International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 02, February-2015

GIS based GALDIT-AHP Method for Assess the Impact of Shrimp Farms in Coastal Watershed of Tamil Nadu, INDIA.

R.Gangadharan,
Bule Hora University,
Department of Geology,
Bule Hora, Oromia Region,
Ethiopia.

Dr. P. Nila Rekha
Central Institute of Brackishwater Aquaculture (CIBA),
75, Santhome high road, R.A.Puram,
Chennai-28,
India.

***Abstract*— Coastal area is a complex ecosystem and fragile one and the coastal aquifers in particular is impacted by multiple sources and multiple criteria which warrants an evaluation of multicriteria analysis for the assessment of the aquifer systems and its vulnerability to degradation. In the present study the versatile methodology of GIS based GALDIT-AHP model has been applied to characterize the coastal hydrogeological setting and aquifer vulnerability of the coastal watershed of Lower Vellar and Colleroon covering shrimp farm area in Tamilnadu. The main objective of the study is to ascertain whether shrimp farming influences the aquifer vulnerability. GALDIT is the acronym of six thematic layers i.e. Groundwater occurrence; Aquifer hydraulic conductivity; Depth to groundwater Level; Distance from the shore; Impact of existing status of sea water intrusion in the area; and Thickness of the aquifer. Pair wise comparison of all these parameters were done in GIS environment as per AHP and groundwater vulnerability map has been prepared. The result visibly points out shrimp farms is not the main reason for salinization and it is due to natural phenomenon.**

Keywords*— *Shrimp farming, GALDIT, AHP, GIS, and Groundwater quality.

I. INTRODUCTION

Shrimp culture is considered as ‘Aqua gold’ due to harvesting in a short gestation period and earning of significant foreign exchange through exports. The growth rate of aquaculture between 1970 and 2006 was 6.9 per cent per annum [1], although it appears to be slowing in average 5.8% between 2004 and 2008. In India, shrimp is being predominantly cultured in about 1.4 lakh ha with a production of 1.43 lakh tones (2005-06) which is roughly 15% of the total brackishwater potential. Brackishwater aquaculture contributes immensely to food and nutritional security, substantial income and employment generation, productive utilization of coastal waste lands and significant seafood export earnings. However, brackishwater aquaculture has a number of environmental impacts; including salinization of drinking water and groundwater quality; but, no scientific studies has been carried out to understand the vulnerability of the aquifer in shrimp farming area.

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. Seashore is an area that has direct boundary to sea; that would increase possibility for seawater intrusion in coastal areas. For this study, GALDIT model can provide an effective means of mapping the extent of seawater intrusion vulnerability of coastal aquifers [2]. [3] Developed this GALDIT index model from the DRASTIC method which was originally developed by [4]. DRASTIC model was used to assess the vulnerability to groundwater contamination, which includes seven distinct influencing hydrogeological parameters [5]. But GALDIT method, with six similar hydrogeological parameters, has been mostly used to perform the seawater intrusion in coastal aquifer [6]. GALDIT-based investigations have been performed in several coastal belts of India [7], [8]. Geographical information system (GIS) to represent and understand the spatial variation of groundwater quality has been proved by several researchers [9]. The overlay/index weightage approaches gained popularity particularly with the ease of usage of GIS technology. The spatial groundwater quality index for ranking or weights, which reflected the influence of different parameters [10]. The weights (or relative importance) of main-criteria and its corresponding sub-criteria under consideration were defined by pairwise comparison method [11]. The application of Analytical Hierarchical Process (AHP) method in GIS has been used by many researchers in recent years which includes the work of [12], [13] for groundwater investigations and [14] for selection of aquaculture sites. In this study, GALDIT based AHP weighted index overlay analysis is used to determine, so as to draw a conclusion on the salinization whether it is natural or anthropogenic. Finally, the groundwater vulnerability map is drawn to understand the vulnerability area in shrimp farming region.

II. MATERIALS AND METHODS

A. Study area

The study area Chidambaram taluk falls in the Cuddalore district it comprises of sedimentary formation located in eastern part of Tamilnadu and bounded by Bay of Bengal. This study area occurs within the survey of India toposheet No.58 M/10, 58 M/11, 58 M/12, 58 M/13, 58 M/14, 58 M/15 in the scale: 1:50,000 and is located between 11°30’N to 11°20’N latitude and 79°38’E to 79°48’E longitude. The watershed boundary has been delineated using toposheet and satellite data as well as with the help of Mini and Micro-watershed boundary in the sub basin collected from Agricultural Engineering Department, Tamil Nadu. The total extent of the study area is about 213.44 sq km in which the water spread area of shrimp farms is approximately 4 sq.km.

B. *Data used*

The groundwater sample for HCO_3, CO_3 and Cl were collected from the identified 46 groundwater wells and was collected once in two months starting from October 2011 to October 2013. The concentration ions were estimated in the laboratory using the standard methods as suggested by the American Public Health Association [15]. Groundwater levels were measured using water level indicator (Solinst 101), once in two months in the monitoring wells from April 2012 to February 2013. Pumping tests was carried out in order to determine the aquifer characteristics and it was conducted during the end of November 2012 in 5 locations. The study area and sampling location point is shown in the *Fig.1.*

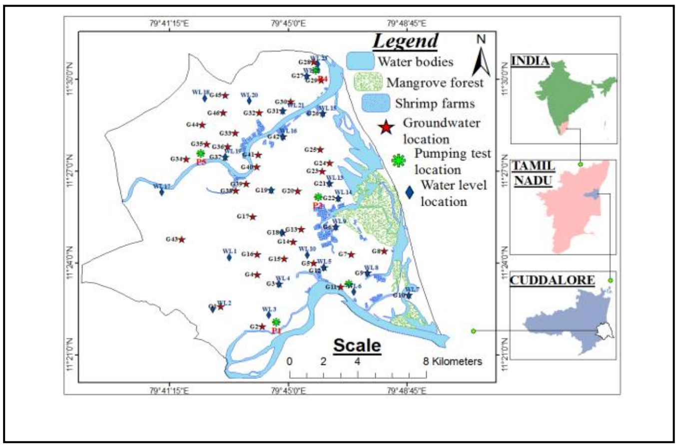

Fig: 1. Sampling location map.

C. *GALDIT based AHP method*

The vulnerability of the aquifer for seawater intrusion has been done using GALDIT based AHP multicriteria method. The most important factors controlling seawater intrusion were found to be the following: Groundwater occurrence (aquifer type; unconfined, confined and leaky confined); Aquifer hydraulic conductivity; Depth to groundwater Level; Distance from the shore (distance inland perpendicular from shoreline); Impact of existing status of sea water intrusion in the area; and Thickness of the aquifer, which are being mapped. These factors, in combination, are determined to include the basic requirements needed to assess the general seawater intrusion potential of each hydrogeological setting. GALDIT factors represent measurable parameters for which data are generally available from a variety of sources without detailed examination. From these, the GALDIT (Combining the first letters of the above significant factors) Index is calculated as:

$$GALDIT\ Index = G_R\, G_W + A_R\, A_W + L_R\, L_W + D_R\, D_W + I_R\, I_W + T_R\, T_W \qquad (1)$$

where, W and R are the relative weights and rating assigned to the six factors. The ratings of all the factors were assigned by reclassifying the influencing factors with different ranges through AHP method. AHP technique analyzes the multiple datasets in a pair-wise comparison matrix, which is used to calculate the geometric mean and normalized weight of parameters [16]. For different features of each parameter, they were assigned weights on a scale of 1 to 9 according to their relative influence on groundwater vulnerability. A comparison matrix M is a (Lx L) matrix in which L is the number of either main-criteria or its corresponding sub-criteria being compared. To fill the matrix M, He [17] proposed the use of a one to nine scale to express the expert’s preference and intensity of that preference for one element over the other (Table: 1 Scale for pairwise comparison). The consistency ratio (CR) was obtained by dividing the consistency index by the random index. The consistency ratio is designed in such a way that if $CR< 0.1$, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, $CR \geq 0.1$, the values of the ratio are indicative of inconsistent judgments [18]. Inverse Distance Weighing (IDW) spatial analysis was applied to generate the raster graphical output for each parameter. However, AHP weightage system is applied to assess seawater intrusion in hydrogeological settings and has been devised using GALDIT factors in study area. The methodology flow chart was given in *Fig.2.*

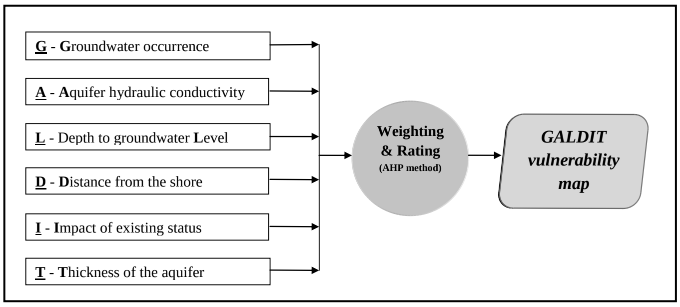

Fig: 2. Methodology flow chart of GALDIT based AHP model.

Table: I. Scale for pair wise comparison

Intensity of relative importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance
Reciprocals of above non-zero numbers	If the activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared to i.

Source: Saaty (2000).

III. RESULT AND DISCUSSION.

The parameter G (aquifer type) affects the degree of advancement of the marine water into the groundwater. For example, an unconfined aquifer, in natural conditions, is more affected by marine water intrusion than a confined one. The Groundwater occurrence in the study area is unconfined type of aquifer *(Table: II a and Fig: 3a).*

Table: IIa. Pairwise comparisons matrix for groundwater occurrence (G)

Groundwater occurrence (G)		
Type	*Ratings (D_r)*	*Sub - Index (D_r*D_W)*
Unconfined aquifer	5.39	1.98
Weight (D_w)	0.367	

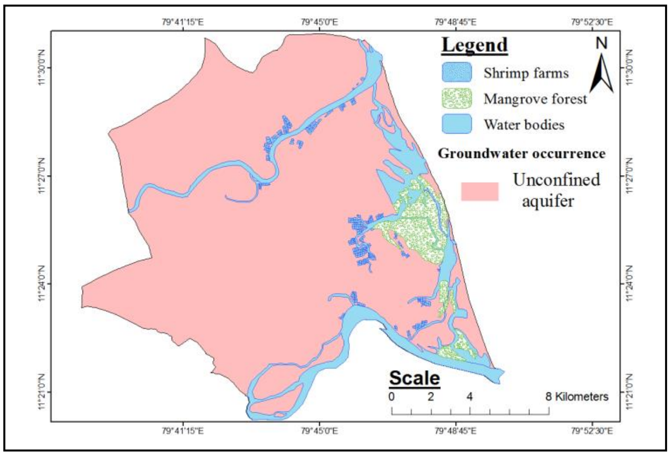

Fig: 3a. Groundwater occurrence

Aquifer hydraulic conductivity (A) or the permeability is the aptitude of a soil or rock to let itself cross by water under the effect of a hydraulic gradient. The value of hydraulic conductivity is controlled by the properties of the aquifer and determines the rate of groundwater movement in the saturated zone. As hydraulic conductivity increases, groundwater velocity as well as the speed at which pollutants are transported also increases, raising aquifer vulnerability. In study area the hydraulic conductivity is categorized into five divisions such as < 0.23 (m/h), 0.23 – 0.33 (m/h), 0.34 – 0.43 (m/h), 0.44-0.53 (m/h), >0.54 (m/h) *(Table: II b and Fig: 3b).*

Table: IIb. Pairwise comparisons matrix for aquifer hydraulic conductivity (A)

Aquifer hydraulic conductivity (A)		
Ranges (m/h)	*Ratings (R_r)*	*Sub - Index (R_r*R_W)*
> 0.54	5.02	0.93
0.44 - 0.53	2.73	0.50
0.34 - 0.43	1.34	0.25
0.23 - 0.33	0.55	0.10
< 0.23	0.35	0.07
Consistency Ratio	0.073	
Weight (R_w)	0.185	

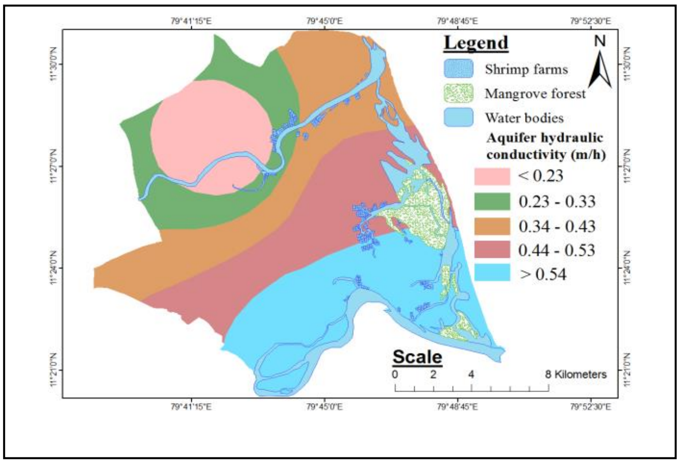

Fig: 3b. Aquifer hydraulic conductivity

The depth of groundwater level (L) compared to the average altitude of the sea is a very significant factor in the evaluation of the sea water intrusion in any area. By this it determines the possibility of the water pressure to move back the sea front. In general the minimal values of groundwater level below the sea level remain most significant, because they provide the strongest possible vulnerability to this marine water intrusion. Depth to groundwater level *(Table: II c and Fig: 3c)* ranged from 1.8 to 2.7m and its categories into five divisions such as 1.25-1.74m, 1.75-1.99m, 2.00-2.21m, 2.22-2.42m and 2.43-2.75m.

Table: IIc. Pairwise comparisons matrix for depth of groundwater level (L)

Depth to groundwater level (L)		
Ranges (in meter)	*Ratings (T_r)*	*Sub - Index (T_r*T_w)*
1.25 - 1.74	3.81	0.40
1.75 - 1.99	2.56	0.27
2.00 - 2.21	2.03	0.21
2.22 - 2.42	1.21	0.13
2.34 - 2.75	0.38	0.04
Consistency Ratio	0.078	
Weight (T_w)	0.105	

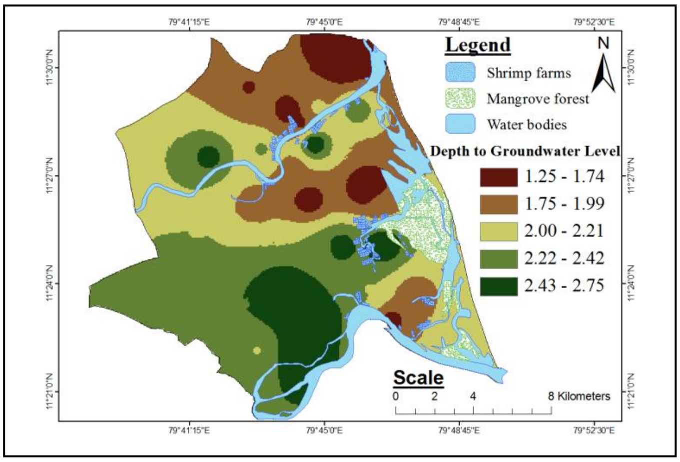

Fig: 3c. Depth of groundwater level.

Distance from the shore (D), the impact of the intrusion of sea water generally decreases when moving perpendicularly to the shore towards the interior. This parameter was estimated according to four distances (below 2 km, 2-5 km, 5-10 km and above10 m) perpendicular to the line of coast. The maximum weightage is adopted for the distance lower than below 2 km from the coast line, whereas the minimal one is allotted for all those higher than 10 km *(Table: II d and Fig: 3d).*

Table: IId. Pairwise comparisons matrix for distance from the shore (D),

Distance from the shore		
Ranges (km)	*Ratings (S_r)*	*Sub - Index (S_r*S_w)*
> 10 km	5.04	0.85
05-10 km	1.76	0.30
02-05 km	2.05	0.35
< 2 km	1.16	0.20
Consistency Ratio	0.013	
Weight (S_w)	0.170	

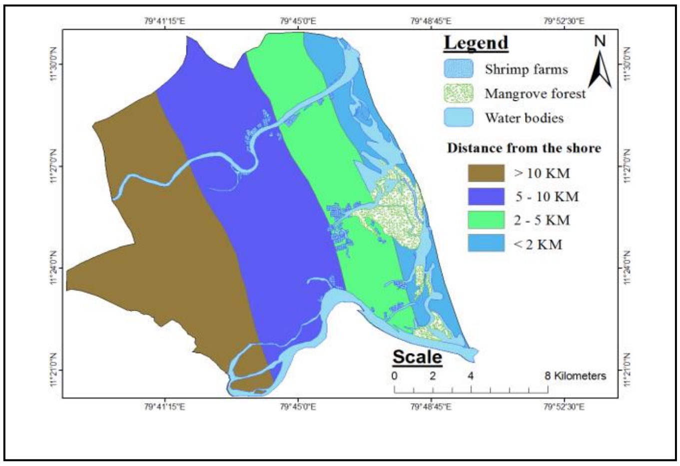

Fig: 3d. Distance from the shore.

Impact of existing status of seawater intrusion is calculated by a ratio Cl / [HCO_3 + CO_3] and it's a criteria to identify the extent of seawater intrusion into the coastal aquifers and can be used if the chemical analysis data is available. In this study, the Cl / (CO_3+HCO_3) ratio is used to delineate the interface. Chloride is the most dominant ion in sea water and normally occurs in small amounts in ground water, while HCO_3 is usually the most abundant negative ion in ground water but it occurs in minor amounts in the seawater. The Cl/ (CO_3+HCO_3) ratio is calculated for all the wells and it is divided into three categories such as < 1.5, >2, <2 *(Table: II e and Fig: 3e).*

Table: IIe. Pairwise comparisons matrix for Impact of existing status (I)

Impact of existing status		
Ranges (meq)	**Ratings (C_r)**	**Sub - Index (C_r*C_w)**
Cl/ (HCO_3+CO_3) < 1.5	6.06	0.72
Cl/ (HCO_3+CO_3) > 2	3.14	0.37
Cl/ (HCO_3+CO_3) < 2	0.79	0.09
Consistency Ratio	0.093	
Weight (Cw)	0.118	

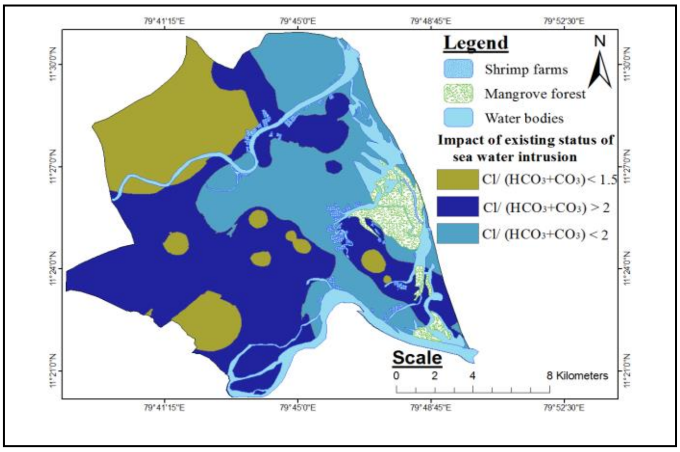

Fig: 3e. Impact of existing status.

Generally in study area the thickness of aquifer (T) is higher than 10 m and equal value is given in watershed *(Table: II e and Fig: 3e).*

Table: IIf. Pairwise comparisons matrix for thickness of aquifer (T)

Thickness of the aquifer		
Ranges (m)	*Ratings (I_r)*	*Sub - Index (I_r*I_w)*
>10	3.81	0.21
Weight (Iw)	0.056	

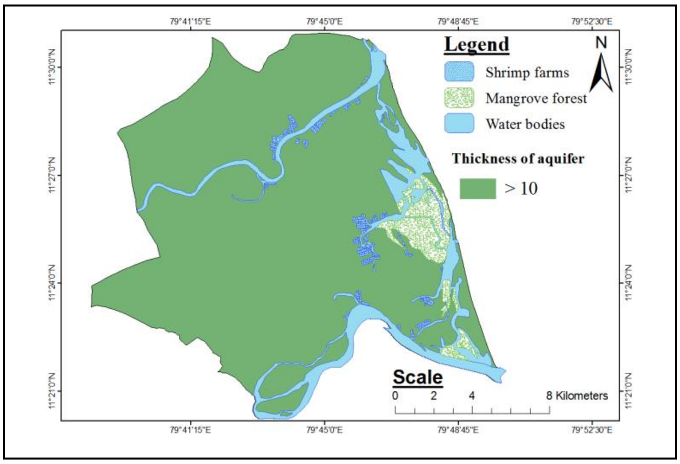

Fig: 3f. Impact of thickness of aquifer

The final vulnerability map *(Fig.4)* was obtained by running the model in the GIS environment by using the six hydro-geological data layers. Consistency Ratio for overall parameter in GALDIT method is 0.005. These values were reclassified into four classes i.e., less vulnerable, medium vulnerable, vulnerable and high vulnerable. The results of this study show that the less vulnerability is observed in the entire western side of the study area were shrimp farm activity is 0.216 sq.km. Medium vulnerability are noted in northern, north western, north eastern, central and south eastern side of the study area were shrimp farm activity is 2.394 sq.km. Vulnerable area are covered by central, central eastern, south eastern and few part in north eastern of the study area were shrimp activity in that area is 1.293 sq.km. High vulnerability is observed in north eastern side, few parts in central and south eastern side were shrimp farm activity is 0.093 sq.km.

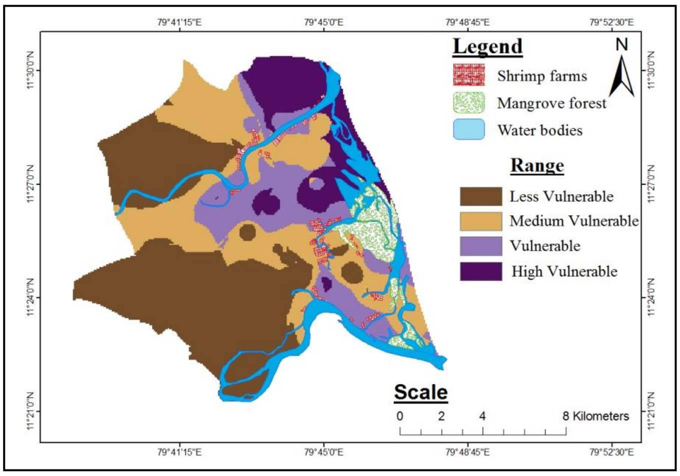

Fig: 4. GALDIT vulnerability map.

IV. CONCLUSION

The vulnerability map of shrimp farm region has been derived to show the impact of seawater intrusion along the coastal zone. The new GALDIT method has been successfully used to assess the extent of aquifer contamination due to sea water intrusion. GALDIT method parameters in the study area which were used to assess groundwater occurrence were of unconfined aquifer. Hydraulic conductivity index was 0.23 to 0.54 m/h were higher conductivity are observed in southern part of the study area. Groundwater level elevation was 1.25 to 2.75 meters and higher water levels are noted in northern eastern side. Distance from shore was categorized into four divisions were more weightage is given for less than 2 km. Impact of existing status shows higher concentration are observed in entire eastern side, few parts in central part and southern part. Thickness of aquifer is higher than 10 meters in the study area. Weightage and ranking value was assigned to each parameter by pairwise comparison method to calculate the GALDIT index. The vulnerability rate for GALDIT index was classified into low vulnerable, medium vulnerable, vulnerable and high vulnerable. Highest numbers of shrimp farms were noted in medium vulnerable area and it is 2.394 sq.km. Next to that vulnerable area is noted and it is having 1.293 sq.km. Followed by low vulnerability were shrimp farm activity is 0.216 sq.km. Only less area of shrimp farms is observed in high vulnerable and it is about 0.093 sq.km. The above results clearly suggest that the impact of salinization, due to shrimp farming along the region were independent and it is a natural phenomenon.

.

ACKNOWLEDGMENT

The author likes to thank Dr. P. Ravichandran, former Head, CCD Division and Dr.A.G.Ponniah, former Director, Central Institute of Brackishwater Aquaculture (CIBA), for providing facilities for conducting this research. Also author wish to thanks for financial support in the form of Senior Research Fellowship from Ministry of Water Resources (MoWR), Government of India, New Delhi, India.

REFERENCES

[1] FAO 2009, Fish Stat fishery statistical collections: aquaculture production (1950–2007; released March 2009). Rome, Italy: Food and Agriculture Organization of the United Nations. See http://www.fao.org/fishery/statistics/software/fishstat/en.

[2] J.P.Lobo Ferreira and A.G. Chachadi AG (2005) Assessing aquifer vulnerability to saltwater intrusion using GALDIT method: Part 1 – Application to the portuguese aquifer to Monte Gordo, Proceedings of this 4thInterselticColloquim on Hydrol. Mangt. Water Resor., Portugal.1-12.

[3] A.G.Chachadi and J.P.Lobo-Ferreira (2001) Seawater intrusion vulnerability mapping of aquifers using GALDIT method. COASTIN: a coastal policy research newsletter, TERI, New Delhi. http://www.teriin.org/teri-wr/coastin/newslett/coastin4.pdf.

[4] L. Aller ,B. Bennet, J.H.Leher, R.J.Petty ,G. Hack (1987) "DRASTIC: A Standardized System For Evaluating Ground Water Pollution Potential Using Hydrogeological Settings," EPA 600/2-87-035, 1987, p. 622.,

[5] M.G. Rupert (2001) "Calibration of the DRASTIC Groundwa-ter Vulnerability Mapping Method," Ground Water, Vol. 39, No. 4, 2001, pp. 625-630. doi:10.1111/j.1745-6584.2001.tb02350.x.

[6] J.P. Lobo-Ferreira, A.G Chachadi, D.Catarina, C. Diamantino, M.J.Henriques (2005) Assessing aquifer vulnerability to seawater intrusion using GALDIT method: Part 1. In: IAHS and LNEC proceedings of the fourth interceltic colloquium on hydrology and management of water resources, Portugal.

[7] V. Lenin Kalyana Sundaram, G.Dinesh,G. Ravikumar , D.Govindarajalu (2008) Vulnerability assessment of seawater intrusion and effect of artificial recharge in Pondicherry coastal region using GIS, Indian Journal of Science and Technology, Vol.1 No 7 (Dec. 2008).

[8] M.Santha Sophiya, Tajdarul H. Syed (2012) Assessment of vulnerability to seawater intrusion and potential remediation measures for coastal aquifers: a case study from eastern India. Environ Earth Sci (2013) 70:1197–1209, DOI 10.1007/s12665-012-2206-x.

[9] S.Shahid, S.K.Nath (2002) GIS integration of remote sensing and electrical sounding data for hydrogeological exploration. Journal of Spatial Hydrology, 2, pp 1–10.

[10] C.R.Ramakrishnaiah,C.Sadashivaiah, G.Ranganna (2009) Assessment of Water Quality Index for Groundwater in Tumkur Taluk, Karnataka State, India, E-Journal of Chemistry, 6.(2)., 523-530.

[11] T.L.Saaty and L.G. Vargas (2000) Models, Methods, Concepts and Applications of the Analytic Hierarchy Process, Boston: Kluwer Academic Publishers.

[12] D. Machiwal,M.K. Jha, B.C.Mal (2011) Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. Water Resour Manag 25(5):1359–1386.

[13] S.Kaliraj, N.Chandrasekar, N.S.Magesh (2013) Identification of potential groundwater recharge zones in Vaigai upper basin, Tamil Nadu, using GIS-based analytical hierarchical process (AHP) technique. Arab J Geosci DOI 10.1007/s12517-013-0849-x.

[14] P.Mahalakshmi,A. Panigrahi ,T. Ravisankar, J.Ashok Kumar , B.Shanthi (2014) Multi criteria decision making for identification of optimal location for aquaculture development, Proceedings of 4th IRF International Conference, Chennai, 9th March-2014, ISBN: 978-93-82702-64-1.

[15] APHA (2005) Standard methods for the examination of water and waste, 19 th ed. Public Health Associations, Washington, Am.

[16] A. Chowdhury, K.Madan,C.V.M Jha (2010) Delineation of Groundwater recharge zones and identification of artificial recharge sites in West Medinipur district using RS, GIS and MCDM techniques. Environ Earth Sci 59:1209–1222.

[17] T.L.Saaty (1987) The Analytic Hierarchy Process: McGraw Hill.1-287.

[18] P.Mahalakshmi and K.Ganesan K (2009) Relative importance of evaluation criteria for predicting the optimal location in aquaculture – a pairwise comparison method approach. Indian Journal of Fisheries, 56 (4), 313-316.