Assessing Groundwater Vulnerability to Seawater Intrusion in Morbi-Maliya Using GALDIT Method

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Abstract--- This study presents the application of the GALDIT method, for the mapping of ground water vulnerability to sea water intrusion in the Morbi- Maliya region of the saurashtra coast line. Chachadi andLlobo-ferreira initially in 2001 had developed the GALDIT method. Later in 2005, they had modified the method which is specific for coastal aquifers. The GALDIT index is based on four intrinsic hydrogeological parameters, one spatial parameter and one boundary parameter. The parameters of GALDIT index are: Ground water Occurrence (aquifer type), aquifer hydraulic conductivity, depth of ground water level above the sea level, distance from the shore, impact of existing status of sea water intrusion in the area, and thickness of the aquifer. Each GALDIT parameter has been evaluated with respect to the other to determine the relative importance of each factor. GALDIT index is calculated after deciding the Weightage, range and rate of each factor. GALDIT index is used for study of the Ground water Vulnerability to sea water intrusion. Results shows that Maliya taluka is more prone to sea water intrusion as compare to Morbi taluka.

Key words: - Ground Water, GALDIT index, Morbi-Maliya, sea-water intrusion,

I. INTRODUCTION

Water is the elixir of life. It is the important component to human for survival after the oxygen three-fourth part of earth is being surrounded by water although a little portion of ground water is used for drinking purpose [1].

Ground water is the major source of drinking and irrigation water in both urban and rural areas [2]. The rate of depletion of ground water levels and deterioration of ground water quality is of immediate concern in most of country because of large scale disposal of urban and industrial wastes and use of chemical fertilizers and pesticides in agricultural fields[3],[4], [5], and[6]. Problems related to sea water intrusion have a significant rise over the last decades. Sea water intrusion related problems have been reported in various countries and are especially of great concern to Gujarat state of India, as it has the longest coastline of about 1800 km [7]. However, environmental problems especially in the coastal areas have multiplied over the years because of rapid industrialization and excessive use of the natural resources. There has been an intensive use of ground water resources by various stockholders for their individual benefit. In the absence of any concreted management plan, ground water quality has therefore seen a drastic deterioration in the recent years [8]. Coastal regions, especially in the low laying areas are more prone to sea water intrusion problems, as is the case of the study area.

Sea water intrusion is a process of mixing sea water into fresh ground water. Ground water vulnerability to sea water intrusion is defined as "the sensitivity of ground water quality to an imposed ground water pumpage or sea level rise or both in the coastal belt, which is determined by the intrinsic characteristics of the aquifer"[9].

II. STUDY AREA

The Morbi district has been amalgamated on 15th August 2013. It contains Morbi, Wankaner, Maliya (miyana), Jodiya and Halvad. Maliya (miyana) and Jodiya are situated at Shore of Arabian Sea. Total population of Morbi district is 10, 07, 954[10].

Maliya Taluka is bounded by Morvi Taluka towards South, Halvad Taluka towards East, Bhachau Taluka towards west, Tankara Taluka towards South. Maliya consist of 52 Villages. Total population of Maliya taluka is 83,471[11].

Climate condition of Morbi taluka is tropical while there is chance of humidity in Maliya taluka. The maximum and minimum temperature variation is between 35 -42 degree centigrade in April & 10 – 22 degree centigrade in January. Average rainfall is 450mm. Wind direction during the year is generally from southwest direction. The soil is black and land is flat [12]. In the present study 10 villages of morbi-maliya region is considered which is listed at table 1.

Table 1: Latitude and Longitude of villages of Morbi-Maliya Taluka adopted for the study.

Sr.No	Village	Latitude	Longitude
1	Mota Dahisara	$22^0$57'27"	$70^0$37'03"
2	Jasapar	$23^0$04'07"	$70^0$40'10"
3	Navagam	$23^0$01'34"	$70^0$44'42"
4	Chachavadarda	$22^0$56'49"	$70^0$41'08"
5	Khakharala	$22^0$52'50"	$70^0$44'45"
6	Chachapar	$22^0$45'00"	$74^0$42'25"
7	Rajpar	$22^0$46'07"	$70^0$46'15"
8	Trajpar	$22^0$49'26"	$70^0$51'00"
9	Rafaleswar	$22^0$47'25"	$70^0$54'12"
10	Nichi Mandal	$22^0$51'43"	$70^0$57'55"

III. METHODOLOGY

GALDIT index is based on six parameters: Groundwater Occurrence (aquifer type), aquifer hydraulic conductivity, depth of groundwater level above the sea level, distance from the shore, impact of existing status of seawater intrusion in the area, and thickness of the aquifer. Each of these six indicators has a pre-determined fixed weight that reflects its relative importance to seawater intrusion. The weightage and rating of the parameter as decided by the researchers considering the hydrogeology of Morbi-Maliya taluka are presented at Table 2. The GALDIT Index is then obtained by computing the individual indicator scores and

summing them and dividing by the total weight as per the following equation.

GALDIT index = $\sum_{i=1}^{6}\{(W_i)R_i\}/\sum_{i=1}^{6} W_i$

Where, Wi is the weight of the ith parameter.
Ri is the rating of the ith parameter.

Table 2: Weightage and Rating of the GALDIT index parameters

Parameters	Weight	Rating			
		2.5	5	7.5	10
Ground water occurrence (G)	1		Leaky	Unconfined	Confined
Aquifer Hydraulic conductivity (A)	3	<5	5-10	10-40	>40
Height of Ground water above sea level (L)	4	>2	1.5-2	1-1.5	<1
Distance from the shore (D)	4	>30	20-30	15-20	<15
Impact of existing status of sea water intrusion (I)	3	<1	1-1.5	1.5-2	>2
Thickness of aquifer (T)	2	<5	5-7.5	7.5-10	>10

The minimum value and maximum value of GALDIT index are 2.5 and 10. The highest value of GALDIT index indicates greater vulnerability to sea water intrusion. The sea water intrusion vulnerability classification based on GALDIT index showing at Table 3[13].

Table 3: vulnerability classification based on GALDIT index

Sr, No	GALDIT INDEX Range	Vulnerability classes
1	≥ 7.5	High vulnerability
2	5 to 7.5	Moderate vulnerability
3	< 5	Low vulnerability

IV. RESULT

A. Groundwater Occurance

Ground water occurrence effects the extent of the seawater into the groundwater, in natural condition confined aquifer is less affected by seawater intrusion than an unconfined aquifer .unconfined aquifer is under atmospheric pressure while confined aquifer is underneath an aquitards and its pressure is higher than atmospheric pressure. In the present study area, the aquifer is unconfined. So, rating of groundwater occurrence corresponds to value 7.5. Fig 1 shows the representation of parameter (G).

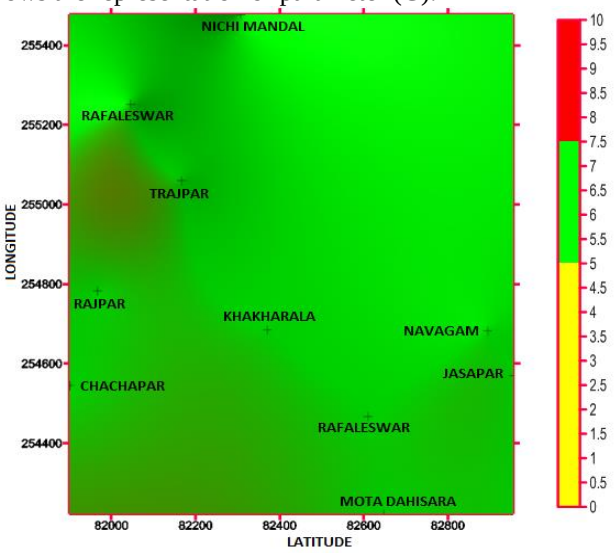

Fig. 1: Representation of G parameter

B. Aquifer Hydraulic Conductivity

Aquifer hydraulic conductivity is the measure of the rate of flow of water in the aquifer. By definition aquifer hydraulic conductivity is ability of aquifer to transmit water under the effect of hydraulic gradient. The higher hydraulic conductivity results in a wider cone of depression and larger extent of sea water intrusion. In the present study hydraulic conductivity is smallest at Jasapar village (2.97 m/day) and highest at Rafaleswar village (14.34 m/day). Rating of the hydraulic conductivity varies between 2.5 to 7.5. Fig. 2 shows the representation of parameter (A).

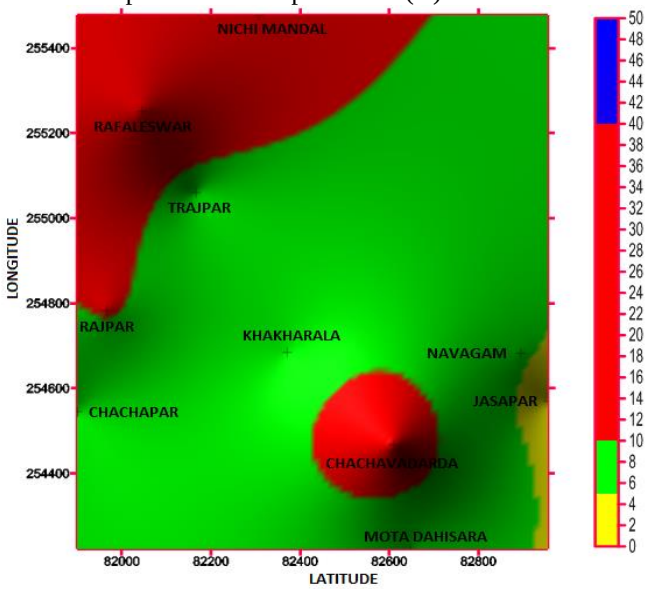

Fig. 2: Repesentation of A parameter.

C. Height Of Ground Water Level Above Sea Level

The height of ground water above mean sea level is very important factor in the evaluation of the sea water intrusion in an area. Height of groundwater determines the hydraulic pressure. Hydraulic pressure has ability to push back the sea water front. If the groundwater level is below mean sea level then its lead to strongest possible vulnerability to sea water intrusion. The height of groundwater above mean sea level is calculated for pre-monsoon and post-monsoon season from period of year 1998 to 2012. Minimum Height of groundwater above mean sea level is recording at Navagam village for Pre-monsoon season (-2.6 m) and Post-monsoon season (-4.7 m). Maximum Height of groundwater above mean sea level is recording at Trajpar for Pre-monsoon season (47.4 m) and Post-monsoon season (50.7 m). The rating of Height of ground water above mean sea level varies between 2.5 to 10. Fig. 3.1 shows the representation of parameter (L) for pre-monsoon season and Fig. 3.2 representation of parameter (L) for post-monsoon season

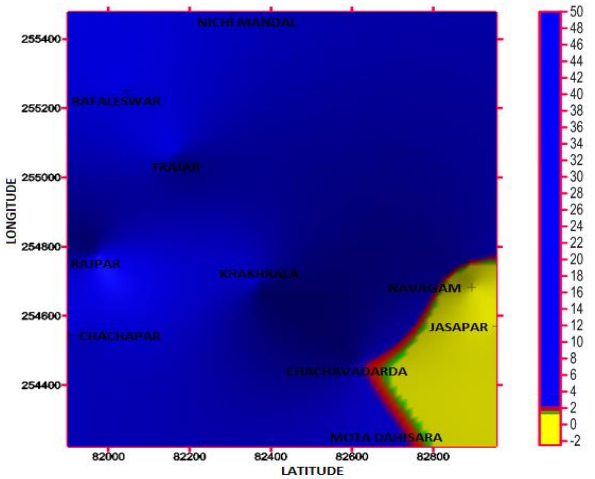

Fig. 3.1: Representation of L parameter for pre-monsoon season

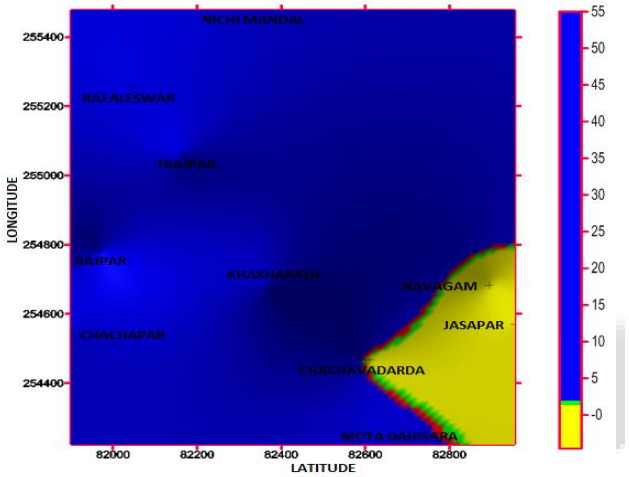

Fig. 3.2: Representation of L parameter for post-monsoon season

D. Distance From The Shore

The impact of the intrusion of sea water intrusion decreases when moving perpendicularly from shore towards the land. Mota Dahishara is nearest village from the sea at 16.70 km. Nichi mandal is Fareast village from the sea at 63.91 km. the rating for distance from shore is varies between 2.5 to 7.5. Fig. 4 shows the representation of parameter (D).

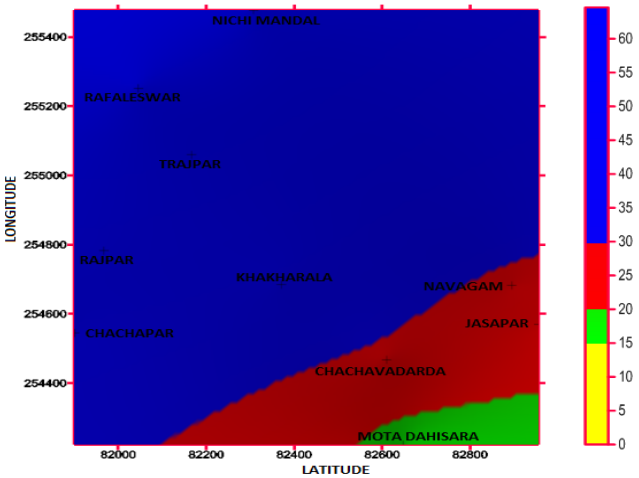

Fig. 4: Representation of D parameter

E. Impact Of Existing Status Of Seawater Intrusion

The ratio Cl/HCO_3 is used to evaluate sea water intrusion into the coastal aquifer if the area under mapping is invariably under stress and this stress has already modified the natural hydraulic balance between seawater and fresh groundwater. Cl/HCO_3 greater than one (>1) clearly indicate the presence of the sea water intrusion. Chloride is the dominate ion in the sea water and Bicarbonate is dominate ion in the ground water. Minimum Ratio of Cl/HCO_3^{-1} is recording at rajpar village for Pre-monsoon season (0.48) and post monsoon season (0.28). Maximum Ratio of Cl/HCO_3^{-1} is recording at Trajapr village for Pre-monsoon season (8.64) and post monsoon season (6.41). The rating for Impact of existing status of Seawater Intrusions varies between 2.5 to 10. Fig 1 shows the representation of parameter (G). Fig. 5.1 shows the representation of parameter (I) for pre-monsoon season and Fig. 5.2 representation of parameter (I) for post-monsoon season

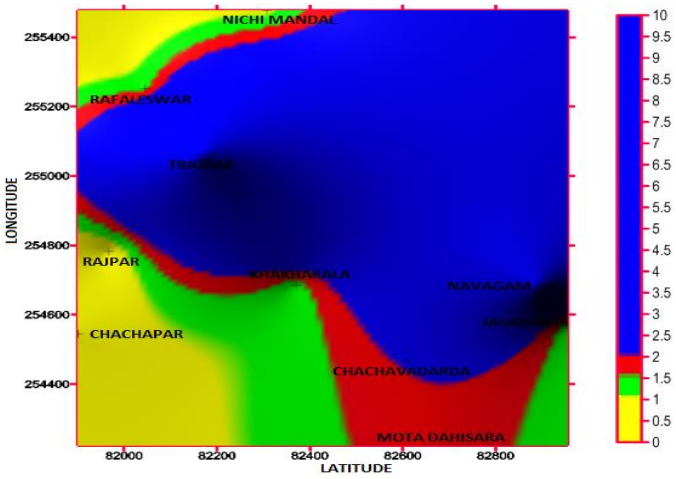

Fig. 5.1: Representation of I parameter for pre-monsoon season

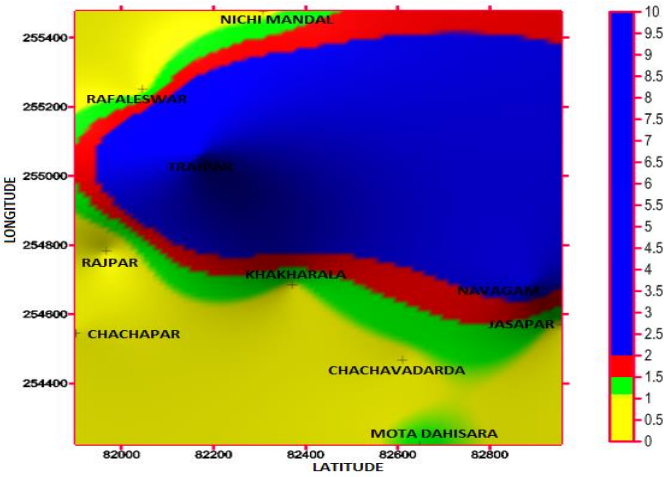

Fig. 5.2: Representation of I parameter for post-monsoon season

F. Thickness Of Aquifer

Saturated thickness of an unconfined aquifer plays crucial role in determining the extent of seawater intrusion in the coastal area. Extent of sea water intrusion is more if the thickness of aquifer is large. Saturated thickness of aquifer was minimum at Navagam village (1.06 m) and maximum at Khakhrala village (9.4 m). The rating for thickness of

aquifer varies between 2.5 to 7.5. Fig. 6 shows the representation of parameter (T).

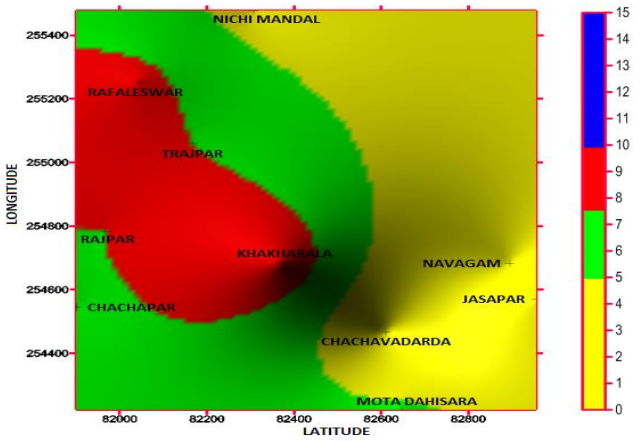

Fig. 6: Representation of T parameter

G. Galdit Index

Computation of GALDIT index for Pre-monsoon season

SR.NO		$R_i \vee$						GALDIT index = $\sum_{i=1}^{6}\{(W_i)R_i\}/\sum_{i=1}^{6} W_i$
	$W_i >$	1	3	4	4	3	2	
	VILLAGE	G	A	L	D	I	T	
1	MOTA DAHISARA	7.5	5	2.5	7.5	7.5	5	5.6
2	JASAPAR	7.5	2.5	10	5	5	2.5	5.6
3	NAVAGAM	7.5	5	10	5	10	2.5	6.9
4	CHACHAVADARDA	7.5	7.5	2.5	5	10	2.5	5.6
5	KHAKHARALA	7.5	5	2.5	2.5	5	7.5	4.3
6	CHACHAPAR	7.5	5	2.5	2.5	2.5	5	3.5
7	RAJPAR	7.5	7.5	2.5	2.5	2.5	7.5	4.3
8	TRAJPAR	7.5	5	2.5	2.5	10	7.5	5.1
9	RAFALESWAR	7.5	7.5	2.5	2.5	5	7.5	4.7
10	NICHI MANDAL	7.5	7.5	2.5	2.5	2.5	2.5	3.7

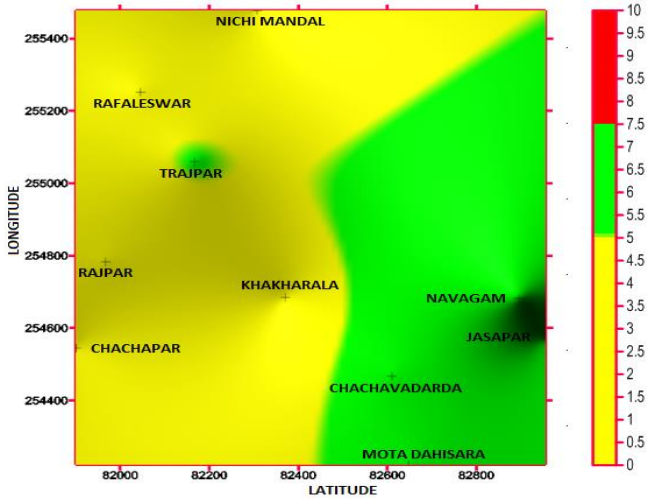

Fig. 7.1 Representation of GALDIT index for pre-monsoon season.

Computation of GALDIT index for Post-monsoon season

SR.NO		R_i ∨						GALDIT index = $\sum_{i=1}^{6}\{(W_i)R_i\}/\sum_{i=1}^{6}W_i$
	W_i >	1	3	4	4	3	2	
	VILLAGE	G	A	L	D	I	T	
1	MOTA DAHISARA	7.5	5	2.5	7.5	5	5	5.1
2	JASAPAR	7.5	2.5	10	5	2.5	2.5	5.1
3	NAVAGAM	7.5	5	10	5	10	2.5	6.9
4	CHACHAVADARDA	7.5	7.5	10	5	2.5	2.5	6.0
5	KHAKHARALA	7.5	5	2.5	2.5	2.5	7.5	3.8
6	CHACHAPAR	7.5	5	2.5	2.5	2.5	5	3.5
7	RAJPAR	7.5	7.5	2.5	2.5	2.5	7.5	4.3
8	TRAJPAR	7.5	5	2.5	2.5	10	7.5	5.1
9	RAFALESWAR	7.5	7.5	2.5	2.5	2.5	7.5	4.3
10	NICHI MANDAL	7.5	7.5	2.5	2.5	2.5	2.5	3.7

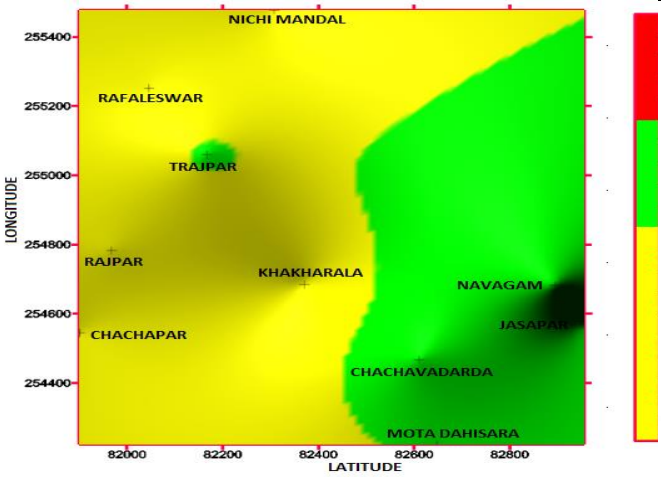

Fig. 7.2 Representation of GALDIT index for post-monsoon season.

V. CONCLUSION

The sea water vulnerability maps derived using GALDIT method is indicating that the aquifer is low to medium vulnerable to sea water intrusion. GALDIT index of Maliya region villages are higher as compared to Morbi region villages. Maps of GALDIT index are clearly showing that Maliya region is more vulnerable to sea water intrusion as compared to Morbi region. The results obtained from the investigations may be useful for judicious planning of ground water development in coastal aquifer of Morbi-Maliya region.

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