Application of Geo-Spatial Technologies in Identification of Groundwater Potential Zones

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Abstract- *Groundwater is an important resource contributing significantly in total annual supply. However, over exploitation has been depleted due to land subsidence. Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems. Groundwater potential zones are demarked with the help of GIS techniques. In this study a standard methodology is proposed to determine groundwater potential zone using integration of GIS technique. The composite map is generated using GIS tool. The accurate information to obtain the parameters that can be considered for identifying the groundwater potential zones such as geology, slope, drainage density, geomorphic units and groundwater levels are generated using the satellite data and Survey of India toposheets of scale 1:50000. It is then integrated with weighted overlay in ArcGIS. Suitable ranks are assigned for each category of these parameters. For the various geomorphic units, weight factors are decided based on their capability to store groundwater. This procedure is repeated for all the other layers and resultant layers are reclassified. The groundwater potential zones are classified into five categories like very poor, poor, moderate, good and very good.*

Keywords- Remote sensing, GIS, Weighted overlay, Thematic maps, Groundwater, Data management tools, Spatial analyst tools and Integration.

I. INTRODUCTION

Geographical Information System is a computer based tool for collecting, storing, trans-forming, retrieving and displaying spatial data from the real GIS world. GIS provides facilities for data capture, data management, data manipulation, analysis, and the presentation of geo-graphical data. GIS is not simply a system for making maps, a GIS is an analysis tool as well. The geographical data represent phenomena from the real world in terms of their position with respect to a known coordinate system, their attributes that are unrelated to position and their spatial interrelations with each other. The spatial relations describe how they are linked together. The study of groundwater is important since it is the main source for drinking, irrigation and industry use in all over the world.

There are different perspectives of groundwater studies have been done by several researchers based on their purpose, notably researchers do study the physical and chemical properties of groundwater to find out the quality of it and groundwater level fluctuation have been found using temporal water depth data while some have studied potential groundwater zones using Geographical Information Systems and Remote Sensing techniques. The Present study is conducted to explore the potential zones of ground water availability using remote sensing and GIS technologies. GIS and RS techniques are suitable method to find out the potential groundwater zones as well as it can reduce the time and cost and human power than the traditional methods. For the analysis of potential groundwater zones totally five parameters have been considered for the study such as, drainage density, geology, geomorphology, slope and groundwater levels.

II. OBJECTIVE AND STUDY AREA

The primary objective of the study is to contribute towards systematic groundwater studies utilizing Remote Sensing and Geographic Information systems in the exploration of Ground-water potential areas.

Kurnool district is the third largest district in Andhra Pradesh situated between North latitude 14°35'35" to 16°09'36" East longitudes 75°58'42" to 78°56'06". It is bounded by Tungabhadra and Krishna rivers and Mahabubnagar district in the North and Prakasam district in the East, Bellary district of Karnataka State in the West and Anantapur and Kadapa districts in the South.

The total geographical area of the district is 17600 sq.km with headquarters at Kurnool and divided into 54 revenue mandals. Major crops grown in the district are paddy, jowar, bajra, cotton, sunflower, groundnut etc. The population density, which was 66 persons per sq.km during 1901, has increased to 200 persons as per 2001 census and 229 persons per sq.km as per 2011 census. The study area consists of four villages under Koilkuntla mandal namely Amadala, Bijinavemula, Souderdinne and Velagaturu.

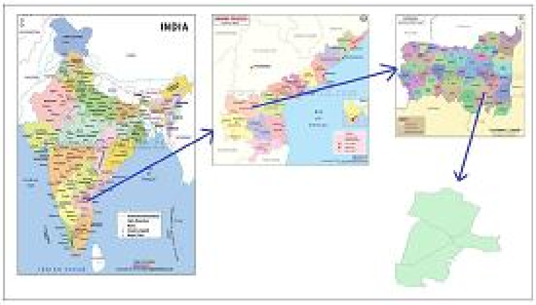

Fig. 1. Location Map of the study area

A. Rainfall

The average annual rainfall of the district is 665.5mm, which ranges from nil rainfall in January and December to 139.6mm in September. August and September are the wettest months. The mean seasonal rainfall distribution is 459.1mm in Southwest monsoon (June-September), 133.7mm in Northeast monsoon (October-December),1.9mm rainfall in winter (Jan-Feb) and 70.8mm in summer (March - may)[2011 census]. The year 1999 and 2011 experienced drought conditions in the district as the annual rainfall recorded in these two years is 27 percent and 28 percent less than the long period average(LPA) respectively .The below bar chart shows last six years rainfall data in mm.

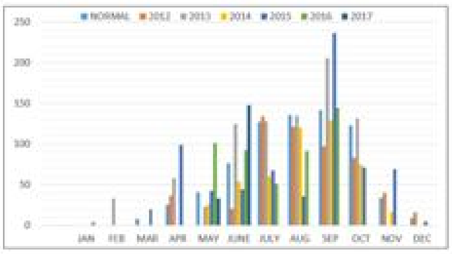

Fig. 2. Average Rainfall Map of the study area

B. Geology

With the passage of time, the basin in the west was again submerged beneath a shallow sea and in the upper Precambrian and Cambrian times, the sedimentary rocks of Kurnool group comprising of Limestones, Shales, Quartzites and Conglomerates were deposited. The Sedimentary Group of rocks are mainly composed of limestone and calcareous shale and attained a thickness of about 600 meters. The Panyam Group of rocks which comprises of the plateau quartzite at the bottom and the pinnacle quartzite at the top, constitute the flat topped ridges and plateau to the west of Kundru pains. The Kundair formations are the youngest of Kurnool Group comprising of Koilkuntla beds at bottom and Nandyal shale at the top. They attain a thickness ranging from 60 to 300 meters and exposed in the plains of Kunderu river, south of Allagadda to north of Atmakur. The Koilkuntla consists of grey, flaggy, limestones, while the Nandyal are made up of calcareous shale and shaly limestone.

III. METHODOLOGY

The proposed methodology of study involved various activities such as base map preparation, LULC map preparation, Digitization and image processing using software and interpretation of the outputs. First stage includes development of spatial data base by using survey of India (SOI) toposheet on a 1: 50000 scale and google earth satellite data. GIS and remote sensing technology is applied to prepare various thematic maps with reference to groundwater like drainage density and contour. Additionally, the Land Utilization Survey Database, geologic maps and on site investigation are adopted to quantitatively and qualitatively describe the hydro geological conditions of the area. In the second stage, digital image processing of the satellite data is done for geo-referencing and geometric correction. This is followed by creation of different thematic layers using supervised classification technique. All the attributes from the collected data then summed to create the buffer map for agriculture area and settlement area.

It is then followed by creation of other important data which is used to determine the ground water potential at the later stage like slope, geology, geo-morphological map, drainage density map and ground water level(IDW map). In the third stage all above themes are further processed and analyzed in overlay and ranking is given to evaluate suitable groundwater potential zone. All the thematic layers will overlay by using GIS to find the final integrated output of groundwater potential zones in the present study, geomorphology, slope, drainage density, geology and ground water levels are considered for the identification of groundwater potential zones.

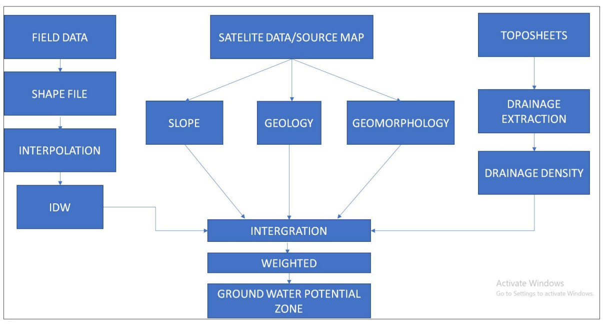

Fig. 3. Methodology Flowchart

A. Ground water levels by IDW

Inverse Distance Weighting (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points. Groundwater depth levels were identified for the total area using IDW method based on known point values.

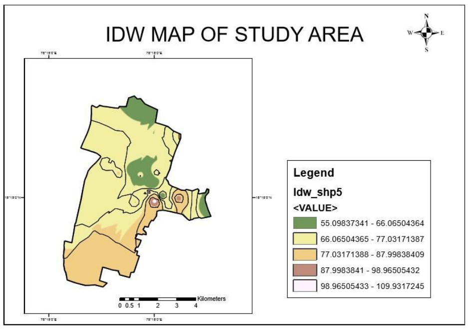

Fig. 4. Groundwater depth level Map of the study area

TABLE I Groundwater depth levels

S.NO	DEPTH RANGE	WEIGHT CLASS	PROSPECT
1	55.09-66.06	1	Very Good
2	66.06-77.03	2	Good
3	77.03-87.99	3	Moderate
4	87.99-98.96	4	Poor
5	98.96-109.93	5	Very Poor

B. Drainage and Drainage density map

A drainage basin is a natural unit draining runoff water to a common point. This map consists of water bodies, rivers, tributaries, perennial and ephemeral streams, ponds. The study area is fourth order basin joining the rivers, tributaries based on topography. Drainage network helps in delineation of watersheds. Drainage density and type of drainage gives information related to runoff, infiltration relief and permeability. Dendritic drainage indicates homogenous rocks, the trellis, rectangular and parallel drainage patterns indicate structural and lithological controls. The coarse drainage texture indicates highly porous and permeable rock formations; whereas ne drainage texture is more common in less pervious formations.

Major faults, lineaments sometimes connect two or more drainage basins and act as conduits. Flow of groundwater along these week zones is an established fact. Drainage pattern reflects surface characteristics as well as subsurface formation. Drainage density indicates closeness of spacing of channel as well as the nature of surface material, thus providing a quantitative measure of average length of stream channel for whole basin. It has been observed from drainage density measurement made over a wide range of geologic and climatic type that a low drainage density is more likely to occur in region and highly resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to ne drainage texture. The drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence the lesser the drainage density, the higher is the probability of recharge or potential groundwater zone. The entire drainage map is divided into five categories such as very poor, poor, moderate, good, very good as shown in below table.

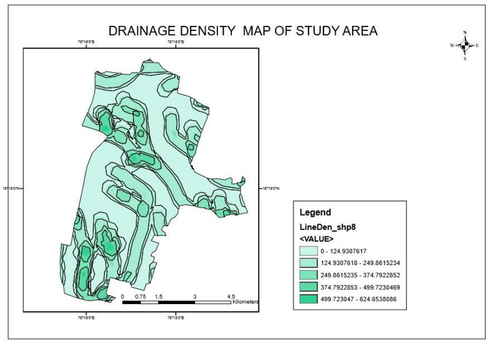

Fig. 5. Drainage Density Map of the study area

TABLE II Drainage Density values

S.NO	DENSITY RANGE	WEIGHT CLASS	PROSPECT
1	0-124.93	1	Very Good
2	124.93-249.86	2	Good
3	249.86-374.79	3	Moderate
4	374.79-499.72	4	Poor
5	499.72-624.65	5	Very Poor

C. Slope Map

Slope is one of the important terrain parameters which are explained by horizontal spacing of the contours. In general, in the vector form closely spaced contours represent steeper slopes and sparse contours exhibit gentle slope whereas in the elevation output raster every cell has a slope value. Here, the lower slope values indicate the flatter terrain and higher slope values correspond to steeper slope of the terrain. In the elevation raster, slope is measured by the identification of maximum rate of change in value from each cell to neighboring cells. The slope values are calculated either in percentage or degrees in both vector and raster forms. The slope amount derived from digitized contours and spot heights have shown that elevation decreases from the northern part to the southern part with slope 0 to 10 in at and mountainous areas respectively. In the nearly level slope area (0-1) degree, the surface runoff is slow allowing more time for rainwater to percolate and consider good groundwater potential zone, where as strong slope area (10-15) degree, facilitate high runoff allowing less residence time for rainwater hence comparatively less in filtration and poor groundwater potential. The entire slope map is divided into five categories as very poor, poor, moderate, good, very good.

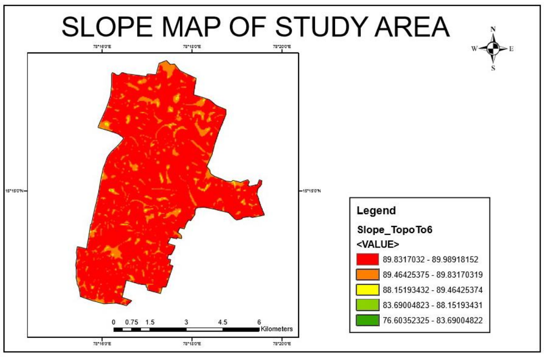

Fig. 6. Slope Map of the study area

TABLE III Slope values

S.NO	SLOPE RANGE	WEIGHT CLASS	PROSPECT
1	89.83-89.98	1	Very Good
2	89.465-89.83	2	Good
3	88.15-89.46	3	Moderate
4	83.69-88.15	4	Poor
5	76.60-83.69	5	Very Poor

D. Geomorphology Map

Geomorphology is the study of the form of the earth (landform), its description and genesis. It is a branch of earth science, which has grown after the advent of aerial photographs and satellite data. Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. Geomorphology of an area depends upon the structural evolution of geological formation. Geomorphology reflects various land form and structural features. Many of the features are favorable for the occurrence of groundwater and classified in terms of groundwater potentiality. The geomorphic units of the basin can be divided into moderately dissected lower plateau, low dissected lower plateau, pediment-pediplain complex, anthropogenic terrain, water bodies. Among these pediplain are good in groundwater potential. The present study follows the classification of geomorphology by National Remote Sensing Centre.

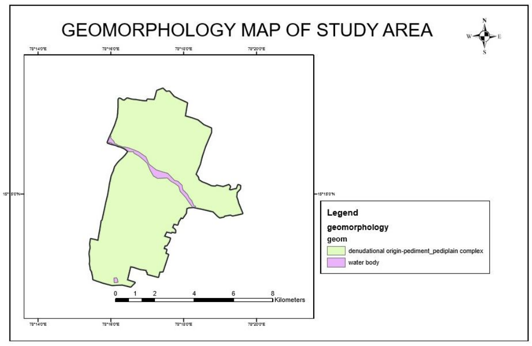

Fig. 7. Geomorphology Map of the study area

TABLE IV Geomorphology Classes

S.NO	GEOMORPHOLOGY	WEIGHT CLASS	PROSPECT
1	Pediment and Pediplain, complex	1	Very Good
2	Water bodies	2	Good

E. Geology Map

Geology describes the structure of the earth beneath its surface, and the processes that have shaped that structure. The study area is in Kurnool district, so the geology of study area is completely sedimentary formations of cuddapah basin.

TABLE V Geology Class

S.NO	GEOLOGY	WEIGHT CLASS	PROSPECT
1	Sedimentary formation	1	Good

IV. ASSIGNING RANK AND WEIGHT

The groundwater potential zones are obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS 10.1. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. All the thematic maps are converted into raster format and superimposed by weighted overlay method. For assigning the weight, the slope and geomorphology were assigned higher weight, whereas the drainage densities were assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the GIS layer on geomorphology, and slope and drainage density were analyzed carefully and ranks are assigned to their sub variable.

The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. The landforms such as moderately dissected plateau are given highest rank and lower value is assigned for pediplain. As far as slope is concerned, the highest rank value is assigned for gentle slope and low rank value is assigned to higher slope. The higher rank factors are assigned to low drainage density because the low drainage density factor favors more infiltration than surface runoff. Lower value followed by higher drainage density. Among the various lineament density classes the very high lineament density category is assigned higher rank value as this category has greater chance for ground-water infiltration. Lower value is assigned for very low lineament density. In LU/LC high rank is assigned to crop land and low value is assigned to barren land.

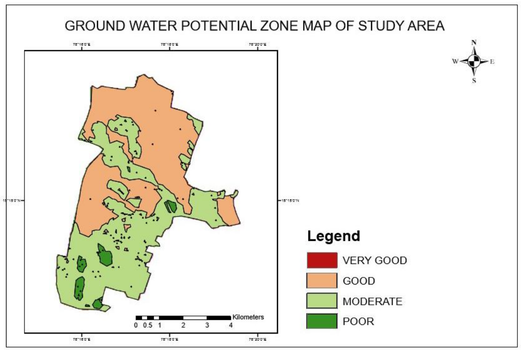

Fig. 9. Groundwater Potential Zones Map of the study area

TABLE VI Rank and weight of groundwater zones

PARAMETERS	CLASS	G.W. PROS	WEIGHT	RANK
GW Level	55.09837341-66.06504364	very good	30	1
	66.06504365-77.03171387	good		2
	77.03171388-87.99838409	moderate		3
	87.9983841-98.96505432	poor		4
	98.96505433-109.9317245	very poor		5
SLOPE CLASS	89.8317032-8998918152	very good	20	1
	89.46425375-89.83170319	good		2
	88.15193432-89.46425374	moderate		3
	83.69004823-88.15193431	poor		4
	76.60352325-83.69004822	very poor		5
DD	0-124.9307617	very good	20	1
	124.9307613-249.8615234	good		2
	249.8615235-374.7922852	moderate		3
	374.7922853-499.7230469	poor		4
	499.723047-624.6538086	very poor		5
GEOMORPHOLOGY	pediment and pediplain complex	very good		1
	water bodies	good	20	2
GEOLOGY	Sedimentary formation	good	10	2

TABLE VII Groundwater potential zones of the study area

S.NO	POTENTIAL ZONE	AREA (SQ.KM)	AREA (%)
1	Very Good	0.012125	0.0168
2	Good	34.472899	47.99
3	Moderate	35.36616	49.235
4	Poor	1.979455	2.755

V. CONCLUSIONS

This present study, it can be concluded that the Kurnool region of Andhra Pradesh state is found to be utilizing surface water more than ground water. The successful use of the remote sensing data on GIS platform has helped in obtaining detailed scenario of groundwater situation in the study area. Various algorithms which were essential for the hydrological applications were used in AR-CGIS which were useful in creating study area boundary, stream network, lineament and drainage density maps. The integration of all the thematic maps in result in five ground-water potential zones -very poor, poor, moderate, good, and very good. The very poor zone was indicating the least favorable area for groundwater prospect whereas very good zone indicates the most favorable area for ground water prospect. The results which were secured from the integration of various thematic maps shows that the study area falls in the range of good to moderate which accounts 97% percent of the study area. Finally, by this study we conclude that area like Amadala is poor in groundwater prospect, Bijinavemula and Velagaturu has good groundwater prospect, remaining area and Soulderdinne is moderate in groundwater prospect.

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