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Spatial Modeling of Water Quality in South Asian Semiarid Region

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Abstract:

The Aquifer Vulnerability Assessment in Thamirabarani river basin is the study demarking the pollution zones in GIS environment using DRASTIC model. Protecting and controlling water resources are the need of the hour to meet out the challenges of increasing in population and demand on water. Development in agriculture, urban, and industrial activities are the major contributing factors which contaminate the groundwater at the study area. An attempt was made to study and identify aquifer vulnerability zone in Thamirabarani river basin by implementing Geographic Information System-based DRASTIC model. This study identifieshighlyprone zones to groundwater contamination occupying most of the study area, which alerts the Thamirabarani river basin management people to take mitigation measurements against the pollution sources. This model identifies three vulnerability zones, namely, low with 60 to 80 indices, medium with 80 to 120 index and high with 120 to 150 indices. The output of the study gives a better approach for understanding the quality of the basin groundwater and to identify the vulnerable area in Thamirabaraniriverbasin.

***Keywords:** DRASTIC, groundwater, vulnerability, river basin, GIS.*

1. Introduction

The importance of groundwater for society cannot b e exaggerated.

Across both the urban and rural parts of India, drinking water is sourced mainly from groundwater aquifers. (Rahman, 2008),(Jesiya and Gopinath, 2019).

Water source for the agriculture and industry; gives necessary information's about the semiarid environment and alluvial Aquifer (Abdeslam, Fehdi and Djabri, 2017). The usage of ground water utilization projections is about 50%.In India, majority of the groundwater is used forirrigation and industrial purposes. Thus, an idea about Aquifer vulnerability is an essential factor in watershed management.(Thirumalaivasan *et al.*, 2019). Groundwater is essential for the most of urban and ruralcommunities to have a decentralized water source, which cannot be overestimated (Hasan *et al.*, 2019). Human activities on the earth are causes major pollution on this precious resource. It eventually gives a weightage of DRASTIC calculation (Pacheco *et al.*, 2015). over-exploitation causes aquifer contamination in some instances (Pacheco and Sanches Fernandes, 2013).The aim is to illustrate the use of the Geographical Information Systems and DRASTIC as an effective strategy for analyzing the vulnerabilities of polluting groundwater. Ground water vulnerability relies majorly on agriculturalpractice in using pesticides and fertilizers. Another main issue in cities and agricultural fields in India for groundwater contamination is industrial effluent and municipal wastewater (Muhammad *et al.*, 2015). DRASTIC is a well-established model to identify risk in groundwater. (Ckakraborty, 2007),(Rahman, 2008)(Ahmed, 2017).Several DRASTIC models have been executed for various study areas, albeit

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the identification and developing the vulnerability maps of the Thamirabarani Basin is the principal objective of this research.

2.Methodology

2.1 Study Area

Thamirabarani River is named as Tambaraparani which rises from the Western Ghats in Tirunelveli district of south Tamil Nadu, India. The river originates from in Agasti Hill an altitude of 2000 meters above MSL, which is a part of the Annamalai Ranges in south India. The river flows through the Tirunelveli and Tuticorin districts of Tamil Nadu, India. The Thamirabarani River enters the Gulf of Mannar of the Bay of Bengal near Palayakayal, Tamil Nadu, India. The length of the river is 130 kilometers, and the latitudes and longitudes lie between 8.21' N and 9.13' N and 77.10'E. Figure 1 illustrates the research area index map.

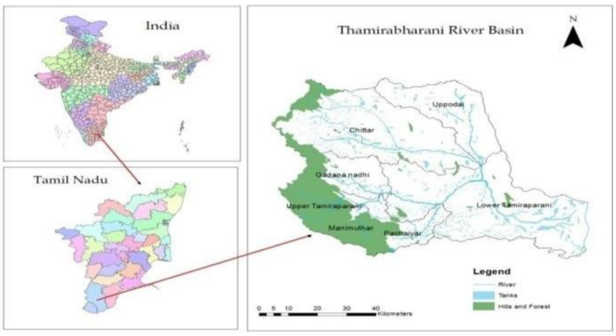

Fig. 1 Study area Index map

A geospatial empirical model called the DRASTIC model is created to meet the objectives of this study. DRASTIC is an index model that willlead to groundwater vulnerability sources from the study area by combining various thematic layers in the GIS environment. The United States Environment Protection Agency (USEPA) introduced the DRASTIC model to identify the contaminated zones in groundwater aquifers.This model generates a numerical index through rankings and weight assigned to the model's seven parameters.For each parameter, the mainstream media types or groups reflect the ranges from 1-10 based on their relevant impact on the risk in the basin.The required data were collected from the Tamil Nadu Public Works Data Centre. In GIS, the Inverse-distance weighted (IDW) interpolation technique is adapted to compute the accumulated recharge in the area of study of this research work.And the DRASTIC index is computed accordingly. The accuracy of the data was assessed using the primary data collected from the same observation of the sample points. The parameters are later allotted with weights varying between 1 and 5, based on their comparative significance.

$$DI=A_RA_W+T_RT_W+I_RI_W+C_RC_W+S_RS_W+D_RD_W+R_RR_W \quad (1)$$

Where, A=Aquifer media;
R=Net value of Recharge;
D=water depth;
S=Soil media;
I= Vadose region mediaimpact;
T=Topography/slope;
C=Aquifer Hydraulic Conductivity;
Subscriptions ' r 'weightsand ' w ' rankings.

2.2 Water Depth

The water depth is the parameter which measures the deviation of the water table value from thesample pointelevation. The corresponding rates to the depth of water table is tabulated in Table 1.

SERIES (m)	***RATE***
0-1.5	9
1.5-4.5	10
4.5-9.0	6
9.0-15.0	3
15.0-22.5	4
22.5-30.5	1
>30.5	1

Table 1 water depth

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2.3Aquifer media

It is necessary to transfer groundwater in the aquifer system to find time for impedance procedures, such as sorption, sensitivity and dispersion.Contaminant movement is regulated by interconnected fracturing, porosity, or sequence of openings.The aquifer media is categorized into four regions namely, porous sediments, Igneous sediments, meta sediments and alluvium.

Table 2 Aquifer Media

SERIES	*RATE*
0-50	1
50-100	2
100-175	5
175-255	7
>255	10

2.4 Net Recharge

Net Recharge (R) helps to indicate the surface water infiltration into the groundwater table. The slope % to the study area is computed with the aid of Digital elevation model (DEM). For the study area Soil permeability is calculated based on soil type, and recharge index is calculated from the average rainfall. The recharge values range from 2 to 9. The rate of net recharge is represented in Table 3.

Table 3 Net Recharge

SERIES	*RATE*
ALLUVIAL	9
POROUSSEDIMENTS	5
IGNEOUS/METAMORPHIC	4
METASEDIMENTS	2

2.5 Soil Media

Soil is perceived to be the weathered top layer on earth at 1.8 m or less.The groundwater recharge, absorption, and therefore pollutant movement has a notable impact on the soil.The range and ratescorresponding to soil media is presented in table 4.

Table 4 Soil Media

SERIES	*RATE*
RED SANDY SOIL	9
GRAVEL	10
SAND	8
DEEP RED SOIL	6
SHRINKING CLAY	7
SANDY LOAM	8
ALLUVIAL SOIL	3
BLACK SOIL	5
LATERITE SOIL	2
NO SHRINKING CLAY	1

2.6Hydraulic Conductivity

Hydraulic conductivity is defined as the Aquifer materials' capacity to transport water which is obtained from test dataof pumping.This study area's hydraulic conductivity is sound as from 2.16m/day to 17.76m/day.Spatial hydraulic conductivityis obtained from Geological survey of India map data which is tabulated as follows in table 6.

Table. 6 Range and Rates for Hydraulic Conductivity

SERIES	*RATE*
<4.0	1

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4.0-12.25	2
12.25-28.50	3
28.50-41.00	5
41.00-85.00	7
>85.00	10

The weights allotted to different variables are given in the table below 7.

Table 7 Weights Assigned to DRASTIC Parameters

VARIABLE	***WEIGHT***
Water Depth	3
Net-Recharge	5
Aquifer	2
Soil	1
Hydraulic Conductivity	3
Vadose Zone	6
Topography	2

2.7 Unsaturated zone

The unsaturated area above the water table is marked as Unsaturated region.Soil horizon and rock next to the aquifer, gravel cum sand, gravel, clay cum sand and clay are labeled as the vadose region of the areaof study shown in Table 5.

Table. 5 Vadose zone Impact

SERIES	***RATE***
CONFINING LAYER	1
SHALE	3
SANDSTONE	3
W. SILT	7
SILT/CLAY	2
LIMESTONE	4
SAND AND GRAVEL	4
BEDDED LIMESTONE	5
BASALT	10

2.8 Topography

The topography plays major role in pollution transport, where there are low the slope, the runoff will be little, and there will be a greater potential for pollution. On the other side, when the slopes are steep, there is high drainage capacity, and low groundwater contamination potential.Using satellite data from Cartosat a topography / slope map of the proposed study area was developed.

3. Result and Discussion

To investigate Thamirabarani River basin's unique groundwater vulnerability, the first thing to consider is the effect on groundwater of agricultural input variables. Although some regions belong to vulnerable nature fields that are not readily contaminated, their vulnerability to groundwater is also powerful due to the effect of human operations, such as the outskirts of Tirunelveli town and Palayamkottaitown, which have elevated groundwater contamination values. The effect of unique vulnerability variables should therefore be considered. The final DRASTIC index is generated by overlaying of all DRASTIC thematic parameter in a GIS environment. The DRASTIC index is determined by overlaying, the concentrations and weights components of all seven factors to measure the potential for contamination.The calculated DRASTIC index will help us identify the region that are more likely to have potential for pollution.Vulnerability ranges were classified on the basis of DRASTIC index values and were below 80 as low, 80-120 moderate, 120-150 high.

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The concluding intrinsic vulnerability of zonation map of this research work area is mapped and presented in Fig. 2. The regions that comprise the medium and high classifications are more prone to pollution and thus more attention needs to be given.Because the weights assigned are subjective, the low-pollution area identified in the study area is still prone to groundwater contamination, but its exposure is less than the area marked as extreme in the DRASTIC model.

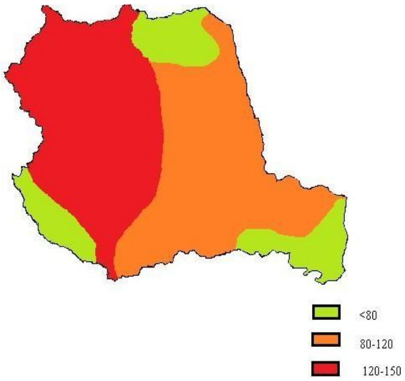

Fig.2 Vulnerability potential map

4. Conclusion

In this analysis an attempt was made to determine the insecurity of aquifers in the basin of the Thamirabarani River using the DRASTIC model.To produce the aquifer hydro-geological configurations, seven risk factors were considered.These findings show that the index of vulnerability present in the research area varies from 64 to 150.It is divided into three main categories, respectively the low, medium and high-risk areas.Farming is intensive in this province, fertilizer input is dense, and the possibility of nitrate pollution is significant.The groundwater map's vulnerability potential indicates some parts of the central region and western region come under high risk, it also identified as medium risk in eastern areas.Therefore, the risk map provides assistance in determining influencing factors those are more vulnerable to the contamination of groundwater.This study confirms the possibility of using the DRASTIC method as a method of evaluating the vulnerabilities in groundwater management.

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