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Analysis of Vulnerability Assessment in the Coastal Dakshina Kannada District, Mulki to Talapady Area, Karnataka

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ABSTRACT
The areal extent of the study area is about 40 kms. The wells were located on the map using GPS values obtained after conducting GPS survey in the field. Environmental preservation of the coastal regions constitutes a socioeconomic element of major importance for both the present and the future. The term vulnerability refers to the potential degree of damage that can be expected depending on the characteristics of an element risk with respect to a certain hazard. Seawater intrusion is a global issue, by increasing demand for freshwater in coastal zones. Based on GALDIT Index, the aquifer vulnerability index mapping was carried out. The distributions of vulnerability areas are high, medium and low class are 7.5, 5 and 2.5 respectively. The main purpose of the study is to determine the vulnerability of the groundwater in the south western part of the Dakshina Kannada coast against seawater intrusion to the current sea level. The methodology used in the study consists of assessment of vulnerability to groundwater contamination using GALDIT method, identification of saltwater intruded area using indicators of saltwater intrusion like Cl/(HCO3+CO3) ratio and NA/Cl ratio etc.

KEYWORDS: *Coastal aquifer, GALDIT index, saltwater intrusion, vulnerability assessment, GIS, overlay.*

I. INTRODUCTION

Environmental preservation of the coastal regions constitutes a socioeconomic element of major importance for both the present and the future. These areas have been weakened because of various pressures exerted including over exploitation of groundwater for agricultural purposes and intensive domestic use of soil and fertilizer. This resulted in decline of resources such as soil and groundwater resources and in their quality and also in the increase of their vulnerability to different impact factor.

Generally, the term of vulnerability refers to the potential degree of damage that can be expected depending on the characteristics of an element at risk with respect to a certain hazard (Varmes, 1984; Georgescu, et al., 1993). Relating to groundwater, the vulnerability is defined by Lobo-Ferreira and Cabral (1991) as “the sensitivity of groundwater quality to an imposed contaminant load, which is determined by the intrinsic characteristics of the aquifer”. Thus the vulnerability of groundwater to different pollutants or to seawater intrusion constitutes a subject of analysis in several studies (Chachadi et al., 2002; Cardona et al., 2004; Lobo-Ferreira et al., 2005). Also the vulnerability of soil to salinization is demonstrated in many studies (George et al., 1997; Kotb et al., 2000; De Paz et al., 2004; Asa Rani et al., 2008; Zhang et al., 2011). The main purpose of the study is to determine the vulnerability of the groundwater in the south western part of the Dakshina Kannada coast against seawater intrusion to the current sea level.

Study area

The study area is located in the south western part of Karnataka, adjoining the Arabian sea. Its geographical area is about 4770 sq. km and the study area for the investigation is the coastal basin between Talapady and Mulki (Honnanagoudar et al., 2012). The areal extent of the study area is about 40 kms. The wells were located on the map using GPS values obtained after conducting GPS survey in the field. The elevation of the locations, lithology, depth to water table (later reduced to mean sea level), and distance of the well from the shore and river were noted. Water samples were collected from each well during September 2011 to August 2013 (two years) and subjected to chemical analysis by following standard procedures (APHA, 1998; Trivedi and Goel, 1986). The most important factors controlling the saltwater intrusion are considered in determination of vulnerability of aquifers. Elevations of water levels and well locations were determined with respect to mean sea level by conducting field survey.

Methodology

The methodology used in the study consists of assessment of vulnerability to groundwater contamination using GALDIT method, identification of saltwater intruded area using indicators of saltwater intrusion like $Cl/(HCO_3+CO_3)$ ratio and NA/Cl ratio etc.

Assessment of ranks to various parameters required for GALDIT

The Parameter such as GALDIT was weighted depending on the suggestions of local knowledge and the field conditions for assessing the vulnerability of the groundwater aquifer. The weight and the ranks for GALDIT parameters are given in the Table 1.

Table 1 GALDIT Parameter

	G	A	L	D	I	T
Parameters	Groundwater Occurrence	Aquifer Conductivity	Height of the ground water level	Distance from the shore	**I**mpact of existing status	Aquifer **T**hickness
Weight / Rates	1	3	4	4	1	2
2.5	Bounded aquifer	Very Low < 5m	Very Low > 2 m	>1000 m	<1	< 5
5.5	Leaky confined aquifer	Low 5 -10 m	Low 1.5 -2 m	750 -1000	1 -1.5	5-7.5
7.5	Unconfined aquifer	Medium 10-40 m	Medium 10-40 m	500-750	1.5 -2	7.5-10
10	Confined aquifer	High >40m	High >40m	<500	>2	>10

Vulnerability Evaluation and Ranking

The most important factors that control the saltwater intrusion are found to be the following.

- **G**roundwater occurrence (aquifer type; unconfined, confined and leaky confined).
- **A**quifer hydraulic conductivity.
- Height of groundwater **L**evel above sea level.
- **D**istance from the shore (distance inland perpendicular from shoreline).
- **I**mpact of existing status of saltwater intrusion in the area.
- **T**hickness of the aquifer which is being mapped.

The acronym GALDIT is formed from the highlighted letters of the parameters for ease of reference. These factors, in combination, are used to assess the general saltwater intrusion potential of each hydro-geologic setting. The GALDIT factors represent measurable parameters for which data are generally available from a variety of sources without detailed reconnaissance.

The system contains three significant components - weights, ranges and importance ratings. Each GALDIT factor has been evaluated with respect to the other to determine the relative importance of each factor. The basic assumption made in the analysis is that the bottom of the aquifer lies below the mean sea level.

Mapping of GALDIT Index

Mapping of GALDIT index gives its variation in the study area, which is done by Arc GIS 9.5 software. Location of sampling stations and the water GALDIT index at each sampling site is required for mapping. The important steps involved for mappings are georeferencing, digitization and spatial interpolation. Georeferencing is the process of fixing of the locations of the real world features within the framework of a particular coordinate system. A series of concepts and techniques are used that progressively transforms the measurements that are carried out on the field to the map. Digitization usually begins with a set of control points, which are used for converting the digitized map to real world coordinates. Spatial interpretation is the process of using points with known values to estimate values at other points. Spatial interpretation is therefore a means of creating surface data from sample points so that the surface data can be used for analysis.

II. RESULTS AND DISCUSSION

Groundwater occurrence, G

From the pump test data it is evident that the aquifer is unconfined in nature with rich groundwater potential and hence a rating of 7.5 is adopted as per the specifications. Also, from the field observations it is evident that the aquifer is shallow and unconfined in nature.

Aquifer hydraulic conductivity, A

Finally from all the studies conducted to evaluate the hydraulic conductivity in the study area, we can conclude that the hydraulic conductivity varies from 5.43 m/day to 85.59 m/day and hence a common GALDIT rating of 10 can be assigned for the entire study area.

Height of water above the sea level, L

The groundwater levels were measured every month at the monitoring wells identified. The parameter required for the present study, 'L' is obtained by reducing the water level with respect to mean sea level and is presented in Table 2.

Table 2 Height of water above mean sea level

Well No.	Sept. 2011	Sept.2012	Well No.	Sept. 2011	Sept.2012
1	0.44	0.34	16	10.04	9.64
2	11.44	10.44	17	5.04	5.14
3	10.64	11.94	18	7.14	7.04
4	14.64	15.54	19	12.74	15.74
5	6.04	6.34	20	14.54	14.24
6	3.06	3.34	21	18.04	18.24
7	3.69	4.14	22	10.94	11.04
8	4.00	3.94	23	6.74	7.24
9	5.14	5.44	24	-2.86	-1.46
10	7.34	7.44	25	6.34	6.54
11	26.06	26.24	26	4.44	4.84
12	26.24	26.44	27	5.34	5.54
13	5.04	5.14	28	10.64	11.94
14	-1.06	-1.34	29	6.64	6.94
15	10.09	10.54	30	21.74	22.44

In the study area coastal wells are sunk in the porous soil. The water level gradually declines after the rains. As evident from Table 2; we can see some negative values indicating the possibility of salt water intrusion. The water table distribution of the area is presented in Fig 1 and Fig 2. Wells 14 and 24 have water level below ground level i.e. less than 1m throughout the year and well no. 1 is less than 1m i.e. 0.44 m to 0.34 m. The rating given for the above class is 10, remaining wells are more than 2 m and ratings are 2.5.

Distance from the shore/river, D

The magnitude of the saltwater intrusion is directly related to the perpendicular distance from the coast. Out of the monitoring network of wells, the nearest location to the saline source is well no.15 (Distance, D=27.70 m) and the farthest location is well no.19 (D=5035m).

Impact of existing status of saltwater intrusion, I

The chloride concentration of groundwater defines the extent of saltwater intrusion. The chloride concentration in the range of 40 to 300 mg/l is indicative of saltwater intrusion. (Edet et al., 2011). The present results in Table 3 infer that the aquifer water is contaminated with saltwater as Cl^-, the most abundant ion in saltwater, is in higher proportions. The HCO_3^- ion which is the most dominant ion in fresh groundwater occurs generally in small amounts in saltwater. Chloride concentration greater than 250 mg/l is considered unfit for drinking purpose.

Table 3Ratio of Cl/HCO_3 for the samples taken from monitoring wells

Well No.	Sept. 2011	Sept. 2012	Well No.	Sept. 2011	Sept. 2012
1	1.22	1.19	16	1.41	0.64
2	1.15	1.20	17	0.32	0.70
3	0.71	0.68	18	0.49	0.70
4	0.29	0.5	19	0.84	0.75
5	0.29	0.47	20	1.81	2.28
6	0.33	0.26	21	1.59	1.48
7	0.43	0.26	22	0.53	0.70
8	0.14	0.78	23	0.94	3.24
9	0.17	0.15	24	2.17	2.08
10	0.79	0.75	25	0.84	0.82
11	0.15	0.16	26	0.70	0.67
12	2.15	1.37	27	0.41	0.32
13	0.25	0.23	28	0.14	1.45
14	1.39	2.78	29	4.51	0.26
15	0.43	0.35	30	0.53	0.88

From Table 3 we can observe that in monsoon season well no.12, 24 and 29 are high in saltwater intrusion Fig. 3 and Fig. 4. Well no. 14, 20, 23 and 24 are high in saltwater intrusion for the month of September 2012.

Thickness of the aquifer, T

The thickness of the aquifer is obtained from the electrical resistivity survey conducted in the study area at 14 locations. The resistivity survey indicated that the area consists of shallow unconfined aquifer with the thickness ranging from 18 m to 30 m. From the resistivity survey we can observe that all the values are greater than 10 m, and hence the GALDIT rating of 10 is adopted throughout the study area.

III. VULNERABILITY ANALYSIS AND VULNERABILITY ZONING

The GALDIT scores for all parameters were obtained by analysing the generated data and it has been done for monsoon session is given in Table 4. The GALDIT index has also been calculated. The spatial variation of GALDIT index is depicted in Fig.5 and Fig.6, the vulnerability of aquifers of the study area is divided into 3 classes such as highly vulnerable, moderately vulnerable and low vulnerable with respect to saltwater intrusion. Most of the study area comes under moderately vulnerable and highly vulnerable.

Table 4 GALDIT index during monsoon, from Sept. 2011 and Sept. 2012

Well No.	Sept. 2011	Sept. 2012	Well No.	Sept. 2011	Sept. 2012
1	9.5	9.50	16	5.50	5.33
2	5.5	5.50	17	5.33	5.33
3	5.33	5.33	18	5.33	5.33
4	5.33	5.33	19	5.33	5.33
5	5.33	5.33	20	5.66	5.83
6	6.00	6.00	21	5.66	5.50
7	7.33	7.33	22	6.00	6.00
8	6.66	6.00	23	7.33	7.83
9	6.00	6.00	24	9.83	9.83
10	5.33	5.33	25	7.33	7.33
11	5.33	5.33	26	5.33	5.33
12	5.83	5.50	27	5.33	5.33
13	7.33	7.33	28	5.33	5.50
14	8.16	8.50	29	7.16	6.66
15	7.33	7.33	30	5.33	5.33

It was found that in monsoon coastal that stretches at well no 1, 14 and 24 are highly vulnerable to saltwater intrusion as shown in Fig. 5 and Fig. 6. Thus the present study indicates that the coastal groundwater system within the study area is under the threat of seawater intrusion.

IV. CONCLUDING REMARKS

GALDIT Model shows that

- In pre monsoon coastal stretches are viz., Mulki, Pavanje, Mukka and Haleyangadi are highly vulnerable to saltwater affected area.
- In post monsoon the coastal stretches of the study area Talapady and Kavoor are also highly affected area on southern side in the month of April and December.

Based on indicators of saltwater intrusion

- $Cl/(HCO_3 + CO_3)$: In monsoon season, contamination due to saltwater intrusion is found high at Kavoor, Haliyangadi and Mulki for the month of September 2011. In the month of September 2012, the saltwater intrusion is found at Kavoor, Surathkal, Mukka and Pavanje.
- In the post monsoon season, contamination due to saltwater intrusion at Talapady, Uchilla, Kavoor, Surathkal, Mukka and Pavanje for the month of December 2012.
- In the pre monsoon season, contamination due to high saltwater intrusion at Talapady, Kavoor, Thokuru, Mukka and Pavanje for the month of April 2012. In the month of April 2013 the saltwater intrusion is found high at Talapady, Ullal and Pavanje.
- The tidal nature of the river is affecting the adjoining well fields up to a distance of about 22 km. along the river course from the sea during April –May.
- Over all the values of Cl/HCO_3 ranges 0.14 to 7.41. Well no. 12 located close to Gurupur, Pavanje andMulki are very near to Pavanje river.
- From the GALDIT analysis, it is found that the wells located within 250 m on either side of the river are highly vulnerable during Feb – May. The wells located at farther locations (250-700 m) are found to be moderately vulnerable and beyond 700 m, low vulnerable.

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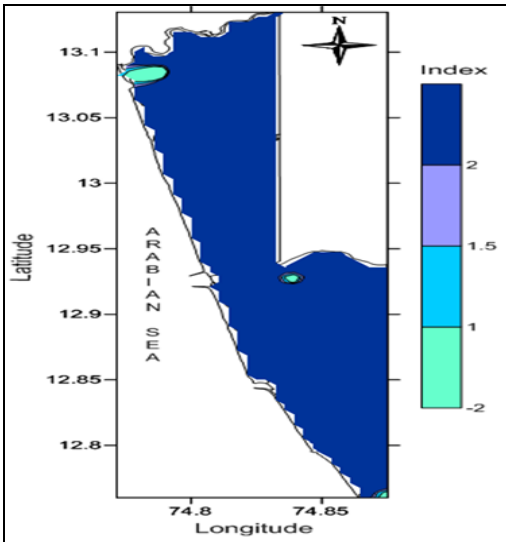

Fig.1. Sept 2011

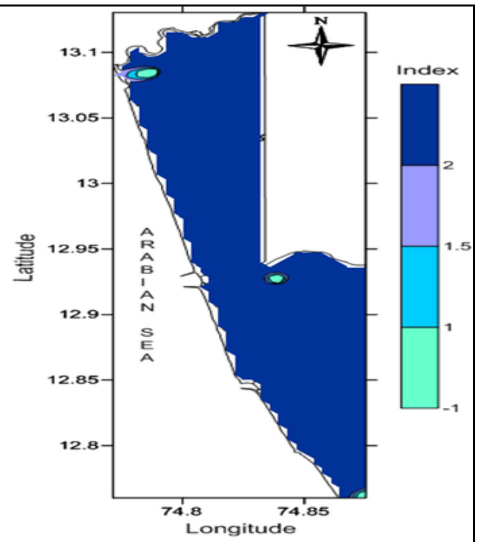

Fig.2. Sept 2012

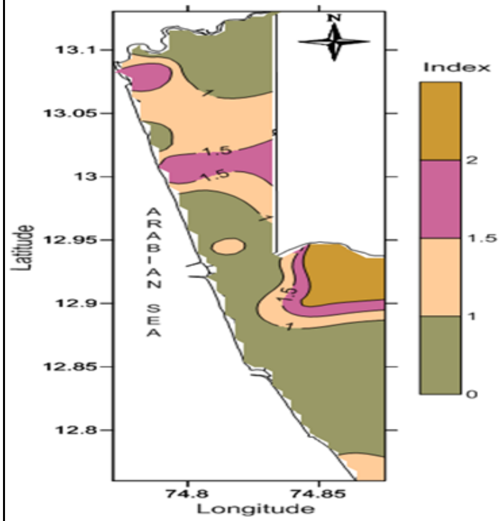

Fig.3. Sept 2011

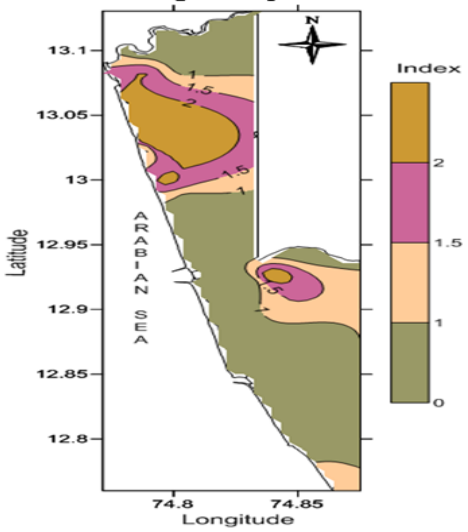

Fig.4. Sept 2012

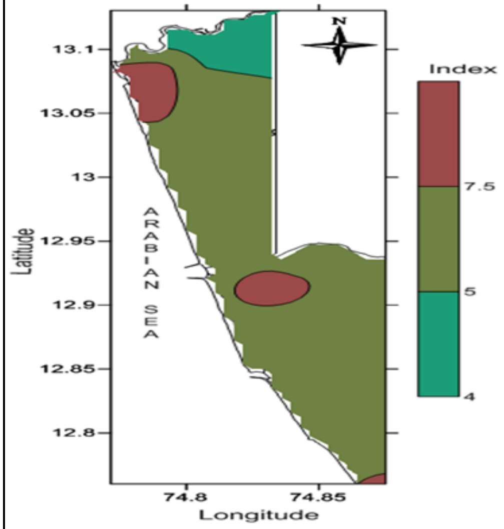

Fig. 5. Sept 2011

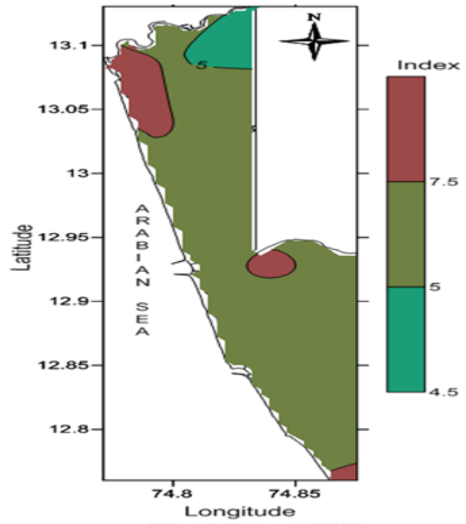

Fig.6. Sept 2012