.

Assessment of water quality is essential in planning, design and operation of irrigation systems to ensure that no deleterious salts or compounds occur in the irrigation water (Sangodoyin and Ogedengbe, 1991). The suitability of water for agricultural purpose should be assessed on the basis of criteria indicative of their potentials to create soil conditions hazardous to crop growth or crop use. The extent to which chemical quality limits the suitability of water for irrigation depends on the nature, composition and drainage of the soil and subsoil, the amounts of water used and methods of application, the kinds of crops grown and the climate of the region, including the amounts and distribution of rainfall. Arumugam and Elangovan (2009) have studied groundwater quality based on Piper diagram and Sodium Percentage values for drinking and irrigation purposes in Tirupur region in India

Generally, the suitability of water for agricultural purpose is determined by its mineral constituents and type of the plant and soil to be irrigated. In order to find the suitability of groundwater for agricultural purpose, some chemical characteristics should be highlighted. Some of the characteristics of irrigation water that are to be most important in determining its quality are TDS (Total dissolved salts), EC, Relative proportion of sodium to other elements such as calcium and magnesium, Bicarbonate concentration as relative to calcium and magnesium.

STUDY AREA

The study area of Veeranam tank and its drainage basin is situated in between the Latitude of 11° 15'E and 11° 25'E and the Longitude of 79° 30'N and 79° 38'N. The tank is irrigating an extent of 44856 acres of wet lands in this basin. The Drinking water need of Chennai City is also supplemented from this veeranam tank. The climate in this area is sub tropical and the maximum temperature varies from 30 to 38 C. Average rainfall in the study area is 1025 mm. It is a rural area having small villages. The main occupation of the people of this area is agriculture. They cultivate mainly rice, black gram and green gram.

MATERIALS AND METHODS

A total of 24 ground water samples were collected from dug and deep bore wells randomly so as to represent the entire irrigation command area. Ground water samples, both in summer and winter seasons were collected in a cleaned and washed one-liter PVC bottles after rinsing the bottles several times with water to be sampled. The samples were analyzed for various chemical parameters by standard procedures as described by American Public Health Association (ALPHA 1995)

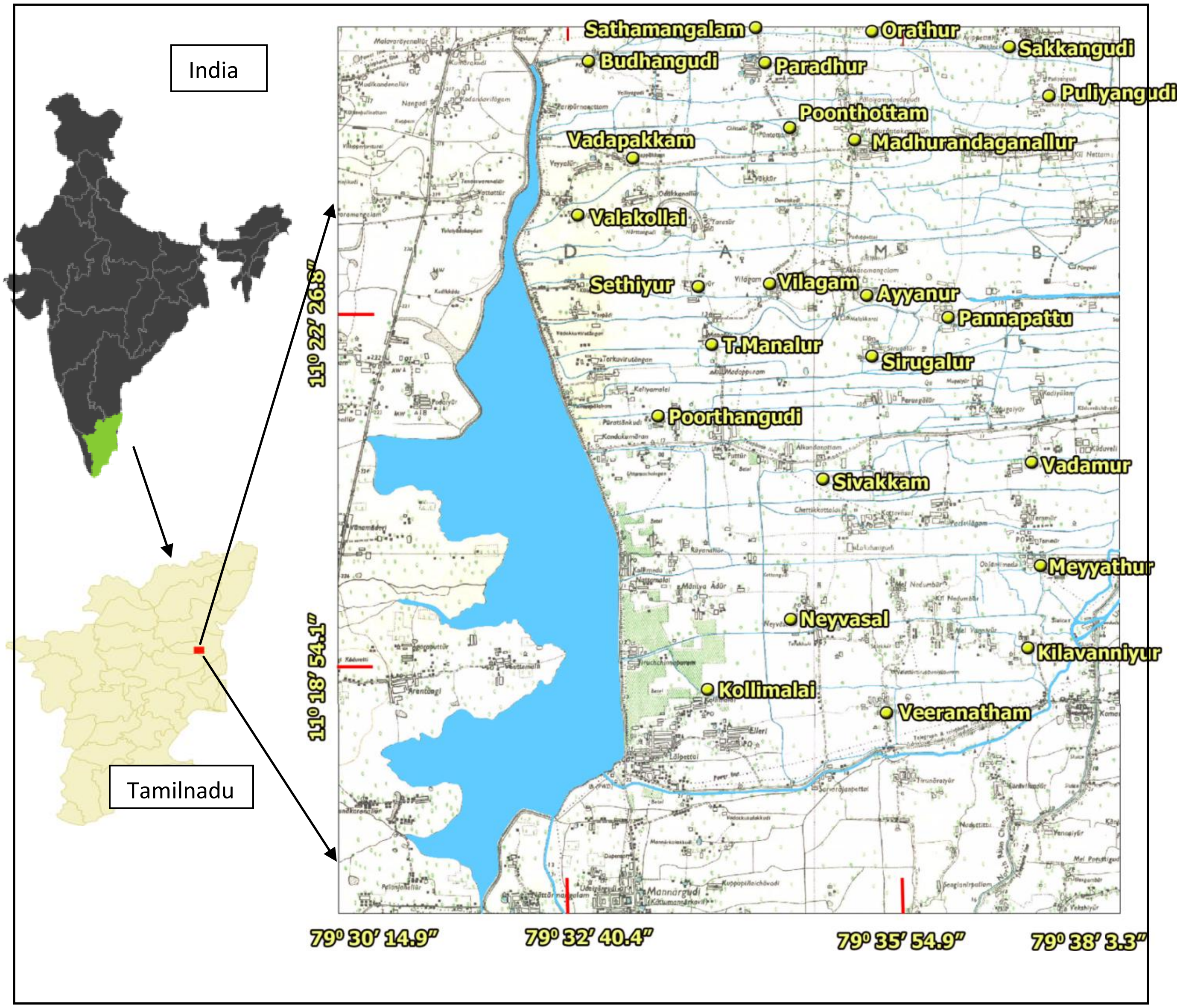


Figure 1 Study area with locations of sampling villages

These parameters include pH, EC (electrical conductivity),TDS (total dissolved solids), and important cations such as Ca^{2+}(calcium), Mg^{2+}(magnesium), Na(sodium) and K(potassium) as well as anions such as, bicarbonates, chlorides, nitrates and sulfates.

The pH and electrical conductivity (EC) were measured in the field by means of a pH meter and digital conductivity meters, respectively. Sodium and potassium were determined by flame photometer. Ca^{2+} (Calcium), Mg^{2+} (magnesium), HCO_3^-(bicarbonate) and Cl^- (chloride) were analyzed by volumetric methods. SO_4^{2-}(Sulfates) were estimated by using the calorimetric technique. The quality parameters like salinity (EC) toxicity due to chloride and sodium absorption ratio (SAR), were determined to assess the irrigation suitability of the groundwater. The analytical data obtained were processed for detailed geochemical and statistical analysis.

The SAR value and Percent sodium (Na%) were determined to evaluate the suitability of the ground water quality for agricultural purposes . A semi- log plot is prepared with the values of EC in X axis and SAR value in Y axis in accordance with the US Salinity Laboratory scheme. Wilcox diagrams were also plotted to determine the suitability of the groundwater for agricultural purpose in the study area.

RESULTS AND DISCUSSION

The descriptive statistics of the physicochemical characteristics of the analytical data are presented in the Table-1.

Parameters	**Summer**				**Winter**			
	Maximu	**Minimu**	**Mean**	**S.D.**	**Maximu**	**Minimu**	**Mean**	**S.D .**
p^H	8.2	6.3	7.51	0.41	7.7	6.9	7.28	0.21
E C	3300	700	1787.82	894.49	3622	762	1667.32	842.32
Mg	132	30	63.09	23.79	148	27	60.77	28.52
Ca	190	18	60.91	43,03	198	17	64.86	47.07
K	41	2	14.09	12.44	36	2	15.50	11.45
Na	436	92	166.45	135.23	642	86	180.41	147.72
$SO4_2$	150	3	42.36	50.43	142	6	41.59	40.32
Cl^-	824	92	404.36	248.01	836	146	400.77	270.47
HCO_3	824	168	455.82	198.81	902	196	469.77	214.06
TDS	2112	448	1143.60	572.43	2318	532	1067.18	539.06

Table 1 Statistical parameters of analytical data

Electrical conductivity (EC) indicates the presence of ions and concentrations of dissolved components and has a direct connection with salinity and TDS which are used for classification of . groundwater The EC values ranges from 700 to 3300 micro mhos/cm in summer and 762 to 3622 micro mhos/cm in winter. Groundwater was reclassified using a TDS (after Todd 1980) into very fresh (0–250 mg/l), fresh (250–1,000 mg/l), brackish (1,000–10,000 mg/l) and saline (10,000–100,000 mg/l). Based on the classification, therefore, only about 21% of groundwater samples qualify as fresh, while over 79 % comes under brackish water category. (Freeze and Cherry, 1979).

The concentration of bicarbonate varies from 168 to 824 mg/l with a mean of 456 mg/l in summer and in winter it varies from 196 to 902 mg/l. Bicarbonate is responsible for the alkalinity of groundwater. The chloride concentration in the study area was recorded from 92 to 824 mg/l in summer and 146 to 836 mg/l. The various causes for the increasing chloride content in the groundwater are weathering and dissolution of salt deposits, seawater intrusion and irrigation return flow (Jeevanandam et al. 2012).The amount of calcium and magnesium ranges from 18 to 190 mg/l & 30 to 132 mg/l, in summer and 17 to 198 mg/l &27 to 148 mg/l in winter respectively. The calcium and magnesium ions present in the groundwater are possibly derived from leaching of calcium and magnesium-bearing rock-forming silicates, limestone, dolomite, gypsum and anhydrides. The concentration of sodium and potassium varies from 92 to 585 mg/l and from 2 to 41 mg/l, respectively in summer.

In winter sodium varies from 86 to 642 mg/l and potassium varies from 2 to 36 mg/l. According to USDA classification, the salinity hazard in irrigation water can be expressed in terms of EC (electrical conductivity). Classification of groundwater according to salinity hazard is presented in table 2.

Salinity class	EC(micro mhos/cm)	Remarks	Percentage of samples	
			Summer	winter
C1 - Low	100 to 250	Can be used safely	0%	0%
C2 - Medium	250 to 750	Can be used with moderate leaching	0%	0%
C3 - High	750 to 2250	Cannot be used for irrigation But salt tolerant plant can be grown	71%	71%
C4 – Very High	2250 to 5000	Not suitable for irrigation	29%	29%

Table 2: Salinity hazard classes

SODIUM ABSORPTION RATIO

Sodium hazard is usually expressed in terms of SAR or the sodium adsorption ratio. SAR is calculated from the ratio of sodium to calcium and magnesium. The latter two ions are important since they tend to counter the effects of sodium. Soil permeability can be reduced by of high sodium concentration. (Todd 2007). SAR is calculated by the given formula,

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

Where the concentrations of sodium, calcium and magnesium ions are expressed in milligram equivalents per litre (meq/l).. The sodium adsorption ratio relates the concentration of sodium to the concentration of Calcium and Magnesium. .According to SAR value the entire study area falls in low Sodium water class (Table 3.).

Sodium Hazard class	SAR Value	Remark on quality	Percentage of samples	
			Summer	winter
S1	0 - 10	Low	100%	96%
S2	10 - 18	Medium	0%	4%
S3	18 - 26	High	0%	0%
S4	>26	Very High	0%	0%

Table 3 USSL classification of Sodium hazard based on SAR.

SODIUM PERCENTAGE

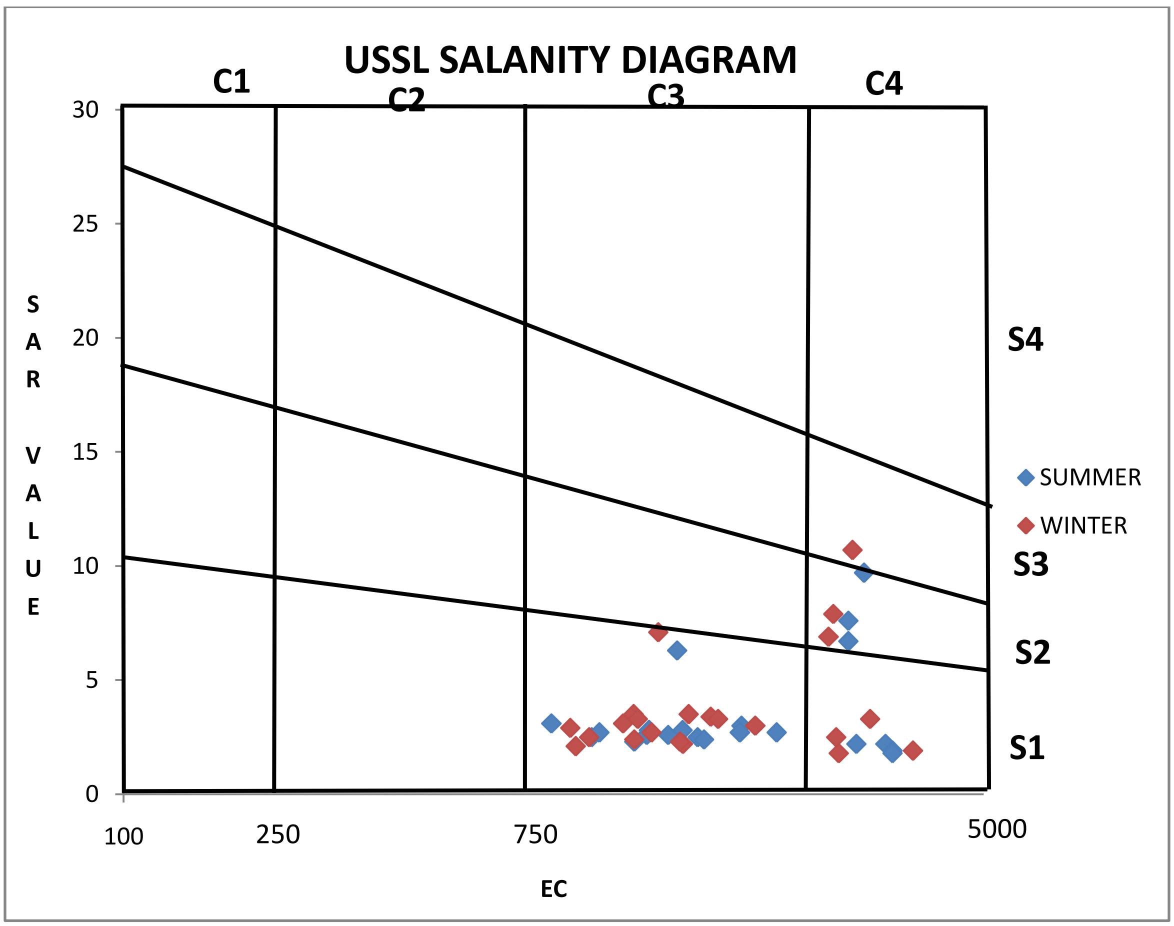
Soluble sodium per cent (SSP) is also used to evaluate sodium hazard. SSP is defined as the ration of sodium in epm (equivalents per million) to the total cation epm multiplied by 100. A water with a SSP greater than 60 per cent may result in sodium accumulations that will cause a breakdown in the soil's physical properties. Sodium reacts with soil and reduces its permeability. Sodium is usually expressed in terms of percent sodium or soluble-sodium percentage (Na %). Percentage of Na+ is widely used for assessing the suit- ability of water for irrigation purposes. Soluble Sodium Percentage (SSP) is determined by the following equation . (Todd and Mays 2005).

The Na% is computed with respect to relative proportion of cat ions present in water as

$$Na\% = \left(\frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \right) \times 100\%$$

Here all the concentrations are expressed in meq/l.

Here the value of sodium percent is in the range of 24% to 65%. If the sodium ion concentration is rich in irrigation water, then the sodium ions were absorbed by the clay particles and the magnesium and calcium ions were displaced. This ex- change process of sodium ion in water for Calcium and magnesium ions in soil reduces the permeability and eventually results in soil with poor internal drainage.



Sodium Hazards	
S1 – Low	S2—Medium
S3—High	S4 —VeryHigh

Salinity Hazards	
C1—Low	C2—Medium
C3— High	C4—Very High

Figure 2 U.S. salinity diagram for classification of irrigation water .

USSL PLOT

The United States Salinity Laboratory (USSL) has constructed a diagram for the classification of irrigation waters (Wilcox1955) describing 16 classes with reference to SAR as index for sodium hazard and EC as an index for salinity hazard. Based on the United States Salinity Laboratory (USSL) results of C3-S1 class is good and could be used for all types of crops The US Salinity diagram highlights that 75 % of the samples fall under the field of C3S1, which indicates water having high salinity and low sodium alkali hazard (Figure.2). Thirteen percent of the samples fall under the C4S1 and 8 % of samples in ,C4S2 category, indicating high to very high salinity hazard, while the remaining fall under the C4S3 regions indicating very high saline and high sodium hazards.

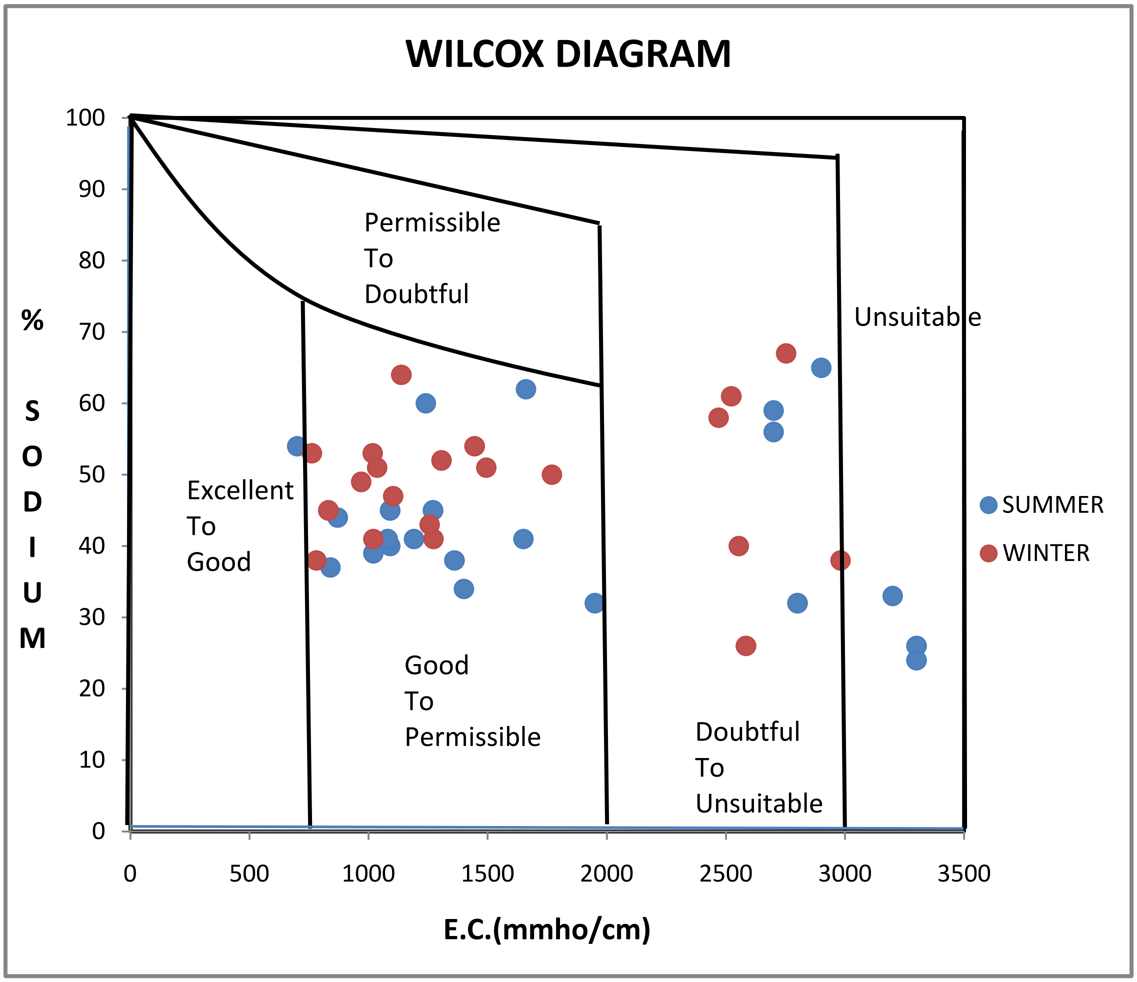


Figure 3 Wilcox diagram for the classification of irrigation water.

WILCOX DIAGRAM

Wilcox (1955) classification of irrigation water is based on the correlation between EC and sodium percent. From this Wilcox classification of irrigation water, 75 % of the total samples fall under good to permissible limit and 21% fall under doubtful to unsuitable limit. And the remaining 4 % samples fall under unsuitable limit (Figure.3) which concludes the groundwater is not suitable for irrigation purpose. In these areas we recommend to use only canal water for irrigation.

CONCLUSION

The USSL, SAR–EC classification schemes confirm that the majority of groundwater samples are high salinity and low sodium and Wilcox diagram shows the groundwater is good to permissible for agricultural purpose. Samples at villages Sirugalur, Ayyanur akkaramangalam and Keelavaniur were high in EC sodium concentrations and are not suitable for irrigational use. The study concludes that to use only canal water for irrigation in these locations and also the quality of the groundwater is moderately suitable for irrigation. If the water is continuously used for irrigation, the salinity and alkalinity of soil will be increased.

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