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GROUNDWATER VULERABILITY ASSESSMENT USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

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Abstract: *In countries with restricted resources of water, groundwater is the only water supply for domestic, commercial and agricultural activities. During the past few years, excessive agriculture activities and fertilizer programs have resulted in pollution of groundwater which has emerged as a vital trouble. In addition to this industrial activities, the release of dangerous wastes with the aid of deep well injection has increased the pollution of groundwater. The vulnerability mapping techniques play a key function in decision making process and improving planning to identify susceptible regions and to reduce the groundwater pollution. In this paper, the ground water vulnerability is evaluated the use of 3 models: GOD, SWAT and proposed model. The GOD model is used for mapping vulnerability in huge regions. The GOD refers as Groundwater confinement, Overlying strata and Depth of floor water. The SWAT is known as Soil and Water Assessment model which is widely used for assessing water quality. In this paper a new model is proposed called, GRODS model is an aggregate of parameters of GOD and SWAT. It classifies the take a look at place into two classes of vulnerability. These models may be applied using GIS (Geographic Information System) and remote sensing tools. These maps are used to divide a place into greater classes, which are used for the identification of vulnerable areas.*

Key Words: *Water, Quality Monitoring, IoT, Cloud, Machine Learning, Decision Tree Model.*

1. INTRODUCTION:

Groundwater pollution has become one of the most serious issues in the country. In last few decades with increase in intense agriculture activities, fertilizer applications and hazardous industries have resulted the ground water contamination. Groundwater quality depends on the parameters like recharged water, atmospheric precipitation, inland surface water, and on sub-floor geochemical activities [19]. Temporal changes inside the recharged water, hydrologic and human elements may cause periodic modifications in groundwater quality. Water pollution not only affects water quality but also threatens human wellness, financial improvement, and social prosperity of an area. During past few decades groundwater evaluation has been primarily based on laboratory investigation, however the advent of satellite technology and Geographical Information System (GIS) has made it very clean to integrate numerous databases. GIS is an effective tool for developing solutions for water assets problems, assessing water quality, preventing floods, determining water resource availability, understanding the natural environment and for handling water assets in a local and regional scale. Nitrate is a crucial form of pollutants inside the groundwater system. It is one of the main contaminants associated with agricultural and industrial activities. It has excessive solubility and might reach groundwater without difficulty [1]. Thus, it can be a severe risk to groundwater resources. Therefore, the measured nitrate concentrations from monitoring wells may be used to accomplice and correlate the concentration in the aquifer to the vulnerability index [19].

The capability of a hydrological model must be predicting the result with enough accuracy for long-term hydrological scenario analysis. In India, where the variation of climate is excessive and the supply of water is constrained [10]. According to paper [18] in India, availability of annual water sources has decreased from 5176 m^3 in 1951 to 1588 m^3 in 2015, respectively, and it'll further lower to 1434 m^3 in 2025 [10]. According to USDA, Agricultural Research Service Soil and Water Assessment Tool (SWAT) model is evolved to delineate watershed and river basin evaluation analysis study [17]. The SWAT model is full of hydro meteorological datasets, to simulate the flow of rivers, the sediment and the water quality. SWAT model proved to be an effective proof to assess the land management practices in flood- plain and agricultural chemicals and water resources [6]. In various nations, SWAT model has been appreciably used as a river discharge estimator [7]. Paper [18] conducted a studies to apprehend the model performance on water sources in China. Paper [13] predict the flow and compared with the observed data in south-eastern parts of Australia. Physical and chemical characteristics of water are the essential parameters to study hydrology and its interplay with the surroundings. Increase in demand of fresh water is due to an increase in pattern of consumption and its overexploitation [7].

The ultimate goal of the present study is to assess the aquifer vulnerability of Hosur location to apprehend the susceptible areas of pollution.

1.1. STUDY AREA:

Hosur block of Krishnagiri district is geographically located in the Northern part of Tamilnadu (Fig 1), lies between 12°38’52.4” N and 12°52’7”N latitude and 77°44’11”E and 77°55’11” E longitude. It covers a total area of 275 square kilometre incorporating 30 panchayats and 89 villages with a population of 116,821 as per 2011 census. The region receives an average rainfall of 850 mm. The study area is an industrial hub comprising of major industries like Ashok Leyland, TVS Motor Company, Hindustan Motars, Titan Industry and many other small scale industries paves the way for urbanization, that leads to increase in population, industrialization and commercialization, consequently has led to scarcity of water for drinking and other usage. As there is no perennial source of water, the people are depending on groundwater for all water usage which made it essential for investigation of groundwater potential and groundwater quality. This paper highlights about groundwater modeling for potential vulnerable zones for groundwater pollution.

The field data collected for the study includes rainfall data, groundwater level data from five observation wells, and topographical data of the study area was used to analyze of groundwater quality. Topographical characteristics were analyzed using remote sensing and GIS. From the land use/land cover map, it was observed that 36 percent of land area was covered with stony waste and built up areas which do not allow water to percolate. From the rainfall characteristic study, it was observed that the mean annual and monsoon rainfall was 810 mm and 516 mm with a standard deviation of 387 mm and 314 mm and coefficient of variation of 47 percent and 55 percent respectively. Contribution of rainfall during pre-monsoon, monsoon and post monsoon were 12 percent, 84 percent and 4 percent respectively. This shows that study area receives more rainfall during monsoon season which can be effectively conserved over this period.

Figure 1. Study area with Sub basins

2. METHODOLOGY:

- *Dataset Collection:*

The data required for this system is remotely sensed images of LANDSAT 8 satellite. This can be obtained from the ESRI earth explorer. The dataset contains eleven .TIFF files each constituting bands of LANDSAT 8. The dataset is dated on march 2019. The geospatial data covers the land span of approximately 3600 sq.km.

- *Preprocessing and image enhancement:*

In this module the empty pixels are removed with the help of convolutional neural network (CNN). Then the quality of the image is enhanced for the better identification of the pixels. The comparison of images between two images are shown in the Fig 2.

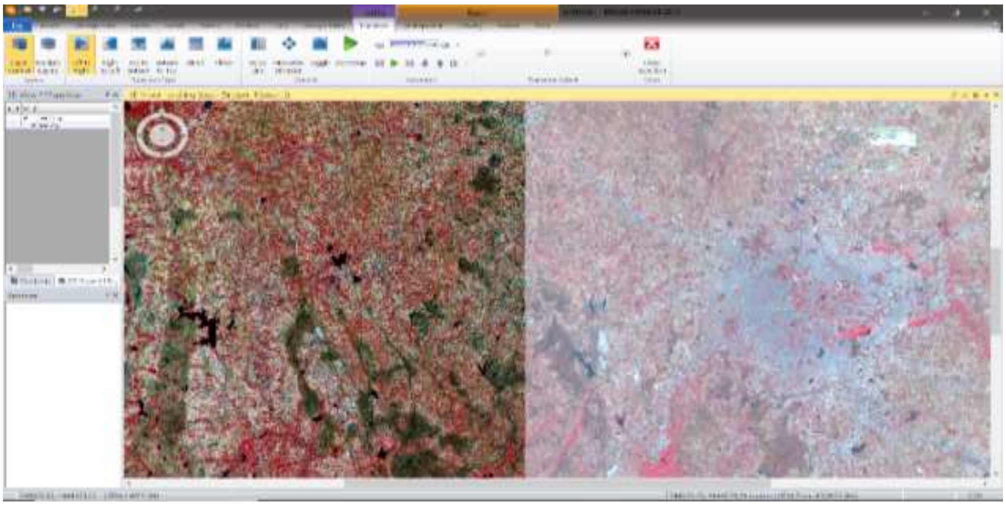

Figure 2. Image Enhancement

- *Software Requirements:*
  - ✓ **<u>ERDAS:</u>** Erdas Imagine is an image processing software package that allows users to process both geospatial and other imagery as well as vector records. Erdas can also cope with hyperspectral imagery and LiDAR from numerous sensors. Erdas also gives a 3D viewing module (VirtualGIS) and a vector module for modeling [3]. The native programming language is EML (Erdas Macro Language). Erdas is incorporated within different GIS and remote sensing packages and the storage format for the imagery can be read by different applications (*.img files). Leica Geosystems additionally bought ER Mapper to add to their mapping software program. Imagine is tightly woven into the GIS material more than other image processing software packages and that is the advantage of this package. Refer paper [9].
  - ✓ **<u>ArcGis:</u>** ArcGIS is a Geographic Information System (GIS) for working with maps and geographic data maintained by Esri. It is used for developing and using maps, compiling geographic records, analysing mapped statistics, sharing and discovering geographic facts, the use of maps and geographic data in various application, and dealing with geographic information in a database refer paper [2].
- *Models:*

In this work, the ground water vulnerability is evaluated using three models: GOD, SWAT and the proposed GRODS model.

✓ **<u>GOD:</u>**

GOD is an overlay and index method designed to map groundwater vulnerability over large regions based on three parameters (Groundwater confinement, Overlying strata, and Depth to groundwater) [5]. The information layers for models had been furnished through geographic information system. The overlap technique was used to offer and produce the vulnerability map of the study areas considering weight coefficients of every layer. The GOD model is an empirical technique for the assessment of aquifer vulnerability developed in Great Britain.

GOD = Ci×Ca×CpGOD = Ci×Ca×Cp [16]

Where in Ci, aquifer kind; Ca, saturated sector and Cp, depth.

✓ **<u>SWAT:</u>**

Soil and Water Assessment Tool (SWAT) is a river basin- scale model this is evolved to measure the effect of land management practices in large, complicated reservoirs. It deals with the subsequent elements with the hydrology model: Weather, surface waterway, return flow, water supply, ventilation, transmission loss, pond and reservoir storage, growth of crops and irrigation, underground flow, nutrients, pesticide loading, and water transfers. SWAT makes use of Hydrological Response Unit (HRU), which describes local diversity, which constitutes the land cover, soil traits, and land slope characteristics of specific land use. [8]

SWAT model is based on the principle of water balance equation:

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

where SW_t is the ultimate water content in (mm), SW_o is the amount of water content on the first soil of the day *i* (mm), *t* is time (days), R_{day} is the amount of rainfall on day *i* (mm), Q_{surf} is the amount of surface runoff on specific day *i* (mm), E_a is the amount of evapotranspiration on day *i* (mm), W_{seep} is the amount of percolated water into the vadose zone from the soil profile on day *i* (mm) and Q_{gw} is the amount of return flow on day *i* (mm) [8]. The SWAT model not only provides the water quality data but also sedimentation, plant growth information, Hydrological index and so on.

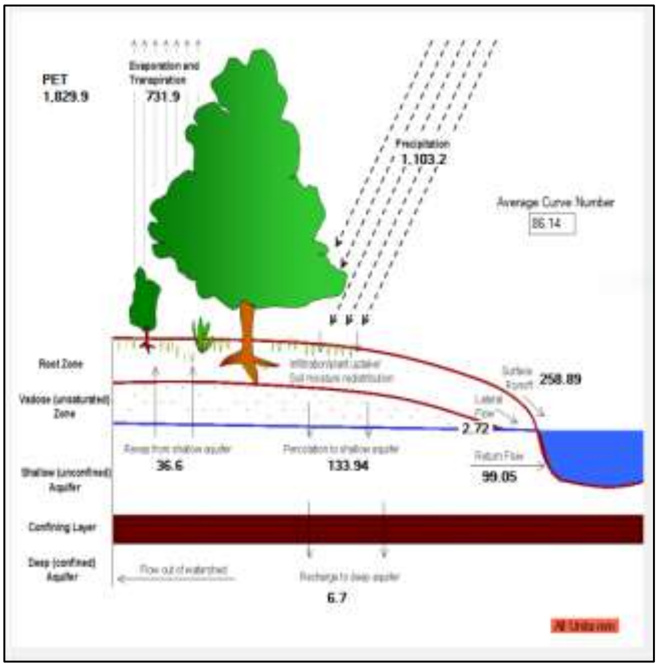

Figure 3. Hydrology of study area

In Fig 3 the Hydrology chart gives the information regarding water loss during evaporation and transpiration. It yields information about surface runoff, vadose zone and water confinement.

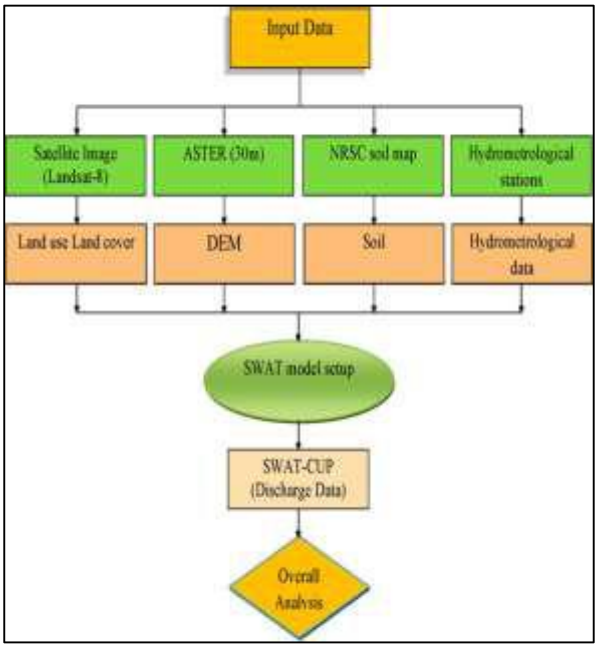

Figure 4. SWAT Framework

In Fig 4 the SWAT Framework depicts the work flow of the SWAT model. The landuse image, DEM, soil map and weather data are given as input to the SWAT model setup and it processes into a SWAT cup and yields final analysed data regarding Hydrology, water quality, Sedimentation etc.,

- ✓ **GRODS:**

The ground water vulnerability can be calculated using various models and has its own limitations. For instance, in GOD ground water vulnerability can be calculated using only three parameters and has low accuracy. In SWAT model the model focus is mainly on net recharge level of the ground water. But this proposed GRODS model uses five parameters which increases the possibility of identifying the vulnerable zones accurately. GRODS is the

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proposed model which is the combination of GOD and SWAT model. It takes the following parameters: Groundwater confinement, Rainfall data, Overlying strata (topography), Depth of groundwater and Soil data as shown in Fig 5.

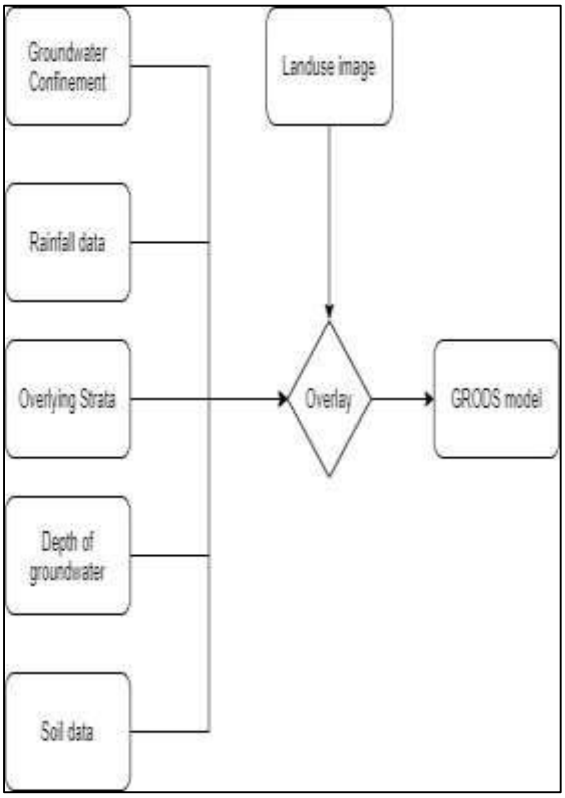

Figure 5. GROD methodology

3. RESULT AND DISCUSSION:

In this section the results of GOD model, SWAT model and the proposed GRODS model are presented.

- *GOD:*

The parameters required for GOD model are: Groundwater Confinement, Overlying Strata and Depth of groundwater. A confined aquifer is an aquifer underneath the land surface that is saturated with water. Layers of impermeable material are both above and underneath the aquifer, inflicting pressure so that once the aquifer is penetrated by using a well, the water will be pushed above the top of the aquifer. An unconfined aquifer is an aquifer whose top water surface (water table) is at atmospheric pressure, and is able to rise and fall. Unconfined aquifers are typically closer to the Earth's surface than confined aquifers, and are impacted by drought conditions earlier than confined aquifers as shown in Fig 6.

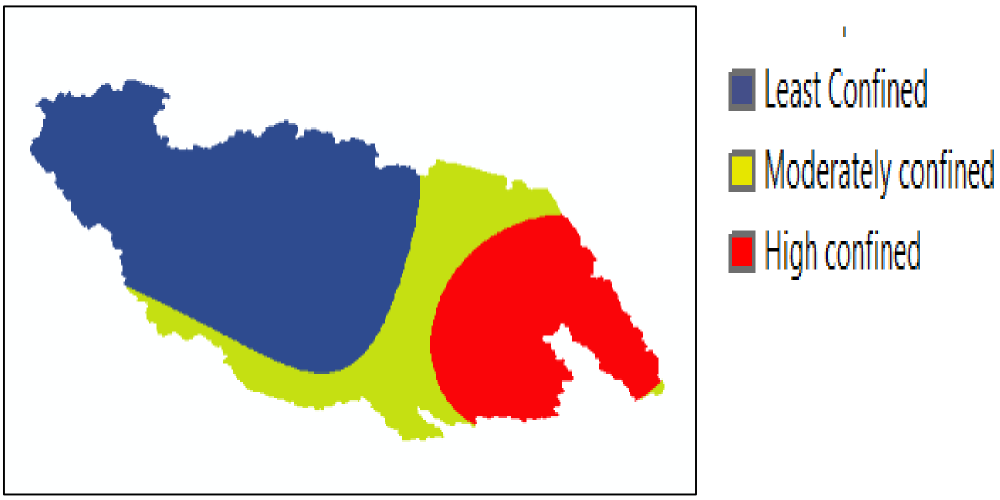

Figure 6. Confinement map

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In Fig 6 the rate of confinement increases from 1 to 3. Here the least confined zones are more vulnerable as the contaminants can easily reach the ground water than the highly confined zones. Overlying strata refers to the slope. Topography indicates whether a pollutant will runoff or continue to be long enough to infiltrate. Where slopes are high, there's excessive runoff, for this reason aquifer vulnerability is low. When slopes are under 2%, the rate of direct runoff is quite small, hence favoring infiltration and evapotranspiration [3]. In Fig 7 value 1 refers to lower slope and 3 refers to the highest altitude. The lower altitude regions are more susceptible to vulnerability because the surface run off is low.

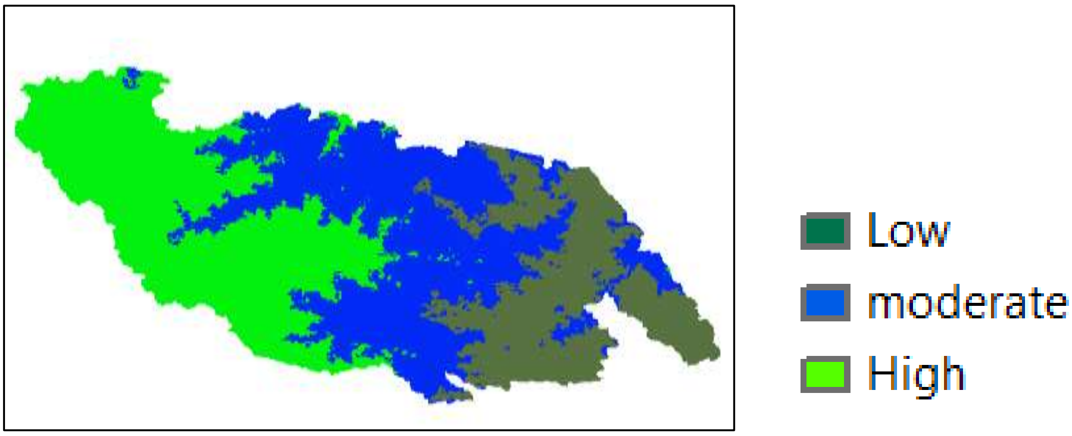

Figure 7. Topography map

Depth of groundwater represents the depth of material from the ground surface to the water table through which a contaminant travels before reaching the aquifer. The shallower the water depth, the more vulnerable the aquifer is to pollution and vice versa.

The Final output of the GOD model of our study area is represented in Fig 8.

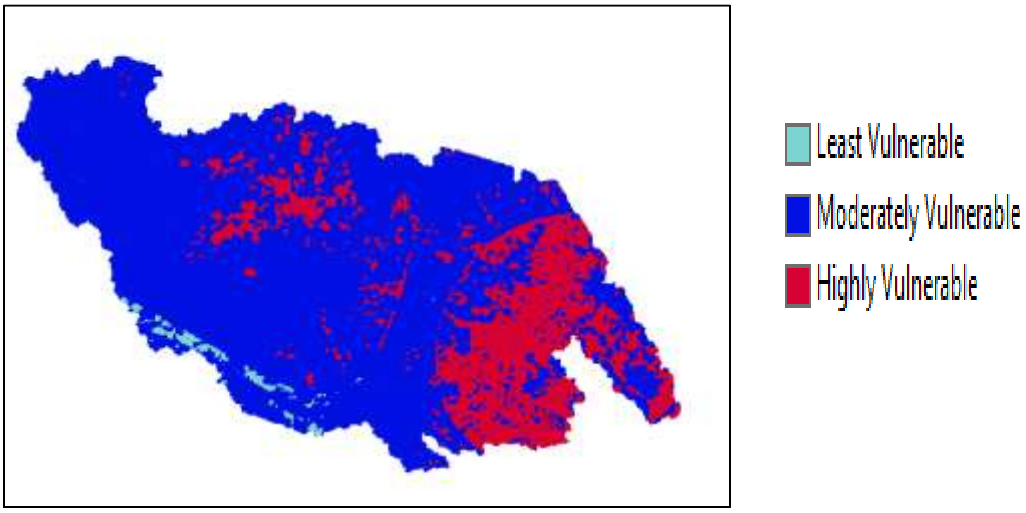

Figure 8. GOD model

From the GOD model output we can identify that the regions with lower altitude, lower confinement and lower depth are more susceptible to ground water vulnerability.

- *SWAT*:

A sensitivity evaluation has been implemented during calibration duration using SWAT-CUP to discover sensitive parameters. The hydrological size, the sensitivity evaluation plays a critical parameter that is sensitive for model performance was calibrated until a satisfied agreement among the model simulated and observed records was received the use of sensitivity evaluation technique. Surface runoff is an essential aspect of water sources which depends on SCS curve number (CN2), permeability of soil characteristic, land use and presence of water in soil.

Here the SWAT model is used to project the Nitrate in and out as well as to determine the water quality of our study area as shown in Fig 9.

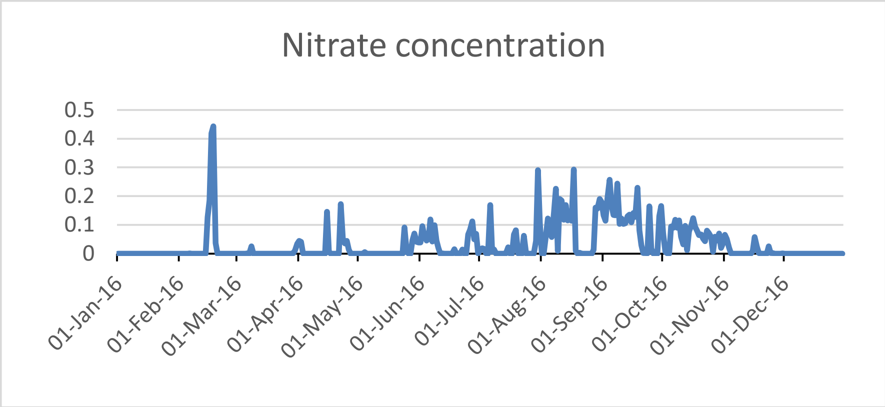

Figure 9. Nitrate Concentration (Actual Data)

The comparison between the simulated the actual values are shown in Fig 10.

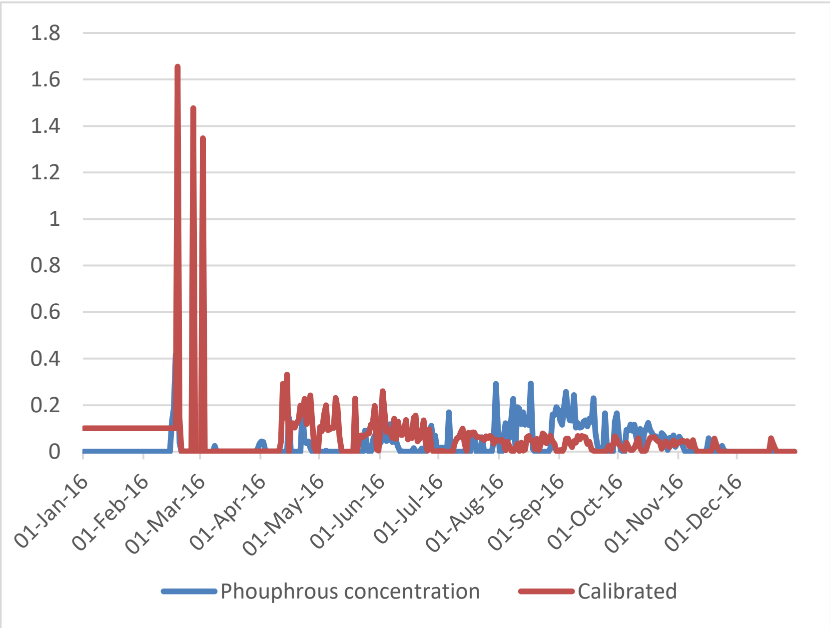

Figure 10. Actual values

In the above graph it is observed that in few months the value of experimented result is similar to the actual value. The readings from the SWAT model is used in the creation of the map for the identification of areas with low water quality as shown in Fig 11.

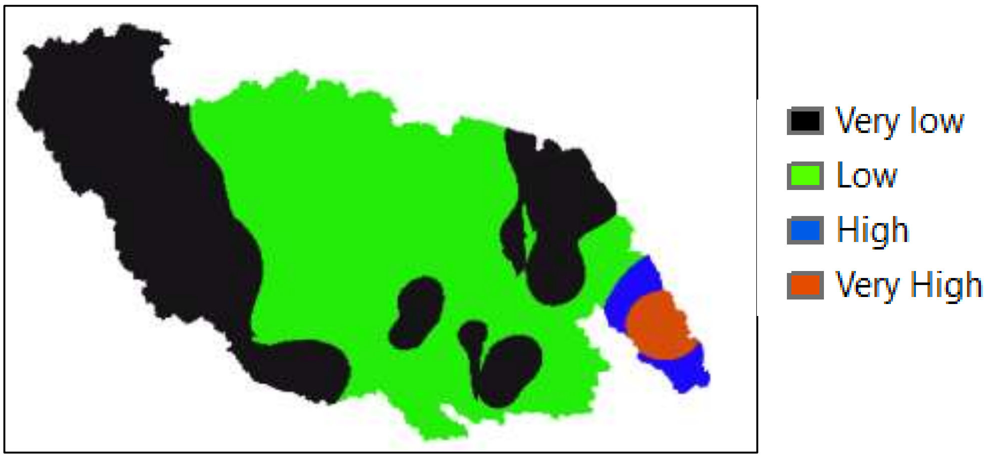

Figure 11. SWAT output

Based on the water quality data of SWAT model a vulnerable map of four classes is created as shown in Fig 11.

- *GRODS:*

The GRODS model uses the parameters such as Ground water density, Soil data, Rainfall data, Overlying Confinement on the classified landuse image on the study area.

The Rainfall data is collected from Data-Climatic Research Unit-UEA which provides high resolution gridded datasets. From this dataset the rainfall data of our study area is processed and generated in the form of tiff file which is shown in Fig 12.

Figure 12. Rainfall Map

In Fig 12 the rate of rainfall increases from 1 to 5. The low rainfall region will have low ground water and less flooded this leads to less contamination of water compared to flood potential zones. Our study area is mainly composed of clay_loam soil texture. The soil composition consists of 33% clay, 25% slit and 41% sand. The other parameters are similar to the GOD model and this model splits the study area into two classes has areas with more vulnerability and less vulnerability. The output of the GRODS model is shown in Fig 13.

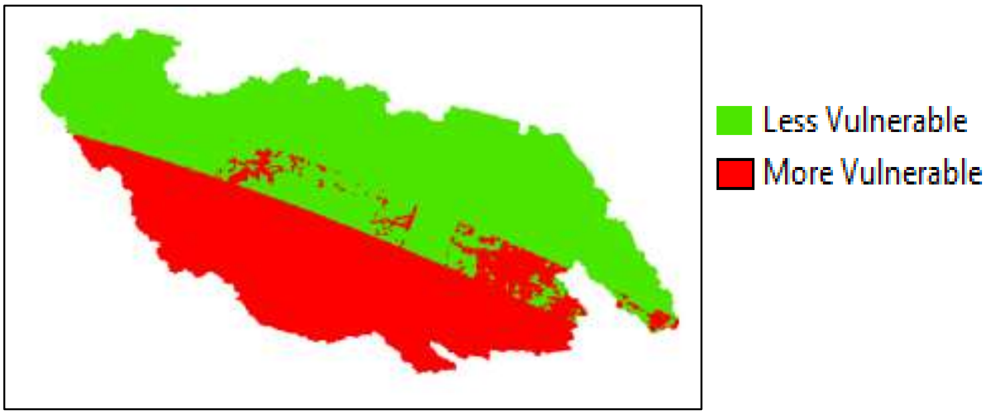

Figure 13. GRODS Model

In GRODS model the vulnerable zones would be in the region with highest rainfall and least altitude.The GOD model is suitable for regions with larger area yet since it takes fewer parameters the accuracy for identifying potential vulnerable zones is low. Whereas SWAT is a tool for conducting soil and water analysis on the study area. But it mainly, focusses on identifying groundwater recharge. Therefore, the GRODS model takes the parameter from the both and identifies the vulnerable risk zones with greater potential as shown in Fig 13. Therefore, with the proposed model the vulnerability potential areas are identified. The comparison between parameters of various vulnerability models are depicted in Table 1.

Table 1: Comparison of Parameters between models

Parameters	GOD	SWAT	GRODS
Depth	✓	×	✓
DEM	✓	✓	✓
Confinement	✓	×	✓
Soil	×	✓	✓
Weather	×	✓	×
Rainfall	×	✓	✓
Landuse	✓	✓	✓

4. CONCLUSION:

Water resources are becoming increasingly scarce, so especially in industrial regions like Hosur located at Krishnagiri District in northern Tamilnadu, which is considered as an economic resource priority because it is used in irrigation and domestic consumption. The GIS techniques are used to identify contamination risk by mapping. The databases which are behind all layers can anytime be updated. Also, the use of GIS facilitates the rapid visualization of some elements in the map by selecting them from the attribute table. The vulnerability maps, contamination data and groundwater quality can be used because of the rapid and correct evaluation of pollution risk. The overall results show that the region at the lower altitude are more prone to pollution because the water at the higher altitude are washed off at the lower plain.

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