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Assessment of Groundwater Vulnerability in Coimbatore South Taluk, Tamilnadu, India Using Drastic Approach

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Abstract- Assessment of groundwater vulnerability using DRASTIC model in GIS environment has become more widespread for effective groundwater resource management. A study was carried out in Coimbatore south taluk, Tamilnadu, India to develop a empirical model DRASTIC to identify the vulnerability index owing to groundwater contamination with increasing population, industrialization and agricultural activities. The most important mappable factors that control the groundwater potential are depth of water, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity of the aquifer. Estimation of DRASTIC Index involves multiplying each parameter weight by its rating corresponding to its study area and summing the total. Based on DRASTIC index values it was observed that the vulnerability class in the study area falls between low vulnerability to high vulnerability. The results provide important information for the local authorities and decision making personals for effective management of ground water resource.

Index Terms- Groundwater, Vulnerability, DRASTIC Index, Coimbatore South taluk

I. Introduction

Water is the basic element of social and economic infrastructure and is essential for healthy society and sustainable development. 97% of Earth's water is in the form of saline water present in ocean and only 3% of fresh water is available [1]. It is scientifically proved that 68.7% of fresh water is found to be stored in the form of glaciers and icecaps and 30.1% is available in the form of groundwater. Groundwater is one of the valuable earth's renewable resources for human life and economic development, which occur as a part of hydrologic cycle [2]. Amongst the natural water resources, groundwater forms an invisible component of the system. In last 50 years it is observed that development of groundwater resources is unpredictable. An estimated 2 billion people worldwide rely on aquifers for drinking water supply. The annual utilizable groundwater resources in India are estimated as 428 km^3 per year. This accounts for about 80% of domestic water requirement and more than 45 % of the total irrigation requirements of the country [3].

In recent years, the utilization of groundwater is increasingly at a faster rate which leads to the depletion of groundwater. On the other hand contamination of groundwater due to various anthropogenic sources is growing at faster rate, so that it is no longer fit for a use for which it has previously been suited. This resulted in increasing pressures on available groundwater resources in terms of both quality and quantity. The quality of groundwater depends on a large number of individual hydrological, physical, chemical and biological factors. Prevention of contamination is therefore critical for effective groundwater management [Jamie Bartram and Richard Ballance, 1996]. To properly manage and protect the resource, it is therefore important to determine areas with more aspects of vulnerable to contamination. Groundwater vulnerability is considered an intrinsic property of groundwater that depends on its sensitivity to humans and natural impacts and can be defined as the possibility of percolation and diffusion of contaminants from ground surface into the groundwater system [4].Vulnerability maps have become an essential tool for groundwater protection and environmental management [5]. Several methods have been proposed for vulnerability assessment of aquifers. This paper presents a standardized system DRASTIC approach which incorporates physical characteristics of any area into a methodology which can be used to evaluate the groundwater vulnerability of any hydrogeologic setting.

II. Study Area

Coimbatore is an important district in western part of Tamilnadu and the Coimbatore South Taluk falling in the southwest part of the district. The study area falls between North latitudes 10^{o}50'0'' to 11^{o}0'0'' and East longitude 76^{o}40'0'' to 77^{o}0'0'' (Fig. 1) and covers an area about 767.64 km^2. It is well connected with adjoining towns and almost all the villages of the area are approachable by roads.

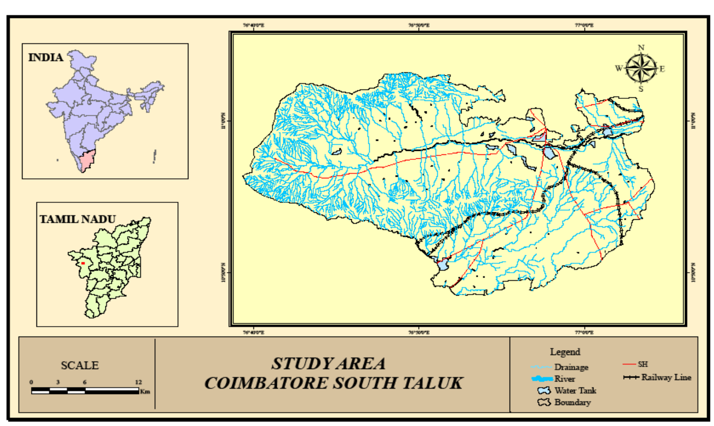

Fig.1 Location map of the study area

Generally a sub-tropical, climatic condition prevails in this area. The maximum temperature ranges from 36ºC to 41ºC and the minimum temperature varies from 14ºC to 31ºC. The mean daily temperature during summer varies from 33ºC to 40ºC and the mean daily temperature during winter varies from 15ºC to 31ºC. Rain occurs during South-West and North-East monsoons. The north-east monsoon contributes the maximum of 328.2mm during October to December. The average annual rainfall of this district is 647.2mm from four distinct seasons [6]. The Coimbatore district is bounded on the west and south by steeply rising mountains of Western Ghats. Of these, the Nilgiris on the Northwest and Anaimalai on the south are important rages, which attain heights of over 2500 m above mean sea level (MSL) and the highest elevation in the plains adjoining the hills is 600 m above MSL. In between the hill ranges, east-west trending mountain ranges are traversing and it is known as Palghat gap. Besides these western ghat ranges, the other hills of the district are Vellingri and Boluvampatti hills which is located in our study area i.e. in Coimbatore South taluk. The Vellingris are the spurs of the Nilgiris mountain lying on the west and north-west of the district. Boluvampatti hills lies on the north-eastern side of the district. The Coimbatore South taluk is bounded with Vellingri and Boluvampatti hills on the north-eastern side. The Noyyil river has its origin in the Boluvampatti valley of the Vellingri hills and called as the Swami Mudiyar. The Noyyil river is ephemeral and remains dry for a major part of the year. Further south, it joins with Periyar and Chinnar. Then it takes east – northeast course and forms the boundary of Coimbatore and Avinashi Taluk. About 5km east of Coimbatore, the river takes north-eastern course in Tiruppur and forms the boundary between Palladam and Erode taluks. The Noyyilriver is ephemeral and remains dry for a major part of the year [6]. Rocks are composed of minerals and amorphous solids. Since the geological set up controls the occurrence and movement of groundwater, the ability of the parent rock to store and transport groundwater is of great importance for its occurrence. Water quality parameters controlling the occurrence of groundwater to a large extent are porosity, hydraulic conductivity, transitivity etc. The major rock types occurring in the study area are fissile hornblende biotite gneiss, sand and silt, granite, amphibolites, metagabbro, pyroxenite, pyroxene granulite, charnockite, garnet sillimanite – graphite gneiss, calc-granulite and limestone and pink migmatite [6]. Knowledge of land use and land cover is important for many planning and management activates and is considered an essential element for modeling and understanding the earth as a system. Land cover maps are presently being developed from local to national to global scales. Satellite image have been utilized for land use/land cover mapping [6]. The spatial distribution of land use/land cover of the study area is given in Table 1.

Table 1 Detail of Land Use / Land Cover in Study Area

Types of Land Use / Land Cover	Area (km^2)	% of area
Barren Rocky/ Stony Waste	4.86	0.63
Crop land	339.76	44.26
Deciduous forest	80.29	10.46
Dense forest	25.71	3.35
Fallow land	31.54	4.11
Forest Blanks	4.49	0.58
Forest Plantations	22.46	2.93
Gullied/ Ravenous Land	3.27	0.43
Industrial	1.86	0.24
Land with scrub	3.31	0.43
Land without scrub	1.06	0.14
Mining process	0.72	0.09
Open forest	19.92	2.59
Plantations	100.36	13.07
Quarries water	0.22	0.03
Recreational	0.54	0.07
Reservoir	2.04	0.27
Residential	46.74	6.09
River	3.83	0.50
Scrub Forest	56.22	7.32
Tanks	6.97	0.91
Villages	11.47	1.49
Total	**767.64**	**100**

III. DRASTIC MODEL

DRASTIC is a methodology proposed by Aller et al., (1987) which allows the pollution potential of any area to be systematically evaluated. The physical characteristics are the inherent in each hydrogeologic setting which affects the groundwater pollution potential. The most important factors that control the groundwater potential are D-Depth to water, R-Net recharge, A-Aquifer media, S-Soil media, T-Topography, I-Impact of Vadose zone and C-Hydraulic conductivity of the aquifer. These factors have been arranged to form the acronym, DRASTIC for ease of reference. In determining DRASTIC INDEX (DI) each factor has been assigned a relative weight ranging from 1 to 5, the most significant factors have weights of 5 and the least significant factor, a weight of 1 as shown in Table 2. Further, factor has been divided into either ranges or significant media types which have an impact on pollution potential. The range for each DRASTIC factor has been assigned a rating which varies between 1 (least pollution potential) and 10 (Highest pollution potential). The equation for determining the DRASTIC index is:

$$DI = D_RD_W+R_RR_W+A_RA_W+S_RS_W+T_RT_W+I_RI_W+C_RC_W \text{ ---------------------------} \textbf{ (1)}$$

Where D, R, A, S, T, I and C are the parameters, R is the rating of each parameter for the study area and W is importance weight parameter.

Table 2 Assigned weights of DRASTIC features

Feature	Weight
Depth to water	5
Net recharge	4
Aquifer media	3
Soil media	2
Topography	1

Impact of vadose zone	5
Hydraulic conductivity of aquifer	3

IV. RESULTS AND DISCUSSIONS

A numerical ranking system to assess ground water pollution potential in hydro geologic settings has been devised using the DRASTIC factor. The system contains three significant parts: weights, ranges and ratings. The weight and ratings of different hydro geological parameters of Coimbatore South Taluk has been calculated based on the pumping test data, rainfall and using various thematic maps.

Depth to groundwater (D)

The value of the variable D (Depth of water table) was obtained using pumping test data. The depth of water in the study area varies between 24 m to 44 m below the ground surface. In general, the deeper the water levels are, the longer the pollutant takes to reach the groundwater table [7]. The rating scores ranges between 1 and 3 on the basis of DRASTIC classification. The ratings assigned in the study area were presented in Table 3 and the spatial variation is shown in Fig.2 respectively.

Table 3 Range and Ratings corresponding to depth of water table

Range m	Rating
20- 25	3
25-30	2
>30	1

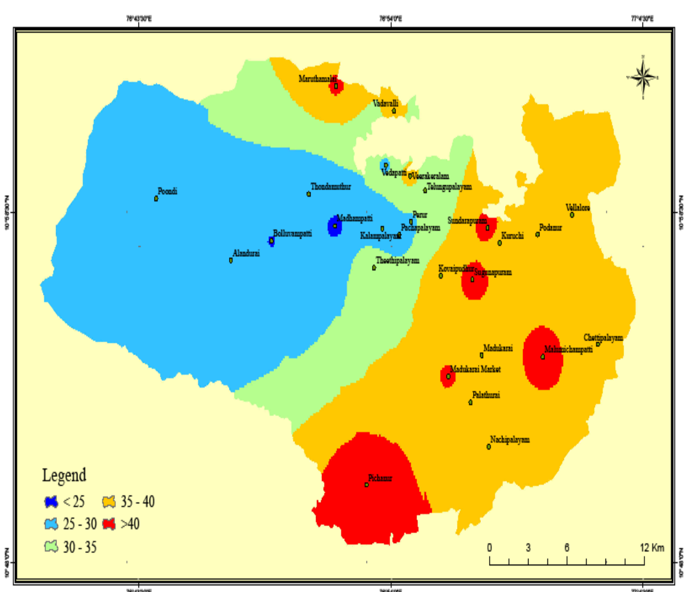

Fig. 2 Spatial distribution of depth of water table

Net Recharge (R)

Net recharge represents the amount of water that infiltrates into the ground and reaches the water table. The map incorporates available features like slope, soil permeability and rainfall, which are important for the calculation of recharge component [8]. A digital elevation model (DEM) of the study area was used to identify the slope % and soil permeability was calculated from soil type, average rainfall of the study area was used as a recharge index and the finalized recharge value was calculated and the ratings were assigned as presented in Table 4.

Table 4 Net recharge assigned to the study area

Slope		Rainfall (mm/year)		Soil Permeability	
Range	Rating	Range	Rating	Range	Rating
< 2	4	< 800	5	High	4
2-10	3			Moderate	3
10-33	2			Low	2

The recharge values observed in the study area ranges from 6 to 13. The ratings assigned to net recharge in the study area were presented in Table 5 and the spatial variation is shown in Fig. 3 respectively.

Table 5 Range and Ratings corresponding to Net Recharge

Range	Rating
0-2	1
2-4	3
4-7	6
7-10	8
Above 10	9

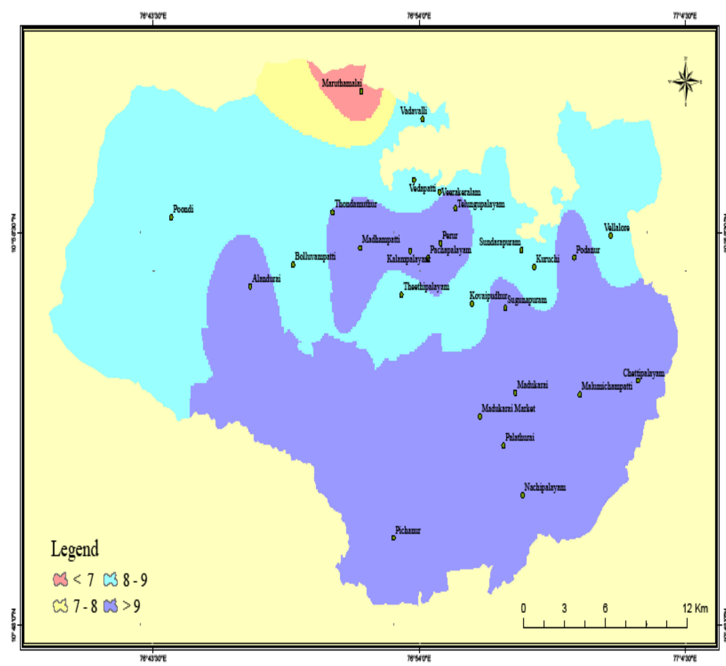

Fig. 3 Spatial distribution of net recharge

Aquifer media (A)

Movement of groundwater in the aquifer medium is important in determining the time for attenuation processes, such as sorption, reactivity and dispersion to occur along with the amount of effective surface area of materials with which the contaminant may come in contact within the aquifer. The migration of contaminants is strongly influenced by fracturing, porosity, or by interconnected series of openings. Based on the geological description of the study area, the aquifer media was classified as alluvium, porous sediments, igneous/ metamorphic and meta sediments, which has a rating of 1 to 10. The ratings assigned in the study area were presented in Table 6 and the spatial distribution of aquifer media is shown in Fig.4 respectively.

Table 6 Range and Ratings corresponding to Aquifer Media

Range	Rating
Alluvium	10
Porous Sediments	6
Igneous / Metamorphic	3
Meta Sediments	1

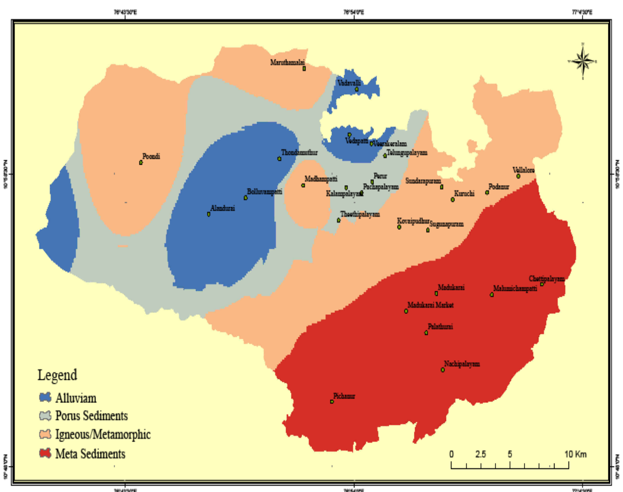

Fig. 4 Spatial distribution of aquifer media

Soil Media (S)

Soil is commonly considered the upper weathered zone of the earth which average 1.8 m or less. Soil has a significant impact on the amount of recharge allowing infiltration to the water table and hence contaminant movement. The study area is characterized by clay, sand, gravel and thin, which corresponds to ratings of 1, 8, 9 and 10 respectively as presented in Table 7. The spatial variation of soil media in the study area is shown in Fig. 5.

Table 7 Range and Ratings corresponding to Soil Media

Range	Rating
Thin	10
Gravel	9
Sand	8
Clay	1

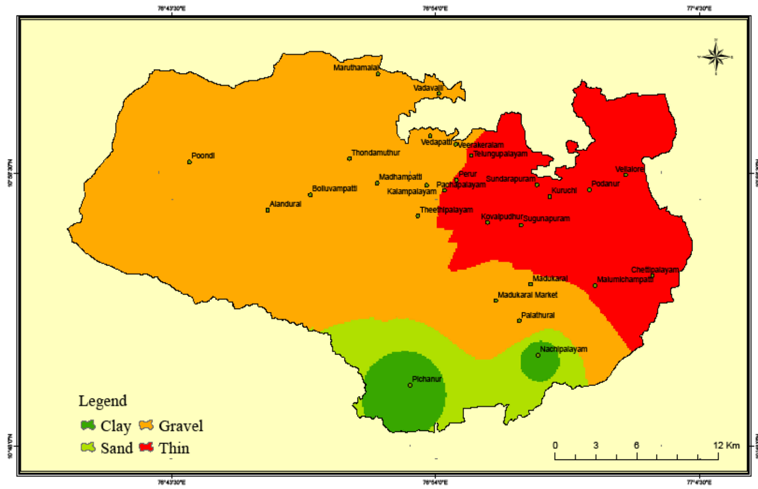

Fig.5 Spatial distribution of Soil type

Topography (T)

Topography is considered as the slope and slope variability of the land surface. Topography helps to control pollutants runoff or retention on the surface. Slopes that provide a greater opportunity for contaminants to infiltrate will be associated with higher groundwater pollution potential. The slope index, which was derived from the DEM to find the ratings for recharge, was reclassified on the basis of DRASTIC classification [9]. The ratings assigned in the study area and spatial distributions of slope were presented in Table 8 and Fig. 6 respectively.

Table 8 Range and Ratings corresponding to Topography

Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
>18	1

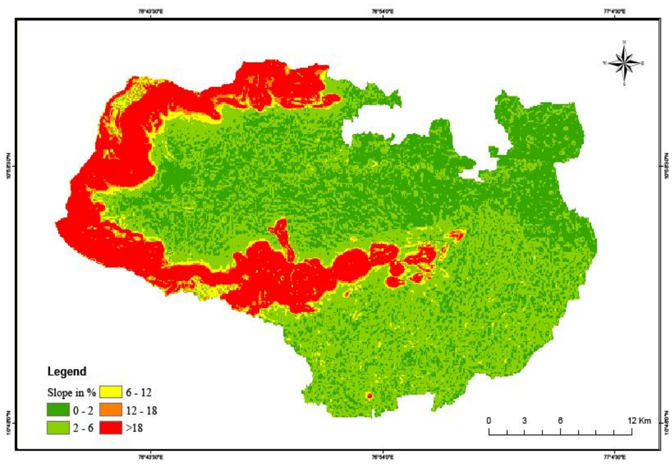

Fig. 6 Spatial distribution of slope in the study area

Impact of Vadose Zone (I)

The vadose zone refers to the zone above the water table, which is unsaturated and its type determines the attenuation characteristics of the material including the typical soil horizon and rock above the water table gravel, gravel-sand, clay-sand and clay are considered the vadose zone of the study area. According to the DRASTIC ratings the value for impact of vadose zone is shown in Table 9 and spatial variations were presented in Fig.7.

Table 9 Range and Ratings corresponding to Impact of vadose zone

Range	Rating
Gravel	7
Sand and Gravel	6
Sand	5
Clay - Sand	3
Clay	2

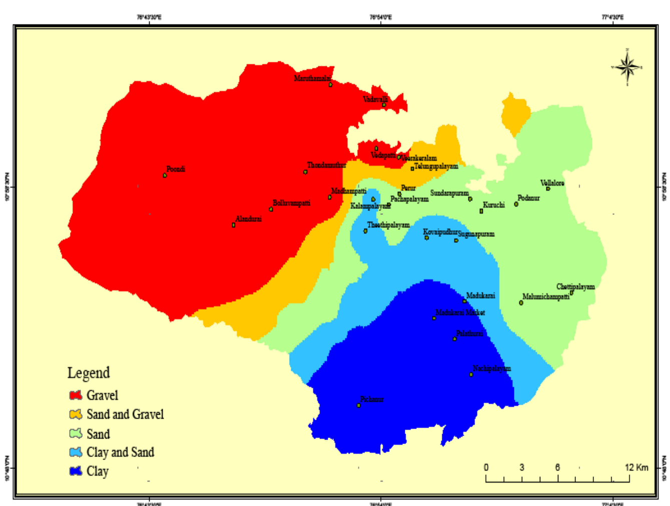

Fig. 7 Spatial distribution of impact of vadose zone

Hydraulic Conductivity

Hydraulic conductivity is defined as the ability of aquifer materials to transmit water and it is controlled by the amount and interconnection of void spaces within the aquifer that may occur as a consequence of inter-granular porosity, fracturing and/or bedding planes. For the purposes of the present study, hydraulic conductivity has been calculated from the pumping test data and spatial hydraulic conductivity map obtained from geological survey of India. The hydraulic conductivity ranges between 2.16 m/day to 17.76 m/day in the study area. The ratings based on hydraulic conductivity are shown in table 10. The spatial distribution is shown in Fig.8.

Table-7.8 Range and Ratings corresponding to Hydraulic Conductivity

Range (m/day)	Rating
<4.1	1
4.1 – 12.28	2
12.28 – 28.5	4

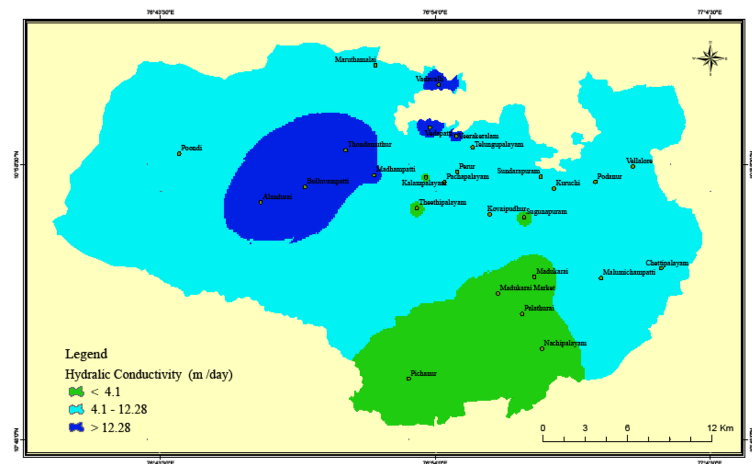

Fig. 8 Spatial distribution of hydraulic conductivity

DRASTIC Index

The DRASTIC index, a measure of the pollution potential, is computed by summation of the products of rating and weights of all seven parameters as discussed above. From the computed DRASTIC index it is possible to identify areas which are more likely to be pollution potential. The vulnerability index ranges from 64 to 150 and is classified into three groups i.e. 64-80, 80 to 120 and 120 to 150 corresponding to low, medium and high vulnerability zones respectively [10,11 & 12]. Using this classification a groundwater vulnerability potential map (Fig.9) was generated which shows that 25.93% area falls in low vulnerability zone and 51.85% falls in medium vulnerability zone. About 22.22% of the study area falls in high vulnerability zones. The vulnerability map thus generated helps in identifying areas which are more likely to be susceptible to groundwater contamination relative to one another.

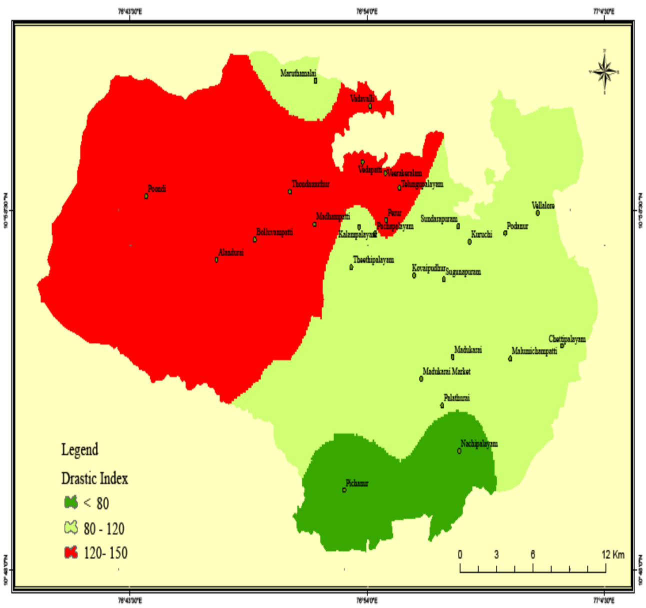

Fig. 9 DRASTIC vulnerability map

V. CONCLUSION

An attempt has been made to assess the aquifer vulnerability of Coimbatore South Taluk employing the empirical index DRASTIC model of the U.S. Environmental Protection Agency (EPA). Seven environmental parameters were used to represent the natural hydrogeological settings of the aquifer, Depth to groundwater, Net recharge, Aquifer media, Soil media, Topography, Impact of vadose zone and Hydraulic conductivity. The results shows that vulnerability index ranges from 64 to 150 and is classified into three classes i.e., 64-80, 80 to 120 and 120 to 150 corresponding to low, medium and high vulnerability zones respectively. The groundwater vulnerability potential map shows that the majority of the in western part and some areas central region fall under high vulnerability followed by medium vulnerability in the central and eastern regions of the study area. The vulnerability map thus generated helps in identifying areas which are more likely to be susceptible to groundwater contamination relative to one another.

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