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IMPACT OF SEAWATER INTRUSION ON COASTAL AQUIFER OF BHAVNAGAR, GUJARAT, INDIA USING GALDIT METHOD

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Abstract – Salinity always exists in groundwater, but in variable amounts. In places where groundwater is being pumped from aquifers that are in hydraulic connection with the sea, the induced hydraulic gradients may cause the migration of salt-water from the sea towards the well. This study presents the application of GALDIT method to evaluate the ground water vulnerability due to seawater intrusion in the Bhavnagar, Ghogha, Talaja and Mahuva taluka region of the saurashtra coast line. The GALDIT index is based on four intrinsic hydro geological parameters, one spatial parameter and one boundary parameter. The parameters of GALDIT index are: Ground water Occurrence (aquifer type), Aquifer hydraulic conductivity, High 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 GALDIT index is calculated after deciding the weightage, range and rate of each factor. GALDIT map of Bhavnagar coastal area indicated that most of the coastal zone is vulnerable to salinity ingress.

Key words: Seawater intrusion, Groundwater vulnerability, Bhavnagar, Ghogha, Talaja, Mahuva taluka, GALDIT parameter, GIS,

I. INTRODUCTION

Coastal aquifers constitute an important source of fresh water supply but are often confronted with the problem of seawater intrusion. In coastal plains, due to inadequate storage facilities, most of the rainwater flows towards sea as runoff. Population growth, agricultural, industrial and domestic requirements exploit the available ground water with decreasing recharge areas. Regulation of ground water extraction is essential to optimize the overdraft, reducing the risk of seawater intrusion. The entire seawater intrusion phenomenon is governed by Ghyben-Herzberg relation (Todd, 1980). The lighter fresh water lies over the seawater and the boundary surface between them is known as the freshwater–seawater interface. This distribution was attributed to a hydrostatic equilibrium existing between the two fluids of different densities. For each meter of fresh ground water found above sea level, 40 m of freshwater exists below sea level at that point. When drawdown occurs, the base of the freshwater lens is adjusted at a rate of 40 m for each meter of drawdown in the well through up coning effect.
Seawater intrusion is the movement of seawater into fresh water aquifers. It is one of the main causes for ground water pollution. The definition of groundwater vulnerability to seawater intrusion is defined as "the sensitivity of groundwater quality to an imposed groundwater pumpage or sea level rise or both in the coastal belt, which is determined by the intrinsic characteristics of the aquifer".

Bhavnagar district coast has been considered for the present study as it affected by sea water intrusion. The length of the coast line in this district is 198 covering Bhavnagar, Ghogha, Talaja and Mahuva Talukas. The study aims to identify and delineate the ground water contamination zones using GALDIT method.

II. STUDY AREA

The study area comprise of four coastal Talukas i.e. Bhavnagar, Ghogha, Talaja, and Mahuva of Bhavnagar District in Gujarat State (Fig. 1). The study area falls in the longitude range of 71° 30' 56" E and 72° 22' 16" E and latitude range of

22° 07' 02" N and 20° 59'04"N.The climate of Bhavnagar, Ghogha, Talaja and Mahuva tehsil is humid because of Gulf of Khambhat. The main river of Talaja tehsil is the Shetrunji river and in Mahuva Tehsil is the Bagad River.

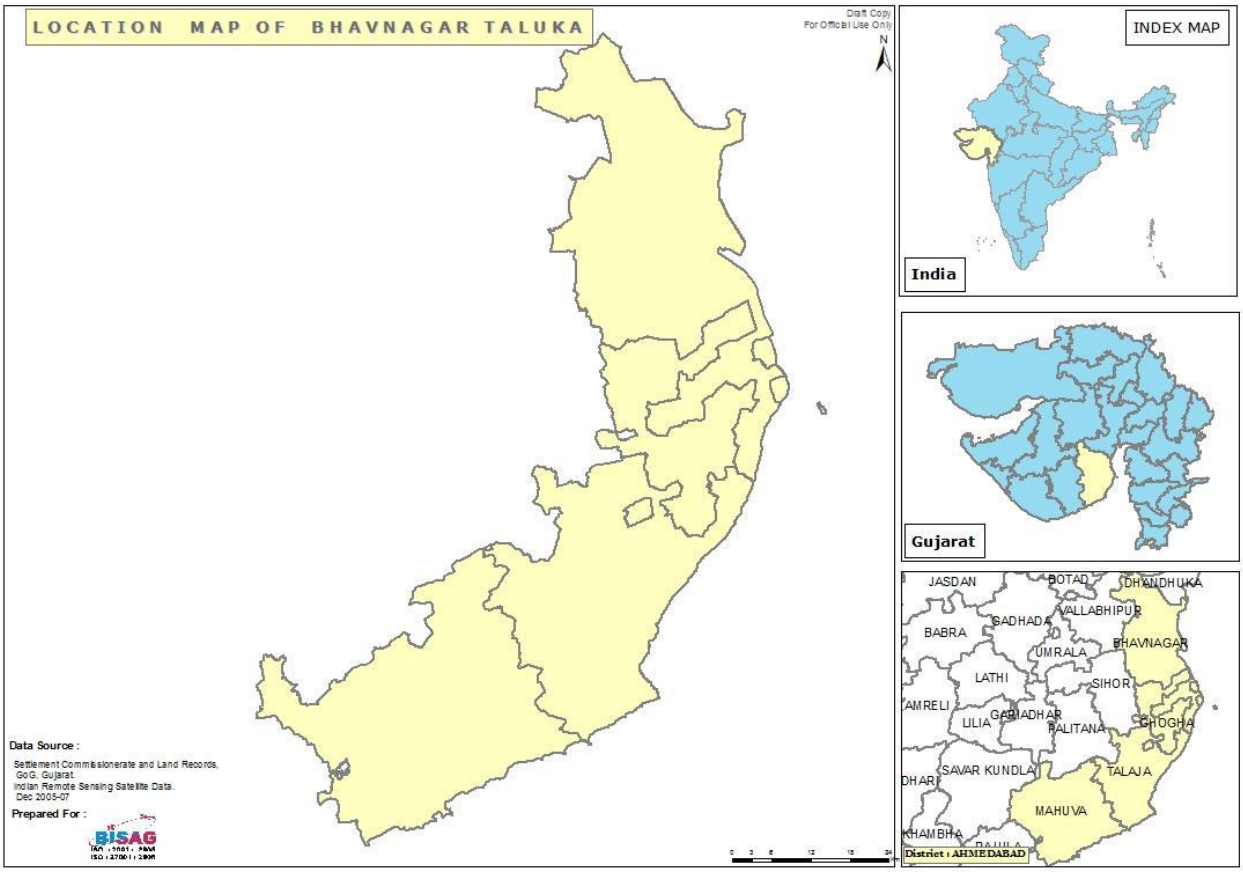

Figure 1: Location Map of Study area

III. METHODOLOGY

GALDIT factors are used to devise a numerical ranking system to assess seawater intrusion in hydrogeologic settings. The system contains three significant parts: weights, ranges and importance ratings. GALDIT index is based on following parameters: Groundwater Occurrence (aquifer type; unconfined, confined and leaky confined), Aquifer Hydraulic Conductivity, Height of Groundwater Level above Sea Level, Distance from the Shore (distance inland perpendicular from shoreline), Impact of existing status of seawater intrusion in the area and Thickness of the aquifer. Each GALDIT factor has been evaluated with respect to the other by assigning a relative weight to determine the relative importance of each factor.

Each of the six indicators has a pre-determined fixed weight that reflects its relative importance to seawater intrusion. The GALDIT Index is then obtained by computing the individual indicator scores and summing them as per the following expression:

$$\textbf{GALDIT-Index}=\sum_{i=1}^{6}\{(W_i)\,\mathbf{R_i}\}/\sum_{i=1}^{6}W_i$$

Where W_i is the weight of the i^{th} indicator and R_i is the importance rating of the i^{th} indicator.

Table.1 : GALDIT INDEX CALCULATION

No.	indicator	weight	Range of importance rating				Range of Scores(WEIGHT*RATINGS)			
			Min.	In between		Max.	Min.	In between		Max.
1	Groundwater Occurrence (Aquifer Type)	1	2.5	5	7.5	10	2.5	5	7.5	10
2	Aquifer hydraulic conductivity	3	2.5	5	7.5	10	7.5	15	22.5	30
3	Depth to ground water level above sea	4	2.5	5	7.5	10	10	20	30	40
4	Distance from the shore	4	2.5	5	7.5	10	10	20	30	40
5	Impact of existing status of sea water intrusion	1	2.5	5	7.5	10	2.5	5	7.5	10
6	Thickness of aquifer	2	2.5	5	7.5	10	5	10	15	20
GALDIT INDEX CALCULATION						Total score	37.5	75	112.5	150
						GALDIT Index=TS/15	2.5	5	7.5	10

A. Groundwater Occurrence (Aquifer Type):

Groundwater is found in the geological layers (Aquifer) and these layers may be confined, unconfined, leaky. Confined aquifer has pressure higher than atmospheric pressure and unconfined aquifer is under atmospheric pressure. Here in the study area, the aquifer is unconfined. So, the rating of the parameter groundwater occurrence is. Figure shows representation of parameter (G).

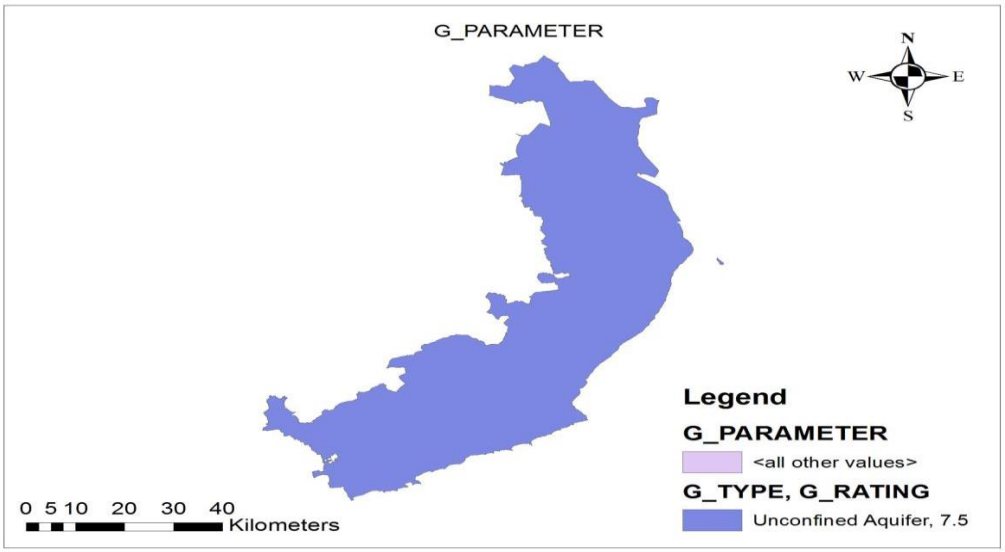

Figure 2: Ground water occurrence

B. Aquifer hydraulic conductivity (A):

Aquifer hydraulic conductivity is used to measure the water flow rate in the aquifer. Aquifer hydraulic conductivity is the ability of aquifer to transmit water under the effect of hydraulic gradient. High conductivity value is more vulnerable for inland movements of the seawater intrusion.

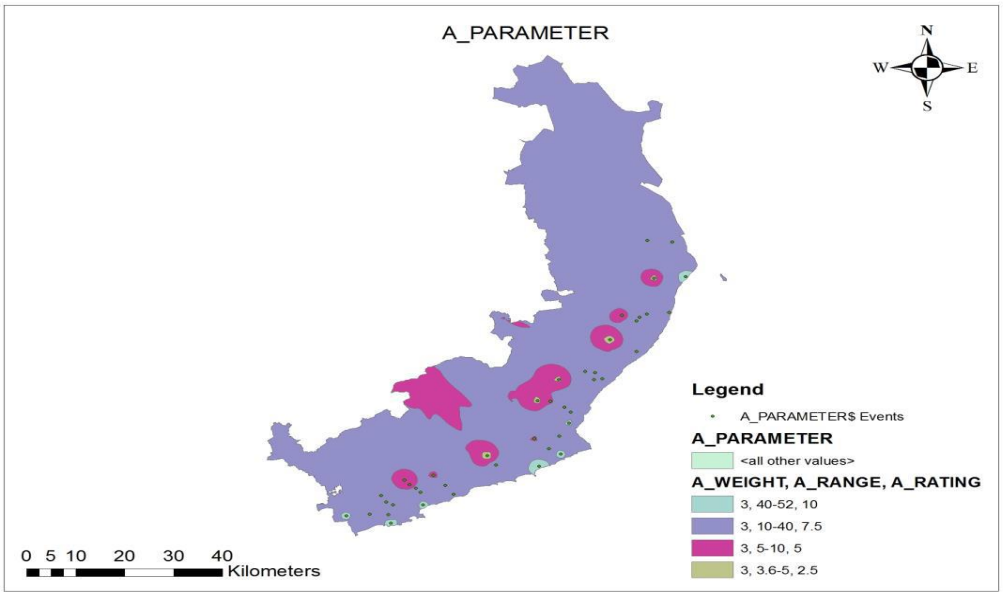

Figure 3: Aquifer hydraulic conductivity (A)

C. Height of Groundwater level above sea level (L):

Height of groundwater is used in determining the hydraulic pressure. Hydraulic pressure has ability to push back the sea water front. For the ratings of GALDIT parameter L, one should consider the sequential long-term variation of the groundwater level. The values with minimum groundwater levels above sea level may be considered, as this would give the highest possible rate of vulnerability risk.

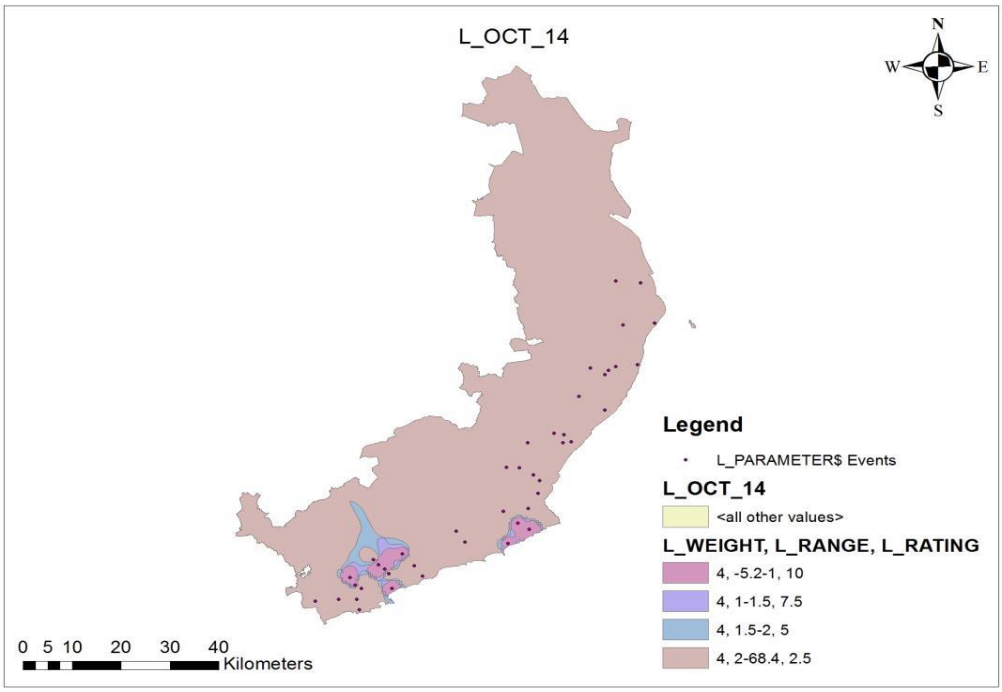

Figure 4: Height of Groundwater level above sea level (L)

D. Distance from the shore (D):

The impact of seawater intrusion generally decreases if the area is inside towards right angles to the shore. The rating of the parameter distance from shore ranges between 2.5 to 10. Fig. shows representation of parameter (D).

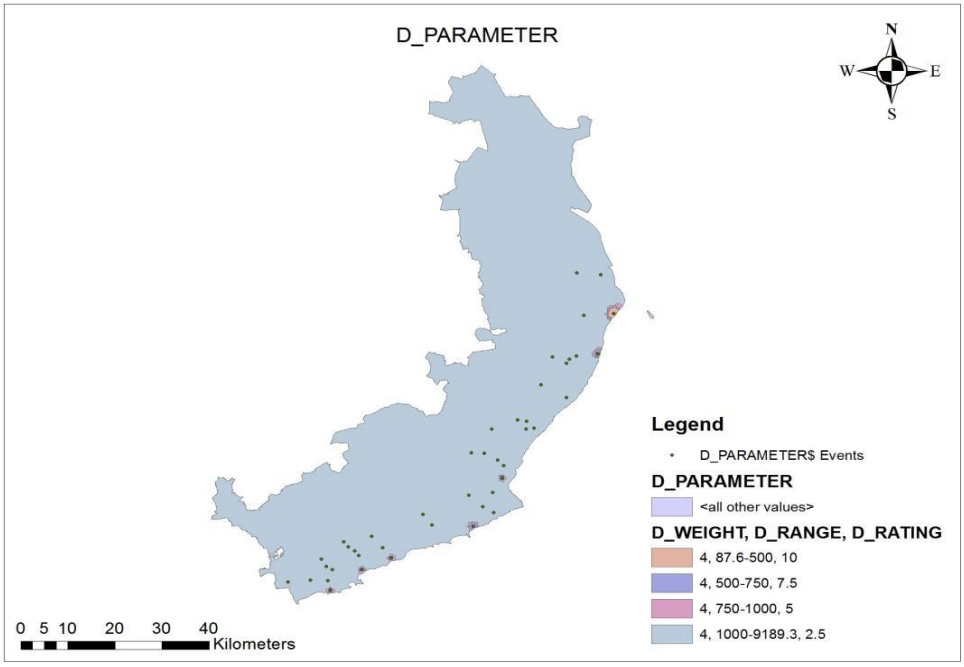

Figure 5: Representation of parameter D

E .Impact of existing status of Seawater Intrusion (I):

The ratio Cl/HCO3 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 fresh groundwater and seawater. If Cl/HCO3 is greater than one (>1) it clearly indicates the presence of sea water intrusion. Chloride ion is the dominate ion in sea water and Bicarbonate ion is the dominate ion in ground water.

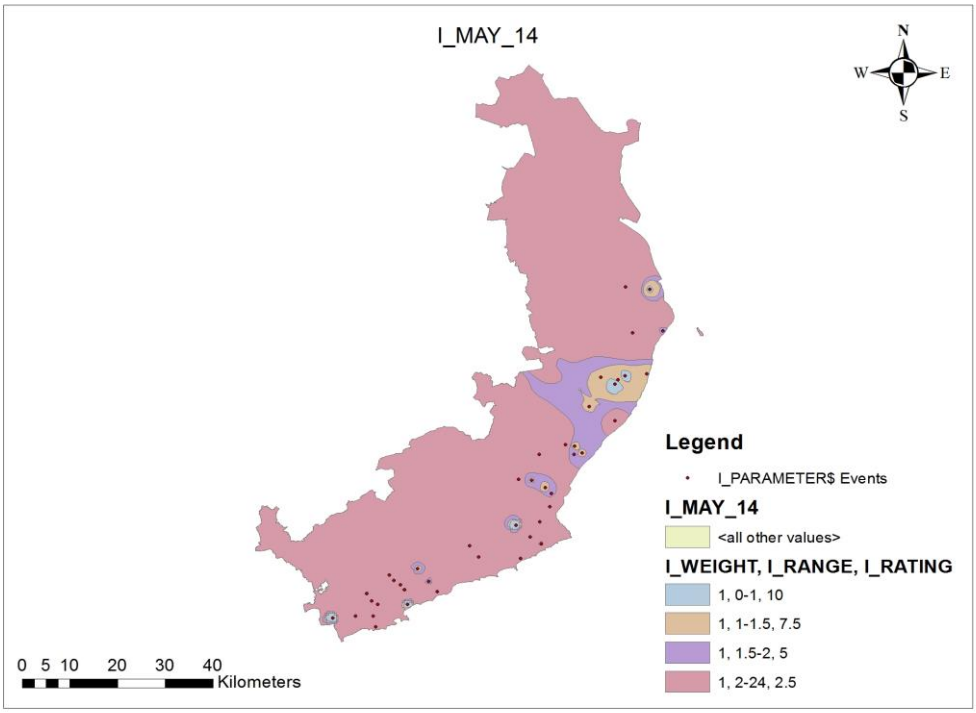

Figure 6: Representation of parameter I for pre-monsoon season for year 2014

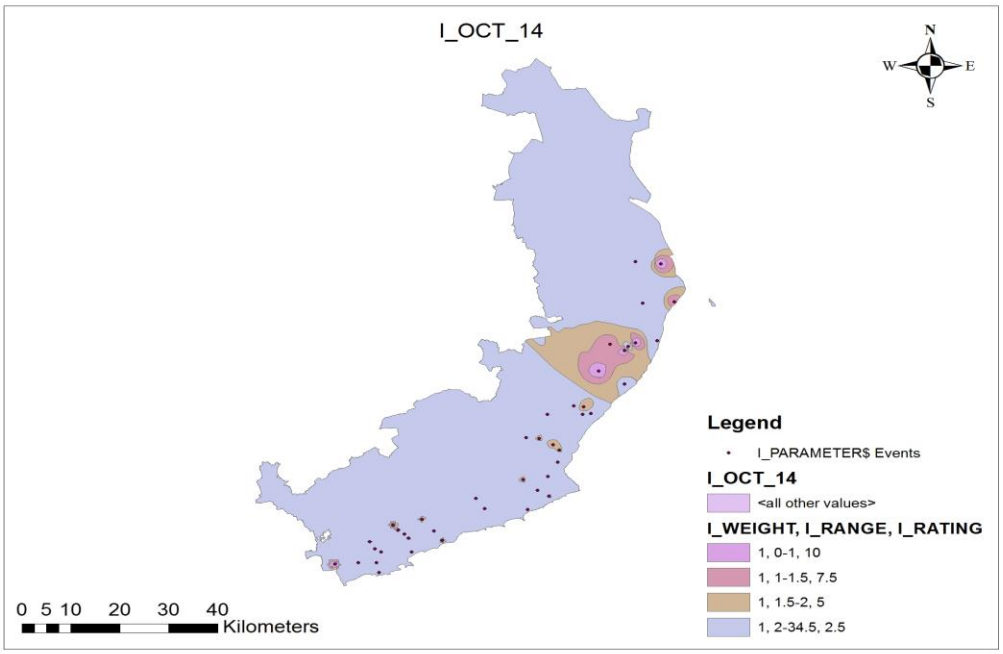

Figure 7: Representation of parameter I for post-monsoon season for year 2014

F. Thickness of Aquifer (T):

Aquifer thickness or saturated thickness of an unconfined aquifer plays an important role in determining the extent of vulnerability of seawater intrusion in the coastal areas. Larger the extent of seawater intrusion is there if the thickness of Aquifer is large.

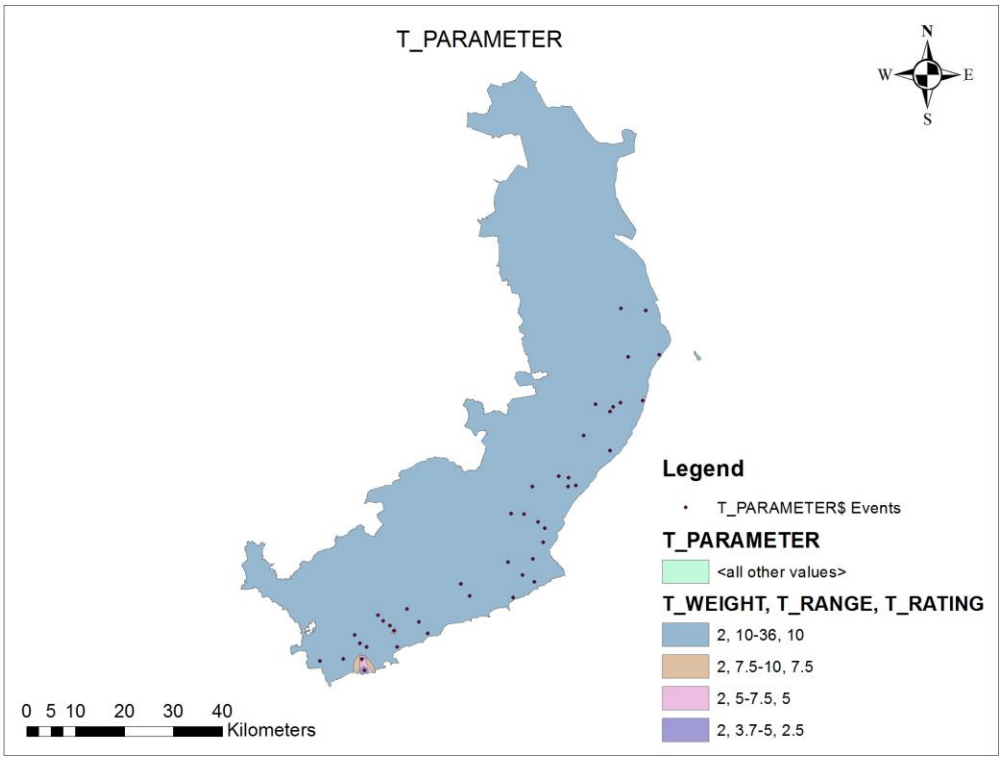

Figure 8: Representation of parameter T

IV. RESULT AND CONCLUSIONS

The Bhavnagar coastal area is inundated by sea water during the high tide affecting the groundwater by percolation of the saline water from the surface depending on the porosity and permeability of rocks and soil. Ground water is also contaminated constantly by the sea water intrusion in the coastal aquifers directly from the side of the sea even below the low tide levels. Assessment of the sea water intrusion has been done by applying GALDIT method. The area of low , medium, high vulnerability due to sea water intrusion have been delineated. In the present study around 85% area is in low vulnerability, 10 % area is in medium vulnerability and 5 % area is in highly vulnerable.

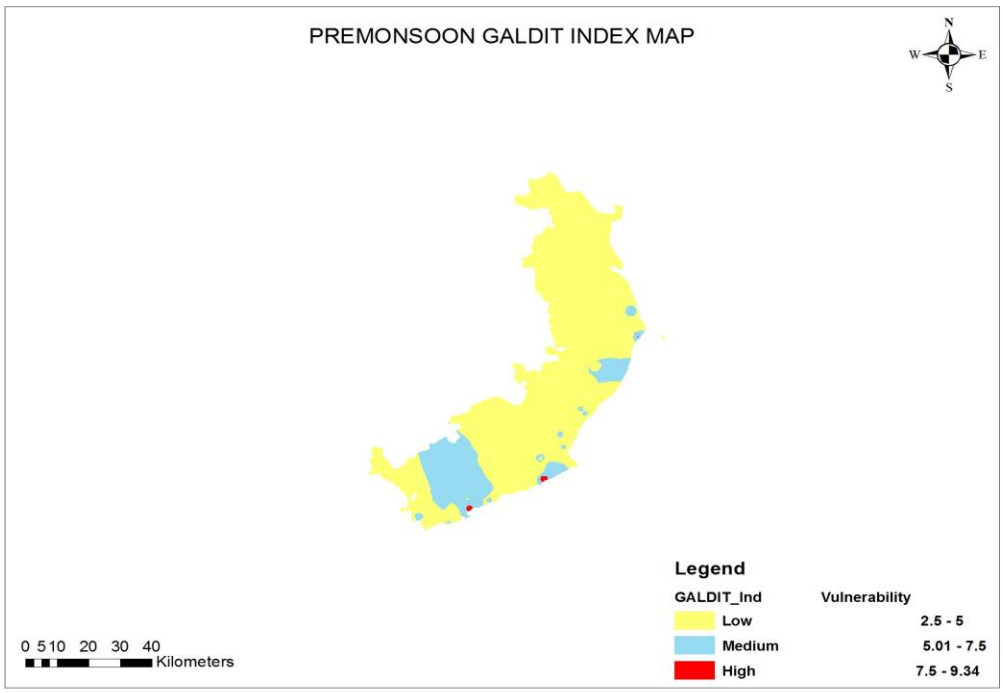

Figure 9: PREMONSSON GALDIT INDEX MAP

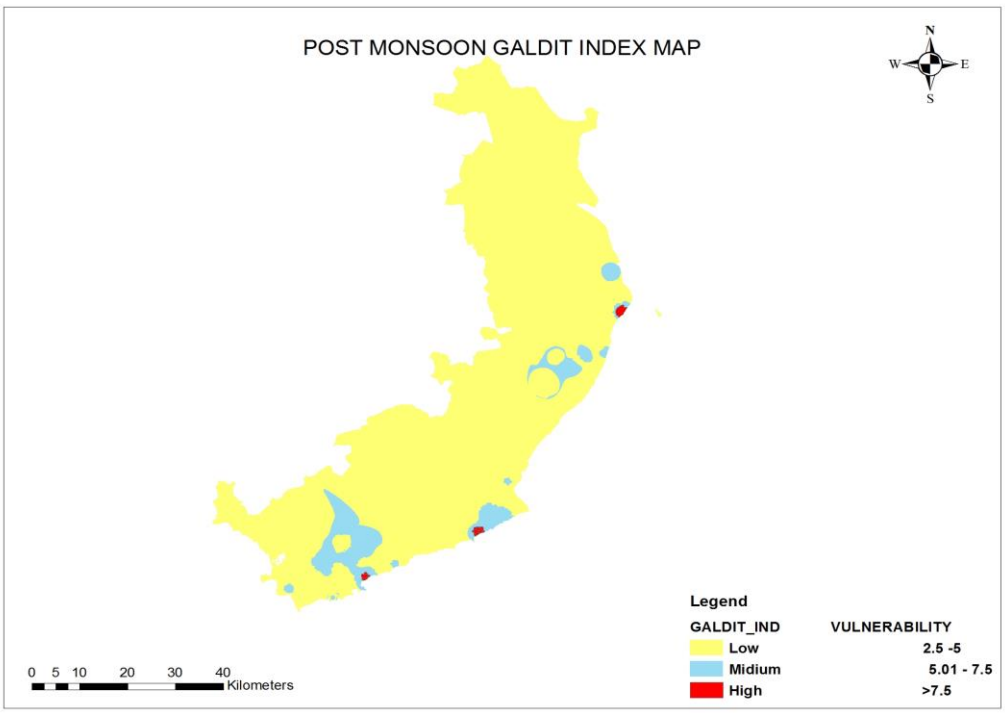

Figure 10: POSTMONSOON GALDIT INDEX MAP

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