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Groundwater Suitability for Irrigation in Pulicat Using GIS

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ABSTRACT

In India, 75 % of population depend on agriculture for their earnings and survival. Rainfall in India is erratic, which received from the month of June to September. Irrigated Agriculture does not depend only on surface water available. It can be sustained by combined usage of surface water and groundwater available. In order to ascertain the quality of groundwater in Pulicat region for irrigation, the various physic-chemical parameters like pH, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, carbonate, and bicarbonate were selected and the selected irrigation indices are sodium adsorption ratio, soluble sodium percentage, residual sodium bicarbonate, magnesium adsorption ratio, and Kelly's ratio. The obtained results were depicted using GIS tool to suggest the better place for farming. The results of irrigation indices have proved that the water is unfit for cultivation, but, some salt tolerant crops may be grown in a selected study area.

Keywords: Ground water, Irrigation water quality indices, Physico-chemical parameters.

1. INTRODUCTION

Watering is essential for cultivating of all types of crops. If rainfall is not adequate, then agriculture depends on only rainfall. Rainfall in India is also erratic and people receive this rainfall only between the month of June and September. This rainfall is not sufficient to grow all types of crops. The rainfall also varies from season to season. Thus, it needs to regulate the watering for crops through irrigation.

This study aimed to focus on fitness of groundwater in Pulicat Lake for irrigation purpose. Pulicat Lake is the second largest brackish water lake in India. It situated in the border of Andhra Pradesh and Tamil Nadu. Pulicat Lake is about 60 km North of Chennai and extending between the Andhra Pradesh and Tamil Nadu is a natural coastal wetland of about 30,000 to 46,000 ha. The Lake covered the ranges between 13.33° to 13.66° N and 80.23° to 80.25°E, with a dried part of the Lake extending up to 14.0°N.

For this study, physico-chemical parameters like pH, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, carbonate, and bicarbonate and irrigation indices like sodium adsorption ratio, soluble sodium percentage, residual sodium bicarbonate, magnesium adsorption ratio, and Kelly's ratio were selected. Further, groundwater quality of Pulicat Lake was compared with irrigation standards.

2. MATERIALS AND METHODS

The entire Pulicat is divided into 3 zones and in total of Twenty Eight samples (well and bore points) were collected randomly in the area and their corresponding latitudes and longitudes were noted using gram in hand held GPS. The groundwater samples were collected using plastic bottles without the presence of air bubbles. The sampling locations were randomly selected throughout the study area. Physico-chemical parameters, anions and cations for these samples were determined as per APHA, 2005. The values of these physico-chemical parameters are used to determine the irrigation water quality indices such as sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium bicarbonate (RSBC), permeability index (PI), magnesium adsorption ratio (MAR) and kelly's ratio (KR).

Table.1.Details about water sample in area

Sample No	Position		Place	Type Of Sample
	LAT	LON		
1	N 13°25.31′	E 80°19.47′	AREA 1 (LEFT TO THE BRIDGE)	BORE
2	N 13°25.39′	E 80°19.49′		
3	N 13°25.41′	E 80°19.54′		
4	N 13°25.36′	E 80°19.53′		
5	N 13°25.31′	E 80°19.56′		
6	N 13°25.34′	E 80°19.60′		
7	N 13°25.37′	E 80°19.68′		
8	N 13°25.39′	E 80°19.65′		
9	N 13°25.44′	E 80°19.61′		

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Table.2.Details about water sample in area 2

Sample No	Position		Place	Type Of Sample
	LAT	LON		
1	N 13°25.22′	E 80°19.54′	AREA 2 (RIGHT TO THE BRIDGE)	BORE
2	N 13°25.16′	E 80°19.58′		
3	N 13°24.93′	E 80°19.53′		
4	N 13°24.97′	E 80°19.63′		
5	N 13°24.90′	E 80°19.67′		
6	N 13°25′	E 80°19.62′		
7	N 13°25.01′	E 80°19.57′		
8	N 13°25.03′	E 80°19.54′		
9	N 13°25.03′	E 80°19.60′		
10	N 13°25.11′	E 80°19.59′		

Table.3.Details about water sample in area 3

Sample No	Position		Place	Type Of Sample
	LAT	LON		
1	N 13°24.43′	E 80°19.13′	AREA3 (SATTANKUPPAM)	OPEN WELL
2	N 13°24.40′	E 80°19.17′		OPEN WELL
3	N 13°24.42′	E 80°19.21′		BORE
4	N 13°24.45′	E 80°19.25′		BORE
5	N 13°24.50′	E 80°19.24′		BORE
6	N 13°24.51′	E 80°19.24′		BORE
7	N 13°24.51′	E 80°19.26′		OPEN WELL
8	N 13°24.50′	E 80°19.20′		BORE
9	N 13°24.55′	E 80°19.18′		BORE

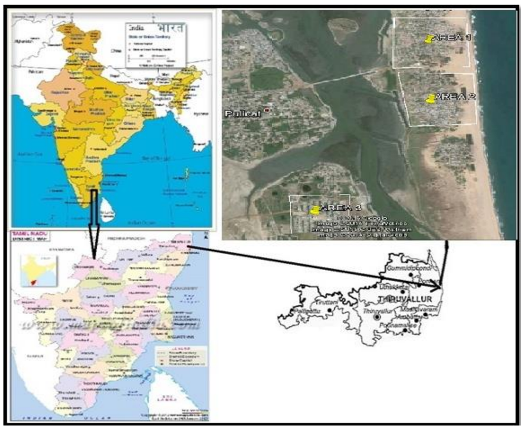

Figure.1.Study Area

Sodium Adsorption Ratio: The sodium adsorption ratio gives the data on how much soil holds sodium. It is the proportion of presence of sodium, calcium and magnesium, which in turn affects the availability of the water to the crop. The Sodium Adsorption Ratio (SAR) can be determined using Richards (1954) equation as:

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}$$

where all the ions are expressed in meq/L.

Soluble Sodium Percentage (SSP): Sodium percent is an important factor for studying sodium hazard. It is also used for judging the quality of groundwater for agricultural purposes. High percentage sodium water affects the growth of plants and reduces soil permeability (Joshi et al., 2009). The SSP can be obtained (Todd, 1995) as

$$SSP = \frac{(Na+K)\times 100}{Ca+Mg+Na+K}$$

where, all the ions are expressed in meq/L.

Residual Sodium Carbonate (RSC): The concentration of bicarbonate and carbonate influences the relevance of water for agriculture purpose. High RSBC reflects the high pH in water. Therefore, irrigated land become infertile because of deposition of sodium carbonate (Eaton, 1950). The Residual Sodium Bicarbonate (RSBC) can be obtained (Gupta and Gupta, 1987) as

$RSBC = HCO_3 \times Ca$

where, RSBC and the concentration of the constituents are expressed in meq/L.

Magnesium Adsorption Ratio (MAR): Magnesium content of water is also determining the quality of groundwater for agricultural purposes. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More magnesium leads to saline condition, as a result, crop yields is affected (Joshi, 2009)

The Magnesium Adsorption Ratio (MAR) can be obtained (Raghunath, 1987) as

$$MAR=\frac{Mg\times 100}{Ca+Mg}$$

where, all the ionic constituents are expressed in meq/L.

Kelly's Ratio (KR): The Kelly's Ratio can be calculated (Kelly, 1963) as

$$KR=\frac{Na}{Ca+Mg}$$

where, all the ionic constituents are expressed in meq/L.

Total Dissolved Solids (TDS): Salts of calcium, magnesium, sodium and potassium present in the irrigation water may affect the plant growth. The TDS was calculated (Richards 1954) as

$$TDS = 0.64 \times EC \times 10^6$$

where, Electrical Conductivity (EC) and TDS are expressed in μ-mhos/cm and mg/L, respectively.

3. RESULTS AND DISCUSSIONS

Geochemical properties and principles that govern the behaviour of dissolved chemical constituents in groundwater are referred to as hydro geochemistry. The dissolved constituent exists as ions, molecules or solid particles, these constituent not only undergo chemical and physical reactions but also redistribution takes place among the various ionic species this can also take place between the liquid and solid phases.

The physico-chemical characteristics of groundwater is directly related to the solid product of rock weathering and changes with respect to time and space surrounding it. Therefore, concentration levels variation of the different physico-chemical constituent's dissolved in water determines its utility for domestic, industrial and agricultural purposes.

For this study, physico-chemical parameters results were interrelated with those of the various irrigation indices. The Table 2 shows the experimental results of physico chemical properties and various irrigation water quality indices.

Table.4.The Experimental Results of Physico-Chemical Properties and the Values of Various Irrigation Water Quality Indices

Parameters/Area	Area 1(10 Samples)	Area 2(10 Samples)	Area 3(9 Samples)
pH	7.16	7.42	7.69
EC µs/cm	984.44	2312	1940
Ca mg/l	46.84	79.65	48.312
Mg mg/l	25.94	53.02	52.44
Na mg/l	98.35	303.14	246.08
K mg/l	8.42	20.41	7.84
TDS mg/l	518.67	1303.5	1051.5
RSC	0.11	0.72	1.71
SAR	2.68	3.9	6.7
SSP	49.40	62	62.17
MAR	45.51	52.61	66.97
KR	0.93	1.57	1.62
PI	2.82	1.62	1.87

Electrical Conductivity: The electrical conductivity of the collected groundwater samples ranges between 985 and 2312 (Table 2), only very few groundwater samples comes under good and excellent classes and most of the groundwater samples have salinity hazard leading to its unsuitability for irrigation purpose.

Table.5.The Standard Values for EC

Salinity Hazard Class	EC, (µs/cm)	Remark on quality
C1	100-250	Excellent
C2	250-750	Good
C3	750-2250	poor
C4	>2250	Unsuitable

Sodium Adsorption Ratio (SAR): The SAR value can be used to determine the sodium hazards. The SAR values of all the samples are below 10 (Table 2), which show that the groundwater quality of all samples of the study area with respect to SAR is excellent (Table 4).

Table.4.The Standard Values for SAR

Sodium hazard class	SAR	Remark on quality
S1	<10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4	>26	Unsuitable

Soluble Sodium Percentage (SSP): The SSP values of shallow groundwater samples ranges between 49 and 62.17 (Table 2) indicating very high alkali hazards. Thus the water has to treat before being used for the purpose of irrigation otherwise there is a serious possibility of crop failure which may lead to huge economic loss for the farmers.

Residual Sodium Bicarbonate (RSC): The RSC values of groundwater samples varied from 0.11 to 1.71 meq/L. The RSC values are less than 3.0 meq/L and are therefore considered as safe, for irrigation purposes. The RSC of groundwater from Pulicat ranges from 9.6 in area 1 to 19.02 in area 2 while area 3 has a RSC value of 16.95 meq/l. Since, the values are greater than 3 meq/l the water has to treat before being used for irrigation.

Magnesium Adsorption Ratio (MAR): The values of the MAR of shallow groundwater in present study varied from 46 to 67 (Table 2) indicating that they are above the acceptable limit of 50% (Ayers and Westcot, 1985). The most of the water samples are prone to magnesium hazard.

Total Dissolved Solids (TDS): The excessive quantities of TDS reduce the osmotic activities of the plants and may prevent adequate aeration. The TDS value of the study area ranges from 519 to 1304 mg/L (Table 2) and can be classified as unsuitable as irrigation water according to Robinove et al. (1958), since the value of TDS is higher than 450 mg/L.

Kelly's Ratio (KR): The Kelly's Ratio (KR) values of the study area ranged between 0.93 and 1.62. The results indicated that most of the KR for the shallow groundwater samples does not fall within the permissible limit of 1.0 and are considered unsuitable for irrigation purposes.

Spatial distribution of parameters using GIS:

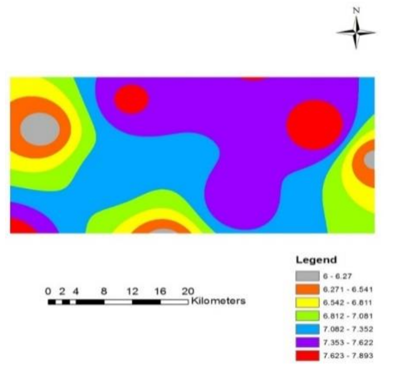

Figure.2.pH distribution in study area 1

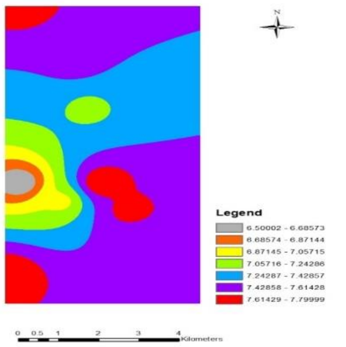

Figure.3.pH distribution in study area 2

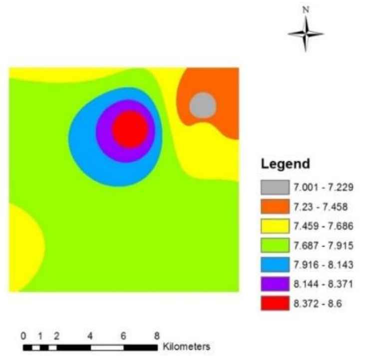

Figure.4.pH distribution in study area 3

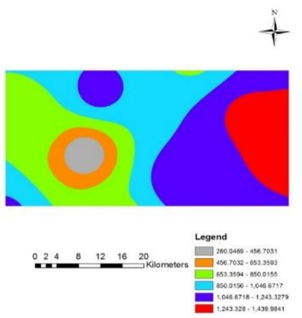

Figure.5. Electrical conductivity distribution in study area 1

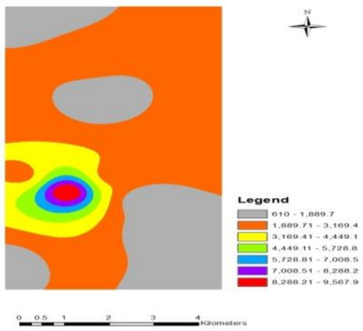

Figure.6. Electrical conductivity distribution in study area 2

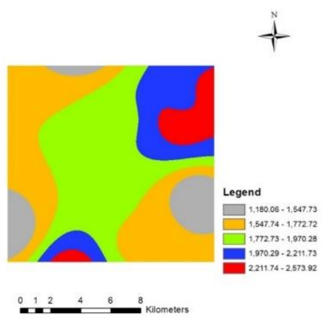

Figure.7. Electrical conductivity distribution in study area 3

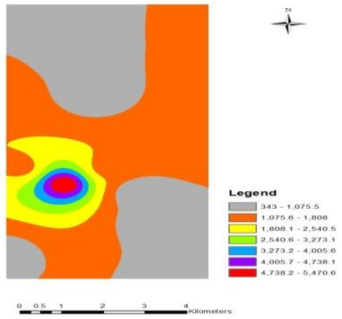

Figure.8.Total dissolved solids distribution in study area 1

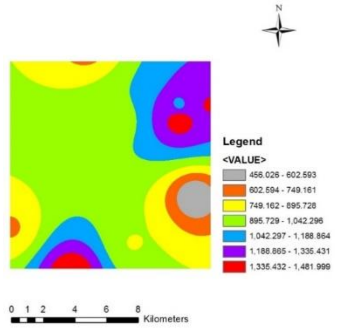

Figure.9.Total dissolved solids distribution in study area 2

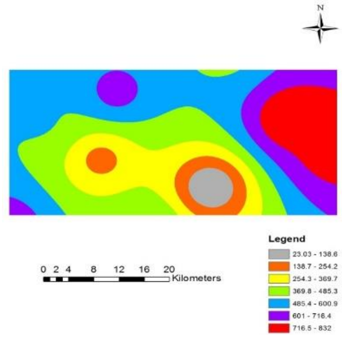

Figure.10.Total dissolved solids distribution in study area 3

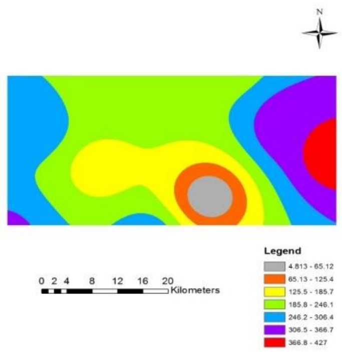

Figure.11. Bicarbonate distribution in study area 1

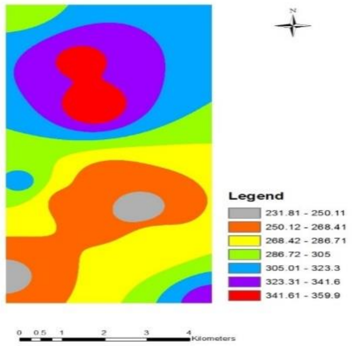

Figure.12. Bicarbonate distribution in study area 2

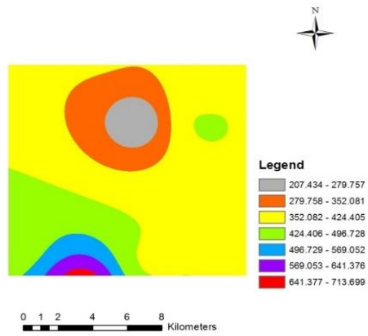

Figure.13. Bicarbonate distribution in study area 3

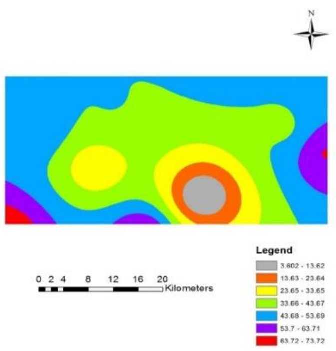

Figure.14. Calcium distribution in study area 1

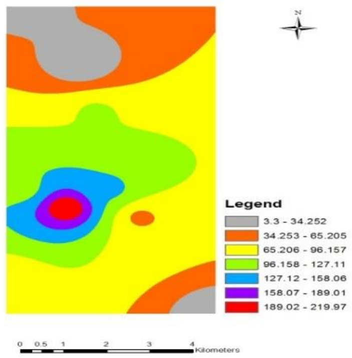

Figure.15. Calcium distribution in study area 2

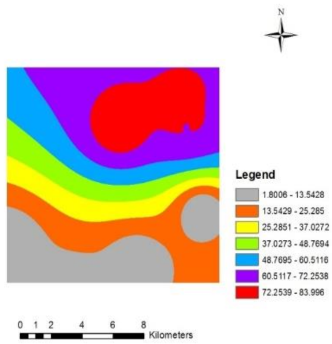

Figure.16. Calcium distribution in study area 3

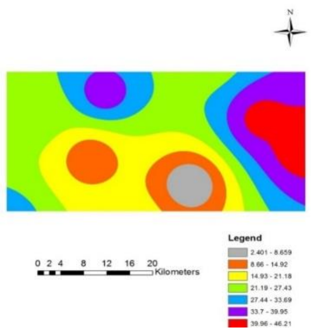

Figure.17.Magnesium distribution in study area 1

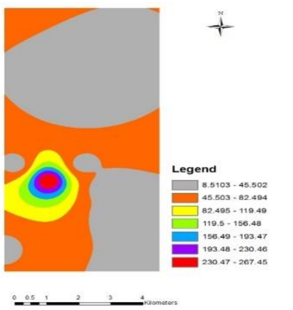

Figure.18.Magnesium distribution in study area 2

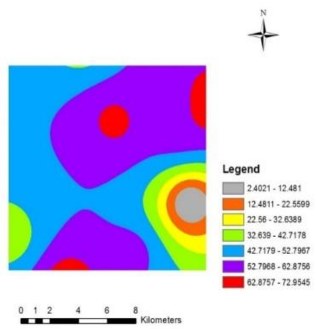

Figure.18.Magnesium distribution in study area 3

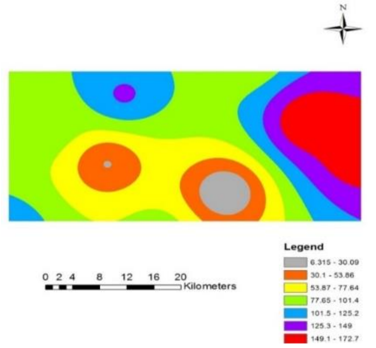

Figure.19.Sodium distribution in study area 1

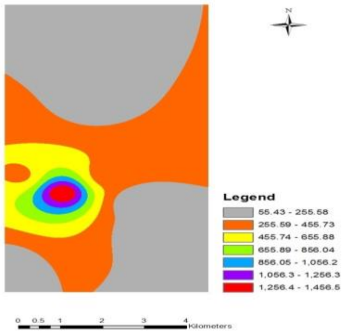

Figure.20.Sodium distribution in study area 2

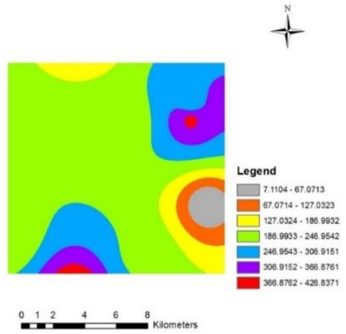

Figure.21.Sodium distribution in study area 3

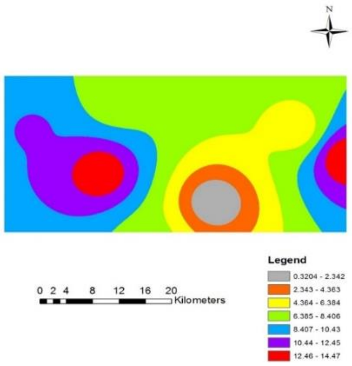

Figure.22.Potassium distribution in study area 1

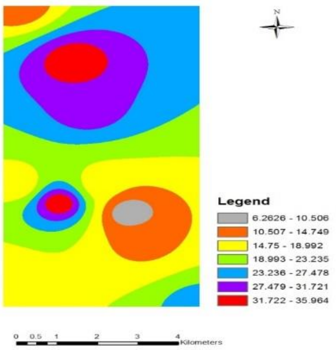

Figure.23.Potassium distribution in study area 2

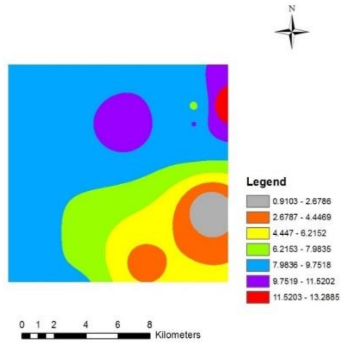

Figure.24.Potassium distribution in study area 3

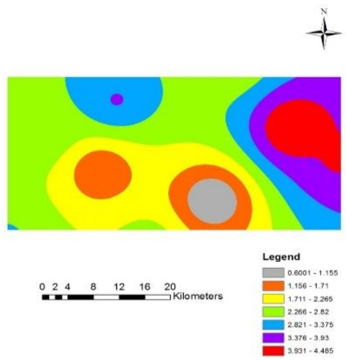

Figure.25.Sodium Adsorption Ratio (SAR) distribution in study area 1

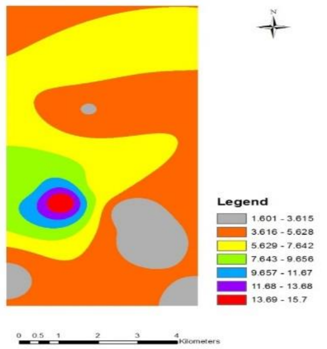

Figure.26.Sodium Adsorption Ratio (SAR) distribution in study area 2

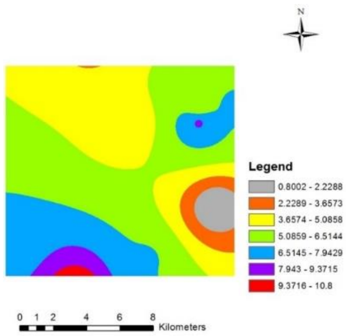

Figure.27.Sodium Adsorption Ratio (SAR) distribution in study area 3

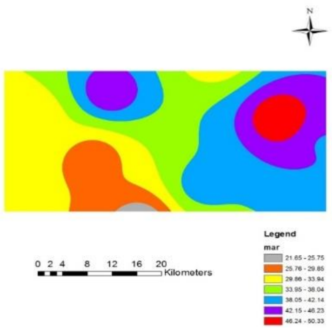

Figure.28.Magnesium Adsorption Ratio (MAR) distribution in study area 1

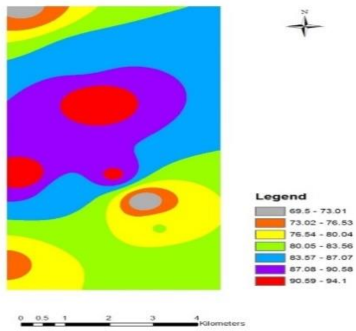

Figure.29.Magnesium Adsorption Ratio (MAR) distribution in study area 2

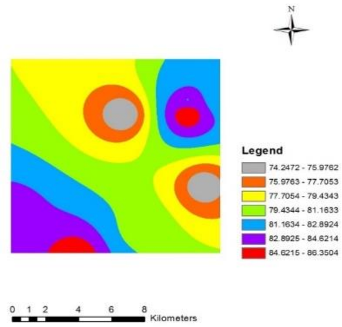

Figure.30.Magnesium Adsorption Ratio (MAR) distribution in study area 3

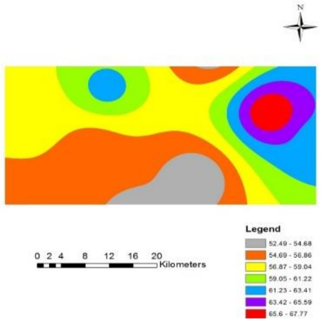

Figure.31.Soluble Sodium Percentage (SSP) distribution in study area 1

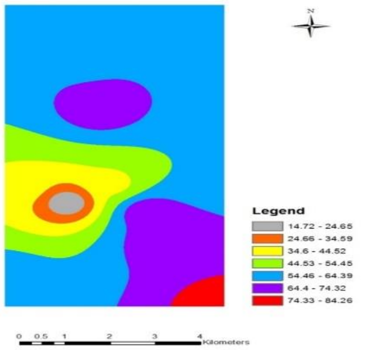

Figure.32.Soluble Sodium Percentage (SSP) distribution in study area 2

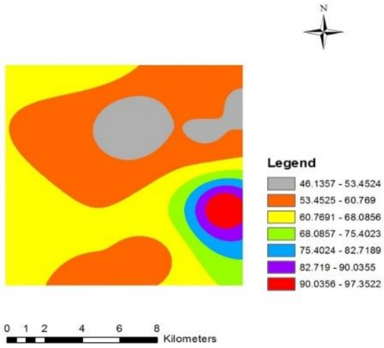

Figure.33.Soluble Sodium Percentage (SSP) distribution in study area 3

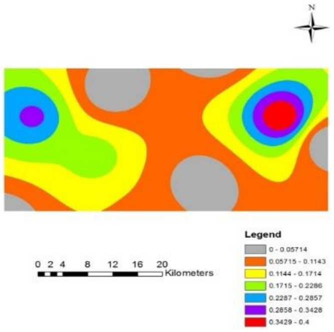

Figure.34.Residual Sodium Bicarbonate (RSBC) distribution in study area 1

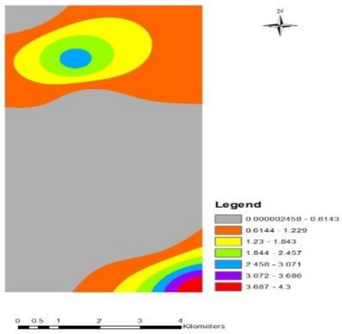

Figure.35.Residual Sodium Bicarbonate (RSBC) distribution in study area 2

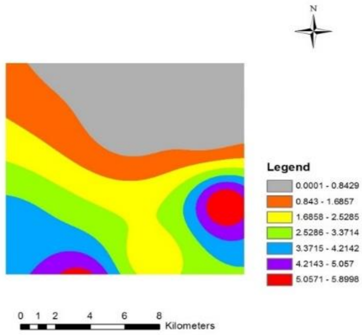

Figure.36.Residual Sodium Bicarbonate (RSBC) distribution in study area 3

4. CONCLUSION

Thus, the present study has proved experimentally that most of the irrigation water quality indices determined a show unsatisfactory result which proves that the water is flabby for cultivation. It can be found that the irrigation water quality indices are not to the extreme poor, thus some salt tolerant crops may be grown in the selected area, which meet the economic support not only from fisheries but also from agricultural sector. Conjunctive use of groundwater will sustain agriculture in coastal areas. High salt tolerant crops like rice, tobacco can be grown in the area 2 with EC ranging between 2to 2.5 ds/m. Also some other crops like foxtail millet, musk melon, pigeon pea, pumpkin, watermelon etc, have the potential to be grown in area 1 and area 2 with less than 2 ds/m electrical conductivity. Intensive agriculture is not both socially and politically viable, however few vegetable and fruit crops can be grown commercially or in a small scale as kitchen gardening which sustains the people income.

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