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Spatial Assessment of Ground Water Quality for Neelambur using GIS and AHP Techniques

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ABSTRACT: Ground water is a major source of fresh water supply. The identification of good quality ground water sources is required for tapping those sources for distribution to public. The research work presented in this paper focused on the preparation of a spatial distribution map for quality of ground water in Neelambur, based on physio-chemical quality. 24 points within the study area were identified for ground water sample collection. Laboratory test was performed to identify the values of 9 water quality parameters namely Potential Hydrogen (pH), Iron (Fe), Nitrate (NO^{3-}), Sulphate (SO_4^{2-}), Total Dissolved Solids (TDS), Sodium (Na), Potassium (K), Total Hardness (TH) as $CaCO_3$ and Phosphate (PO_4^{3-}). The laboratory test results were used in the Geographic Information System (GIS) and the individual thematic maps for the water quality parameters were prepared using the Inverse Distance Weighted (IDW) interpolation method. The spatial ground water quality map for the study area was prepared using the criteria weights determined by Analytical Hierarchy Process (AHP) and weighted overlay analysis in GIS. The overlay analysis results indicated that 61.8% of the study area covering 4.6sq.km was having the ground water of medium to high quality which can be used as the sources of ground water for public distribution.

KEYWORDS: Ground water, Spatial distribution, GIS, AHP, Weighted overlay, IDW.

I. INTRODUCTION

Water, along with air, food and shelter are the basic needs for sustaining life on earth. In India, ground water accounts for 38.6% of utilizable water resources. Among the available ground water, 89% of is used for irrigation, 2% for industrial use and the remaining 9% is used for domestic purpose. 50% of urban and 85% of rural drinking water requirements is satisfied by the ground water. But, it is estimated that around 70% of water is contaminated and not potable for use as drinking water. The water quality index released in 2018 ranked India 120th among 122 countries in the world [1, 2]. This has increased the need to identify the good sources of potable ground water. In India, the local body administrations are responsible for water distribution. They require the sources of available good quality ground water to tap those sources and distribute potable water for the public. In this regard, the current research focused on identifying the areas having good ground water quality in Neelambur village. Many previous researchers have used the Water Quality Index (WQI) for preparing spatial variation maps for ground water quality for different study areas. The various physio-chemical parameters considered by them include pH, Na, F, TDS, TH, Ca, Mg, K, TDS, EC, TA, Nitrates, Sulphates, Nitrites, Bicarbonate, Chlorine, Sodium absorption ratio, Carbon, Residual sodium carbonate and Hydrogen Carbonate [3–10]. Some researchers have also used the AHP method to determine criteria weights for the water quality parameters (EC, As, TDS, NO3, Na, NH4+, TH, CaCO3, SAR, Fe, PI, pH and RSC). The criteria weights were used to prepare the spatial variation maps for ground water quality

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using GIS [11, 12]. The present research study aimed to prepare spatial variation map for quality of ground water in the current study area based on the AHP criteria weights determined for the considered physio-chemical parameters pH, K, TDS, Na, TH, NO3-, Fe, SO42- and PO43- and using the overlay analysis techniques in GIS. The GIS and AHP techniques has been used for the present research as these techniques have been proved effective in the identification of good quality ground water sources based on the previous research studies conducted by various researchers.

II. Materials and Methods

2.1. Study Area

The study area considered for the current research was Neelambur. It is a village panchayat situated in the Sulur block of Coimbatore district in Tamil Nadu state of India. The geo-coordinates of the study area are 11.060506 N and 77.097684 E. The total population of the study area as per 2011 census is 8,382. Many manufacturing, textile industries and metal casting foundries are located in Neelambur, which is also famous for its educational institutions and agriculture. The total area of study is 7.45sq.km and is depicted in Figure 1.

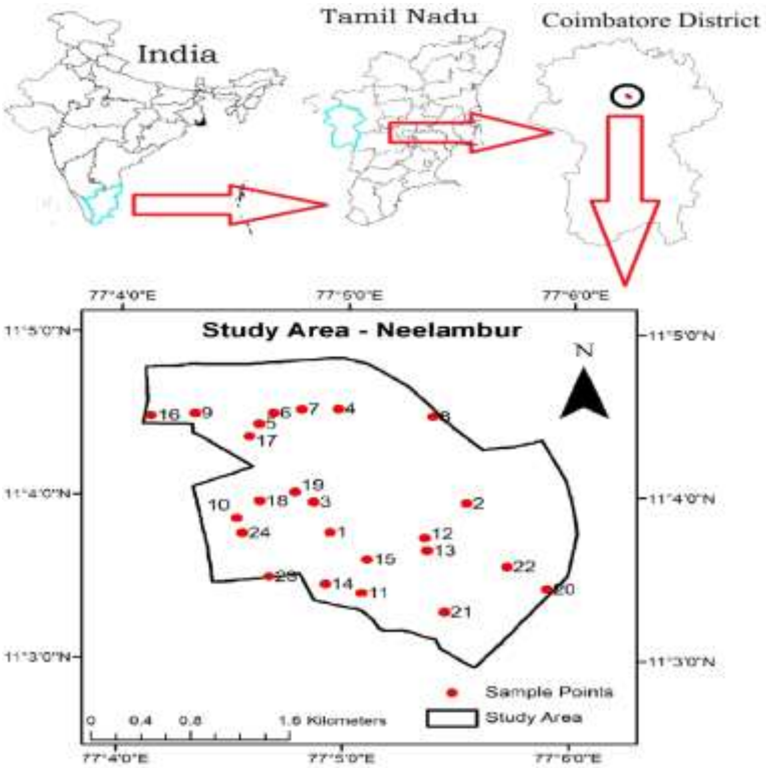

Figure 1. Study area map

2.2. Water Quality Analysis

24 sample points were identified within the study area for collection of ground water samples. Well cleaned 1 liter polyethylene HDPE bottles were used for collecting the samples. The bottles were tightly capped and immediately sent to the laboratory for testing. The collected samples were tested in the laboratory for determining the physio-chemical parameters pH, K, TDS, Na, TH, NO_3^-, Fe, SO_4^{2-} and PO_4^{3-}. The methodology of research adopted is indicated in Figure 2.

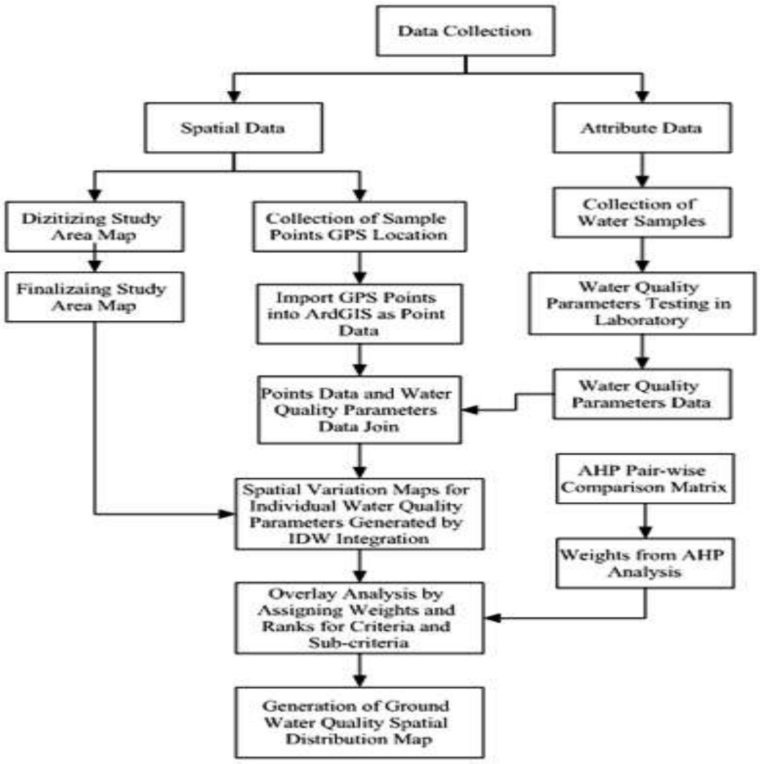

Figure 2. Research Methodology Adopted

2.3. AHP Analysis

AHP is a powerful tool in Multi Criteria Decision Making (MCDM) technique. It uses the pair-wise comparison matrix for determining the relative weights for criteria's considered. In the present study, an AHP pair-wise comparison matrix to determine criteria weights for the water quality parameters considered was developed as shown in Table 1 based on the evaluation scale developed by Saaty [13]. The relative importance of one parameter over another is indicated by the use of numbers from 1 to 9, wherein 1 indicates equal importance of parameters considered, while 9 indicates extreme importance of one parameter considered over the other. The AHP pair-wise comparison matrix developed for the current study resulted in a Consistency Ratio (CR) value less than 0.1, indicating the correctness and consistency of the comparison matrix.

Table 1. Criteria AHP Pair-wise Comparison Matrix

Criteria	pH	$CaCO_3$	PO_4^{3-}	NO_3	SO_4	Fe	TDS	Na	K	AHP Weights
pH	1	1	3	3	3	3	1/3	3	3	0.16
TH	1	1	3	3	3	3	1/3	3	3	0.16
PO_4^{3-}	1/3	1/3	1	1	1	1/3	1/3	1/3	1/3	0.04
NO_3	1/3	1/3	1	1	1	1/3	1/3	1/3	1/3	0.04
SO_4^{2-}	1/3	1/3	1	1	1	1/3	1/3	1/3	1/3	0.04
Fe	1/3	1/3	3	3	3	1	1/3	1/3	1/3	0.08
TDS	3	3	3	3	3	3	1	3	3	0.26
Na	1/3	1/3	3	3	3	3	1/3	1	3	0.12
K	1/3	1/3	3	3	3	3	1/3	1/3	1	0.10
									Total Weight	**1.00**

2.4. GIS Analysis

Mobile GPS was used to collect the GPS locations of the considered 24 sample points and the GIS analysis was carried out in ArcGIS. The spatial data consisting of the latitude and longitude and the attribute data consisting the water quality parameters of the sampling points was used to create a point shape file which was integrated with the study area shape file. The individual thematic maps for the water quality parameters were prepared using the Inverse Distance Weighted (IDW) interpolation method. Based on the criteria weights determined by AHP analysis and the ranks assigned for the sub-criteria based on the BIS standards for the physio-chemical parameters, raster weighted overlay analysis technique was used to prepare the final ground water quality spatial variation map.

III. Results and Discussions

3.1. Laboratory Test Results

The statistical analysis of the laboratory results for the collected ground water samples with the desirable limits of the considered water quality parameters are indicated in Table 2.

Table 2. Laboratory Test Results for Water Quality Parameters

Water quality parameter	Average	Standard Deviation	Minimum value	Maximum value	Desirable limits as per IS 10500
pH	7.21	0.66	6.32	8.26	6.5-8.5
TDS	2094.17	1075.73	1060.00	5550.00	500-2000
TH	869.58	371.21	100.00	1850.00	300-600
NO_3	34.38	6.11	21.27	45.96	45-100
SO_4^{2-}	40.27	20.91	3.29	75.00	200-400
Fe	1.03	0.18	0.73	1.28	0.08-0.1
Na	131.00	39.29	15.00	186.00	20-100
K	19.33	16.15	1.00	68.00	100
PO_4^{3-}	0.10	0.06	0.02	0.30	0.1

The laboratory test results indicated that for pH, the minimum value was observed as 6.32, while the maximum value was observed as 8.26. The pH values of the sample points 3, 8 and 16 were less than the desirable limits. Lower pH values indicate that the ground water was more acidic. The average value of the TDS being 2094.17ppm is more than the maximum desirable limit of 2000ppm. The TDS values of all the sample points are more than the minimum desirable value limit, while the TDS value of 8 sample points were above the maximum desirable limit. The minimum value of TDS was observed as 1060ppm, while the maximum value was observed as 5550ppm. The results indicated that the average TH value of the study area of 869.58ppm was higher than the maximum desirable limit of 600ppm. Out of 24 sample points, the TH value of 21 sample points were above the maximum desirable limit. The increase in TDS and TH values can be attributed to the intrusion of chemicals from manufacturing and textile industries and metal casting foundries in the study area. The excessive application of lime to the soil in agricultural lands within the study area was also a reason for the increased values. The minimum value of TH was observed as 100ppm, while the maximum value was observed as 1850ppm. The average value of NO_3^- for the study area was 34.38ppm, which was well below the desirable limit and the minimum value of NO_3 was observed as 21.27ppm, while the maximum value was observed as 45.96ppm. The average SO_4^{2-} value for the study area of 40.27ppm was observed to be well below the minimum desirable limit of 200ppm and the minimum value of SO_4^{2-} was observed as 3.29ppm, while the maximum value was observed as 75ppm. Although 14 samples reported higher Fe content than the maximum desirable limit of 1ppm, the average was observed as 1.03ppm with the minimum value of 0.73ppm and maximum value of 1.28ppm. The average Na value in the study area was observed to be 131ppm was very high compared with the minimum desirable limit of 20ppm, but it was lower than the maximum desirable limit of 200ppm. The minimum value of Na was reported as 39.29ppm, while the maximum value was 186ppm. The results indicated that the average value of K for the study area of 19.33ppm was lower than the desirable limit of 100ppm, with the minimum value of 16.15ppm and maximum value of 68ppm. The results showed that the PO_4^{3-} values exceeded the desirable limit of 0.1ppm for 13 samples. The average value of PO_4^{3-} for the study area was observed as 0.1ppm with the minimum value of 0.06ppm and maximum value of 0.3ppm.

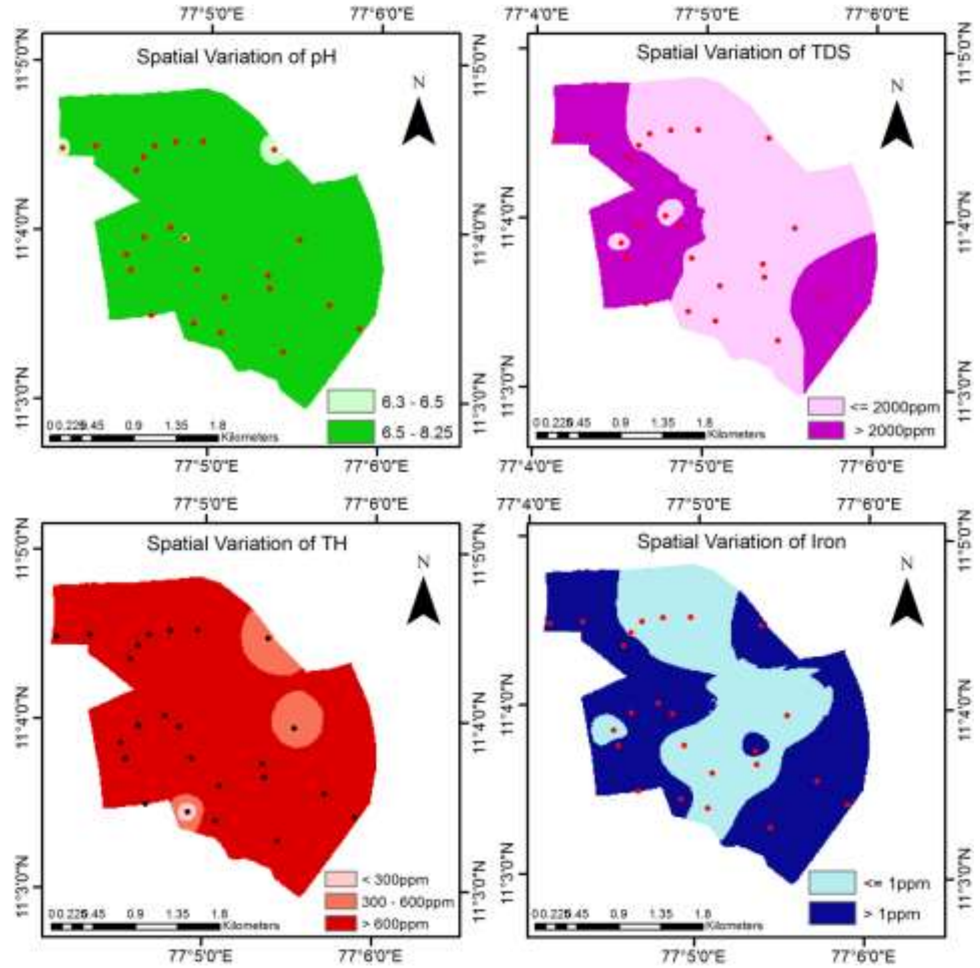

Figure 3. Spatial Variation of pH, TDS, TH and Fe

3.2. Spatial Analysis Results

The individual thematic maps for physio-chemical parameters were prepared using the Inverse Distance Weighted (IDW) interpolation technique in ArcGIS. The thematic maps indicating the spatial variability for the individual water quality parameters are represented in Figure 3, 4 & 5. The minimum and maximum desirable limit values of the individual physio-chemical parameters were used for the classification of the thematic maps.

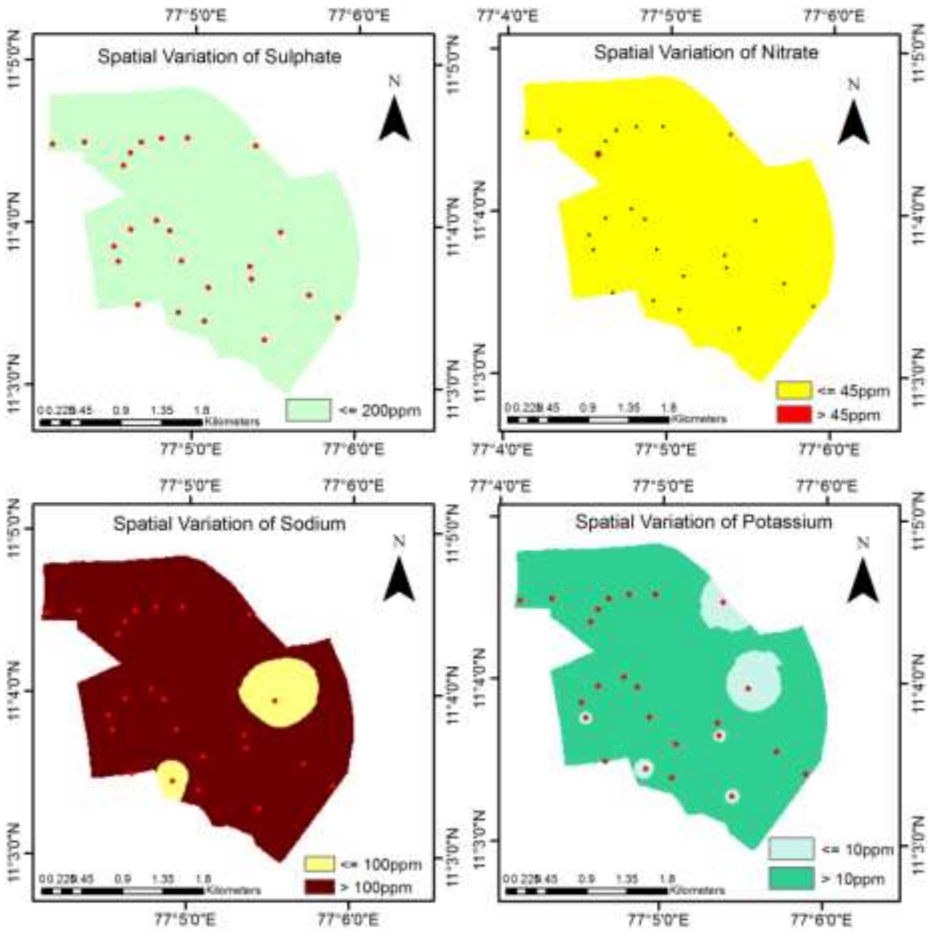

Figure 4. Spatial Variation of SO_4^{2-}, NO_3, Na and K

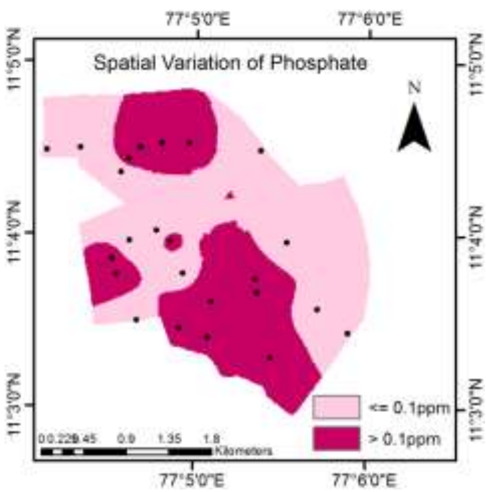

Figure 5. Spatial Variation of PO_4^{3-}

3.3. Weighted Overlay Analysis Results

For the purpose of preparing overall ground water quality spatial variation map, the weighted overlay method in ArcGIS was used. The individual water quality parameter spatial variation maps were assigned with criteria weights from the AHP analysis and the sub-criteria were assigned with ranks based on the desirable limit values. The weights and ranks assigned for the physio-chemical parameter criteria's and sub-criteria's are represented in Table 3.

Table 3. Criteria Weights and Sub-criteria Ranks Assigned for Weighted Overlay Analysis

Criteria	AHP Weights	Sub-criteria	Rank	Criteria	AHP Weights	Sub-criteria	Rank
pH	16	<6.5	1	Fe	8	<1ppm	5
		6.5-8.5	5			>1ppm	1
TDS	26	<2000ppm	5	Na	12	<100ppm	5
		>2000ppm	1			>100ppm	1
NO_3	4	<45ppm	5	K	10	<10ppm	5
		>45ppm	1			>10ppm	3
SO_4^{2-}	4	<200ppm	5	PO_4^{3-}	4	<0.1ppm	5
		>200ppm	1			>0.1ppm	1
TH	16	<300ppm	5				
		300-600ppm	3				
		>600ppm	1				

The overlay analysis resulted in the ground water quality spatial distribution map as represented in Figure 6. The map indicated that in the study area considered, only two small pockets, one on the eastern side and the other on the south-east had a very good quality of ground water. The western and eastern pockets of study area covering sampling points 3, 9, 16, 17, 18, 20, 22, 23 and 24 had a low quality of ground water. This was mainly attributed to the presence of major textile and manufacturing industries and metal casting foundries in these locations. The TDS and TH values of all these points are very high compared to the desirable limits as per IS 10500:2012 [14]. Based on the results of the area wise distribution of ground water quality, it can be determined that only 3.9% of study area covering 0.29sq.km was classified to have ground water of good quality, while 57.9% of study area covering 4.31sq.km was classified to have ground water of medium quality and 2.85sq.km accounting for 38.3% of the study area was classified to have ground water of low quality.

IV. Conclusions

The present study aimed at identifying the potential areas for tapping ground water sources based on its physio-chemical characteristics for the Neelambur panchayat. The research methods used the Geographic Information System techniques and Analytical Hierarchy Process to identify locations within the study area having ground water of low, medium and high quality. Results obtained in the study indicated that only 3.9% of the study area was found to have high quality, 38.3% with low quality and 57.9% with medium quality ground water. This research study had helped in preparing a spatial distribution map indicating the quality of ground water in Neelambur. This map could be used by the Neelambur village panchayat administration to identify the locations where the ground water source can be located to distribute water within the panchayat administration area. The present research has mainly focused on a single village panchayat and the research methods used has proved to be effective when applied for a small study area. The proposed research methods used in this study can be used over large areas in the future studies for effective identification of ground water resources based on the analysis of physio-chemical parameters of ground water.

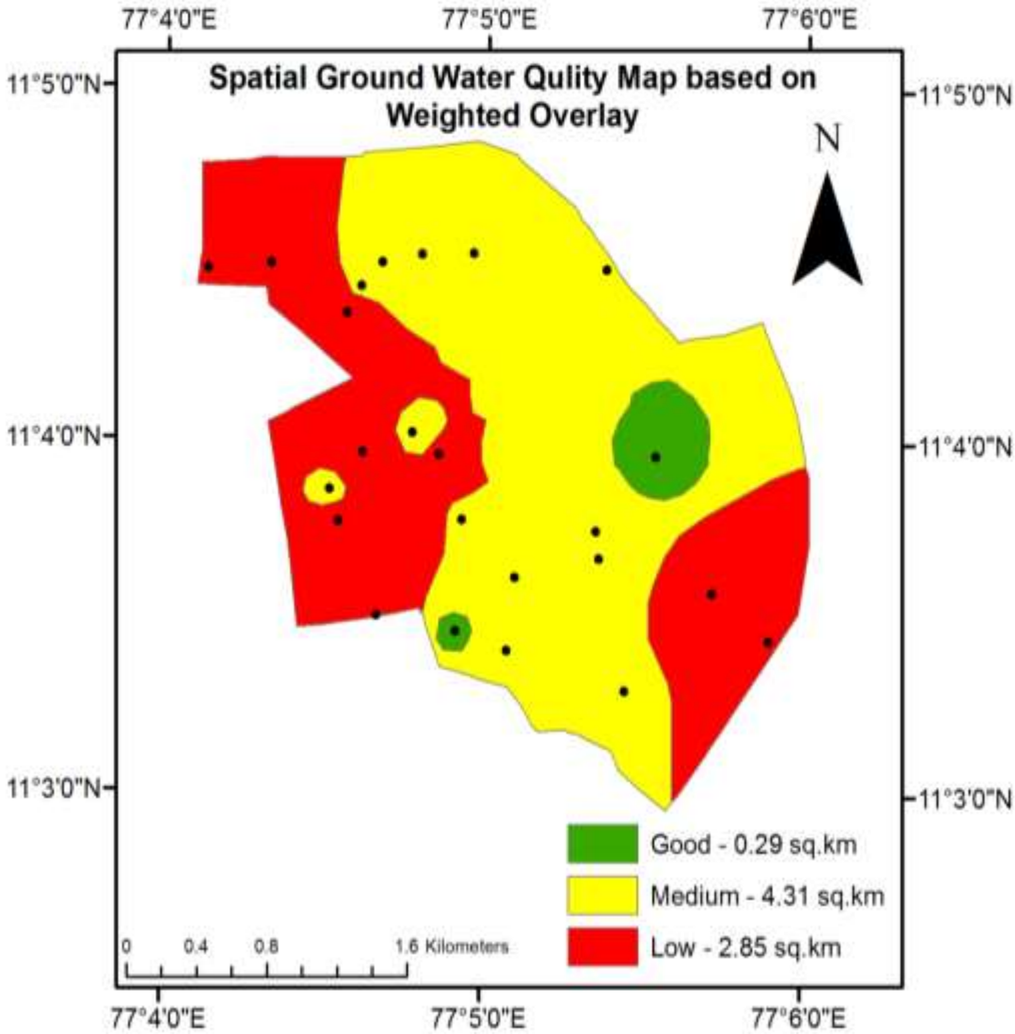

Figure 6. Weighted Overlay Analysis Result

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