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An Integrated Approach to Analysis Groundwater Quality Using Remote Sensing and GIS

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ABSTRACT– Evaluation of groundwater potential zones and their suitability for consumption in villages severely afflicted by drought in the Vemula mandal of Cuddapah District, Andhra Pradesh. This study utilises remote sensing and GIS techniques. In this method, IRS P6 LISS III Data (23.5 m Spatial Resolution) with Path: 100; Row: 063 of the Indian Remote Sensing Satellite Resources at IRS-P6 LISS-III were used to analyses the onscreen interpretation and delineate various geomorphological units, lithological formations, and geological structures. The Papaghni and Chitravati granite formations are characteristic of the study area. Based on their origin, the lithological formations in this study have been categorized as fluvial, denudational, or structural. The majority of lineaments trend in the orientations of NE-SW and NW-SE. The fluvial landforms valley fills moderate and valley have excellent groundwater prospects, whereas the shallow Pedi plain that has been weathered and interred has moderate to poor groundwater prospects. The chemical quality parameters of groundwater samples indicate that the water samples are suitable for human consumption, agriculture, and industry.

Keywords- *Water Quality, Remote Sensing, GIS, Groundwater, Hydrogeomorphology*

INTRODUCTION

Due to population growth and urbanisation, India's water supplies are under stress and fast running out. Prospecting for, exploring, and managing groundwater has generally grown into a major undertaking in India. Around the globe, groundwater is a significant source of drinking water because it accounts for roughly 20% of the fresh water supply and around 0.61% of all water, including oceans and permanent ice. When this recharge reaches the water table, ground water is naturally replaced by surface water from rivers, streams, and precipitation. In India, the residential water needs of around 95% of the rural population are met by groundwater. The world's vital groundwater supplies have been severely constrained in terms of both quality and quantity due to the dramatic rise in population, urbanisation, and contemporary land use applications and demands for water supply. Groundwater is used for household purposes by over 95% of India's rural population. Consequently, it is now essential in the present situation to not only identify groundwater potential zones but also to monitor and maintain this valuable natural resource. Groundwater extraction must be done responsibly in order to avoid groundwater mining and should not exceed the pace at which it is recharged annually. Given how crucial water quality is to preserving both human and ecological health, it has received a lot of attention in recent years. Serious issues with water supply and quality may result from inappropriate water system management. In addition, the groundwater is heavily exploited for agriculture and industrial uses, as well as a range of land- and water-based human activities, which is polluting this valuable resource. Public worry over drinking water quality has grown over the last ten years as a result of several instances of groundwater pollution. Any groundwater's quality and use depend on its chemical composition. The usefulness of groundwater for home, drinking, agricultural, and industrial uses is mostly based on its quality, hence it is crucial to comprehend this aspect of the resource. The composition of recharge water, the interaction of soil's geological components and constituents with it, the amount of salt present, and many other elements in the aquifer's soluble state all affect water quality. In addition, factors including lithology, structures, geomorphology, slope, land use, and land pattern, among others, greatly influence the groundwater regime of each region. For an understanding of the hydrological structure of any place, these aspects are interconnected and crucial. A specific thematic layer in the GIS environment may be created and used for analysis to provide the relevant baseline data on such characteristics. These thematic layers, which were created using remote sensing data, may then be linked into a GIS framework and further analysed using models created under logical conditions to demarcate the various groundwater potential zones. Studies of ground water now have new directions because to remote sensing and GIS technologies. Urban planning and ground water research may now be effectively linked thanks to the notion of integrated remote sensing and GIS. In light of this, research has been conducted to comprehend the significance of remote sensing and GIS methods for ground water quality of the Tummala- Palle region, Cuddapah District.

CASE STUDY AREA

The Tummalapalle region is situated in the Vemula mandal of the Cuddapah district in Andhra Pradesh. It is approximately 70 kilometres from the district's headquarters and is a severely drought-affected region. The closest village is Pulivendla, approximately 15 kilometres distant via road.It is located on the Survey of India Toposheets No. 57 J/3 and 57 J/7 at a scale of 1:50,000 and between the latitudes 14 16'00" to 14 24'00" and longitudes 78 13'00" to 78 23'00" shown in Figure 1. The total study area encompasses 112,48 square kilometres and includes portions of the localities of Vemula, Velpula, Kottalu, Mobbu- chintalapalle, Medipentla, Bhumayagaripalle, Rachakuntapalle, Gondipalle, and V. Kothapalle.

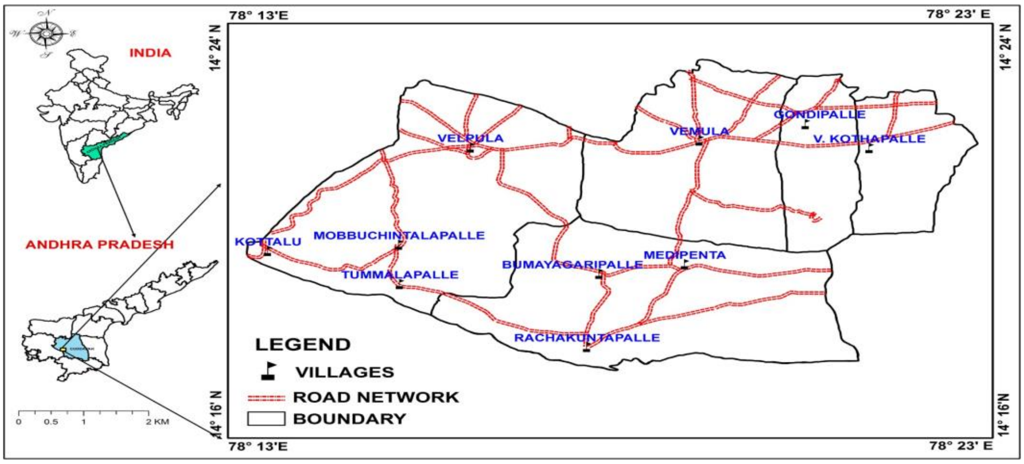

Figure 1: Map of Case Study Area between the latitudes (14 16'00" to 14 24'00" and longitudes 78 13'00" to 78 23'00”)

METHODOLOGAL ANALYSIS

In this study, we have included three categories of data sets that were utilised in groundwater evaluation and inspections. A topographical map (57 J/7) of the Survey of India at a scale of 1:50,000; Analysis of geo-coded remotely sensed data, specifically IRS-P6-LISS-III data with Path: 100 and Row: 063 and a spatial resolution of 23.5 m covering Thummalapalle area and selected field checks to confirm various geomorphic units. Geometric correction has been applied to the preprocessing of the satellite picture for this study's effective cartographic applications. A hydro geomorphological map is created by merging the aforementioned data and outlining various geomorphological units/landforms, lithological formations, and geological structures on the screen. Further, the hydro geomorphological/groundwater prospects map of the research region is finalised using the well inventory data gathered during fieldwork. Images' tone, texture, pattern, form, association, drainage, and other attributes were utilized to distinguish between various aspects and their corresponding units. As a result, several thematic maps were created and afterwards digitalized in the GIS environment using Arc GIS 9.3 software. In and around the Thummalapalle region, forty groundwater samples are taken, and Table 1 shows the results of chemical analyses for pH, total dissolved solids, total hardness, alkalinity, bicarbonate, carbonate, chloride, calcium, magnesium, fluoride, sodium, and potassium. The collection, preservation, analysis, and interpretation procedures and techniques used are those recommended by Todd and Mays and APHA.

Sl. No.	ample No.	EC (μ mhos/cm)	pH	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO_3 (mg/l)	CO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	F (mg/l)	TDS (mg/l)	Hardness as $CaCO_3$ (mg/l)	Alkalinity as $CaCO_3$ (mg/l)
1	S.N 1	2020	7.3	67	84	22	19	349	137	33	22	0.28	1313	372	108
2	S.N 2	2040	7.4	93	35	27	13	262	93	49	12	0.45	1326	160	98
3	S.N 3	2060	7.6	47	42	35	9	222	67	53	9	0.32	1339	188	95
4	S.N 4	2240	7.4	73	55	34	9	289	106	49	9	0.42	1456	244	98
5	S.N 5	2160	7.3	65	85	34	10	356	131	55	10	0.52	1404	376	98
6	S.N 6	1210	6.8	25	75	13	21	251	101	31	9	0.11	787	332	36

7 S.N 7	1530	7.1	29	56	15	11	214	74	27	12	0.38	995	248	52
8 S.N 8	1840	7.9	73	93	31	2	367	135	65	16	0.44	1196	412	102
9 S.N 9	1340	7.2	45	69	26	5	244	106	53	10	0.38	871	308	49
10 S.N 10	2000	7.3	59	73	22	15	306	117	43	8	0.42	1300	324	82
11 S.N 11	1860	7.5	69	55	20	19	267	93	53	15	0.36	1209	244	89
12 S.N 12	1640	7.3	109	108	26	3	435	162	93	18	0.56	1066	480	85
13 S.N 13	1980	7.4	173	133	55	5	509	222	207	28	0.38	1287	596	72
14 S.N 14	2020	7.5	67	100	54	7	390	164	67	19	0.25	1313	444	72
15 S.N 15	1940	7.5	63	81	44	73	389	135	85	16	0.34	1261	360	144
16 S.N 16	2060	7.4	69	72	24	2	308	113	45	18	0.28	1339	320	89
17 S.N 17	1780	7.2	83	49	19	3	277	95	35	19	0.42	1157	220	95
18 S.N 18	1940	7.4	77	76	20	3	294	122	29	65	0.37	1261	340	75
19 S.N 19	2140	7.5	67	72	13	3	229	96	35	94	0.27	1391	320	66
20 S.N 20	1730	7.2	81	49	31	24	294	112	45	10	0.48	1125	220	79
21 S.N 21	2160	7.5	47	39	33	3	193	61	59	8	0.30	1404	172	95
22 S.N 22	1980	7.4	69	35	11	4	199	74	33	10	0.44	1287	156	79
23 S.N 23	1430	7.3	55	43	6	2	183	66	37	16	0.40	930	192	66
24 S.N 24	1980	7.5	95	44	13	3	294	101	21	12	0.54	1287	200	85
25 S.N 25	2060	7.3	67	37	48	5	253	87	51	8	0.28	1339	168	102
26 S.N 26	2120	7.2	45	27	51	7	130	38	113	11	0.46	1378	120	82
27 S.N 27	1850	7.1	83	43	43	2	236	72	109	12	0.28	1203	192	98
28 S.N 28	1780	7.2	95	63	75	22	320	120	151	10	0.62	1157	280	89
29 S.N 29	2150	7.5	69	45	30	2	254	93	37	8	0.54	1398	200	92
30 S.N 30	1630	7.1	121	71	44	21	390	146	101	13	0.43	1060	320	115
31 S.N 31	2160	7.3	89	64	28	3	294	117	73	12	0.52	1404	288	85
32 S.N 32	1940	7.2	93	64	22	2	343	123	33	15	0.48	1261	288	102
33 S.N 33	1720	7.1	101	59	27	3	338	121	41	20	0.39	1118	264	102
34 S.N 34	1960	6.9	69	56	25	12	205	62	129	18	0.45	1274	250	120
35 S.N 35	1940	7.1	83	81	45	45	370	129	115	14	0.40	1261	360	118
36 S.N 36	1660	6.7	77	97	86	32	393	154	161	13	0.38	1079	430	101
37 S.N 37	1850	6.8	79	58	45	16	307	109	77	12	0.48	1203	259	65
38 S.N 38	2060	7.5	109	82	39	25	376	161	97	12	0.44	1339	365	113
39 S.N 39	1880	7.1	91	101	45	41	433	170	101	13	0.42	1222	450	99
40 S.N 40	1520	7.2	95	85	26	36	349	120	135	14	0.34	988	380	86

Table 1: Analyses of water samples collected from the case study area

In the weathered zones of the Papaghni and Chitravati group of rocks, groundwater exists under water table conditions. The various joints, cracks, and fissures that are found in these rock types are what primarily cause the water to be present in the excavated wells. The permanent water table in the quartzites and the enormous limestone's base are both excellent aquifers, and they are both typically shallow. Alkaline by nature, water is suitable for drinking and irrigation. Since water found outside of the community in the surrounding region is typically sweet, it is discovered that the groundwater in the Tummalapalle village is salty owing to unsanitary conditions. In Vemula mandal, the sea depth is between 10 and 20 meters.

3.1 Geology Analysis

The Cuddapah Super Group's Papaghni and Chitravati group of rocks typically occupy for the research area. The Gulcheru formation, which consists of quartzite, arkose, and conglomerate, and the Vempalli formation, which consists of dolomites, chert, mudstone, quartzite, basic flows, and intrusive, are both parts of the Papaghni group. The Pulivendla formation, which consists of quartzite and conglomerate, the Tadipatri formation, which consists of shales, dolomite, and quartzite, and the Gandikota formation, which consists of quartzite and shale, are all parts of the Chitravati group. The Vempalli formation is composed lithological of cherty limestone, massive limestone, dolostone uraniferous, shale, and purple shale. Pitchblende, coffinite, and the U-Ti complex have been identified as the radioactive minerals in the ore zone.

3.2 Hydrogeomorphology Analysis

The hydrogeomorphological mapping in the present work is done using IRS P6 LISS-III satellite data. Three kinds of geomorphic units, namely fluvial, denudational, and structural, are classified in figure 2 to encompass these lithological formations based on genesis, lithology, physiography, and landform features. The research region includes valleys and valleys with modest valley fill under fluvial landforms. The denudational landforms include bazada, inselberg, pediment, and buried pediplain with shallow weathering. The term "structural landforms" includes structural hills. In order to effectively prospect for groundwater, it is crucial to consider the depth of weathering and the kind of soil cover. The pediplain is further split into pediplains with shallow weathering and pediplains with substantial weathering. Thus, fifteen geomorphic units that have evolved on seven lithological formations are identified based on the genesis. The lineaments are mostly in the NE-SW and NW-SE directions. All of these landforms, which include fluvial landforms, denudational landforms, and structural landforms, are described using different lithological units. Valley fills moderate (VFM-UCS) and Valley (V-VD) are the two classifications that have been used to categorise the fluvial landforms. The materials that have been eroded into the valley fill the valley. The sediments used to fill the valleys range in thickness from 10 to 20 metres. This unit is designated as a good recharge zone in the current research region and is classified as having a moderate to excellent groundwater potential. The chances for groundwater in this valley fill zone range from good to outstanding. This is because of the geological composition, which is made up of very porous minerals, and the topographical placement at the foot of the hill. These valley fills also have high to great subsurface water potential. Within the hills along the stream, The Valley (V-VD) is a low-lying depression with negative landforms of various sizes and shapes. The valley bottoms serve as ground water discharge points for catchments at higher elevations. The potential for groundwater in this landform is generally favourable. In order to explore the potential for ground water, A gently sloping, flat, and smooth surface made of Tadipatri shale, Vempalli dolomite, and Vempalli quartzite that has undergone less than 10 metres of weathering is known as the "Shallow Weathered Buried Pediplain," and it is typically covered in black soil. In this unit, poor to average returns are anticipated. Along the fracture or lineament, moderate yields are anticipated. The most of the time, the water is brackish in character. Similar discoveries were made by Sree Devi and colleagues in the Pullampally hamlet of the Cuddapah region of Andhra Pradesh's Pageru river. Between a hill and a plain, the Pediment is a gently sloping, smooth surface made of erosion-resistant bedrock made of Tadipatri shale, Vempalli chert, Vempalli dolomite, and basic flows (Vempalli Flows). The possibilities for groundwater in this landform are generally low. Furthermore, Suresh Babu and Gautham have backed this research. The Bazada is an extensive, continuous alluvial slope or gently sloping detrital surface made of Vem-palli dolomite that runs beside and from the foot of mountain ranges. The possibilities for groundwater in this landform are low. Similar results were discovered by Krishna et al. in the Andhra Pradesh Errakalava watershed basin. The Inselberg is a sizable, solitary hill made of Vempalli chert and Vempalli dolomite that rises abruptly above the lowlands below. It creates a run-off zone with little groundwater possibilities and recharging potential. Similar occurrences have been seen by Raghu and Mruthyunjaya Reddy in the Akuledu Vanka Watershed region of Andhra Pradesh's Anantapur District. Structural Hill is a part of the structural landforms. These hills are built of Vempalli dolomite, basic flows (Vempalli flows), and Gulcheru quartzite, and they range in shape from linear to arcuate. These landforms primarily serve as runoff zones and have very little potential for groundwater. Moderate pros-pects are seen along the hills' valleys. It has been observed that the Bata watershed in Sirmaur District, Himachal Pradesh, characterises the landscape and aquifer characteristics using remote sensing data in combination with traditional techniques.

3.3 Analysis Groundwater Quality

The quality of groundwater varies according to geological formation, temperature, drainage conditions, and pollution. Archaean rock groundwater is usually neutral to alkaline. The quality of groundwater found in the Cuddapah and Kurnool formations is typically poor. Data interpretation entails comparing water quality data, analysing water quality trends, developing cause-effect relationships between water quality data and environmental data (geology, hydrology, land use, pollutant sources inventory), judging the adequacy of water quality for various uses, and assessing the environmental significance.

RESULTS

Scatter plots were created between TDS and EC, Na and K, Ca and Na, Mg and K, Cl and Hardness, CO3 and Hardness, CO3 and Cl, HCO3 and Hardness, HCO3 and CO3, and HCO3 and Cl in order to determine the association of chemical characteristics of groundwater in the research region shown in Figure 2. TDS and EC have a strong association (r2 = 1), as do CO3 and hardness (r2 = 0.81), HCO3 and hardness (r2 = 0.76), and HCO3 and CO3 (r2 = 0.94). According to the findings of this research, the correlation coefficients of several physicochemical parameters have a substantial link with one another. Conductivity varies with temperature and indicates the kinds of ions present as well as their concentrations. TDS is an indicator of conductivity that has a direct link to salinity, and high total dissolved solids reduces the quality of water for potable use. Total dissolved solids are an estimate of all dissolved compounds in water. Total dissolved solids are mostly derived from agricultural and residential runoff, soil contaminated leaching, and point source water pollution discharged from industrial or household wastewater treatment facilities. Electrical conductivity (EC) and total dissolved solids

(TDS) are important criteria for determining the concentration of solid particles in any waste water sample. The linear regression of EC on TDS is seen in Figure 2. The regression equation was y = (0.50) + (1.54), and the r2 was about one. Electrical conductivity and total dissolved solids have a very significant linear connection, according to the regression analysis. Previous research has also shown a significant degree of association between EC and TDS. Figure 2 again shows a favourable connection between carbonate and bicarbonate. Hardness in ground water is caused mostly by carbonate, bicarbonate, and chloride of Ca^{2+} and Mg^{2+}. Total hardness of water is primarily determined by calcium and magnesium cations, which mix with bicarbonates and carbonates temporary hardness and sulphate, chlorides, and other mineral anions permanent hardness. Higher hardness levels are caused by evaporation of water at higher temperatures during the summer months, low water level, and increased human activity. The source rocks are primarily responsible for the huge quantities of chemical components found in the current research region. By viewing these findings, it is possible to infer that the water quality characteristics studied meet the requirements for different applications such as home, agricultural, and industrial usage. The chemical characteristics of groundwater sampled for our investigation of the Tummalapalle region are within the drinking water quality standards and meet the requirements for diverse applications such as household, agricultural, and industrial. Because of the uneven distribution of uranium deposits in the earth crust and geological formations around the Tummalapalle mining site, the concentration of uranium in groundwater varies dramatically from place to place. Approximately 96% of the drinking water samples had uranium concentrations under the allowable limit (30 g/l) as recommended by the USEPA for drinking purposes.

CONCLUSIONS

Remote sensing and GIS methods offered information on hydrogeomorphic characteristics that was highly beneficial in understanding the nature and water potentiality of various landforms. The varied landform units addressed are the outcome of several geomorphic processes. The research demonstrated the capabilities of remote sensing technologies to create a hydrogeomorphological map. The research also demonstrates the interdependence of hydrogeomorphic units and other topographical features, as well as their significance in designating the ground water potential zone in the landscape. The integrated modelling and analysis of multiple geospatial topics such as topography, geomorphometry, geomorphology, and hydrology in the GIS environment aided in recreating the hydrogeomorphological situation of the Tummalapalle region. Groundwater prospects are favourable in fluvial landforms, but moderate to poor in shallow weathered buried pediplains. According to the physicochemical parameters (pH, EC, total dissolved solids, carbonates, bicarbonates, alkalinity, chlorides, sulphates, fluoride, calcium, magnesium, sodium, and potassium) of groundwater in the Tummalapalle area, the majority of the groundwater samples can be used for irrigation and domestic purposes.

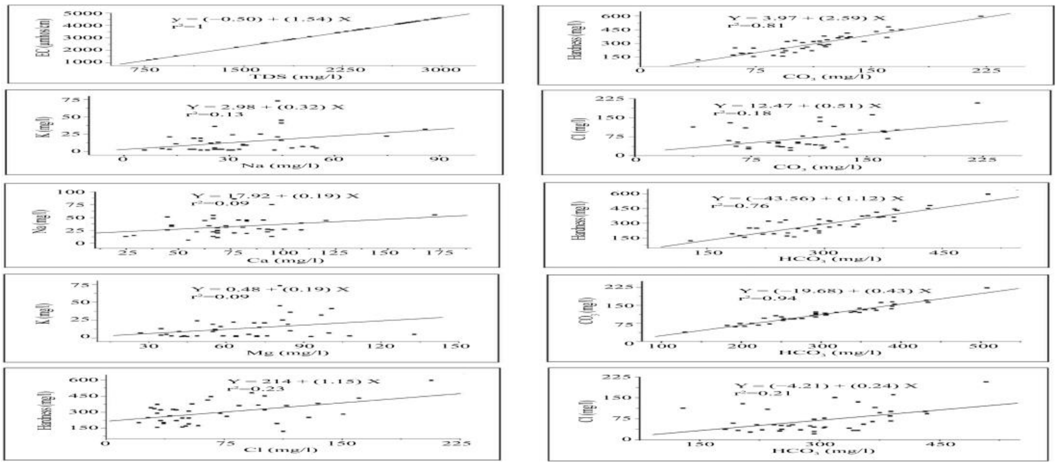

Figure 2: Scatter plots of several chemical parameters

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