A CATASTROPHIC DRASTIC APPROACH FOR GROUNDWATER POTENTIAL ASSESSMENT IN TIRUNELVELI DISTRICT, TAMILNADU

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Abstract- The evaluation of the vulnerability of groundwater is considered to be a crucial factor in todays environment due to the depletion of groundwater resources. In this article, a catastrophic drastic approach for the assessment of potential of groundwater in Tirunelveli district, Tamilnadu, India is analysed. The map indicating the overall groundwater potential is obtained utilizing geographic information system and the analysis of hydrogeological parameters are performed. Adopting the catastrophic concept, the parameters are assigned with fuzzy membership function instead of weights to obtain normalized maps. The potential of groundwater is classified depending on the ability of recharge and the total percentange acconts to 30% of the complete area which equals to 170 km^2 and a moderate coverage area of groundwater is obtained as 383 km^2.

Keywords: groundwater, geographic information system, DRASTIC, Aquifer, 3D tool.

1 INTRODUCTION

In many countries around the world, groundwater contributes freshwater to meet consumption requirements in agricultural, manufacturing, domestic, and for maintaining ecosystems [1, 2]. It is a readily accessible source of consumable water in developing nations like India. The drinking water sector in world countries including India is heavily reliant on aquifers. Currently, groundwater supplies 85 percent of rural domestic needs. With the enormous negative effect of contaminated water on health, India's consumption towards fresh water has been increasing over the last few decades [3].

People use groundwater for various activities such as consumption, farming, and industrial use all over the world, making it a vital resource for humanity's survival. Its pollution has always been a major concern for such practises, and in recent years, it has piqued the interest of academics, government officials, and environmental organisations. In contrast to surface water, groundwater is less susceptible to pollution. Since, the rate of purification which is natural is slowed due to the quantity of discharge of industrial effluent into the atmosphere, industrialization and urbanisation posed a significant warning to supplies of water [4-6]. As a result, using tools for aiding the blocking of polluting groundwater is a demanding and a necessary strategy. The capacity of groundwater vulnerability assessment to recognise regions which are increasingly subjected to be polluted due to anthropogenous issues surface has been recognised. Establishing these areas pave the way for its utilization towards proper regulation of land usage as well as rigorous monitoring to avoid contamination of groundwater supplies [7-9].

The two categories of vulnerability of groundwater are : intrinsic as well as specific vulnerability. The facileness of introduction of a contaminant in the surface of ground and its penetration alon with diffusion is known as intrinsic vulnerability. The term specific vulnerability describes how vulnerable groundwater is to particular pollutants [10, 11] Vulnerability or contamination risk of ground water must be assessed before any strategy for maintaining groundwater supplies and protecting these water bodies from pollution is implemented.

Groundwater vulnerability is evaluated utilizing a variety of techniques, including(1) overlay index methodology,(2) process-dependent schemes, (3) statistical approaches. A collection of subjective scores and a weight-allocating scheme are among the overlay index methods. Process-dependent schemes model flow of contaminant as well as locomotion in the subsurface. Furthermore, statistical techniques vary from basic statistics for description to increased intricated analyses of regression that combine explanatory parameters for determining significance of impaired parameters on vulnerability of groundwater [12-16]. The outputs in these cases are vulnerability maps capable of representing numerous as well as complicated hydrogeological characteristics in an incorporated as well as clear manner, and is easily rendered as well as utilized as a realistic factor for planning of urban, safety zone description, and assessing risk [17].

To aid vulnerability analysis, a geographic information system (GIS) provides tools for managing, processing, analysing, mapping, and spatially organising data. It is a reliable method for evaluating the outcomes of different management options but the uncertainities of the assessment are not addressed [18, 19]. Groundwater vulnerability mapping may indicate regions that are highly vulnerable regarding pollution. Maps of aquifer vulnerability are a useful tool for the regulation of groundwater as well as security. Groundwater risk maps are useful for evaluating the ability towards improved quality of water along with improvements regarding agriculture practises and applications of land usage, as well as for protecting groundwater resources [20].A commonly adopted technique to assess the groundwater resource vulnerability is DRASTIC. DRASTIC controls the moving of pollutants in an aquifer by using hydrogeological factors. Despite its widespread use, the original DRASTIC model has never been validated against field measurements like groundwater nitrate concentrations [21-24].

The contributions of this study are given as,

- Assessment of the hydrogeological parameters to find out the contamination nature of groundwater.
- Geostatic modeling and catastrophic DRASTIC technique has been carried out for predicting the groundwater potential.

The arrangement of paper is: Section 2 elucidates the related works. Proposed framework is presented in section 3. Results and discussion are explained in section 4. Finally, work summary is given in section 5.

2 RELATED WORKS

Abdelwaheb et al [25] presented a study of vulnerability in which maps for risk pollution were generated utilizing an analysis of GIS dependent decision with many criteria and the validation of outputs was done adopting nitrate concentration. Eight appreciation criterias were choosed and rating was given to these criterias in a single general range utilizing fuzzy enabled membership functions. Analytic Hierarchy Process (AHP) is exploited for weighting the assessment of factors.

Nerantzis et al [26] studied the DRASTIC approach and performed its modification for estimaing vulnerability as well as risk of pollution of penetrable aquifers with nitrate. The aquifer's factors, soil as well as impact were replaced by quantitative parameters. In addition, each parameter's class range as well as concluded index were altered utilizing the correlation of nitrate concentration with four grading approaches.

Ata et al [27] presented a Supervised Intelligent Committee Machine (SICM) framework for assessing the vulnerabilities of groundwater indices of an aquifer. The training of these models were carried out for modifing or conditioning their DRASTIC index values by estimated concentration of nitrate-N. The framework of Ardabil aquifer indicated that the index for vulnerability from DRASTIC generated fronts which are sharp and the AI smoothened the fronts as well as improvingly correlated with attained data of nitrate.

Stefania et al [28] proposed an approach in which the natural as well as anthropogenic factors were combined for identifying areas showing crucial icorporation of higher levels as well as increasing trends of concentration of nitrate. Specifically, this methodology determined the potential impacts over groundwater resources since natural factors are varying with climatic or anthropogenic conditions.

Alper et al [29] introduced a procedure for calibration whicht resulted in the assessment of vulnerability of groundwater in a more accurate manner. The enhancement of assessing was established as an optimizing issue for parameter utilizing an objective parameter dependent on the correlation within original contamination of groundwater a well as data of vulnerability index.

Mohammad et al [30] prepared the maps for vulnerability of Shiraz aquifer utilizing DRASTIC index of composite type, index for nitrate vulnerability, as well as artificial neural network and their effectiveness were compared. The index factors exploited in this research were weighted, rated, as well as incorporated utilizing GIS, further, utilized for developing the risk maps.

3 PROPOSED METHODOLOGY

3.1 Materials and Methods

The figure 1 indicates the process flow of the proposed methodology. Initially, the study area is analysed and the required data is collected. The approach is studied environmentally and hydrogeological investigation is performed. Next, the vulnerability of the ground water is anlaysed and applied to the proposed DRASTIC model. The vulnerability map and the map of land usage are obtained along with the map of ground water risk contamination. The vulnerability map is applied to the map of land usage for accessing the risk map of ground water contamination. Utilizing these maps, the projects for the protection of water resources and its quality are established. The groundwater resource is protected by evaluating the area which is more susceptible to contamination. A map indicating the protection zone priority is established and help to planners as well as decision makers is offered. The possible contamination of groundwater is monitored and these vulnerability maps are utilized for hydrogeological learning. The risk maps are utilized for protecting the resources of groundwater from possible risks.

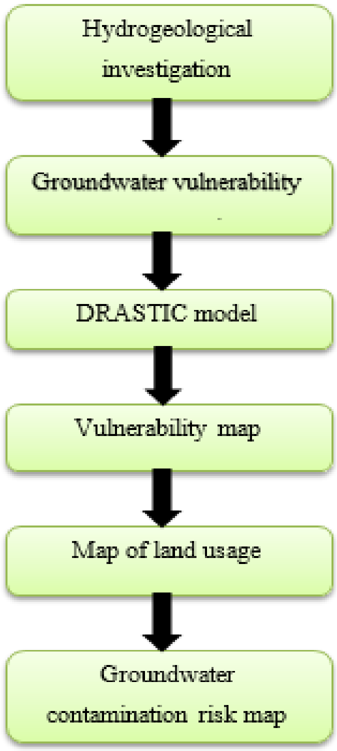

Figure 1 Process flow of the proposed method

The geographical coverage of Tirunelveli in Southeastern Tamil Nadu is 6,759 sq.km and resembles the shape of a triangle. It locates within 8°.05' as well as 9°.30' N and 77°.05' as well as 78°.25'E. It is situated in southern Tamil Nadu and is bounded in north by Virudhunagar district, in west by Western Ghats, in south by Kanyakumari district, in east by Tuticorin district. Tamiraparani river is the major source of water feeding the district. The climate is extremely sunny in May as well as June with an increased temperature of 45°C. Major usage of land as well as land coverage of the district is agriculture which in turns gives a wide range of crop land.

Figure 2 indicates the map of Tirunelveli district. Tables 1 and 2 indicates the data obtained for before monsoon as well as after monsoon respectively in Tirunelveli district.

Table 1 Data obtained for pre-monsoon

Sample	Min	Max	Average	STD
pH	6.8	8.2	7.320	0.3201
TDS (mg/L)	94	1268	802.420	330.598
TH (mg/L)	53	662	338.54	149.202

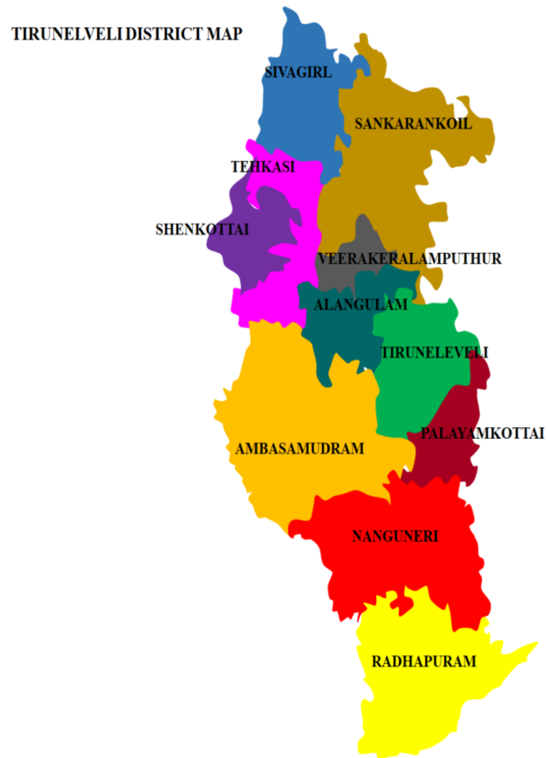

Figure 2 Map of Tirunelveli district

Table 2 Data obtained for post-monsoon

Sample	Min	Max	Average	STD
pH	7.1	8.6	7.772	0.36643
TDS (mg/L)	276	2238	975.054	575.291
TH (mg/L)	135	1296	496.420	352.073

3.2 Catastrophic DRASTIC Approach

The DRASTIC methodology depends on considerations like,

- A watershed comprising a flatter relief as well as area greater than 0.4 km^2.
- Location of potent factors for contaminating the surface.
- Infiltration process occurs during which the potent contaminants move from the surface to aquifer.
- Vulnerability index does not depend on the type and nature of potent contaminants.
- The porous media make up the aquifer model and the climate is semi-arid to arid.

The index in the DRASTIC methodology is estimated by,

$$DRASTIC\ index = D_r * D_w + R_r * R_w + A_r * A_w + S_r * S_w + T_r * T_w + I_r * I_w + C_r * C_w$$

In which, D_r , D_w → rating and weight of water table depth,

R_r, R_w → rating and weight of net recharge
A_r, A_w → rating and weight of aquifer media
S_r, S_w → rating and weight of soil media
T_r, T_w → rating and weight of topography
I_r, I_w → rating and weight of vadose zone impact
C_r, C_w → rating and weight of hydraulic conductivity

These parameters possess a particular variability range which is dependent on the parameter's effect over pollution.It indicates the susceptibility of contamination and the increased vulnerability index is present in increased sensitivity ground water area to be contaminated.

The hydrogeological parameters regarded in the DRASTIC methodology are given as follows.

3.2.1 Depth of Water Table

It indicates the static range depth of the aquifer estimated from the surface of the soil. It controls the transfer of pollutant and the contamination possibility. When the water table depth is minimum, the vulnerability is maximum. Classification of the depth of groundwater table is performed in a range as given by DRASTIC concept with the range of 1 indicating the minimal impact of vulnerability to 10 indicating the maximal impact of vulnerability. Minimal rate indicate deeper groundwater table.

3.2.2 Net Recharge determination

It indicates the infiltrated water quantity reaching aquifer. The recharge of groundwater is a major process which involves transferring of contaminant from soil to underground. Features like permeability of soil, rainfall and slope are considered and these play a major role in determining recharge component. While considering GIS, return flow of irrigation is added for generating recharge value. It is give by,

$$Recharge\ value = permeability\ of\ soil + rainfall + slope + return\ flow\ of\ slope$$

3.2.3 Analysis of Aquifer Media

It indicates the porous as well as permeable geological formation serving as hydrogeological server. The flow of groundwater considers the permeability, porosity and aquifer transmissivity.

3.2.4 Analysis of Soil Media

The soil type regulates the process of infiltration as well as recharge of aquifer. It also influences the percolation of contaminant from the surface. It is determined utilizing the soil properties like texture, soil classes, structure and colour.

3.2.5 Analysis of Topography

It denotes the topography present over the aquifer.The probability is regulated by the slope enabling diffusion of pollutant in the surface. It is developed utilizing the topography map of the ared to be studied in the form of digital elevation model. The sensitivity rates are assigned based on the nature of the slope.

3.2.6 Impact of Vadose Zone

It denotes the temporarily unsaturated portion of aquifer. The pollutant's transfer facility is influenced by the lithology of vadose zone media.

3.2.7 Hydraulic Conductivity analysis

It indicates the aquifer capacity for conducting water and performs controlling of infiltration as well as dispersing of pollutant from the surface of the soil to the reservoir. The hydraulic conductivity is calculated by,

$$C = Td^{-1}$$

In which, C → hydraulic conductivity ms^{-1}
T → transmissivity in m^2s^{-1}
d → aquifer thickness in m

This methodology is superimposed to geological settings indicating its efficiency. As a result of interpolation, the hydraulic conductivity map is attained and transferred to raster grid as well as multilplied by the weighting factor.

3.2.8 Usage of Land

For introducing the usage of land factor, the corresponding map is transferred to raster grid as well as multiplication is performed with weightage. The resulting grid is added and then, the research region's vulnerability map is created with the overlay of all parameters generated using GIS environment.

The drastic weights assigned to the features are given in table 3.

Table 3 Drastic weightage

Features	Weightage
Water table depth	4
Soil media and hydraulic conductivity	3
Land use and cover	2
Parameter	1

The subjectivity of the traditional DRASTIC approach is minimized by the catastrophic method of decision making. Here, the assignment of weights is replaced by fuzzy membership function through normalization approach. The flowchart for the catastrophic methodology is given in figure 3.

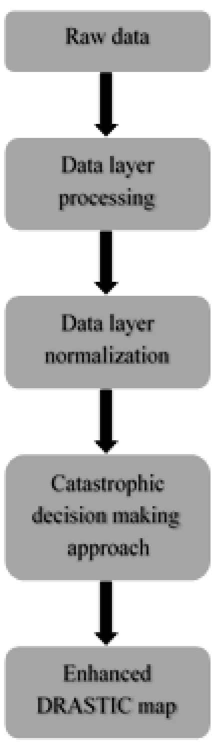

Figure 3 Flowchart for catastrophic methodology

Initially, the data required for preparing DRASTIC layers are obtained either in raw form or as statistical data which is discrete in nature. Pre-processing is performed to convert its discrete nature to continuous. Further, normalization is performed to solve the issues due to absence of dimensions in unit as well as non location of band in similar layer ranges.

Considering the layers of directly proportional,

Normalization, $Q_i^n = \frac{Q_i - Q_{min}}{Q_{max} - Q_{min}}$

For layers of inversely proportional,

Normalization, $Q_i^n = \frac{Q_{max} - Q_i}{Q_{max} - Q_{min}}$

In which, $i \rightarrow$ arbitrary cell counter

Q_{max} , $Q_{min} \rightarrow$ maximal, minimal parameter value

$Q_i^n \rightarrow$ i[th] normalization value

Following normalization, the total count of the control parameters are identified with their classification number. Then the catastrophic functions of each layer are selected and a fuzzy membership function is defined to every layer. Finally, the parameters are assigned with mean value termed as weights and analysis of parameters is performed to obtain normalized maps.

4 RESULTS AND DISCUSSION

4.1 Slope Analysis

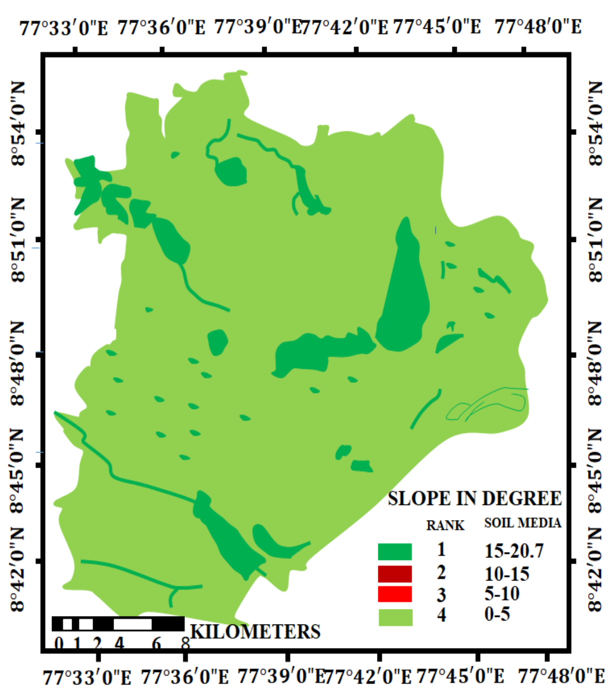

Figure 4 Slope map

Figure 4 indicates the slope map of Tirunelveli district. If the terrain slope is high in a particular area, then the potential of groundwater is very low. The water which is precepited in that area gets drained. Considering Tirunelveli, the slope percentage varies from 0 to 21%. It allows minimal runoff indicating improved potential of groundwater.

4. 2 Usage of Land

Usage of land is aterrain surface parameter affecting infiltration as well as surface runoff. The district has a maximum coverage of agricultural land of about 310 km^2 and water bodies coverage of about 52 km^2. The water bodies at surface and the land for agriculture are better for the recharge of groundwater.Waste land of about 28% ie available with minimal potential of groundwater. The forest coverage is upto 20 km^2. Figure 5 indicates the land usage map of Tirunelveli district.

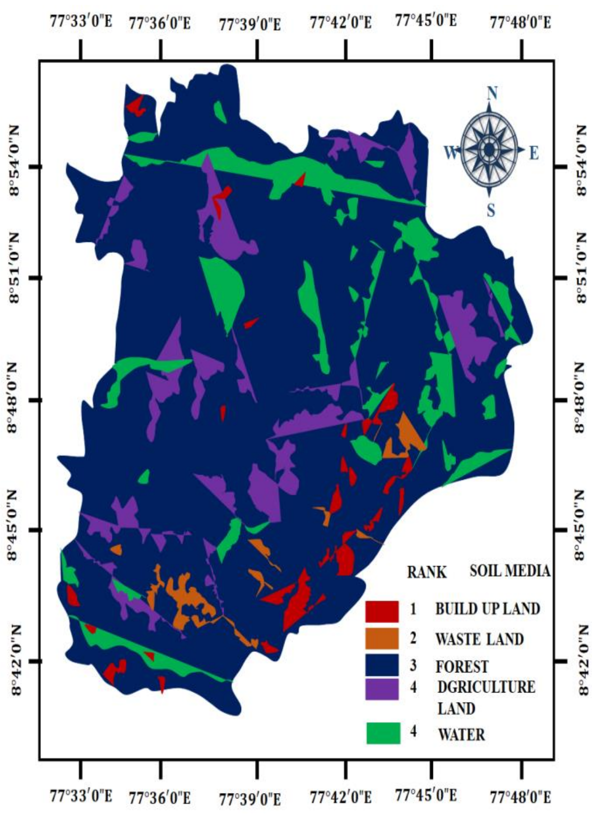

Figure 5 Land Usage Map

4.3 Analysis of Soil

The figure 6 indicates the analysis of soil. The group with increased ability of infiltration is considered highly suitable for ground water. It includes entisols of

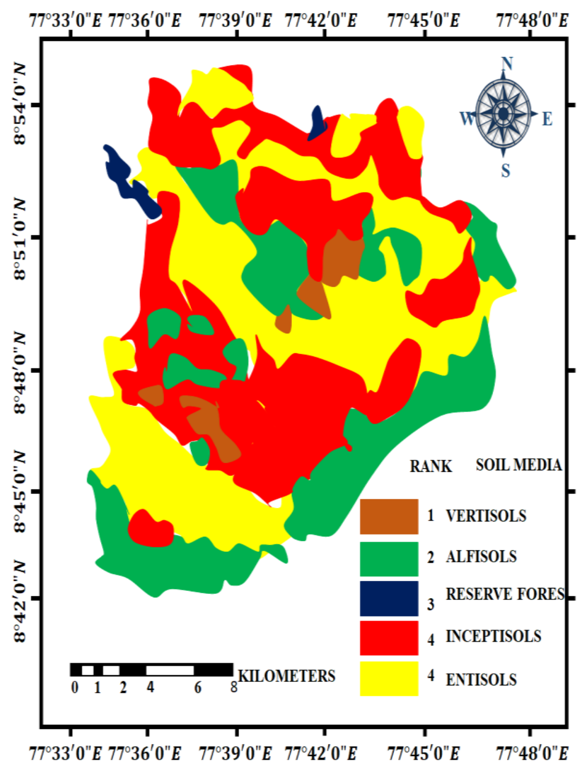

Figure 6 Soil map

219 km^2 as well as inceptisols of 190 km^2. The group with moderate potential of groundwater comprises of alfisols with 129 km^2.

4.3 Potential For Groundwater

Figure 7 indicates the map for groundwater potential. Depending on the capability of recharge and other specific parameters, the potential for groundwater is classified as moderate, good and very good. The zone with improved potential covers about 5.75 km^2 comprising of red sandy soil as well as black soil.

The potential zone which is good occupies about 30% of the complete area approximately equal to 170 km^2. The potential area which is moderate extends upto 383 km^2.

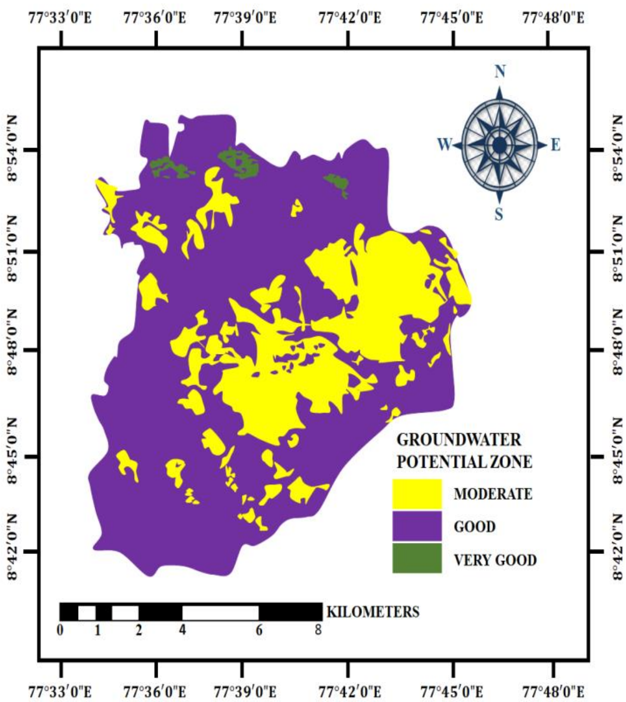

Figure 7 Map for groundwater potential

5 CONCLUSION

The ground water potential of Tirunelveli district, Tamilnadu, India is analysed and the related hydrogeological factors are investigated. A catastrophic DRASTIC approach is utilized to obtain the normalized map for the groundwater potential exploiting GIS. Various impacts of the parameters like soil, usage of land as well as slope are analyzed and the groundwater potential is investigated. Finally, the total coverage zone for good groundwater is obtained as 30% which equals to 170 km^2 and a moderate coverage area of groundwater is obtained as 383 km^2.

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