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GROUNDWATER PREDICTION UNDER THE TERRAIN AREA USING COMPUTATIONAL INTELLIGENCE APPROACH

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ABSTRACT:
Groundwater is the prime natural resource for the living beings to survive on the earth surface. Water may be available in various resource form like rain water, sea, rivers, groundwater etc. but the major available resource is water available under the ground (earth surface). Due to increasing population in India, people are suffering with water crises. Groundwater may be recharged and reused but to maintain the human living balance, there is need to find more resources of groundwater. In this paper, we are using computational intelligence approach for the prediction of groundwater under the terrain area without digging the bore well. For this prediction, we have considered six attribute (Lineaments, Geology, Landform, Landuse, Soil type and slope) based dataset. Groundwater will be predicted as the possibility to be higher, normal (intermediate) or low. This dataset is case sensitive data. So, case based reasoning is applied for the prediction along with computational intelligence concept. In computational intelligence concepts, fuzzy logic is used with their if-else rules based system. The selection of fuzzy logic for groundwater prediction is presence of values in the form of fuzziness of the approach.The overall method is evaluated using the parameters of sensitivity, specificity and accuracy.

KEYWORDS: Groundwater Prediction, Terrain Area, Case Based Reasoning, Fuzzy Logic, Optimization

I. INTRODUCTION

India is the one of the oldest civilization on the earth with a population of more than one billion. It occupies an area of 329 million hectares. Though India occupies only two percent of the total land surface available; it is home to about fifteen percent of the earth's population. The climatic conditions of India are unique in the sense that the country has a distinct rainy season starting from June to October [1]. It is estimated that the annual rainfall in India is about 400 million hectare meter. However less than twenty percent of it is utilized, the remaining reaches the sea or it evaporates. Although there is plenty of water but still many areas in the country remain drought prone. Due to improper planning of water conservation today, India is ranked 122 out of 130 nations in terms of water quality and 132 out of 180 nations in terms of water availability. Water is exceptionally supreme for not only humans but for plants and animals as well. There is no single "magic bullet" that can resolve this rising water deficiency problem. One of the major resources of fresh water on the earth surface is ground water. On the earth surface, groundwater is available in very less amount. Due to unseasonal rain on earth surface, people usually depend upon groundwater [2]. Therefore, groundwater is an important commodity which is having uses for various purposes such as agricultural, industrial and domestic use but with the increase in population its resources are depleting and hence the necessity to find its resources arises [3]. Water contamination is also responsible for the lesser availability of fresh groundwater. Water contamination refers to the impure state of water which is caused by pollution or any other poisonous substance [4]. The use of contaminated water is extremely harmful for health and it cause many diseases. It is one of the major environmental issues worldwide. There are numerous factors which are increasing the pollution level day by day and thus making water contaminated [5][6]. Some of the factors responsible for the contamination of water are Industries, domestic waste, Agriculture pesticides, insecticides, animal wastes etc. and Municipal Waste

In India, most of the rural population depends on ground water for their source of drinking water. The Central Ground Water Board run by Ministry of Water Resources, River Development and Ganga Rejuvenation has issued Ground Water monitoring report January 2016 [7]. In the report, the water level fluctuation is shown from January 2015 to January 2016. According to the report, the total number of 13244 wells were analysed and out of which 35% of wells i.e. approximately 4570 wells have shown rise in water level and 64% of the total wells i.e. approximately 8446 wells have shown a fall in their water level. And the remaining 228 wells i.e. 2% have shown no change in their water levels. This states that in most of the wells the level of ground water has fallen down [8].

So, there is the great need to predict the groundwater resources. The considered concept uses case based reasoning along with fuzzy logic to predict the groundwater possibility under the terrain area. Groundwater is explored for the different land cover features in the form of possibility of low, intermediate and high results. The overall resultsare calculated using the parameters namely Specificity,Sensitivity and Accuracy.

The structures of the other sections of the paper areas mentioned. Section II presents the work related to the groundwater prediction under the terrain area. Section III brief about the considered basic concepts of case based reasoning and Fuzzy Logic, Section IVpresents the considered dataset with the explanation of their attributed, Section V discuses about proposed concept, Section VIshows the calculated results based on the considered parameters and Section VII concludes the paper.

II. RELATED WORK

This section presents the work related to groundwater prediction under the terrain area.

Kaur et al. [9] have reviewed the different methods existing for the exploration of ground water. They have reviewed different approaches like cuckoo search, swarm technology, WA-SVR model, case based reasoning etc. The drawback that the author has stated in this paper is the lack in familiarity with the accuracy of the results according to any expert knowledge. *Jethi et al.* [10] have analysed various approaches to identify the possibility of ground water. The authors have analysed techniques like Swarm Intelligence, Artificial Neural Network (ANN), Robotic Perception Based and many more. They have considered different soil attributes to detect the presence of ground water without digging any bore. The basic concept consists of considering the expert dataset along with the user queries. Then the weight map function of the soil attributes along with user query is evaluated. The optimized case is determined and then it is matched with the expert dataset to get the exact possibility of the presence of ground water.

Gao et al. [11] have done a feasibility study to detect the flow of ground water by estimating the Radial Anisotropy of surface waves. For the detection of the flow of the ground water by Radial Anisotropy two waves are considered SH- wave also known as Love wave and the other wave is SV- wave also known as Rayleigh wave. With the help of both the waves the depth as well as the direction of flow of ground water can be detected. *Saintenoy et al.* [12] have used Ground Penetrating Radar to determine the groundwater table depth and to monitor the shallow water infiltration. During the use of transition of GPR reflection data from unsaturated to saturated soil, proposed tool approximate the soil water retention curve. The geophysical tool is validated with huge resolution GPR data and retains the retention curve.

Suryanarayana et al. [13] have proposed an integrated approach of Wavelet transform model and Support vector Machine for the detection of groundwater level. Data has been decomposed into wavelet series using the discrete wavelet transform with two coefficients. The method proposed namely Wavelet-Support Vector Regression (WA-SVR) has been used for predicting ground water level variations for wells of Visakhapatnam, India viz, Sivajipalem, Madhurawada and Gullalapalem. Based on the statistical parameters and error percentage, the proposed concept shows better results as compare to SVR, ANN and ARIMA but still need of improvement for better accuracy.

Balamurugan et al. [14] have concentrated on Ground Water Potential Mapping (GWPM). The frequency ratio (FR) model is considered for the mapping of the Leh valley. The eight feature vectors considered play a key role in the ground water mapping. The feature vectors considered are: hydro geomorphologic features, ground water level, drainage density, lineament density, lineament, geology, slope, land cover and land use. The mapping area is categorized into five classes according to the presence of ground water. The classes are very high, high, moderate, low and very low. Along with the mapping the authors have also focused on land use and land cover. *Mogaji et al.* [15] have focused on the prediction of the zones having potential of the ground water. The zones considered for the experimentation are the southern areas of Perak situated in Malaysia. The proposed prediction model is based on the EBF i.e. evidential Belief function theory of Dempster-Shafer. In order obtain a prediction model with high reliability the attributes considered are soil type, slope, average annual rainfall, lithology, lineament intersection density, lineament density and drainage density. *Manap et al.* [16] have considered the Langat basin area situated in Malaysia for the prediction of the ground water. For the experimentation, the authors have considered frequency ratio (FR) model based on the probability values. The dataset considered for the experimentation is collected from the different Malaysian Government agencies and eight different attributes are considered depending on the geological data, topographic data etc. The factors considered are namely land use, soil, geology, lineament density, river density, curvature, slope and elevation. *Marker et al.* [17] have worked on ground water uncertanity prediction model based on the hydrological surface structure. The authors have considered the airbone electromagnetic data (AEM) and applied the model to the Kasted site situtated in Denmark. For the experimentation, the attribute values derived from the geophysical, lithological and hydrological data are considered.

III.BASIC CONCEPTS

This section describes the Case Based Reasoning and Fuzzy Logic.

A. CASE BASED REASONING

Case-based reasoning is also aComputational Intelligence based approach but it works differently as compare to other AI based approaches in the manner that CBR uses previously experience based knowledge instead of solely dependent on problem domain, their description and available resources. The previous experienced based knowledge is considered as the cases for the problem solution. These cases are considered as the iterations to solve the problem. Another advantage of CBR approach is have the incremental solution for each time due to repetition of results improved which leads to overall higher efficient solution of each problem. [18].

The internal structure of CBR mechanism is categorized into components: case reasoner and the case retriever [19]. The appropriate cases in the case base can be retrieve by case retriever and further case reasoner uses the retrieved cases to find the solution of the problem [20]. This reasoning process generally involves both determining the differences between the cases retrieved and the current case, and modifying the solution to reflect these differences appropriately. The components of CBR system are as shown in figure 1.

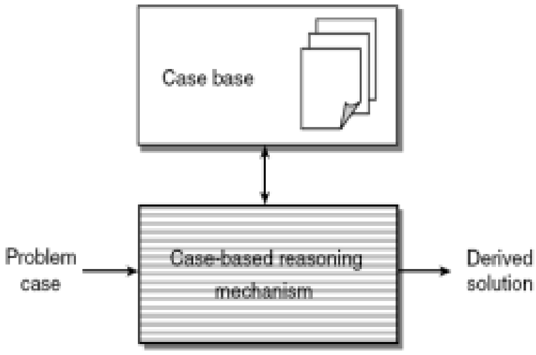


Figure 1: Case Based Reasoning

B. FUZZY LOGIC

The concept of fuzzy logic was introduced by Zadeh during his seminal work of 'Fuzzy Sets'. During this work, he defined the mathematical form of fuzzy set theory and furthers the extension of fuzzy logic concept [21]. This theory came into existence by introducing various new concepts of reasoning and partial existence of a membership function. The partial existence of the membership function means to have the value of values partial True and partial False and that can function over the range of real numbers [0, 1]. For the generalization of classic logics, new operations were proposed in the calculus of logic with the principle to achieve the generalized form of that logic [22]. Fuzzy logic also gives an advanced inference that how knowledge based system can also be useful for the approximate human reasoning capabilities. Fuzzy logic theory strengthens the uncertainties of human cognitive processes like reasoning & thinking by providing the mathematical formulation of these concepts.

The various facets of fuzzy logic are relational facet, logical facet, epistemic facet & set-theoretic facet. Beside the concept of uncertainty, the vague concepts are also possible to represent with fuzzy set theory by allowing partial memberships function. Modal logic & valued logic are two important logics among all the logics of fuzzy set theory that are linked with all the other logics [23]. Fuzzy set operators may be interpreted in terms of logic connectives in many-valued logic and the membership values in terms of truth values of certain propositions.

The selection of fuzzy logic for groundwater prediction is presence of values in the form of interval i.e. fuzziness of the approach. Fuzzy logic can be represented with the help of membership function. The membership function can be provided in various forms. In this groundwater prediction, we are using trapezoidal membership function which can be calculated as below:

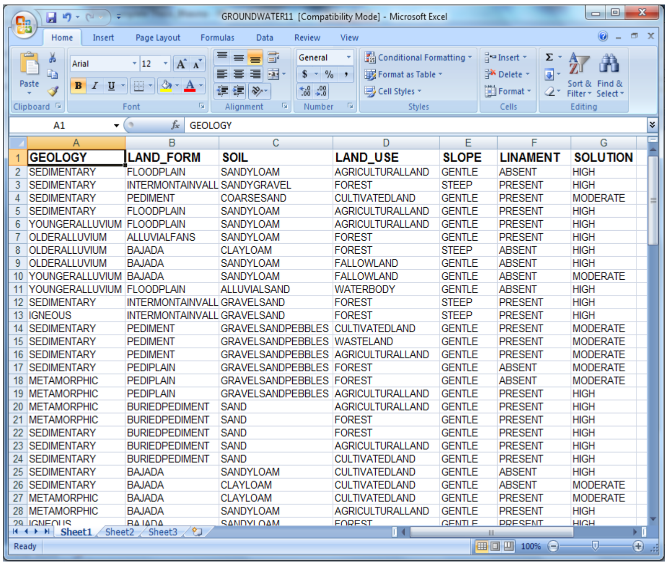
$$\textit{Membership value} = (x-a)/(b-a)$$

Where

x=threshold value,
a = number of packets forwarded,
b = number of packets dropped.

IV. DATASET CONSIDERED

In this research work, groundwater prediction under the terrain area is evaluated based on the expert dataset having six attributes of slope, landuse, landform, geology, soil type and lineament. The considered dataset can be used for any location to test the possibility of groundwater. An instance of expert dataset is given in figure 2.



	A	B	C	D	E	F	G
1	GEOLOGY	LAND_FORM	SOIL	LAND_USE	SLOPE	LINAMENT	SOLUTION
2	SEDIMENTARY	FLOODPLAIN	SANDYLOAM	AGRICULTURALLAND	GENTLE	ABSENT	HIGH
3	SEDIMENTARY	INTERMONTAINVALL	SANDYGRAVEL	FOREST	STEEP	PRESENT	HIGH
4	SEDIMENTARY	PEDIMENT	COARSESAND	CULTIVATEDLAND	GENTLE	PRESENT	MODERATE
5	SEDIMENTARY	FLOODPLAIN	SANDYLOAM	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
6	YOUNGERALLUVIUM	FLOODPLAIN	SANDYLOAM	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
7	OLDERALLUVIUM	ALLUVIALFANS	SANDYLOAM	FOREST	GENTLE	PRESENT	HIGH
8	OLDERALLUVIUM	BAJADA	CLAYLOAM	FOREST	STEEP	ABSENT	HIGH
9	OLDERALLUVIUM	BAJADA	SANDYLOAM	FALLOWLAND	GENTLE	ABSENT	HIGH
10	YOUNGERALLUVIUM	BAJADA	SANDYLOAM	FALLOWLAND	GENTLE	ABSENT	MODERATE
11	YOUNGERALLUVIUM	FLOODPLAIN	ALLUVIALSAND	WATERBODY	GENTLE	ABSENT	HIGH
12	SEDIMENTARY	INTERMONTAINVALL	GRAVELSAND	FOREST	STEEP	PRESENT	HIGH
13	IGNEOUS	INTERMONTAINVALL	GRAVELSAND	FOREST	STEEP	PRESENT	HIGH
14	SEDIMENTARY	PEDIMENT	GRAVELSANDPEBBLES	CULTIVATEDLAND	GENTLE	PRESENT	MODERATE
15	SEDIMENTARY	PEDIMENT	GRAVELSANDPEBBLES	WASTELAND	GENTLE	PRESENT	MODERATE
16	SEDIMENTARY	PEDIMENT	GRAVELSANDPEBBLES	AGRICULTURALLAND	GENTLE	PRESENT	MODERATE
17	SEDIMENTARY	PEDIPLAIN	GRAVELSANDPEBBLES	FOREST	GENTLE	ABSENT	MODERATE
18	METAMORPHIC	PEDIPLAIN	GRAVELSANDPEBBLES	FOREST	GENTLE	ABSENT	MODERATE
19	METAMORPHIC	PEDIPLAIN	GRAVELSANDPEBBLES	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
20	METAMORPHIC	BURIEDPEDIMENT	SAND	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
21	METAMORPHIC	BURIEDPEDIMENT	SAND	FOREST	GENTLE	PRESENT	HIGH
22	SEDIMENTARY	BURIEDPEDIMENT	SAND	FOREST	GENTLE	PRESENT	HIGH
23	SEDIMENTARY	BURIEDPEDIMENT	SAND	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
24	SEDIMENTARY	BURIEDPEDIMENT	SAND	CULTIVATEDLAND	GENTLE	PRESENT	HIGH
25	SEDIMENTARY	BAJADA	SANDYLOAM	CULTIVATEDLAND	GENTLE	ABSENT	HIGH
26	SEDIMENTARY	BAJADA	CLAYLOAM	CULTIVATEDLAND	GENTLE	ABSENT	MODERATE
27	METAMORPHIC	BAJADA	CLAYLOAM	CULTIVATEDLAND	GENTLE	PRESENT	MODERATE
28	METAMORPHIC	BAJADA	SANDYLOAM	AGRICULTURALLAND	GENTLE	PRESENT	HIGH
29	IGNEOUS	BAJADA	SANDYLOAM	FOREST	GENTLE	PRESENT	HIGH

Figure 2: Considered Training Dataset

Different attributes are described with their possible features. These six attributes are further subcategorized into their respective fields as shown in table 1.

Table 1: Attributes and their Subcategories

Attributes	Values
Lineament	Present, Absent
Slope	Steep, Gentle
Geology	Metamorphic, Igneous, Sedimentary, Older alluvium, Younger alluvium
Land use	Wasteland, Forest, Grass, Fallowland, Swampy land, Cultivatedland, Shrubs, Buildup, Agriculturalland, Urban, Waterbody, mixed vegetation etc.
Soil	Gravelsand, Sandygravel, Coarsesand, Sand, Clayloam, Alluvialsand, Gravel Sand Pebbles, Sandyloam, Rocky etc.
Landform	DeltaicPlain, Floodplain, Pediment, Bajada, Riverterraces, Alluvialfans, Pediplain, Buriedpediment, AlluvialPlain, Intermontanevalley, Wadi, Oldmeander etc.

V. GROUNDWATER PREDICTION

This section presents the proposed concept of Case Based Reasoning with fuzzy logicfor the prediction of groundwater possibility without digging the borewell. Here, Case Based Reasoning uses previously experience based knowledge instead of solely dependent on problem domain, their description and available resources. Fuzzy logic is a rule based engine that works on the possible if-else rules. Fuzzy inference System is the mathematical framework of fuzzy logic. It works in three phases of fuzzification, rule generation and defuzzification. Fuzzification is the process to convert the crisp values into terms of membership function. Then fuzzy rules generated in the form of If-Else form. Then defuzzification is applied. In this groundwater prediction, user query is considered as the input and groundwater possibility is determined as output. Initially, use cases are created using the expert dataset which are actually the possible suitable solutions for groundwater possibilities. After the number of iterations, we can get the possibility results of low, moderate or higher.

Input: User Query.
Output: Estimation of Groundwater (Low, Moderate, High).

ALGORITHM

Step 1: Initially, overall dataset is divided into two phases of training and testing.

Step 2: Dataset is trained based on the available six features (slope, landuse, landform, geology, soil type and lineament) and values.

Step 3: Concept is trained based on the available feature set values.

Step 4: Then Testing is performed to find the groundwater possibility as low, moderate or high using Case based reasoning and fuzzy logic.

Step 5: Final step is evaluation of detected groundwater possibility. This is evaluated in terms of Specificity, Sensitivity and Accuracy.

EXPLANATION

Step 1: Insert the user query with the six feature attributes of dataset.

Step 2: Evaluate the Feature weights for the user query data and training dataset as shown in equation (1).

$$wt = numberofoccurance.\log_2\left(\frac{totalnumberoffeatures}{numberofsamplesthedataoccuredin}\right)$$

...Equation (1)

Step 3: Initialize the number of case bases as per case based reasoning and set the value of max_iterationas per total case bases.

Step 4: For max_iteration

{

4.1. Calculate the Cosine similarity of input query with the available case bases by considering equation (2):

$$Similarity = cos(\theta) = \frac{wt_A.wt_B}{\|wt_A\|\|wt_B\|} = \frac{\sum_{i=1}^{n} wt_{Ai} * wt_{Bi}}{\sqrt{\sum_{i=1}^{n}(wt_{Ai})^2} * \sqrt{\sum_{i=1}^{n}(wt_{Bi})^2}}$$

...Equation (2)

Where, wt_A is the query data weight and
wt_B is the data weight of some particular case base.

4.2 Store the similarity for each case base in the form of array matrix.

}

Step 5: Initialize the value for series = 1.

Step 6: Apply the concept of Fuzzy logic and generate fuzzy rules for groundwater prediction.

Step 7: Apply Fuzzification step using trapezoidal membership function which can be calculated as shown in equation (3):

Membership value = (x-a)/ (b-a)

Equation (3)

Where

x=threshold value,
a = number of packets forwarded,
b = number of packets dropped.

Step 8: Generate Fuzzy if-else rules for the groundwater possibility.

8.1. If all the six attributes values in the favour of groundwater generation concept, then groundwater possibility will be high.

8.2. If some of the six attributes values in the favour of groundwater generation and some are not in the favour, then groundwater possibility will be moderate.

8.3. If all the six attributes values are not in the favour of groundwater generation concept, then groundwater possibility will be low.

Step 9: Store the value of all best solutions with iterations

Step 10: The best case is determined by the index of best solution.

Step 11: Apply defuzzification process and declare the results of groundwater prediction as low, moderate or high.

{

11.1. Applyall the available propositional logic condition

11.2. As per available condition, output will be either

{Low, Intermediate or High}

}

Step 12: Set iteration = iteration + 1.

Step 13: Repeat Steps 4 to 11 until initialized iteration reach to Maximum iterationNumber.

Step 14: Consider different case and find the prediction of groundwater.

VI.RESULTS & DISCUSSION

This sectiondetermines the evaluated results for the proposed algorithmin the form of groundwater possibility to be low, intermediate or high. Also the overall comparative parameters of specificity,sensitivity and accuracy are evaluated.

A. Results

The concept of groundwater prediction with possible solutionsis implemented in MATLAB with GUI (Graphical User Interface). The considered input attributes are landuse, lineament, soil type, landform, slope and geology. Output is shown with the groundwater possibility of Low, Moderate and higher. The low probability shows groundwater possibility upto 64%. Moderate probability shows groundwater possibility from 65% to 84% and higher values are from 85% to 100%.

So, here output is determined in low, moderate and high possible value solutions. For the output results, we have considered some test cases which as shown as below.

1). Test Case 1

In test case 1, the considered attributes with their subcategories are shown in table 2.

Table 2: Test Case 1

Attribute	Attribute Value
Lineament	Absent
Slope	Gentle
Land Use	Mixedvegetation
Soil type	Clay
Landform	Bajada
Geology	Sedimentary
Groundwater possibility	?

The considered subattributes of Lineament: Absent, Slope: Gentle, Landuse: Mixedvegetation, Soil type: Clay, Landform: Bajada and Geology: Sedimentary. For these attributes, there is the "**Low**"probability of groundwater possibility.

2). Test Case 2

In test case 2, the considered attributes with their subcategories are shown in table 3.

Table 3: Test Case 2

Attribute	Attribute Value
Lineament	Present
Slope	Gentle
Land Use	Forest
Soil type	Sandyloam
Landform	Intermontainvalley
Geology	Igneous
Groundwater possibility	?

The considered subattributes of Lineament: Present, Slope: Gentle, Landuse: Forest, Soil type: Sandyloam, Landform: Intermontainvalley and Geology: Igneous. For these attributes, there is the "**High**" probability of groundwater possibility.

3). Test Case 3

In test case 3, the considered attributes with their subcategories are shown in table 4.

Table 4: Test Case 3

Attribute	Attribute Value
Lineament	Absent
Slope	Gentle
Land Use	Trees
Soil type	Silt
Landform	Deltaicplain
Geology	Igneous
Groundwater possibility	?

The considered subattributes of Absent, Slope: Gentle, Landuse: Trees, Soil type: Silt, Landform: Deltaicplain and Geology: Igneous. For these attributes, there is the "**Moderate**" probability of groundwater possibility.

From the considered test cases, we can say that groundwater possibility varies in the form of Low, Moderate and High. There are many more cases for the possibility of low, moderate and high. The considered dataset cases are further evaluated with sensitivity, specificity and accuracy values.

B. EVALUATION PARAMETERS

1).Specificity: It denotes the proportion to measure the positiveness of concept. In other words, we can say that it is the method to have the accurate value of groundwater possibility as per expert dataset. This can be calculated as:

$$Specificity = \frac{TP}{TP + FP}$$

...Equation (4)

2). Sensitivity: Itdenotes the proportion to measurethe negativeness of concept. In other words, we can say that it is the method to have the inaccurate value of groundwater possibility as per expert dataset. This can be calculated as:

$$Sensitivity = \frac{FP}{TP + FP}$$

...Equation (5)

3). Accuracy: It defines the combined values of Sensitivity and Specificity. It can be calculated as below:

$$\text{Accuracy} = \frac{\sum \text{TP} + \sum \text{TN}}{\sum \text{Total Dataset Cases}}$$ ...Equation (6)

For the considered test cases, the groundwater possibility is evaluated with their evaluation parameters as shown in table 5,

Table 5: Parametric values

Parameter	Values (%)
Specificity	89%
Sensitivity	63.7%
Accuracy	86%

This can also be respresented in the form of graphical representation as shown in figure 3.

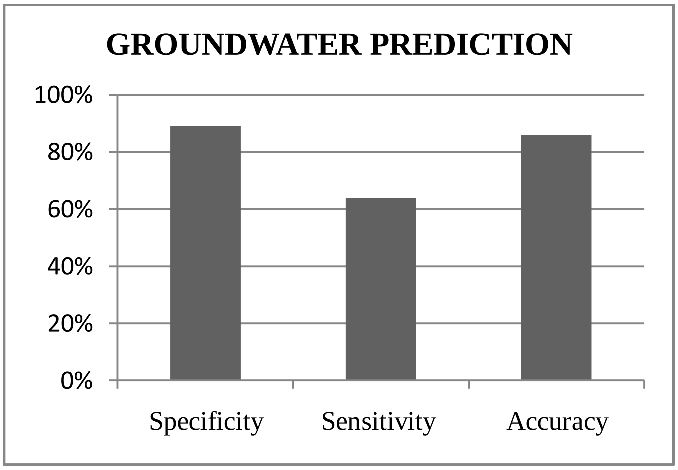


Figure 3: Ground water possibility

VII. CONCLUSIONS

Water is precious for human and living beings. All these living beings directly or indirectly survive due to availability of required water resources. The increasing use of groundwater for industrialization and urbanization, the level of groundwater is decreasing continuously.So, there is the need of some efficient method to find the more groundwater resources. In this research work, we have applied the Case Based Reasoning with fuzzy logic to predict the groundwater resources. Case Based Reasoning uses previously experience based knowledge instead of solely dependent on problem domain, their description and available resources. Fuzzy logic is used to generate the if-else rules to define whether there is low, moderate or high groundwater possibility. With the considered test cases, we havedefined the different test cases with different possible groundwater possibility as low, moderate and high. Also the evaluated parameters show optimized results as shown in table 5 and figure 3. So, we can conclude with groundwater prediction possibility in efficient manner.

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